UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE, INC., Petitioner,

-against-

MASIMO CORPORATION, Patent Owner.

IPR 2022-01465

IPR 2022-01291

VIDEO-RECORDED DEPOSITION OF

BRIAN W. ANTHONY PH.D.

Zoom Recorded Videoconference

03/24/2023

11:14 a.m. (EDT)

REPORTED BY: AMANDA GORRONO, CLR

DIGITAL EVIDENCE GROUP

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11:14 a.m. (EDT)

VIDEO-RECORDED DEPOSITION OF BRIAN W. ANTHONY PH.D., held virtually via Zoom Videoconferencing, before Amanda Gorrono, Certified Live Note Reporter, and Notary Public of the State of New York.

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ALSO PRESENT:

Evidence Group

I N D E X

E X H I B I T S

THE TECH: We are on the record.
This is the remote video deposition of Dr. Brian W. Anthony in the matter of Apple Inc. versus Masimo Corporation in the United States Patent and Trademark Office before the Patent Trial and Appeal Board.

My name is Billy Fahnert. I am the video technician today. The court reporter is Amanda Gorrono. We are here on behalf of Digital Evidence Group.

Today's date is March 24, 2023. The time is 11:14 a.m., Eastern Daylight Time.

All parties have stipulated to the witness being sworn in remotely.

Will counsel please identify yourselves for the record and then the witness will be sworn in.

MR. KIANG: Thank you.

This is Daniel Kiang from Knobbe Martens on behalf of the Patent Owner, Masimo Corporation. And with me today is also Jeremiah Helm also from Knobbe Martens.

MR. SMITH: And this is Dan Smith for Petitioner, Apple, from Fish & Richardson. And with me, also, is Kim Leung also from Fish & Richardson.

BRIAN W. ANTHONY PH.D., called as a witness, having been first duly sworn by a Notary Public of the State of New York, was examined and testified as follows:

THE WITNESS: I do.

EXAMINATION

BY MR. KIANG:

Q. All right. Good morning, Dr. Anthony.

A. Good morning.

Q. Could you please state your full name for the record, please?

A. Brian W. Anthony.

And, Daniel, just noting your audio seems a little bit muffled. I'm not sure if it's me or --

Q. Am I just -- do I need to enunciate more clearly?

A. Yeah, that would be good. I think that was a little better.
Q. Sorry about that.
Dr. Anthony, you've been deposed before, right?
A. Yes.
Q. Many times?
A. Several.
Q. Okay. And you've been deposed before in IPRs that Apple has filed against Masimo; is that correct?
A. Correct.
Q. Is there any reason why you would not be able to provide truthful and accurate testimony today?
A. No.
Q. Are you taking any food, drink or medications that could affect your ability to provide truthful and/or accurate testimony today?
A. No.
Q. Do you have any notes with you?
A. No.

Q. Do you have any methods of communication other than this videoconference?

A. No.

Q. And I understand that counsel has provided you with some clean copies of documents from the IPR record; is that correct?

A. Correct.

Q. There's no notes on those?

A. No, there's not.

Q. Okay. I'll ask you a few questions today -- many questions really. Please wait until I've completed the question before answering. If you don't understand a question or if you didn't hear what I said clearly, please let me know and I'll try to rephrase or restate the question. If you don't ask me to clarify, I will assume that you understood the question.

Is that fair?

A. Yes.

Q. And also, we can take a break at any time today. But I ask that if there is a question pending that you please answer the

question first before we take a break.
Is that fair?
A. Yes.
Q. And you understand that you're being deposed today in connection with two Declarations that you filed; is that correct?
A. Yes.
Q. And that's one Declaration for the IPR, IPR No. IPR2022-01291 and another one for IPR2022-01465; is that right?
A. I would have to confirm on the numbers but that sounds right.
Q. Okay. And you understand that these are in connection -- that these IPRs are in connection with the '745 patent; is that right?
A. Correct. Yes.
Q. And I'll get the full number of the that patent actually.
Do you understand the '745 patent to be Patent No. 10,687,745?
A. Correct.
Q. Dr. Anthony, do you understand what

pulse oximetry is?

MR. SMITH: Objection; form.

A. As I described in my Declaration, it's one of multiple physiological signals.

BY MR. KIANG:

Q. And do you agree that pulse oximetry is a method of non-invasively measuring blood oxygen saturation using light?

A. It is one of multiple physiological monitors can be measured using light.

Q. And pulse oximetry is a non-invasive method of measuring blood oxygen saturation; is that correct?

A. I'm sorry. Please, can you repeat that?

I -- I -- again, from -- I'm not sure if it's just me, but I might try to put in different headphones. I don't have my other headphones. Give me one second. I'm going to put my earbuds in.

Q. Okay. Can you hear me?

A. Are you able to hear me? Testing.

Q. I can hear you. Can you hear me?
A. Okay. I think that'd be better.
Q. Okay. So I'll just repeat the question.
Pulse oximetry is a non-invasive method of measuring blood oxygen saturation; is that correct?
A. Correct. As I describe in my Declaration, it's one of multiple ways that -- multiple physiological signals you can use measuring light in a non-invasive way.
Q. And do you agree that a device that performs pulse oximetry is called a pulse oximeter?
A. Are you referring to a particular place in my Declaration where I'm sort of there's some ambiguity in -- in what I'm describing?
Q. No. I just want to make sure we have a correct understanding between ourselves as to any terms I'm using today.
A. Well, I didn't feel that it was necessary to -- necessary to define any terms

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other than their plain and ordinary meaning as I described in the Declaration, so picking them out of the Declaration is sort of what I was trying to understand where you were reading from or pointing to.

Q. Well, you know what a pulse oximeter is, correct?

A. Correct.

Q. And that's a device that does pulse oximetry?

A. That can measure pulse ox signals, correct.

Q. Okay. And do you understand the term "SpO2" to refer to a measurement of oxygen saturation by a pulse oximeter?

MR. SMITH: Objection; form.

A. Pulse ox SpO2, multiple types of physiological signals that can be measured non-invasively.

Q. Do you know what heart rate is?

A. Do I know what heart rate is?

Q. Yes.

A. It's a physiological signal related to the rate of the heart.

Q. And do you know what a pulse rate -- pulse wave is?

A. It is one of many of the vital signs -- it's physiological signals that you can measure from a -- from the person.

Q. Can you describe what a pulse wave is?

MR. SMITH: Objection; form.

A. Its plain and ordinary use as described in my Declaration is -- you know, it's a vital sign, amongst many, that can be monitored non-invasively.

BY MR. KIANG:

Q. Well, where do you say that in your Declaration?

A. Can you please repeat the question?

Q. Let me rephrase.

I understand you said that a pulse wave is a vital sign that can be monitored non-invasively. Can you describe what a pulse wave is?

A. It was not necessary to construe specific terms here as you're narrowing in on them. As I've described in my Declaration, there are many types of vital signs and signals that can be monitored from a wearable physiological monitor as I described in my Declaration.

Q. I just want to understand what you think a pulse wave is.

Could you please describe that?

MR. SMITH: Objection; form.

A. Did not need -- I did not feel I needed to explicitly describe or define its plain and ordinary use is used in -- throughout the Declaration and used throughout the references that I cite.

BY MR. KIANG:

Q. So we talked about a heart rate -- heart rate, pulse wave, and oxygen saturation.

Do you agree that -- that heart rate is different from oxygen saturation?

A. Do I agree that heart rate is

different than?

Q. Oxygen saturation.

A. Heart rate is a rate and saturation is a saturation.

Q. So they are not the same measurement set, right?

A. Again, they are both physiological monitor -- physiological signals are signals that can be monitored from the person. It was not necessarily construed specifically to a definition of heart rate or a definition of saturation, you know, for --

Q. You haven't answered my question. Is a heart rate --

MR. SMITH: Objection; form.

BY MR. KIANG:

Q. -- different than oxygen saturation?

MR. SMITH: Objection; form.

A. As I described, I answered heart rate is a rate and saturation is a saturation. They are different words, different things, but related in that they are physiological signals

that can be used -- monitored from the body.
BY MR. KIANG:
Q. And is a pulse wave a different measurement than oxygen saturation?
MR. SMITH: Objection; form.
A. As with any of these signals, you're asking them in isolation in context, they are multiple signals that can be taken from the body. They are related in ways. They are different in ways, but they are all physiological signals that come from the body.
BY MR. KIANG:
Q. I'm not asking whether they're both physiological signals. I'm asking: Is a pulse wave a different measurement than an oxygen saturation measurement?
MR. SMITH: Objection; form. Argumentative.
A. I didn't feel it was necessary to call out the specific individual definitions or construe these terms in isolation. Their plain and ordinary meaning is well understood by a

POSITA in the context of the art and -- that I cite.

BY MR. KIANG:

Q. So sitting here today, can you tell me, yes or no, whether a pulse wave is a different measurement than oxygen saturation?

MR. SMITH: Objection; form. Argumentative.

A. A pulse wave is a pulse wave and a saturation is a saturation. It's, as I've described, not necessary to construe their -- their definitions in any other way than their plain and ordinary meaning.

BY MR. KIANG:

Q. So you applied the plain and ordinary meaning of a pulse wave in your analysis; is that correct?

A. Correct.

Q. So what was that plain and ordinary meaning?

A. So as I describe on Page 11, for example, of my first Declaration, the one that's -- let me see. Where are the numbers here? The shorter one, I guess, on Page 11, "...for the purposes of my analysis...the terms appearing in the patent claims should generally be interpreted according to their 'ordinary and customary meaning.'"

And I understand that the ordinary and customary meaning of a claim term is the meaning that term would have to a person of ordinary skill in the art in question at the time of the invention.

Q. Okay. I see that you're reading from a recitation of the case Phillips v. AWH Corporation. I don't think that was what my question was.

My question was: What was the plain and ordinary meaning of the pulse wave that you used in your analysis?

MR. SMITH: Objection; form.

A. The plain and ordinary meaning is in the context of the use as a -- one of multiple physiological signals that can be obtained from wearable physiological monitors. It was not necessary to construe a specific definition as I -- as I comment in Paragraph 28 of my Declaration.

BY MR. KIANG:

Q. Now, you also -- you applied a plain and ordinary meaning of oxygen saturation in your analysis; is that correct?

A. As I say in Paragraph 28, I apply a -- "...the terms appearing in the patent claims should generally be interpreted according to their 'ordinary and customary meaning.'"

Q. Now, is the plain and ordinary meaning of a pulse wave the same as the plain and ordinary meaning of oxygen saturation?

A. I believe I already answered that. One is a wave and one is a saturation. Saturations can be wave -- can sort of oscillate over time. But again, it wasn't -- you know, you're asking me to construe a definition here where it was not asserted to do so.

Q. You're saying that an oxygen

saturation can be a wave. Is that what you're saying?

MR. SMITH: Objection; form.

A. I am not saying that.

BY MR. KIANG:

Q. Then what did you mean?

A. What did I mean? Please clarify.

Q. I believe you said -- I'm trying to quote from the realtime transcript here. I believe I already answered that one is a wave and one is a saturation. Saturations can be wave -- sort of oscillate over time.

So what did you mean by that, saturation can be oscillated over time?

A. What I generally meant is the signals that come from a body can change over time. They can be periodic. They can be transient, but they can change over time.

Q. So if I asked a person of ordinary skill to measure a pulse wave, would they understand me as asking them to measure an oxygen saturation?

A. It was not, again, necessary to construe that particular question in forming my opinions here. A person skilled in the art would understand what you're asking in the context of -- of the -- the art described.

Q. And you've been providing your opinions as to what a person of skill in the art would understand; is that correct?

A. Correct.

Q. So what would a person of ordinary skill understand? Is a pulse wave the same thing as an oxygen saturation?

A. Again, they would -- these terms would be interpreted according to their -- their plain -- ordinary and customary meaning.

Q. I'm not asking you about the law on claim construction. I'm asking you: Would a person of ordinary skill understand a pulse wave to be the same thing as oxygen saturation?

MR. SMITH: Objection to form.

A. Again, it was not necessarily construed specific terms. The person of ordinary skill would understand in the context and as interpreted through the measurements that they are things that can be measured from the body, and that can mean different things.

BY MR. KIANG:

Q. Sitting here today, can you answer me, yes or no, whether a pulse wave and oxygen saturation are the same thing?

MR. SMITH: Objection; form.

A. They are different signals coming from the body. But they are physiological signals coming from the body.

BY MR. KIANG:

Q. Do you know how pulse oximetry is performed?

A. In -- in what context?

Q. In your own words, how would you describe how a pulse oximetry measures oxygen -- how a -- let me rephrase.

In your own words, could you please describe how a pulse oximeter measures oxygen saturation?

A. I would point to the references that I cited.

Q. Are you looking at a document in particular right now?

A. I'm looking at in particular Sarantos. So, for example, in Column 13 of Sarantos, Line 44, photoplethysmographic techniques can be used to measure physiological parameters such as heart rate, blood oxygenation.

And then, for example, let's see. And, for example, in Column 18, Line 44, "...photoplethysmographic techniques, such as -- such as techniques for measuring blood oxygenation levels may be most effective using light or dramatically different wave lengths."

So a person of ordinary skill in the art understand that a plethysmograph is generally measuring changes in volume. A photoplethysmograph uses light to measure those, and blood oxygenation can be estimated from the relative ratio of those signals.

Q. Okay. Okay. I'm going to read you

a few sentences. And I'd like for you to listen carefully and let me know if you agree or disagree with what I'm about to say. Is that all right?

A. Yes.

Q. "Photoplethysmography works by directing light into a person's tissue and measuring the light that is reflected back from or transmitted through the tissue. Different components of blood or tissue absorb different wavelengths of light. By measuring how much light is absorbed by the tissue and how the absorption changes over time, a device can calculate parameters that are related to the properties or tissue or blood."

Do you agree with that?

A. I'd have to see it written down to make sure that you're understanding it correctly. And I also would like to note if it's written down someplace in my Declaration, but that sounds approximately correct.

Q. Let me continue reading. "For

example, hemoglobin (the protein molecule in blood that carries oxygen to the cells) reflects more light -- more red light when it is more oxygen -- more oxygenated than when it is deoxygenated; it absorbs more red light when it is deoxygenated."

Do you agree with that?

A. Are you reading from a particular one of the references that I cited or my Declaration?

Q. No, I'm not. Let me -- let's put this on the screen then.

MR. KIANG: Could I have the hot-seater pull up Tab 13?

(Tech complies.)

BY MR. KIANG:

Q. Dr. Anthony, do you see this on the screen?

A. Yes.

Q. And do you recognize this document?

MR. SMITH: Objection; form. Foundation.

A. This looks like a Declaration -- cover page of a Declaration that is not the ones that we're talking about today.

Q. That's correct. I'll just represent that this is an excerpt of a Declaration that you previously filled in another IPR.

MR. KIANG: Can we please move on to the -- let's see, next page of this?

MR. SMITH: Daniel, are you going to provide him with an electronic copy of this?

MR. KIANG: Yeah.

BY MR. KIANG:

Q. Dr. Anthony, in the e-mail today that gave you the Zoom link for today's deposition there should be a link to Dropbox or some other repository where you should be able to download these documents as they are put on the screen.

Do you have that?

A. I do not. Let me see.

Did you say in the e-mail? Actually is it okay if I go to my e-mail and -- or my calendar? Oh, there is a --

Q. He put it in the chat for the Zoom.

A. Thank you. Thank you.

THE TECH: Also, are we marking this as an exhibit?

MR. KIANG: Yep.

(Whereupon, Exhibit 1, Excerpt of Anthony Declaration regarding '994 Patent, was marked for identification.)

A. Okay. We're on Page 11. It's not the full Declaration?

BY MR. KIANG:

Q. Correct. It's just an excerpt.

A. Okay.

MR. SMITH: Objection to form.

MR. KIANG: Actually, let's have Page 12 on the screen. All right.

BY MR. KIANG:

Q. And, Dr. Anthony, do you have a copy of this document?

A. I have the four -- I don't have the document. I have the five or four -- four pages

that is called Tab 13 excerpt.
Q. Right. That's what I meant.
Dr. Anthony, are you -- do you have everything you need?
A. I have -- I have the document, yes.
Q. Okay. I'm just going to read from Paragraph 25 that's on the screen right now. And just let me know if you agree with what I'm saying.
"For example, hemoglobin (the protein molecule in blood that carries oxygen to cells) reflects more red light when it is more oxygenated than when it is deoxygenated; it absorbs more red light when it is deoxygenated."
Do you agree with that?
A. These are my -- presumably my words from my Declaration -- from a prior Declaration.
Q. So you agree with your own words; is that right?
A. Yes.
Q. And you agree with the next sentence: "Hemoglobin reflects the same amount

of infrared (IR) light when [sic] oxygenated or deoxygenated."

Do you agree with that?

A. Can I make sure? Do you have APPLE -- what's 1013-769, which is presumably what I'm citing here? Just to make sure that the quote there -- other documents.

Q. I'm just asking if you agree with your own words in your --

A. These are the words I wrote in citing that particular reference.

Q. So you agree with what you wrote; is that correct?

A. As I said, that is correct.

MR. KIANG: Let's take this down.

BY MR. KIANG:

Q. Do you agree that the algorithms used to determine oxygen saturation are different than the algorithms used to determine heart rate?

MR. SMITH: Objection; form.

A. Again, it was not necessary for me to opine on particular algorithms for calculating of either in forming my opinions for the case at hand.

BY MR. KIANG:

Q. But a person of ordinary skill would know that the algorithms used for calculating oxygen saturation are than different algorithms used for measuring heart rate; is that correct?

MR. SMITH: Objection; form. Argumentative.

A. A person of ordinary skill in the art would know that algorithms are necessary to calculate and different algorithm would be necessary to calculate different things.

BY MR. KIANG:

Q. And so you would apply a different algorithm to measure oxygen saturation than an algorithm used to measure heart rhythm; is that correct?

MR. SMITH: Objection; form.

A. Can you repeat the question?

BY MR. KIANG:

Q. So a person of ordinary skill would

need to apply a different algorithm to measure oxygen saturation than the algorithm used to measure heart rate; is that correct?

A. As I said, different algorithms would result in different measurements. Algorithms can be connected, and a person skilled in the art would know that algorithms were necessary to go from a measured signal, a raw signal, to information. And different algorithms would be necessary for measuring different things.

Q. And you've agreed earlier today that heart rate is different than -- than oxygen saturation; is that right?

MR. SMITH: Objection; form.

A. I'm sorry. I'm -- please repeat that.

BY MR. KIANG:

Q. Yeah. We'll move on.

Do you agree that for a pulse oximeter to measure oxygen saturation, it would need at least two wavelengths of light?

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A. For, you said, the heart rate or -- I'm sorry.

Q. Oxygen saturation.

A. Oxygen saturation. As I described in -- as is described in Sarantos, right, if you're wanting to get oxygenation, you'll use sort of multiple wavelengths of light.

Q. What are you looking at in Sarantos? Actually --

MR. KIANG: Can we have the hot-seater please pull up, what is this, Tab 5?

(Tech complies.)

(Whereupon, Exhibit 2, U.S. Patent 9,392,946-Sarantos, was was identified.)

A. So, for example, on Column 13 of Sarantos, Line 47 -- 47, "...utilize an LED that predominantly emits light in the red or infrared spectrum for such purposes...it may be desirable to include separate light-emitting devices that are each able to emit different wavelengths of light; each light-emitting device may be used to supply light for a different type of photoplethysmograph measurement. In some implementations, these light-emitting devices or light sources may be distributed across the PPG sensor face..."

But, you know, for example, in Sarantos, describing multiple light sources used to measure different aspects of photo -- photoplethysmographic measurement.

Q. And, Doctor, as -- while you were looking for that, I had the hot-seater pull up this exhibit, Tab 5.

Do you recognize this?

MR. KIANG: Can we please have the hot-seater go back to the prior page?

(Tech complies.)

BY MR. KIANG:

Q. Do you recognize this document?

A. This is Sarantos.

Q. So this was previously marked as Exhibit 1005 in both IPRs. All right.

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So going back to Column 13 and the lines that you're citing, which is around Line 47.

Looking at Line 47 to about Line 49, do you see where Sarantos says, and quote, ...it may, in such situations, be desirable to utilize an LED that predominantly emits light in the red or infrared section for such purpose?

A. Yes.

Q. Was Sarantos describing using an LED that emits red -- one of red or infrared light?

A. What is described here is a light in the red or the infrared spectrum and emitting different wavelengths of light.

Q. So would a person of ordinary skill understand Sarantos to be talking about using either red or infrared or both at the same time?

A. As described at Line 41, "...it may be desirable to include separate light-emitting devices that are each able to emit different wavelengths" -- oops, it's moving as I'm reading.

Line 49: "Thus, it may be desirable

to include" --

THE TECH: Sorry. I thought you said Line 41. That's why I went up.

THE WITNESS: Sorry.

A. At 49: "Thus, it may be desirable to include separate light-emitting devices that are each able to emit different wavelengths of light; each light-emitting device may be used to supply light for a different type of photoplethysmographic measurement."

BY MR. KIANG:

Q. So my question is: Is Sarantos talking about using either red or infrared light for blood oxygenation levels or both red and infrared light?

A. Sarantos talks about using, in some instances, single wavelengths and, in some instances, multiple wavelengths.

Q. In your opinion, is it possible to measure oxygen saturation using a single wavelength of light?

A. Again, it was not essential to opine

as to the feasibility or infeasibility of using the single wavelength. A person skilled in the art would generally know that multiple wavelengths are beneficial and that the much better way to do it.

Q. It's a much better way to do it.

Are you suggesting that it's possible to do it with one wavelength?

A. A person skilled in the art would know that a -- a very good way to do it is using multiple wavelengths.

Q. Is it possible to measure oxygen saturation using one wavelength of light?

A. It was not necessary to opine on the feasibility of having a signal measured. In the realm of infinite possibilities, you could have a very noisy signal with other machine learning techniques and other algorithmic techniques, but it wasn't necessary to opine on the infinite possible ways that you could tackle a problem in this way.

Q. Are you aware of any pulse oximeter

in the world that can measure pulse -- that can measure oxygen saturation using one wavelength of light?

A. Again, it was not necessary -- did not need to opine on the -- the feasibility of doing something like that. A person skilled in the art would know that it is at least one way to do it is using multiple wavelengths of light.

Q. So sitting here today, can you tell me, yes or no -- yes --

Let me rephrase. Got tongue tied a little bit.

Can you tell me sitting here today whether it is possible or not to measure oxygen saturation using a single wavelength of light?

MR. SMITH: Objection; form.

A. I'm amazed at what some of the things that you can now do with advanced algorithmic techniques or machine learning, so I would not preclude the possibility that at some point in the future or even now, there is a way that is not as good or maybe better but in a different way.

But again, it was not necessary to opine on alternative ways of -- of measuring pulse ox as you're -- as you're describing.

Q. So you're not aware of any method by which oxygen saturation can be measured with single wavelength; is that correct?

A. Again, it was not necessary to opine on whether or not there is a feasible way of doing it with one wavelength.

Q. So my question wasn't asking about whether you thought it was necessary to opine on it. I'm asking you: Are you aware of any method by which oxygen saturation can be measured using a single wavelength of light?

MR. SMITH: Objection; form.

A. Is there a place in my Declaration where I provide that -- that sort of commentary?

Again, it was not necessary to opine in the infinite spectrum of different ways to measure different things in forming my opinions here.

BY MR. KIANG:

Q. All right. I'll take that as a no, unless you want to tell me otherwise right now.

MR. SMITH: Objection; form.

A. I'll suggest you take it as my answer, as I indicated previously.

BY MR. KIANG:

Q. I don't think you provided an answer to my question.

MR. SMITH: Objection; form.

BY MR. KIANG:

Q. Dr. Anthony, do you have any specific experience in designing or developing a pulse oximeter?

A. I would point you to my -- my CV which is at the end of both of my Declarations that describe in a lot of detail the various physiological monitors and devices that I point to as my background and experience.

Q. All right. I want to back up a little bit. Now, you've said that a very good way to measure oxygen saturation is using two wavelengths of light; is that right?

A. Please repeat that. Sorry.

Q. You said earlier that a very good way to measure oxygen saturation would be to use two wavelengths of light; is that correct?

A. Sounds approximately what I said.

Q. What other ways are there to measure oxygen saturation?

A. Again, it was not necessary to opine on the multiple ways to measure oxygen saturation in forming my opinions here. You could use multiple wavelengths. You could use three wavelengths, four wavelengths, five wavelengths.

There's also a lot of interesting work where people are trying to make pulse oximetry not racially biased and using more than two wavelengths.

Q. And, again, you're not aware of any technique that is currently available today to measure oxygen saturation using a single wavelength of light; is that correct?

A. Again, it was not necessary for me

to opine on the feasibility or if there's any such algorithm to do it with a single wavelength.

Q. I'm not asking you for feasibility. I'm just asking you: Are you aware of any method by which oxygen saturation can be measured using one ray of light?

A. Daniel, you did not come through there for a bit.

Q. Let me repeat the question.

I wasn't asking you about whether it's feasible. I am just asking you: Are you aware of any method to measure oxygen saturation using one wavelength of light?

A. Not currently aware of a specific way to do it with one wavelength, but I'm not eliminating the possibility that it could be done.

Q. So earlier I had asked you whether you had experience in building or developing, designing a pulse oximeter. I believe you pointed me to your CV.

Without looking at your CV, have you

ever built or designed a pulse oximeter?
MR. SMITH: Objection; form.
A. I've designed many instruments that measure vital signs optically, and that include many of the heart rate, respiration rate signals for both research and -- and our laser ultrasound work, for example.
BY MR. KIANG:
Q. But none of those devices measure oxygen saturation; is that correct?
MR. SMITH: Objection; form. Argumentative.
A. None of those devices were specifically just for oxygenation but provided the signals from which oxygenation could also be extracted.
BY MR. KIANG:
Q. So you've -- you've never personally worked on a device for the purpose of measuring oxygen saturation; is that correct?
A. That's not what I said. I said the devices that I've worked on were not exclusively

for that singular measurement but would also be used for such measurements.

Q. Would you say those devices would be used or could be used for measuring oxygen saturation?

A. I said could be used.

Q. Were they ever used for oxygen saturation?

A. Not for just oxygenation. A lot of our laser ultrasound work, for example, allows us to do both imaging and heart rate and estimate in a noncontact way blood oxygenation.

Q. And did you personally work on any part of the design of either the physical sensor itself or maybe the algorithms to measure or determine oxygen saturation with that device?

A. I am one of the authors and inventors on our optical -- noncontact optical measurement systems.

Q. That wasn't really my question.

Did you personally work on the design of the physical sensor itself or the algorithms that are used for measuring oxygen saturation?

A. As I said, on the devices that we've worked on that are optical measurements, those signals can be used in both the devices that we've designed and the algorithms to measure in addition to laser ultrasound and heart rate, also get oxygenation.

Q. You said that those devices can be used to get oxygenation, but were they ever actually used to get oxygenation?

A. Yes. Not the dominant focus of the work but they are used to -- in a very coarse way, you can get that measurement.

Q. And were you personally involved in designing that device?

A. Yes.

Q. What did you do in designing that device?

A. So the device -- the one device that I have in mind that I'm referring to is our laser ultrasound device which is a bunch of optics and lights to in a noncontact way transmit light into the body, receive light from the body, and estimate everything from the propagation rate of the induced sound to the absorption spectrum, both developing the optics, the signalling, the triggering, the algorithms to interpret the data.

There's a major paper circa 2019 with a focus on laser ultrasound, but that same system can be used. And we're applying that system now in -- in home contexts in order to estimate heart rate, pulse ox, in a noncontact way with sensors mounted in the room.

Q. What do you mean by "noncontact"?

A. Meaning not having it on the body, meaning doing it from a distance.

Q. Have you ever designed a pulse oximeter that is -- that measures oxygen saturation where the sensor is in contact with the person's body?

A. The principle is the same. It's light in and light out. I've designed wearable devices. I've designed noncontact devices.

Q. How is the principle the same for laser ultrasound noncontact monitoring device and a pulse oximeter?

A. The principle of using light into the body and light out of the body, there's nothing -- the -- the idea of it being a watch, which is the main discussion in my Declaration, on the -- worn on the wrist. But it's getting light in and out of the body from a light source and a light detector. The light source and light detector can also, as we've demonstrated, manifest the same result with different levels of noise and when it's not pressed up against the body.

Q. Have you ever designed a pulse oximeter that measures from the wrist?

A. I have not specifically designed a pulse oximeter at the wrist.

Q. How much experience do you have specifically with pulse oximetry?

A. I'm not sure how to quantify that. As I described in my Declaration, in terms of what a person skilled in the art and the design of physiological devices.

Q. How many months or years would you say in your career that you worked specifically on pulse oximetry?

A. I work on many things. Many types of devices, many types of acoustic and optical devices. That is what I do.

Q. But specifically for pulse oximetry, how many months or years do you think you've spent working on that?

A. I do not keep a catalog of my hours of doing particular things. But I design medical devices, as I've described, and those devices are both optical and acoustic techniques.

And, as I described what a person skilled in the art related to physiological monitoring would understand, you know, I certainly have managed people like that. I am one of those people. And so...

Q. So earlier today you mentioned that you or your team had built some laser ultrasound

measuring -- some type of monitoring device.
Do you remember that?
A. Yes.
Q. When was -- when did you work on that device?
A. I think we started that work in 2000 -- let's see. I'm looking at my publication history here so I can remember my context.
When we started that work when we were doing skin analysis and freebase matching of skin deformation. And, you know, a lot of the work I started back in 1999 when we were looking at -- at acoustic waves, using light for characterization of -- of engineering materials. I tried at that point to -- to do it to tissues. But the technology at that point was not achievable for eye and skin safe levels.
So I'd say, you know, in various ways, you know, way back to 2000. You know, we weren't successful for a long time, but...
Q. Where were you working at that time?
A. At which, at circa 2000?

Q. Yes. In developing this laser ultrasound device that you are mentioning. Where were you?

A. I would have been at a combination of MIT, consulting, you know.

Q. And this laser ultrasound device, was it built for a company? University? Who was it for?

A. Well, I mean, it's -- who was it for? I mean it's for the world. It's a -- it's our -- it's active research. You know.

Q. I -- I guess my question should have been phrased a little bit better.

Was your work on this laser ultrasound device done at a university or at a private company or where else?

A. A mix. A lot of the predicate work was started at a private company where the applications were -- were engineered materials and then the -- the bio applications were more on the academic hat where there wasn't yet a -- a commercial -- clear commercial pathway.

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Q. Now, earlier today you mentioned that you weren't aware of any -- you are not currently aware of any method to measure oxygen saturation using a single wavelength of light.
Do you remember that?
A. Yes.
Q. Would a person of ordinary skill in the art as of July 2015 have known of any way to measure oxygen saturation using a single wavelength of light?
MR. SMITH: Objection; form.
A. As I described previously, a person skilled in the art would use generally multiple wavelengths of light.
Q. And a person of skill wouldn't have known about any method by which oxygen saturation could be measured using a single wavelength as of July 2015; is that correct?
A. A person skilled in the art would know of multiple ways to use light to measure physiological signals, including things that use one wavelength and multiple wavelengths.

Q. But specifically for measuring ox -- oxygen saturation, they would not have known of a method that -- that could do it by a single wavelength; is that correct?

MR. SMITH: Objection; form.

A. Again, the area where it described the way a person skilled in the art is, is in the area of physiological monitoring, optical-based physiological monitoring. And a person skilled in the art would know that different signals or things they want to monitor require different wavelengths. Some can be done with one; some require two; some required more.

BY MR. KIANG:

Q. And so a person of ordinary skill in July 2015 would have known that oxygen saturation is a type of signal that would require at least two wavelengths of light; is that correct?

MR. SMITH: Objection; form.

BY MR. KIANG:

Q. And let me rephrase that question actually.

A person of skill in July 2015 would have known that oxygen saturation would require at least two wavelengths of light to measure, correct?

MR. SMITH: Objection; form.

A. 2015, a person skilled in the art in optical-based physiological monitoring would know, for example, that some physiological signals require -- can be done with one, some can be done with two, and some may require more --

Q. And so --

A. -- and a person skilled in the art -- go ahead.

Q. Sorry. I didn't mean to cut you off.

A. That's fine.

Q. And so specifically, though, for the physiological signal known as oxygen saturation, a person of skill would know you need two wavelengths as of July 2015; is that correct?

A. Again, a person skilled in the art would know that pulse ox is one of multiple types of physiological signals, can be measured optically and that some of those, such as heart rate, can be easily done with one, such as pulse ox can more easily be done with two, and others can require more.

MR. SMITH: Counsel, when you get to a stopping point, we've been going for about an hour, so let's -- let's take a break here.

BY MR. KIANG:

Q. Mr. -- Dr. Anthony.

MR. KIANG: I think now is an okay time for a break.

THE WITNESS: Okay.

MR. KIANG: Ten minutes.

THE VIDEOGRAPHER: Going off the record. The time is 12:17.

MR. SMITH: Yeah. Let's do ten minutes.

AUTOMATED MESSAGE: Recording stopped.

(Recess taken.)

AUTOMATED MESSAGE: Recording in

progress.

THE TECH: We are back on the record. The time is 12:29.

BY MR. KIANG:

Q. All right. Dr. Anthony, did you speak to anyone during the break about the substance of your testimony today?

A. No.

MR. KIANG: At this time, I'd like the court reporter or the hot-seater to please bring up Tab 1.

(Tech complies.)

(Whereupon, Exhibit 3, IPR1291 Anthony Declaration, was identified.)

BY MR. KIANG:

Q. And, Dr. Anthony, do you recognize this document? It should also be available in your Dropbox. This is, you know, your Declaration from the 1291 IPR.

A. So this is -- this is what I'm calling Declaration No. 1, the first -- the first, the 1291. Yeah. I see those numbers.

Great. 1291. Okay. It's the Declaration.
It's easier for me to look at the printout.
Q. Okay. No problem.
Dr. Anthony, you reviewed certain documents in forming the opinions you wrote in your Declaration; is that correct?
A. Correct.
Q. Can we go to Paragraph 11 of this Declaration?
MR. KIANG: And can I please have the hot-seater pull up Pages 6 and 7 of this Declaration?
(Tech complies.)
BY MR. KIANG:
Q. So we have Paragraph 11 on the screen. Do you see that, Dr. Anthony?
A. Yes.
Q. Does Paragraph 11 provide a complete and accurate listing of the materials that you considered in forming your opinions in this Declaration?

A. So as I highlight in Paragraph 11, I reviewed the following prior art references and materials and there may be other materials that I cite in the Declaration that I may have missed here, but, you know, this is a reasonably complete list.

Q. So to the extent you relied on anything else, it would have been cited in this Declaration somewhere, correct?

A. These were the references that I cited in my Declaration.

Q. I'm just asking: If you relied on a document that's not listed in Paragraph 11 or an opinion in your Declaration, that would just be cited somewhere in the Declaration; is that correct?

A. Correct.

Q. Okay. In Paragraph 11, before the bullet points, you say, "I have reviewed the '745 Patent and relevant excerpts of the prosecution history of the '745 Patent."

Do you see that?

A. Yes, I do.
Q. Did you review the prosecution histories of any patents related to the '745 patent in forming your opinions for this Declaration?
A. I'm sorry. Can you repeat that?
Q. Yeah. Did you review the prosecution histories of any patents related to the '745 patent in forming your opinions for this Declaration?
A. As I described here, I reviewed the -- the relevant excerpts of the prosecution history of the -- of the '745.
MR. KIANG: Could I have the hot-seater please pull up Tab 3. This was previously marked as Exhibit 1001.
(Tech complies.)
(Whereupon, Exhibit 1001, US Patent 10,698,745, was identified.)
BY MR. KIANG:
Q. Dr. Anthony, do you recognize this document?

A. This is what we are calling the '745, the Al-Ali patent.

Q. Can you see on this cover sheet on the left column, there is a thing called "Related U.S. Application Data"?

A. I'm sorry. Where were you pointing to? Sorry.

Q. On the left column of this broad cover of the patent, there is a "Related U.S. Application Data."

Do you see that?

A. Yes.

Q. And it says this '745 patent is a continuation of another application, correct?

A. Correct.

Q. And if we go on to the next page at the top left, there is more related US application data showing other continuations, other applications of which the '745 patent is a continuation.

Do you see that?

A. Yes.

Q. Did you review the file histories of any of these applications in forming your opinions for this Declaration?

A. I may have skimmed through those. I don't recall the specifics of which ones but certainly the prosecution history of -- of '745.

Q. Do you agree that a person of ordinary skill would find the prosecution histories of related patent applications to be relevant in understanding the '745 patent claims?

MR. SMITH: Objection; form. Argumentative.

A. They are relevant and they are related, but I also am, you know, reviewing the '745 patent itself.

BY MR. KIANG:

Q. How did you prepare -- how did you prepare for today's deposition?

A. I reviewed my Declarations. I had conversation with counsel. I've reviewed the -- the references that I cited.

Q. Did you consider any materials that

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are not listed in your Declaration in preparation for today's deposition?

A. No.

Q. How long did it take for you to prepare your Declaration?

A. I'm sorry. To prepare my Declaration or preparation?

Q. To prepare the Declaration.

A. It -- probably 30 -- 20, 30 hours-ish.

Q. Did you personally type the words in your Declaration?

A. Some of the words I personally typed. Some of the words were captured by counsel based on conversations, but the Declaration is -- is -- represents my opinions.

Q. Apple retained you as an expert -- well, let me back up.

You're aware that there is an ITC investigation between Apple and Masimo, are you?

A. I am aware, yes.

Q. And Apple retained you as an expert

in that ITC investigation; is that correct?
A. Correct.
Q. And are you aware that that ITC investigation -- in that investigation, there was an evidentiary hearing between June 6th and June 10, 2022?
MR. SMITH: Objection; scope.
Scope. Relevance.
A. I am not aware of that, no.
BY MR. KIANG:
Q. So before you signed this Declaration, you were not aware that there was an evidentiary hearing in the ITC investigation; is that correct?
A. I was retained as an expert, but I had very little engagement with the ITC.
Q. So before you signed this Declaration that we're looking at today, you didn't know about the evidentiary hearing in the ITC investigation; is that correct?
A. I did -- in my mind, I'm not thinking of the evidentiary hearing. I don't

have any recollection of what -- or when that would -- what it is or when it would have been.

Q. Maybe I can say it another way. Are you aware of a trial that happened in the ITC investigation?

A. No.

Q. Before you signed this Declaration, did you review any transcripts of testimony that happened during the ITC investigation?

A. Not that I recall.

Q. Before you signed this Declaration, did you review any of the parties' briefing from the ITC investigation?

A. Not that I recall.

Q. I'd like to turn now to Paragraph 25 of your Declaration.

A. Sorry. Paragraph, what number?

Q. 25.

MR. KIANG: And could I have the hot-seater please pull up Tab 1 on the screen. Paragraph 25 will be on Page 10 to 11.

(Tech complies.)

BY MR. KIANG:

Q. All right. So in Paragraph 25, you set forth a definition of level of ordinary skill in the art.

Do you see that?

A. Yes.

Q. Did you independently come up with this definition -- of this description of level of ordinary skill?

A. This is my opinion regarding what a person of ordinary skill is.

Q. And how did you come to that opinion?

A. Based on my experience, based on my years of doing this type of work.

Q. Did you perform any analysis of the '745 patent in coming to this conclusion about the level of ordinary skill?

A. Well, a person of ordinary skill, as I describe here, would have been a person working -- with a working knowledge of physiological monitoring technologies, would have a bachelor of science degree with experience or alternatively additional education and maybe less experience.

Q. I'm just wondering what your analysis was in coming to that conclusion.

A. The general area of the patent is in the physiological monitoring technologies and this is what a person of ordinary skill in physiological monitoring technologies would possess.

Q. You say here in the first sentence, a person with -- a person -- sorry -- "...a person with a working knowledge of physiological monitoring technologies."

Do you see that?

A. Yes.

Q. What does "working knowledge" mean?

A. A person with working knowledge of what physiological monitoring technologies are, the physiological signals, sensors and systems, data acquisition.

As described here, you know, person with bachelor of science that would have the relevant background of design of electrical computer or software technologies, experience with capture and processing and data not limited to physiological monitoring or that person could have more education, a master of science with less experience.

Q. I'm just wondering: Is there a difference between working knowledge and knowledge in general?

A. It's knowledge.

Q. So could a person just know that physiological monitoring technologies exist, and would that be -- would that be considered working knowledge?

A. As I describe here, a person with both education and experience or within various ratios, you know, with less experience but more education or vice versa.

Q. So in other words, working knowledge means somebody who's actually studied or -- or worked on physiological monitoring technologies; is that right?

A. Well, the sentence is the introductory sentence to the paragraph that describes a person with that working knowledge, and that person would have a bachelor of science degree in an engineering field, such as quatro computer or software technologies, with some training and experience with capture and processing of data or information, including, but not limited to, physiological monitoring. Or that person could have a master of science degree in a relevant domain with less experience, but still some experience.

Q. In the same paragraph, what did you mean by "work experience with capture and processing of data or information, including but not limited to physiological monitoring technologies"?

And let me ask a more specific question.

When you say "including but not

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limited to physiological monitoring technologies," are you saying that a person of ordinary skill doesn't need to have any experience with physiological monitoring technologies?

MR. SMITH: Objection; form.

A. What I'm saying is what I wrote. You know, that person is going to have experience with capture and processing of data or information, including but not limited to physiological monitoring technologies.

A lot of the techniques that are used for monitoring and capturing the data are true whether you're doing physiological or other.

Q. So I -- I just want to be clear.

Are you saying that a person of skill needs to have experience specifically with physiological monitoring technologies and can have additional experience elsewhere? Or are you saying that a person doesn't have to have experience with physiological monitoring technologies as long as they have experience with capturing and processing data or information in another field?

A. I don't think what I said here is ambiguous. If I, you know, look at there at the beginning first sentence, "...(a 'POSITA') would have been a person with working knowledge of physiological monitoring technologies."

And that "...person would have had a Bachelor of Science degree...in electrical, computer, or software technologies, in combination with training or at least 12 years...related...to [sic] capture and processing data, including but not limited to physiological monitoring technologies."

Q. And so I'm actually a little bit confused and that's why I'm asking you these questions.

When you say "including but not limited to," are you saying that, that this -- a person of ordinary skill has to have this work experience with physiological monitoring technologies or is it optional?

A. It's including, but not limited to.
Q. So required?
A. Including.
Q. Okay. And so just as an example, I just want to clear this up.
If I had a computer engineer, and he was working on, let's say, autonomous vehicles and they are working on maybe a LiDAR sensor and so they have two years of experience working on capturing and processing data from that LiDAR sensor, that person doesn't qualify as a person of ordinary skill in the art for the '745 patent; is that correct?
A. Again, a person would have a working knowledge of physiological monitoring, you know, which includes electrical, computer, software technologies, including training, including but not limited to physiological monitoring technologies.
Q. Okay. So if that person never touched physiological monitoring technologies and their -- their only experience was in capturing

and processing data for autonomous vehicles, they wouldn't qualify as a POSITA, right?

A. Again, it's a trade-off between their experience and their skills -- or their education and their experience but has a working knowledge of physiological monitoring technologies as outlined in the first sentence.

Q. So they have no knowledge of physiological monitoring technologies, but they have this other experience, it's not enough, correct?

A. As I said in that first sentence, a working knowledge of physiological monitoring technologies.

Q. Okay. Does a person of ordinary skill in the art need to have any knowledge of physiology?

A. They need to have a working knowledge of physiological monitoring technologies.

Q. Do they need to have any knowledge about the physiology of the human body?

A. They need to have an understanding of physiological monitoring technologies for the -- for and various degrees of experience and education.

Q. So a person of ordinary skill, in order to have this experience or working knowledge you say of physiological monitoring technologies, they would need to have at least some knowledge of physiology; is that correct?

A. They would have to have some knowledge of physiological monitoring technologies.

Q. But not necessarily physiology itself?

A. As a singular thing, you need a collection of experiences. You need physiological monitoring techniques, which includes design of electrical, computer, or software technologies, and experience capturing, processing data information, including but not limited to physiological monitoring.

Q. Now, does a person of ordinary skill

in the art need to have any knowledge or experience with optics?

A. So a person or ordinary skill would have physiological monitoring technologies, electrical, computer, software technologies. They would likely have experience with electrical and optical, acoustic. Again, it's a combination of their education and experiences.

Q. Some of the claims of the '745 patent recite oxygen saturation; is that right?

A. Recite? Sorry.

Q. I'll just say it again.

More generally, at a high level, some of -- some of the claims in the '745 patent deal with oxygen saturation, correct?

A. For example, Claim No. 9 of the '745 patent, "The physiological monitoring device of Claim 1, wherein the physiological parameter comprises oxygen saturation."

Q. Does a person of ordinary skill in the art need to have any specific experience with pulse oximetry?

A. A person skilled in the art would have a working knowledge of physiological monitoring technologies.

Q. Would you agree that somebody with a Ph.D. in biomedical engineering, and 20 years of experience, specifically in pulse oximetry, would have more than a level -- than the ordinary level of skill in the art?

A. They would at least be a person skilled in the art.

Q. They would have more skill in the art than a person of ordinary skill, right?

MR. SMITH: Objection; form. Argumentative.

A. Not opining what a -- a -- beyond person of ordinary skill in the art definition is, but a person skilled in the art would as I describe here.

Q. So you agree, a Ph.D. in biomedical engineering, someone who has 20 years of experience in pulse oximetry, they would at least qualify as a person of skill in the art under your definition; is that correct?

A. They would at least qualify as a person skilled in the art.

Q. Okay. Let's turn now to -- well, actually, it's on the same page -- Paragraph 28 of your Declaration under the section heading "Interpretations of the '745 Patent Claims at Issue."

Now, you see in this paragraph every sentence begins with "I understand that," "I understand that," "I also understand that."

Do you see that?

A. Yes.

Q. And after each sentence, there is a citation to the case Phillips v. AWH Corp.; is that correct?

A. Correct.

Q. Are these statements in Paragraph 28 your opinion on the claim construction, or are you just restating the instructions that you're provided for your analysis?

A. I'm sorry. Can you repeat that?

Q. Sure.

Is Paragraph 28 your opinion or are these instructions that you were provided for your analysis?

A. This is my understanding of -- of, as I describe here, for the purposes of my analysis, the terms appearing in the patent are going to be afforded their ordinary and customary meanings. And I also understand the ordinary and customary meanings of a claim term is the meaning that a term would have to an ordinary person skilled in the art.

That's my understanding.

Q. So you're not providing any particular opinions as to the claim construction on any particular claim term; is that correct?

A. I was not construing particular definitions in my understanding of ordinary and customary meanings. This is what I understand as described in Paragraph 28.

Q. As a general matter, do you agree

that if a claim term has been previously construed that you would want to know that for your analysis?

MR. SMITH: Objection; form.

A. I found no need to construe any terms for my analysis, as I indicated here.

Q. So you found no need to construe the terms; is that right?

A. Correct.

Q. Are you aware that in the ITC investigation, the parties addressed the claim construction of the term "second shape" in Claims 1 and 20?

MR. SMITH: Objection to form. Argumentative.

A. No, I'm not.

BY MR. KIANG:

Q. I'll represent to you that the parties did, in fact, address claim construction of second shape. Now, isn't that something you would want to have known before you wrote this Declaration?

MR. SMITH: Objection; form.

A. These are my opinions. I didn't find it necessary to construe a definition.

BY MR. KIANG:

Q. So with Apple advocated -- and let me back up.

Apple hired you as an expert for this IPR, correct?

A. Correct.

Q. And if Apple proposed a construction of second shape in a previous proceeding, don't you think you would want to know that for your Declaration?

MR. SMITH: Objection; form.

A. Apple didn't tell me what my opinions are. I didn't find it necessary in forming my opinions to construe a -- a term here.

BY MR. KIANG:

Q. So in your opinion, you can ignore what happened in previous proceedings on claim construction; is that correct?

MR. SMITH: Objection; form.

Argumentative.

A. I have not ignored anything. This is what I've -- my opinions.

BY MR. KIANG:

Q. You didn't ignore it, but you also didn't know about it. Is that what you're saying?

A. I was -- my opinions were not necessary -- or my opinions here did not require a construction of any terms.

Q. Are you aware of the general rule that the claim term cannot be construed one way for noninfringement and another way for invalidity?

MR. SMITH: Objection; form. Argumentative.

A. I'm not a legal -- I'm not -- I'm not an attorney. Can you repeat that question? Maybe I misunderstood what you were saying.

BY MR. KIANG:

Q. Are you aware that a claim term cannot be construed one way for noninfringement and another way for invalidity?

MR. SMITH: Objection; form. Foundation.

A. Again, I did not construe any terms -- find it necessary to construe terms. I'm not an expert in the law about the difference between invalidity and --

MR. KIANG: At this time I'd like the court reporter or the hot-seater to please bring up Tab 11.

(Tech complies.)

(Whereupon, Exhibit 2052, Respondent Apple Inc.'s Corrected Pre-Hearing Brief, was identified.)

MR. KIANG: And this has been previously marked as Exhibit 2052 from the IPR.

BY MR. KIANG:

Q. Dr. Anthony, have you ever seen this document before?

A. Not that I recall.

Q. Okay. This is Apple's prehearing

brief, public version at least, in the ITC investigation. You didn't see this document before you signed your Declaration; is that correct?

A. Not that I recall.

Q. And have you ever seen it before today?

A. Not that I recall.

Q. If you go to Page 134 of this document -- sorry -- the numbered Page 134 at the bottom.

MR. SMITH: Daniel, if you could provide him with an electronic copy of this so he doesn't have to rely on the hot-seater.

MR. KIANG: Yeah, there should be a copy available in the Dropbox.

THE WITNESS: (Talking to self.)

A. What's the -- what's the -- what's this called?

BY MR. KIANG:

Q. This should be called either Tab 11 or Exhibit 2052 or both.

A. Okay. On Page 134, you said?
Q. Yeah.
A. Okay.
Q. All right. Now, do you see on this Page 134 there is a section heading "Claim Construction," and then "('Second Shape' Claims 1, 20)"?
A. Yes.
Q. And you see here it says, "Independent Claims 1 and 20 require that" the "material positioned between the light-emitting diode and tissue on the wrist of a user be configured to 'change the first shape into a second shape by which the light emitted from one or more of the plurality of light-emitting diodes is projected towards the tissue."
It's quoting and citing the '745 patent at Claims 1 and 20.
Do you see that?
A. Yes.
Q. And do you see the last sentence of this paragraph? "The Parties agree that a mere

difference in size is neither necessary nor sufficient to change a first shape into the claimed 'second shape.'"

Do you see that?

A. I do see that.

Q. Were you aware that Apple had agreed to this before you signed your Declaration?

MR. SMITH: Objection; form. Argumentative.

A. Not aware, no.

BY MR. KIANG:

Q. Now, Apple advocated for this position or at least agreed to this -- agreed to this in the ITC investigation. Don't you think that you should have been made aware of this before you signed your Declaration?

MR. SMITH: Objection; form and argumentative.

A. Again, you know, I didn't find it necessary to construe in my opinion, in this way.

BY MR. KIANG:

Q. So you didn't find it necessary --

are you saying that you knew about this and you decided it wasn't necessary, or are you saying you didn't know about this and that's why you didn't know you should have construed it?

MR. SMITH: Objection; form. Argumentative. Asked and answered.

A. I neither knew nor found it necessary to construe as what they've agreed here.

BY MR. KIANG:

Q. Now that you've seen that Apple previously agreed to this construction, does that affect your opinions in your Declaration?

MR. SMITH: Objection; form. Argumentative.

A. No, it does not.

BY MR. KIANG:

Q. And how do you know that?

MR. SMITH: Objection; form.

A. Because the opinions that I offered in my Declaration are my opinions. I would have to consider this document and review it in detail to understand, you know, what would be -- why they argued it in this way. But, you know, just seeing this does not in any way change my opinions.

BY MR. KIANG:

Q. And you didn't apply this construction in your analysis in your Declaration; is that correct?

A. As I said, yeah, I did not construe any -- any particular definitions in my analysis.

Q. Do you agree with Apple's statement here that "a mere difference in size is neither necessary nor sufficient to change a first shape into the claimed 'second shape'"?

MR. SMITH: Objection; form. Argumentative.

A. Again, I have not reviewed this document. I'm happy to spend some time reading through it and I'll try to understand what is written here in detail --

BY MR. KIANG:

Q. So --

A. -- if you'd like me to.
Q. So you don't have an opinion about this construction; is that correct?
MR. SMITH: Objection; form.
A. Again, I did not find it necessary in forming my opinions to construct a definition like this. I'm happy to spend some time reading this document if that's the appropriate use of time.
BY MR. KIANG:
Q. Do you disagree with this construction at all?
MR. SMITH: Objection; form.
A. I can -- I would need to review this document to know whether I agree or disagree with what's -- what is written in the document.
BY MR. KIANG:
Q. Are you aware that Apple had also argued for another claim construction in Claims 1 and 20 in the ITC investigation?
MR. SMITH: Objection; form. Argumentative.

A. Again, I'm not aware of the ITC arguments here.

BY MR. KIANG:

Q. Okay. Let's go to Page 135 of this document. And I'm looking at the first paragraph on this page.

Do you see the second sentence? And I'll start reading it for you. "Claims 1 and 20 compose two independent requirements. First, the claimed 'material' must receive light same ('first') shape as light that was emitted by the light-emitting diodes. The limitations require this because the claims recite that (a) the light-emitting diodes emit light 'in a first shape' and (2) the 'material' must change the emitted light from "the first shape into a second shape.' The claimed material cannot change light from 'the first shape from the second shape' unless material received from the 'first shape,' which is the shape emitted from the light emitting diode. Thus, the claims require that the 'first shape' of emitted light remains the same shape until it reaches the 'material.'"

Do you see that?

A. I see where you just read from, yes.

Q. Okay. Were you aware of this before you signed your Declaration?

A. As I've previously answered, I am not familiar with this document.

Q. Do you agree with Apple's position that the claims required that the first shape of emitted light remains the same shape until it reaches the material?

MR. SMITH: Objection; form. Argumentative.

A. I'm referencing my Declaration to reflect -- to recollect my memory as to how I -- my position on this particular Claims 9 and 20 -- 9, 1 and 20.

So as I highlight in, for example, starting at Paragraph 33, of my first Declaration, under "[1.1] a plurality of light-emitting diodes configured to emit light in a first shape..." so in the combination of -- of

Iwamiya and Sarantos, "...'light emitting units 6' that are each; composed a light-emitting diode.'...the light-emitting units...are shown...in Figure 3 from Iwamiya."

Paragraph 34: "The light-emitting units...'emit observation light of a specific wavelength...to optically observed in skin tissue in the human body. The emitted observation light is in a first shape characterized by the specific locations of each light emitting unit...at the 3 and 9 o'clock..."

And then, in 1.2, continuing into Paragraph 35, "...material configured to be positioned between the plurality of light-emitting diodes," et cetera, "...the material considered to change the first shape into a second shape by which the light emitted from one or more of the plurality of light-emitting diodes is projected towards the tissue."

So here I describe in 35 Iwamiya describing the physiological sensor, including an annular light guide, guides the light from the light-emitting units -- annularly diffuses and irradiates the observation light. The annular light guide includes a diffusion radiation ring portion.

Continuing on to Paragraph 36, the "Annular light guide...7 changes the shape of the light emitted from the individual light-emitting units 6 to the annular shape (a second shape) and causes the light to irradiate an annular portion of the tissue."

Again, in forming my opinions in terms of what the combination of Iwamiya and Sarantos discloses, I didn't find it necessary to construe a -- any definition.

BY MR. KIANG:

Q. So you didn't think it was necessary for this definition.

Is that what you're saying?

Let me rephrase.

You didn't think any construction was necessary for your analysis of invalidity; is

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that correct?
A. Correct. As I said in paragraphs back at the beginning here, where I did not need to find it necessary to construe any terms but apply the ordinary and customary meaning.
Q. Now, you've said that was for -- with respect to the Iwamiya and Sarantos combination; is that correct?
A. Correct.
Q. What about your other combination of Sarantos and Shie? Do you think that would be relevant to that?
A. I --
Q. In other words, do you think Apple's advocated position that the first shape of emitted light has to remain the same shape until it reaches the material, do you think it's relevant to the Sarantos and Shie combination?
MR. SMITH: Objection; form. Argumentative.
A. Sarantos and Shie start on 35. That's not 35 -- (talking to self).

So as I say on Page 36 of my first Dec, starting in Paragraph 73, this is the combination of -- if this is right -- Sarantos and Shie. "Sarantos describes a sensor that uses a plurality of LEDs. The light emitted from the LEDs is in a first shape, the first shape being characterized by the specific location of each light-emitting device..."

I continue on to -- skipping through here, well, Paragraph 74, "...Sarantos discloses a plurality of light-emitting diodes configured to emit light in a first shape."

And then down to 76, "...in the combination, Shie describes a diffuser that has a 'light diffusing and shaping advantages' and changes a first shape...into a second shape. It would have been obvious to a POSITA to use the light shape changing material of Shie in the wristwatch sensor of Sarantos in between LEDs...and the user's wrist tissue...in order to change the shape of light emitted by LEDs...into a second shape projected onto the tissue."

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So I did not find it necessary to construe any terms other than plan and ordinary meaning in that construction in that combination.

Q. In Paragraph 75 of your Declaration --

MR. KIANG: And if we can have that Tab 1 pulled up on the screen again.

BY MR. KIANG:

Q. -- you have this figure from Figure 22 of Sarantos.

Do you see that?

A. Yes.

Q. And you have an LED highlighted in green, and that's sitting beneath a window 226 [sic]; is that right?

A. As I say in Paragraph 75, "...shine through a window 2226..." highlighted in orange.

Q. Is there a gap between the LED and that window?

A. Is there a gap? What do you -- what do you mean by a "gap"? The window is an opening.

Q. 2208 is not touching 22 -- the window 2226; is that correct?

MR. SMITH: Objection; form. Argumentative.

A. There is an opening in the -- this is a figure from Sarantos. There is an opening there through the materials, 227 -- or through the 2274 is the in-mold labels. This is a -- one embodiment of a configuration of windows and sensors and light block material.

BY MR. KIANG:

Q. Okay. So my question is: That window, 2226, is it touching 20 -- the LED 2208?

A. As drawn in this figure, it does not appear to be touching. But it's not clear that it is drawn to scale or not.

Q. Okay. Do you know in this figure whether the light emitted from the LED would stay the same shape until it hits the window 2226?

MR. SMITH: Objection; form.

A. There will be a shape, depending on the materials and the -- the LEDs, there will be a first shape coming from the -- the light sources.

Q. And is that first shape coming from a light source, is that going to be the same as the shape of light when it hits the window 2226?

MR. SMITH: Objection; form. Relevance.

A. Again, according to a combination here, as I say in Paragraph 76, in -- "...in the combination, Shie describes a diffuser that has a 'light diffusing and shaping advantages' and changes a first shape of light into a second shape...It would have been obvious to a POSITA in use the light shape changing material of Shie in the wristwatch sensor of Sarantos in between LEDs 2208 and the user's wrist tissue...in order to change the...light emitted by LED 2208 into a second shape projected onto the tissue...A POSITA would have been motivated to use a light shape changing material, such as Shie's, in order to precisely direct the light emitted or the tissue so as to increase power efficiency by shining light closer to photodiodes, to increase accuracy of measurements by directing light toward a larger area to decrease irregular readings," et cetera.

So I'm not talking about the reference in isolation. It's in the combination that I'm referring to in my discussion here.

Q. And in that combination that you're referring to, you didn't perform any analysis of whether the first shape would stay the same shape until it hits the material; is that correct?

MR. SMITH: Objection; form.

A. As I described in my analysis is that, in 76, "...Shie describes a diffuser that has a 'light diffusing and shaping advantages'"...that would change "...a first shape of light into a second shape."

Q. And that's not really my question.

I'm just asking, as we've discussed, Apple advocated for this position, that Claim 1 and Claim 20 requires the first shape of light to stay the same shape until it hits the material.

You didn't perform that analysis with respect to this combination of Sarantos and Shie, correct?

MR. SMITH: Objection; form. Argumentative.

A. Again, I did not find it necessary to construe a particular definition of shape in my analysis. And as I describe in the combination, Shie describes a diffuser that has a light diffusing and shaping advantage which would change a first shape of light into a second shape.

BY MR. KIANG:

Q. Sitting here today, do you have an opinion as to whether Apple's position, that the claims require the first shape of emitted light remains the same shape until it reaches the material, whether that position is correct or incorrect?

MR. SMITH: Objection; form. Argumentative. Relevance.

A. I have not reviewed the document

that is the Exhibit 2052. In my analysis, the shape change is putting -- could include a change of both shape -- or change of -- of scale and change of shape. I didn't find it necessary to construe a particular constraining of what's discussed here.

Q. Now, if Apple advocated for this position in another proceeding, don't you think you would have wanted to at least mention or address in it in your Declaration?

MR. SMITH: Objection; form. Asked and answered.

A. I was not aware of this, as I've said, this -- this construction that is in Exhibit 2052.

BY MR. KIANG:

Q. And did you ever ask Apple whether any claim terms have ever been construed or whether they had a position on claim construction that they took in another proceeding when you signed this Declaration?

MR. SMITH: Objection; form.

Argumentative.

A. Not that I recall, no. Didn't find it necessary to do so and my opinions are established here as I described and didn't need to construe a term.

BY MR. KIANG:

Q. So it's not -- are you saying it's not necessary to ask whether a claim term has ever been construed before when performing your analysis of invalidity?

MR. SMITH: Objection; form. Argumentative.

A. I didn't find it necessary to construe a term in forming my opinions.

MR. KIANG: Why don't we take a quick break. How about five minutes?

THE WITNESS: Five minutes, sure.

THE TECH: Okay. Going off the record, the time is 1:23.

AUTOMATED MESSAGE: Recording stopped.

(Recess taken.)

AUTOMATED MESSAGE: Recording in progress.

THE TECH: We are back on the record. The time is 1:29.

BY MR. KIANG:

Q. Dr. Anthony, did you speak to anybody during the break about the substance of your testimony today?

A. No.

Q. So we were just talking about claim construction on the second shape and you said that you hadn't seen or you didn't know that Apple had proposed construction on that term before.

So in the opinions in your Declaration, you applied a plain and ordinary meaning of second shape; is that correct?

A. Correct.

Q. Okay. And what's the plain and ordinary meaning of second shape?

MR. SMITH: Objection.

A. So as I describe in Paragraph 28,

let's see, so towards the end there, I said, "...a person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification."

So it's the plain and ordinary meaning in the context of the patent.

BY MR. KIANG:

Q. So in the context of the patent, what does "second shape" mean?

A. A second shape.

Q. Yes. What does that mean?

A. Again, I didn't mean to construe a definition of the second shape, but it's a second shape as I describe in paragraph -- for example --

Q. All right. Let me give you an example then.

MR. SMITH: Daniel, I have to ask you to please let him finish his answers and don't -- unless you were done, Dr. Anthony.

THE WITNESS: That's fine. We can -- that's fine.

BY MR. KIANG:

Q. All right. Now, I want you to have in your mind a plain and ordinary meaning of second shape as you described in your -- in your definition. And I want you to imagine, let's say we have a flashlight and it's shining a cone of light onto the floor directly perpendicular to the floor. So on the floor, you see a circle of light, right? Do you have that in your mind?

A. Sure, yes.

Q. Okay. Now, if I put a lens in front of that flashlight, and now that cone of light, let's say it started at a, you know, 30-degree angle and now it's now a 60-degree -- 60-degree angle. Is that a different shape now?

A. Again, I did not need to consider flashing -- shining flashlights on floors. And, frankly, a floor is a degenerate case of an object. It's a perfectly flat thing.

So if we were to instead shine that

flashlight onto a person's arm that has a curvature, it's going to be not only a scaled shape but a very different, both three-dimensional shape as well.

Q. If I had a circle -- if I had light in the shape of a circle and I change it so that it's now a bigger circle, still a circle, is that a -- would that bigger circle be considered a second shape compared to the first shape which is the smaller circle?

A. Again, I didn't need to construe sort of specific circles and specific shapes, but a first shape and a second shape.

And -- but as I described the combination of both Iwamiya and Sarantos and then Sarantos and Shie describe changing a first shape into a second shape.

Q. So in performing your analysis and coming to your conclusion that the prior art supposedly changes the first shape into a second shape, you didn't find it necessary to consider what it means for a first shape -- what it means to be a first shape and a second shape; is that correct?

MR. SMITH: Objection; form. Argumentative.

A. As I describe here, there is a first shape and there is a second shape. And as described in the combinations, you know, Shape 1 is changed into Shape 2.

And in your example of shining onto a floor, that's not an example I needed to consider. And, you know, frankly, there are no places on the human body that are as flat as a floor. So a shape has a planar surface. If we were to planarly slice through it, but, you know, the surface of the body is not planar. So it's going to have a three-dimensional shape in addition to a planar shape.

Q. You can understand that places on a body can be locally planar, is that correct, even if it's globally not planar?

A. Again, it's -- there is a first shape and then there is a second shape. You know, the floor example is a very degenerate situation. The floor is not a human body.

Q. Okay. You agree with me that the first shape has to be different than the second shape?

MR. SMITH: Objection; form.

A. That's not what I said. I said there's was first shape and a second shape.

BY MR. KIANG:

Q. Do they have to be different?

A. In forming my opinions as I describe here, I describe in Paragraph 73 on Page 36 that there is a first shape. And then on 76, how Shie describes a light diffusing and shaping that changes the first shape at the light into a second shape.

In my opinion, the combination meets the limitation of there being a first shape and a second shape and didn't need to construe a more narrow definition of that.

Q. How can it be your combination -- or how can it be your opinion that it meets the limitation of the first shape and the second shape if you can't tell me whether the first shape and the second shape have to be different?

MR. SMITH: Objection; form. Argumentative.

A. As I said, there is a first shape and there's a second shape. Didn't need to construe a more narrow definition of -- of what shape --

BY MR. KIANG:

Q. I'm not asking you to construe it right now. I'm just asking you in the context --

MR. SMITH: Please don't -- please don't let cut him off let him finish.

MR. KIANG: Please don't cut off my questions.

BY MR. KIANG:

Q. I'm asking you, Dr. Anthony, in the context of the '745 patent claims, the claims that recited the first shape and the second shape, does the first shape have to be a different shape than the second shape?

MR. SMITH: Objection; form.

A. So Claim 1.1 says, a plurality of light-emitting diodes configured to emit light into a first shape. And 1.2 is a material configured to be positioned between the plurality of light-emitting diodes and tissue on the wrist of the user when the physiological monitoring device is in use. The material configured to change the first shape into a second shape by which the light emitted from one or more of the plurality of light-emitting diodes is projected towards the tissue.

And as I described in the combination, for example, of Iwamiya and Sarantos, they are changing a first shape into a second shape.

BY MR. KIANG:

Q. That was not responsive to my question. I'm asking you: In the context of the '745 patent, not asking you about the prior art, does the first shape have to be different than the second shape?

MR. SMITH: Objection; form. Asked and answered.

MR. KIANG: It's only asked and answered if he actually answered the question, Counselor.

MR. SMITH: Same objection.

A. So I feel that I have answered the question. You know, as I described, there is in -- in how the 1.1 is there is a first shape and then in 1.2, the materials configured to change the first shape into a second shape.

And didn't feel the need to construe a more narrow definition than the plain and ordinary meaning of that. And as I describe in -- in the paragraphs pointed to previously under the combinations, there is a first shape and changed into a second shape.

Q. All right. Let's take a look at that claim limitation 1.2 that you have on your Declaration, Page 16.

A. Page 16?

Q. Yeah. The claim says, "...material

configured to change the first shape into a second shape..."

Right?

A. "...by which the light emitted from one or more of the plurality of light-emitting diodes is projected towards the tissue."

Q. I want to focus on the word "change."

Would a person of ordinary skill in the art understand that if a first shape has to change into a second shape, second shape has to be different than the first shape?

MR. SMITH: Objection; form.

A. I think a person skilled in the art reading this would read it in the entire context; such that the shape is changed and the person would also understand that the shape that is coming out of the -- that the first shape is a function of the materials, the arrangement of the lights. The second shape is a function of the materials, the curvature of the human body. And that there is a first shape and a second shape

and they are being changed from one to the other.
It's a very degenerate solution to have the exact same shape. Doesn't preclude that it could be. But person skilled in the art would know a first shape and a second shape.

BY MR. KIANG:

Q. And how would they know it's the first shape and the second shape?

A. Well, as taught in Shie or as taught in Sarantos, you know, they simply describe using materials that change the shape or have a shaping functionality.

Q. So a person of ordinary skill looking at the '745 patent, trying to understand what Claim 1 is talking about, would look at the prior art?

A. That's not what I said. I was describing how --

Q. That was what you answered.

A. You've asked the same question multiple times, and I'm trying to answer it.
So I'm pointing to my Declaration.

I'm pointing to the opinions that I've offered as to how the prior art demonstrated that a -- a person skilled in the art would see changing -- would know first shape and second shape changing already existed.

MR. KIANG: Let's bring up Tab 11 again, Exhibit 2052, and go back to Page 134.

BY MR. KIANG:

Q. It has a box at the bottom of the screen. It says, "Claim Term, 'second shape.'"

There is a box for "Apple's Construction," and there is a box for "Masimo's Construction."

Do you see that?

A. Yes.

Q. And under "Apple's Construction," Apple says, "Plain and ordinary meaning (i.e., a shape different than the first shape."

Do you agree with that?

A. Again, I have not reviewed this document. I'm happy to -- you're pointing to it in isolation. I would want to read everything else around it to understand everything that's being said.

BY MR. KIANG:

Q. I mean, you -- so you read the '745 patent, correct?

A. Correct.

Q. And you've read the prosecution history of the '745 patent?

A. I'm far more familiar with the '745 patent than all the details in the prosecution history, but yes.

Q. And you've read the claims of the '745 patent?

A. Correct.

Q. And you've read the specification of the '745 patent?

A. Correct.

Q. And I've asked you today probably about ten times whether the second shape has to be different than the first shape.

Now, given that you've reviewed all of these materials, can you tell me, sitting here today, with Apple's previous construction right into front of you whether you agree that a second shape has to be different than the first shape?

MR. SMITH: Objection; form. Argumentative.

A. I agree as stated there that it's material configured to change the first shape into a second shape.

BY MR. KIANG:

Q. And what you haven't said just now is whether you agree that the second shape has to be different than the first shape; is that correct?

A. I'm sorry. Is what -- is what -- sorry. Is which correct?

Q. Your answer just now did not confirm whether you agree that a second shape has to be a shape different than the first shape.

A. Again, I did not construe a definition in my Declaration. I was pointing to, in my opinions, how doing the combination of Sarantos/Iwamiya and Sarantos and Shie that the

limitation is met in the prior art.
Q. Okay. And I've been asking you what the plain and ordinary meaning of second shape was, and you could not tell me whether the second shape has to be different from the first shape. We'll leave it at that.
Let's turn to your Declaration now, Paragraph 107?
A. 107?
Q. Yes.
A. On Page 50, correct?
Q. Correct.
A. Okay.
Q. These are the -- in Paragraph 107, you set forth the legal principles for an obviousness analysis; is that correct?
A. So as I say here in 107, in my understanding, "I have been informed that a patent claim is invalid as 'obvious' under 35 U.S.C. 103 in light of one or more prior art references if it would have been obvious to a POSITA, taking into account...scope and content

of the prior art...the differences between the prior art and the claims...level of ordinary skill in the art, and...any so-called 'secondary considerations' of nonobviousness, which include...'long felt need' for the claimed invention...commercial success attributable to the claimed invention...unexpected results the claimed invention...and 'copying' of the claimed invention by others."

Q. So based on this paragraph, you would agree that in coming to a conclusion that a patent claim is obvious you would need to consider any secondary considerations of nonobvious; is that correct?

A. As I described here, correct.

Q. Okay. And on my -- and you've heard the term "secondary considerations" referred to as objective indicia of nonobviousness before, correct?

A. Say that more clearly. Sorry.

Q. Let me say that again another way.

I'll -- I'll just say that I might

be calling secondary considerations "objective indicia of nonobviousness" or simply "objective indicia."

Will you understand that?

A. As secondary considerations as you defined it, that's fine.

Q. Okay. Now, you don't address any secondary considerations of nonobviousness in your Declaration, correct?

A. Correct.

Q. Now, before you signed this Declaration, were you aware that Masimo had already argued and presented evidence of secondary considerations of nonobviousness for the '745 patent in the ITC investigation?

A. No, I was not.

Q. When you -- before you signed this Declaration, did you ever ask anyone at Apple whether there was evidence of secondary considerations of nonobviousness?

MR. SMITH: Objection to the form.

A. No, I did not.

THE WITNESS: And Dan, just -- Dan Smith, letting you know you're still echoing.

MR. SMITH: Okay. Sorry.

BY MR. KIANG:

Q. And why didn't you ask?

A. I was not aware of any secondary considerations.

Q. If you're not aware of any secondary considerations, but you also didn't felt -- but you also didn't ask anybody whether there were; is that correct?

A. I don't recall anybody, and in my conversations with counsel, sort of any -- or in my review of the references any kind of secondary considerations.

Q. Okay. So nobody ever told you that there was evidence of secondary considerations regarding claims of the '745 patent before you signed this Declaration?

A. Not that I recall.

Q. Now, if that evidence -- given my representations today that this evidence was already litigated in the ITC, don't you think that that's something you would have wanted to consider in your Declaration before coming to a conclusion of obviousness?

MR. SMITH: Objection; form.

A. Again, I was not aware of those arguments.

BY MR. KIANG:

Q. I understand you weren't aware of those arguments or even the evidence.

But sitting here today, now that I've told you that this evidence existed before you signed this Declaration, don't you think you should have addressed it in your Declaration before you signed it?

MR. SMITH: Objection; form.

A. I was not aware of any secondary considerations, so I did not consider that in forming my opinions.

BY MR. KIANG:

Q. Don't you think Apple's counsel should have given this information to you before you signed this Declaration?

A. I don't claim to be counsel or sort of know what -- why people do things. I did not -- I was not aware of any secondary considerations.

Q. Now, given that Apple itself was aware of this evidence of secondary considerations before you signed your Declaration, don't you think your Declaration's analysis of obviousness is now incomplete because they didn't give you -- give you the information on secondary considerations?

MR. SMITH: Objection; form. Argumentative.

A. I'm still unaware of what the secondary considerations are and I would need to review them to determine whether I thought they were secondary considerations or not, so.

BY MR. KIANG:

Q. Okay. Did you review Patent Owner's preliminary response in this IPR before today?

A. Sorry. Did I review what?

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Q. So in this IPR, are you aware that Masimo filed a preliminary response before the institution of this IPR?

A. Yeah, I believe that's standard practice, I believe.

Q. Did you -- did you review that Declaration -- sorry.

Did you review that preliminary response?

A. I did not.

Q. Are you aware that Masimo's expert in this IPR, Dr. Duckworth, that he prepared a Declaration and submitted it with the preliminary response in this IPR?

A. I believe I saw a file name at some point related to that, but I have not reviewed any document such as that.

Q. So before you signed your Declaration, you weren't aware of any secondary considerations evidence, correct?

A. Correct.

Q. And even as of today, you still

haven't seen any secondary considerations evidence, correct?

A. That is correct.

Q. Don't you think that would have been relevant to your analysis in this Declaration?

MR. SMITH: Objection; form. Argumentative.

A. Again, the relevance of the secondary considerations that you're alluding to, I have not seen them so I don't know if it would have changed my opinion or not until I would have the opportunity to review them.

BY MR. KIANG:

Q. Whether it changes your opinion or not, don't you think you would have liked to see them?

MR. SMITH: Objection; form. Argumentative.

A. I was not aware of any secondary considerations. What can I say?

BY MR. KIANG:

Q. If you were provided them -- if you

were provided with evidence of secondary considerations, would you have considered it and addressed it in your Report, had you been aware of it?

A. If I had been aware of secondary considerations that were -- that would have impacted my opinion, then certainly.

Q. So if they didn't impact your opinion, you wouldn't even mention it?

A. I don't know what the secondary considerations are, so I don't know until I would review them whether I would consider them secondary considerations or not.

Q. Let's turn back a page to Paragraphs 105 and 106. You see here you have a heading for "Anticipation"?

A. Yes.

Q. And does your Declaration set forth any opinions that any patent claims in the '745 patent are anticipated by prior art?

A. As I describe here, my understanding is that "I have been informed that a patent claim is invalid as anticipated...if each and every element of a claim, as properly construed is found implicitly or inherently in a single prior art reference. Under the principles of inherency, if the prior necessarily functions in accordance with, or includes the claimed limitations, it anticipates.

"I have been informed that a claim is invalid under 35 U.S.C. § 102 (a) if the claimed invention was known or used by others in the U.S., or was patented or published" elsewhere, before the application's invention. "I further have been informed that a claim is invalid... if the invention was patented or published" elsewhere, or was in public use, or sale, et cetera.

So anticipation, as I understand here, you know, explicitly, inherently in a single prior art references -- in a reference. My prior art analysis, as I described, is in combinations, and so it's not -- and -- and what a person of skill in the art would find obvious.

So I'm not pointing to an anticipatory claim as I understand it.

Q. Okay. Some of the '745 patent claims talk about a dark-colored coating.

Do you recall that?

A. For example, in 1.4 of the '745 patent, a surface comprising a dark-colored coating.

Q. Okay. What is your understanding of a coating?

A. So, for example, I would point to Paragraph 41 on Page 21, you know, highlighting the combination of Sarantos and Iwamiya. "...in the combination, Sarantos discloses a wrist-worn reflectance-based psychological sensor that has a dark-colored coating to block light."

Q. Okay. So what's a coating?

A. Again, applying its plain and ordinary meaning and didn't need to construe definition of coating. It's something that coats or covers.

Q. Something that coats. It has to

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coat something, right?
A. Coats, covers, dark-colored coating to block light as described in Paragraph 41, for example.
Q. If I paint a wall, if I cover a wall with paint, is the paint considered a coating?
A. I didn't need to consider painting walls in my analysis, but a paint of wall -- or a painted wall certainly has a coat of paint on it.
Q. How about the wall itself, is that a coating?
A. The wall itself? I mean, very few things are -- I'm not sure what you mean by "the wall itself." There's always coating on any surface of -- of -- but I mean, you're highlighting a wall and paint.
Q. Right, I'm -- I'm talking about painted wall, and I think you agreed that the paint itself would be considered a coating on the wall, right?
A. Certainly, a coat of paint is a coat of paint.

Q. Okay. Is the wall considered a coating?

A. Again, I'm not sure of the context of --

Q. Same context, painted wall, is the wall itself a coating?

A. A wall is a wall. There's coatings. There's walls. I don't -- did not need to talk about painted walls in...

Q. You would agree with me, it doesn't really make sense, right, to call it a wall by itself painting -- or a coating, right? If I'm talking about painting a wall, it's the paint that's coating, not the wall, correct?

MR. SMITH: Objection; form. Argumentative.

A. Is there a place in my Declaration that I talk about painted walls?

BY MR. KIANG:

Q. No. I'm just asking you.

A. I didn't need to consider painted walls in my Declaration. If you have a particular context, happy to --

Q. Let's imagine I have a wall, right, and I make it super thin, make the wall out of paper. Is the wall now considered a coating?

A. So in the context of the -- the patent, for example, on Page 20, like under Paragraph 40, "In the combination, Iwamiya describes a 'light shielding frame'...surrounding the photodiodes. As shown in FIG 4 from Iwamiya, the light shielding frame...is positioned between the photodiodes...and the tissue."

"...in the combination, Sarantos discloses a wrist-worn reflectance-based physiological sensor that has a dark-colored coating...to block light." And Sarantos also discloses that the light source emits light through the window where the light is reflected, et cetera.

Sarantos discloses the in-mold label may be black or otherwise rendered opaque to the light to prevent light from entering or exiting through the window.

"A POSITA" -- in Paragraph 42 -- "would have been motivated to employ an in-mold label or other black or opaque material... in the light shielding frame..."

And then also when I talk about it Paragraph 79 on Page 39, in the combination of Sarantos and Shie figure -- Paragraph 29 -- 79, "FIG. 22...Sarantos depicts a surface with a dark-colored coating...is positioned between the photodiodes and tissue of the user's wrist."

So I was talking about coatings in context of the patent in terms of my opinion here in terms of the prior art that I was referencing.

Q. So I still want to get your opinion as to if I made a wall very thin, would the wall become a coating?

A. Certainly could be if it's a -- if it's part of another sort of, it's a wall sandwich. What's a coating with a -- you know, it's again, this is matter of context. And, you know, this is not a context that I was considering for as I described here.

Q. What do you mean by "wall sandwich"?

A. You're describing a wall and painting a wall. I don't know what the wall is. I don't know that -- I'm not -- there's no context of what you're describing. I'm talking about the context of the -- of here and the combinations with dark-colored coatings.

Q. Okay. You would agree that a coating has to be applied to some kind of substrate, right?

MR. SMITH: Objection; form. Argumentative.

A. Didn't need to opine on substrate and whether that's an appropriate definition. You know, again, didn't need to construct a particular definition. But using it in the context of plain and ordinary meaning is in the -- in the patent.

Q. Now -- if you have any concern with the word "substrate," let me just take it back a little bit more generally.

A coating has to be applied to

something, correct?

MR. SMITH: Objection; form.

A. Coating is probably attached to something, how it's applied. You know, it's on a "something."

Q. Yeah. Attached to something. Okay. Fair enough.

Let me direct you to Paragraph 42 of your Declaration. Page 22.

THE TECH: Sorry. What paragraph did you say? I missed that.

MR. KIANG: 42.

THE TECH: 42. Thank you.

BY MR. KIANG:

Q. You see kind of towards the bottom of this page you have a sentence: "A POSITA would have known that a light shielding frame 18 or holder portion 43 as disclosed by Iwamiya can be of various proportions, and a thin surface is a coating."

Do you see that?

A. Yes.

Q. Do you agree with that statement?
A. This is my statement, yes.
Q. So you agree that you take a light shielding frame and you make it a thin surface, it become a coating?
MR. SMITH: Objection; form. Argumentative.
A. So as I described in that entire paragraph, "A POSITA would have been motivated to employ an in-mold label or other black or opaque material as disclosed by Sarantos in the light shielding frame...to serve the purpose indicated by the component's name: shielding...from stray light...thereby ensuring accuracy of the sensor... A POSITA would have understood that a dark-colored coating, such as described by Sarantos, would have served this purpose by not only blocking light but also by limiting reflections, which could lead to stray light being incident on the photodiodes...It also would have been obvious to a POSITA to use a dark-colored coating for light shielding

frame...because dark-colored coatings and materials were well known to effectively block light...A POSITA would have know that a light shielding frame...or holder...as disclosed by Iwamiya can be of various proportions, and a think surface is a coating... Because using dark-colored coatings in light blocks was so well known, and Iwamiya and Sarantos are both wrist-worn reflectance-based...sensors, a POSITA would have reasonably understood the combination of Iwamiya and Sarantos to be successful with no unexpected results."

BY MR. KIANG:

Q. Okay. So you just read the paragraph back to me, but I'm still wondering about that -- that sentence.

Are you saying that you can take a light shielding frame, make it thin, and it suddenly becomes a coating?

MR. SMITH: Objection; form.

A. Again, this is a sentence in this larger paragraph describing how the combination of coatings and thin films. And you have a thin film on one -- a film can be of and would maybe potentially be called a film in one scenario and a coating on -- in another scenario, depending on the -- the relative dimensions. But a film coating, this is, you know, plain and ordinary meanings here as to how the combination meets the limitation.

Q. So, again, going back to my hypothetical now, when I was asking you about a wall being made thin enough and whether that would become a coating just by making it thin.

Are you suggesting here that by taking a light shielding frame 18 and making it very thin, it suddenly becomes a coating?

A. Well, for example, if I take my anti-reflective coating on my glasses, you know, that is a thin film. It's a coating. It's a film. It's a thin wall. It's a coating.

Q. But it's still -- that anti-reflective film is still attached to the lenses of your glasses, correct?

A. So when I remove it from the glasses, it would cease to be a film or cease to be a coating?

Q. That's what I'm asking you, yeah.

A. It's -- I think it's a -- there's a -- there's a light blocking material that is a, as I describe here -- hold on -- a dark-colored coating.

Q. So just having the screen by itself qualifies as a coating.

Is that what you're saying?

A. I'm not saying anything in isolation. I'm pointing to the combination of Iwamiya and Sarantos.

Q. So the frame would need to have some kind of coating applied to it, correct?

MR. SMITH: Objection; form.

A. You know, as I say here, it can be -- of various proportions using dark-colored coatings the light block was well known.

Q. So in that sentence, a person -- a POSITA would have known that a light shielding frame 18 or a holder portion 43 as disclosed by Iwamiya can be of various proportions, and a thin surface is a coating.

Are you envisioning that the light shielding frame 18 or holder portion 43 has something applied to it that is the coating, or are you saying that the frame 18 or the holder portion 43 is itself the coating?

MR. SMITH: Objection; form.

A. So as I highlight in figure 4, the next page, Page 23, light shielding frame with a dark-colored coating.

BY MR. KIANG:

Q. So it's not the frame by itself, correct?

A. Again, I'm pointing to the combination. So I'm not pointing to Iwamiya or Sarantos by itself. There's -- there's coatings, there's structure and there's dark -- darkness.

Q. So your opinion as to the dark-colored coating is based on what -- based on the numeral 2276 in Figure 22 of Sarantos, correct?

MR. SMITH: Objection; form.

A. I'm sorry. Can you say that again?

BY MR. KIANG:

Q. Yeah. Let me rephrase. Let's go back to Paragraph 41 of your Declaration.

A. Okay.

Q. So you say here, "...Sarantos discloses a wrist-worn reflectance-based physiological sensor that has a dark-colored coating 2276..."

Correct?

A. Yes.

Q. And Sarantos describes that, what you -- what you're saying is a dark-colored coating as an in-mold label or painted or silk-screened mask, correct?

A. "...Sarantos discloses that 'in-mold label...may be black or otherwise rendered opaque...Sarantos explains that various masking techniques may be used to block stray light from reaching the photodetector...including 'a painted or silk-screened mask' applied to the window."

Q. So what you've been saying is a dark-colored coating is -- is the in-mold label or painted or silk-screened mask in Sarantos, correct?

A. As I described in Paragraph 41.

MR. KIANG: Can I have the hot-seater please bring up Exhibit -- sorry, Tab 5, which is Exhibit 1005.

(Tech complies.)

(Whereupon, Exhibit 1005, U.S. Patent 9,392,946-Sarantos, was identified.)

BY MR. KIANG:

Q. And let's go to Column 17.

And let's focus on the top -- the top left paragraph on Column 17.

Do you see this on the screen, Dr. Anthony?

A. Paragraph at the top of 17, yes.

Q. Is this what you rely on in Sarantos for the dark-colored coating?

A. So, yeah, as I said in Paragraph 41,

I'm referencing Apple 1005, which is the Sarantos, Column 17, 1 through 16, masking techniques may be used to block stray light including a painted or silk-screened mask applied to the window.

Q. Now, do you agree that in Sarantos the in-mold label or the painted or silk-screened mask is applied to a translucent or a transparent material?

If it helps, I'm looking at Column 17, Lines 4 to 6.

A. Sorry. Can you repeat the question?

Q. Yeah. I'm just asking: Do you agree in Sarantos the in-mold label or the painted or silk-screened mask is applied to a translucent or a transparent material?

A. "...in-mold label may be black or otherwise rendered opaque to prevent light from entering or exiting...other masking techniques..." may be "...applied to the window...in this implementation..." be "...translucent or transparent material...special transparent acrylic, with an in-mold label..." is "...embedded within it. The in-mold label may be black or otherwise rendered opaque..."

So, yeah, I agree with what's written there that as what Sarantos says.

Q. And you agree that in Sarantos talks about using this in-mold label or the painted or silk-screened mask to define a window in those translucent or transparent material, correct?

A. So as described roughly at -- in Sarantos, in isolation, you know, keeping in mind that I've been using it in combination with Iwamiya. But in Sarantos by itself, "The window 2278, in this implementation, is made from a translucent or transparent material, such as transparent acrylic, with an in-mold label embedded within it. The in-mold label may be black or otherwise rendered opaque to light to prevent light from entering or exiting the sensor through the window except through the window regions."

Q. So in Sarantos, there is this

in-mold label that's applied to a translucent or transparent material, correct? And without that in-mold label or without that painted or silk-screened mask, the whole thing would just be translucent or transparent, correct?

MR. SMITH: Objection; form. Argumentative.

A. So I guess pointing, to as I described in Paragraph 79, on Page 39, "...Sarantos depicts a surface with a dark-colored coating (window 2226 with in-mold label 2276)...the openings 2226 in the dark-colored coating allow light reflected from the tissue to reach photodiodes." The annotated FIG. 22 shows the window with in-mold labels.

And then in Paragraph 80, "...Sarantos discloses that the in-mold label...applied to the window can be black or opaque...explains that various types of surfaces with dark-colored coatings may be used to block the stray light...including 'a painted or silk-screened mask' applied to the window..."

So there is a coating to change the opacity to black or white except through the window section.

Q. And Sarantos uses that dark-colored coating because otherwise, this material which is translucent or transparent would just let light through, correct?

A. It's defining a window with a dark-colored material.

Q. All right. And if that dark-colored material were not there, you would just have a translucent or transparent material, correct?

MR. SMITH: Objection; form.

A. So at least in Sarantos in isolation, you know, they're highlighting that it's made -- the particular implementation is made from a translucent or transparent material.

So, you know, in that implementation in Sarantos, it's describing that that thing is a translucent or transparent material.

BY MR. KIANG:

Q. Now, going back to your Declaration

around Paragraphs 40 to 41 -- can we have that on the screen.

So in the Iwamiya and Sarantos combination that you've presented an opinion on, you've opined that a person of skill would take a dark-colored coating from Sarantos and put it on the light shield 18 in Iwamiya, correct?

A. So as I describe in Paragraph 42, midway through, would have been -- "...also would have been obvious to a POSITA to use a dark-colored coating for the light shielding frame 18 because the dark-colored coating and materials were well-known to effectively block light."

Q. Does Iwamiya ever describe the light shielding frame 18 as being transparent or translucent?

Let me ask you a different -- let me rephrase the question.

A. Your question was whether or not Iwamiya ever describes the light shielding frame as transparent, correct?

Q. Translucent or transparent, yeah.

A. I was reading through the Iwamiya document.

Q. Iwamiya calls it a light shielding frame 18, correct?

A. Which question do you want me to -- sorry. Do we have two questions in a row now?

Q. You can ignore the first question. It's taking a little bit. I don't want you to sit there and read the whole patent.

You agree that Iwamiya calls numeral 18 a light shielding frame, correct?

A. As described in Paragraph 43, Iwamiya describes -- yeah, "...filter 17 that is 'mounted on the lower side of the light shielding frame 18' between the photodiodes."

This combination is shown in the annotated Figure 4 on Page 23.

Q. Would a person of ordinary skill in the art looking at Iwamiya understand a light shielding frame 18 be translucent or transparent?

A. A person of skill in the art would

read it as a light shielding frame but would also know that, you know, light shielding can be improved with coatings and, you know, the combination. I highlighted how the combination, it maximally helps to improve the performance of the light-blocking characteristics.

Q. So a person of ordinary skill, they see it's called a light shielding frame. They wouldn't think that it's translucent or transparent, correct?

MR. SMITH: Objection; form.

A. They would read it as a light shielding frame. But it's unclear as to whether it is completely opaque or partially opaque but a filter -- a person skilled in the art -- or a dark-colored coating would certainly have the effect of improving that light-blocking characteristic, which would improve performance.

MR. SMITH: Counsel, when you get a chance for a break, we've been going about an hour, just letting you know.

MR. KIANG: Let me finish this line

of questioning first. Probably another 10 minutes or so.

MR. SMITH: Okay.

BY MR. KIANG:

Q. So Iwamiya says to use a light-shielding frame. A person of skill in the art wouldn't think that you can use something that's translucent or transparent to do light shielding, correct?

MR. SMITH: Objection; form. Argumentative.

A. A person of skilled in the art would understand it's a light shielding frame, but that also, you know, shielding doesn't necessarily mean completely blocking. Depending on the design considerations, would look to a reference such as Iwamiya to know how to improve its blocking characteristics as they describe here in the Iwamiya, deploying a dark-colored coating such as described by Sarantos.

BY MR. KIANG:

Q. Can light shielding be performed by

using a reflective material?

A. Again, it depends on the design context of what you're trying to shield and what the overall thing that you're trying to accomplish, but you can prevent -- you know, either light is absorbed or reflected or transmitted. And a coating in a surface is going to have various attributes, so those three energy facts.

Q. And so if a person of ordinary skill wanted to prevent transmission of light through a material, they would know that a reflective material can accomplish that, correct?

A. A person skilled in the art would know there are multiple ways to accomplish the -- an absence of transmission through something. It could be absorption. It could be reflection.

Q. And to prevent transmission of light through material, the material just has to be opaque, correct?

A. And that goes counter to what you were just asking, about something being reflective. You'd want to prevent transmission. Some things can be absorbed. Things can be reflected. So it depends on how you're choosing for the particular design to accomplish the lack of transmission through.

Q. Explain to me why you thought what I just said was counter to what I had previously said.

A. Just prior you asked something about a reflective surface and then you said a opaque surface.

Q. In your opinion, is a reflective surface opaque?

A. That's not what you asked. You asked whether a reflective surface -- I forget now what you asked, but you asked something about a reflective surface blocking light or an opaque surface blocking light. I was highlighting the fact that shielding could be accomplished by reflection, by absorption, to -- to improve the light-blocking characteristics as they're described in the combination with Sarantos and

Iwamiya. A person skilled in the art would be motivated to control the stray light and add a dark-colored coating to the light shielding frame.

Q. Would a reflective material be considered opaque?

A. To what wavelength? It depends on the wavelength. And again, I mean, what we're trying to accomplish here is a blocking of light, shunting between directly there to the photodiode. And so the light-shielding frame as augmented with a dark-colored coating, would -- a POSITA would, given design considerations, know how to use that to improve the light-blocking characteristics.

Q. Would a reflective material that reflects wavelengths in a certain bandwidth or a certain frequency band of wavelengths be considered opaque to those -- that same frequency band?

You know what, let me restart that question. Doesn't make any sense for me to talk

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frequency band and wavelength at the same time.
Would a reflective material that reflects light of certain wavelengths be considered opaque to those same wavelengths?
A. Let me repeat that back. Would a material that is opaque also be considered reflective?
Q. That's not exactly what I answered [sic], but sure, can you please answer that question?
A. So a material, any -- anything that light is going to hit up against, light is either going to reflect off of it, pass through it, or be absorbed by it in various combinations.
So a material can be both reflective partially, and transmissive partially and absorptive partially, and depends on the materials and the wavelength. And if we want to accomplish both light blocking and minimize scattering, for example, and stray light generated, which a person skilled in the art would be motivated to do, I think a person

skilled in the art would understand the benefit, as I describe here, of having the light shielding frame augmented with a dark-colored coating to control both transmission through and stray scattering throughout the noise.

Q. I'm just trying to get at a much simpler question.

Are you considering -- would a person of ordinary -- let me rephrase.

Would a person of ordinary skill consider a reflective material to be opaque?

A. Again, a material -- you're asking an absolute, and a material is not an absolute. It depends on relative transmission, relative thickness, relative wavelength -- wavelength.

So a material can be both reflective and opaque and transmissive to various orders. So it's not a -- it's only this or it's only this unless it's a vacuum.

Q. Are you equating opacity with absorption?

A. The act of being opaque is there is

light that's going to be blocked by, reflected from, and transmitted through a material depending on what it is and what the pigments are and what the -- what the materials are, right? So it's -- again, it's not a binary or a tertiary sort of singular statement.

Q. All right. What do you understand opaque to mean?

A. Didn't need to construe a definition of opacity. But opaque, you're not seeing clearly through it generally. The act of not seeing through it clearly is going to be scattering and/or absorbing light. Opaqueness can be accomplished with nonuniformity of the material, with additional sort of pigments. But, again, a material is going to transmit, absorb, or reflect to various orders.

Q. Let's go to Paragraph 42 of your Declaration. And let's see, in -- all right.

Do you see the first sentence? A person of skill -- "A POSITA would have been motivated to employ an in-mold label or other black or opaque material as disclosed by Sarantos in the light shielding frame 18 of Iwamiya to serve the purpose indicated by the component's name: shielding the photodiodes 9 from stray light..."

What did you mean by "stray light"?

A. Light that you don't want where it's going.

Q. Where does the stray light come from?

A. You want light to pass through the material or through the tissue and not be directly going between transmitter and emitter. And you want to hold their reflections within the device itself, so you are controlling your light paths and where light gets.

Q. So when you're talking about stray light, are you talking about light that's being emitted from LEDs or in the case of Iwamiya, they're called light emission units 6?

A. I'm sorry. Can you repeat the question?

Q. Sure.
When you say stray light here in your Declaration, in Paragraph 42, are you talking about light that's being emitted from the LEDs in the sensor?
A. As I describe further in 42, right, shielding the photodiodes from stray light and thereby ensuring accuracy of the sensor, "a POSITA would have understood that a dark-colored coating...would have served this purpose by not only blocking light but also limiting reflections, which could lead to stray light being incident on the photodiodes..."
Right? So it's -- it's controlling the light paths of directly from emitter to detector.
Q. And so when you're talking about stray light, you're just talking about light that was originally emitted from the LEDs; is that correct?
A. Stray light is any path of light that is either directly from the LED to the --

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from the emitter to the detector. Stray light could also come from external sources of stray light. Let me read here in more detail. Let me see.

Stay light can be both sort of coming from the directly stray that you would not want direct from transmit to emit or sort of controlling the path by which light is coming in from -- from outside the device.

MR. SMITH: Counsel, we've been going for, you know, 13 minutes since the -- you know, since I brought up the break.

Should we go ahead and take the break at this point and then continue?

MR. KIANG: Yeah. That's fine.

MR. SMITH: Okay.

THE TECH: Okay. We are going off the record. The time is 2:43.

AUTOMATED MESSAGE: Recording stopped.

(Whereupon a lunch recess was taken at 2:43 p.m.)

A F T E R N O O N   S E S S I O N

(Time noted: 3:16 p.m.)

* * *

AUTOMATED MESSAGE: Recording in progress.

THE TECH: We are back on the record. The time is 3:16.

MR. KIANG: Sorry. Actually, give me one second. I just realized my door is open. Let me close it. All right. Sorry about that.

BY MR. KIANG:

Q. Okay. Dr. Anthony, did you speak to anybody about the substance of your testimony today during the break?

A. No.

Q. I want to talk about Iwamiya for a bit.

Do you agree that Iwamiya discloses the use of only a single wavelength of light?

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A. So Iwamiya discusses sort of throughout -- for example, in Column 1 talks about 600 nanometers. Then at the bottom and then it talks in Column 6 around Line 42 about 40 nanometers. In Column 18 talks about 900 nanometers or less; and then 940 -- 940 nanometers, more or less. It talks about different wavelengths being possibilities for different levels of sensitivity in devices.

Q. You mentioned in Column 1 a reference to 600 nanometers.

MR. KIANG: Let's -- can I please have the hot-seater pull up Tab -- Tab 4? And let's go to Column 1. This is Exhibit 1004.

(Tech complies.)

(Whereupon, Exhibit 1004, U.S. Patent 8,670,819-Iwamiya, was identified.)

MR. KIANG: And can we please go to Column 1 in this document?

THE TECH: Yeah. I'm trying to find it. I don't know what page it's on.

THE WITNESS: 27.

MR. KIANG: And I think you're talking about something Column 1 around Lines 40 to 50ish, right?

A. That is one of the mentions of 600 nanometers, yes. And then it goes on in other columns to talk about 900 and 940 as being preferential for some applications.

Q. And this is a description of related art, correct? What's discussed here in Column 1 of Iwamiya is talking about related art, correct?

A. Correct. In the background of the invention.

Q. Okay. So it's not talking about Iwamiya itself; is that right?

MR. SMITH: Objection; form.

A. You asked if Iwamiya talked about --

BY MR. KIANG:

Q. Let me rephrase that question.

It's not -- this discussion on Column 1 is Iwamiya, it's not talking about the sensor that's described in Iwamiya's figures; is

that correct?
A. It's providing the background and talking about 600 nanometers or less. And limitations in some applications. And then on Column 18, for example, it talks about different wavelengths and its embodiments both at 940 and at 900.
Q. Go to Column 18 which is on Page 35. Where are you seeing a reference to 900?
A. Column 18, around Lines 51 through 60 is one of the paragraphs, and the paragraph before it talks about 940.
Q. Okay. And the paragraph that begins on Column 18 starting at Line 51, that reference to 900 nanometers, that's talking about the optical filter, correct?
A. So similar to the first embodiment, optical filter 17 is configured to transmit light of a specific wavelength band of 900 nanometers or more and shield light of a wavelength band of 900 nanometers or less and then similarly, it talks about it in the same way in the paragraph

prior. You just get the light at 940 more or less.

Q. Maybe my question should have been a little bit more specific.

Iwamiya only talks about emitting light at a single wavelength of 940 nanometers, correct?

MR. SMITH: Objection; form.

A. I'm sorry. Ask the question again, please?

BY MR. KIANG:

Q. Iwamiya only talks about emitting light at a single wavelength of 940 nanometers, correct?

A. That's not correct because on Line 56, it also says "...configured to transmit light of a specific wavelength band of 900 nm or more..."

Q. Is the optical filter a light emitter?

A. Oh, I see the optical filter there.

So I'm just answering your first

question.

So Iwamiya talks about multiple wavelengths. Indeed in Column 15, it talks about configured to emit in a particular embodiment 940 and then those paragraphs in 18, talking about the spectral sensitivity of the receiving element having bands between 940 and 900, for example. So it's not silent on -- it certainly talks about multiple wavelengths.

Q. But in terms of the light-emitting unit, it's only talking about emitting light at 940 nanometers, correct?

A. So Iwamiya sort of generally focuses on one length, but as I describe in my -- in Declaration No. 2, for example, in Page 32 in Paragraph 53, you know, I don't talk about Iwamiya by itself. But, you know, "...Sarantos discloses including LED configured to emit different wavelengths...and a POSITA would have been motivated to" use "the LEDs in the Iwamiya's sensor" -- to -- and expand the number of physiological measurements that could be measured by having multiple light sources as -- as in Sarantos.

Q. We'll get to your second Declaration a little bit later today.

But looking at your first Declaration for the 1291 IPR, can we go to page -- Paragraph 70?

A. Yes, that is roughly the same paragraph that I described in the earlier -- in the second Declaration.

Q. And so in Paragraph 70, you didn't argue that Iwamiya by itself discloses a first and second wavelength; is that correct?

A. There was Iwamiya in the combination.

Q. So Iwamiya by itself doesn't have the first and second wavelength; is that correct?

MR. SMITH: Objection; form.

A. Again, I was not offering opinions of Iwamiya by itself but in combination. And Iwamiya, as we've discussed, is sort of focused around singular wavelengths, but POSITA, as I describe in Paragraph 70, the first Dec -- my apologies -- would have been motivated to include the sensors, the Iwamiya sensors, and the additional wavelengths to form a larger number of physiological measurements, increasing the functionality of the sensor.

BY MR. KIANG:

Q. And when you say "enable the sensor to perform a larger number of physiological measurements," are you talking about oxygen saturation?

A. I'm talking about a larger number of physiological measurements.

Q. Meaning what?

A. Oxygen saturation is one possibility, yes.

Q. Anything else?

A. Plethysmography, heart rate, better resolution on heart rate to multiple wavelengths, to name a few.

Q. Iwamiya already discloses heart rate; isn't that correct?

A. Certainly but a person skilled in the art familiar with instrumentation sensing know that you'll get better signal to noise if you have multiple techniques to make the same measurement. So even if you wanted to just focus on heart rate, multiple wavelengths would give you sort of redundant signals and improve potentially your signal-to-noise ratio.

Q. Let's turn back now to Paragraph 47 of this Declaration.

And you see in the first sentence of Paragraph 47, you say, "In the combination, Iwamiya discloses a sensor that detects 'biological information,' which includes oxygen saturation..."

Do you see that?

A. Yes.

Q. Do you agree that Iwamiya does not talk about oxygen saturation?

A. Again, I was not offering opinions regarding Iwamiya in isolation, but in the combination, Iwamiya discloses sensors that detects biological information. Biological information does include oxygen saturation. They're talk about in the combination. "...and provides examples of" pulse rate -- "pulse wave and heart rate wherein oxygen saturation different wavelengths."

Q. All right. What do you cite for this sentence?

A. Apple 1004, 1004.

Q. That's Iwamiya, correct?

A. That's Iwamiya, correct.

Q. You don't cite anything else?

A. Well, in the combination -- so in the combination is what I'm discussing in that sentence.

Q. But you'd agree then Iwamiya by itself does not talk about oxygen saturation?

A. Again, I agree that in the combination, it is discussed and Iwamiya discloses sensors that measures biological information. Was not opining about what Iwamiya does by itself but the combination.

Q. Do you think Iwamiya discloses oxygen saturation?

A. It focuses on heart rate broadly as an example but biological information more broadly. There are other examples of biological information as enabled by the combination of Iwamiya and Sarantos using multiple wavelengths.

Q. So are you saying that just by -- in the absence of the combination, Iwamiya by itself doesn't talk about oxygen saturation; is that correct?

A. Again, I was not discussing Iwamiya by itself. It focuses on biologic information and heart rate and then the combination, you know, adding a broader -- broader range of biological information that can be obtained with the multiple wavelengths.

Q. So you would have to add something to Iwamiya for it to get oxygen saturation. Is that what you're saying?

A. I'm saying in the combination, a broader set of biological information such as including heart rate, you know, better measurement of heart rate would be -- would result in the combination. Heart rate by itself is feasible through single wavelength. Pulse ox, you'll need the multiple to get a strong powerful signal so we're talking about in the combination.

Q. So when a person of ordinary skill in the art reads Iwamiya and sees biological information, a person of skill in the art wouldn't understand you have to disclose any type of biological information, correct?

MR. SMITH: Objection to form.

A. I'm sorry. Can you repeat that?

BY MR. KIANG:

Q. When a person of ordinary skill in the art is looking at Iwamiya and sees the words "biological information" they would not understand Iwamiya to disclose any type of biological information, correct?

MR. SMITH: Same objection.

A. Well, a person of skill in the art at this -- what is it -- 2015 date would be very familiar with pulse ox. Would be reading Iwamiya and would know the benefit of adding and including multiple sensors. Would reference, for example, Sarantos for more detail on how to do that.

But if not any possible, as we've said before, you know, you can get some set of things with one, some set of information with two, and a person of skill in the art would certainly understand that.

BY MR. KIANG:

Q. In the same sentence at the very end, you said, "...oxygen saturation comprises heart rate sensing at different wavelengths."

Do you see that?

A. Yes.

Q. What do you cite to support that?

A. What is cited there is -- is Iwamiya.

Q. Let's go to Iwamiya, Exhibit 1004.

A. Go ahead. Sorry.

MR. KIANG: Can we have the -- yeah.

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Bring that up. Let's go to that cited section, which was Column 8, Line 61. And over to Column 9.

BY MR. KIANG:

Q. Now, do you see this on the screen? We have Iwamiya Column 8, Line 61 through 67.

A. Yes.

Q. Does this section say that oxygen saturation comprises heart rate sensing at two -- at different wavelengths?

A. It does not. It says "biological information." A person skilled in the art would know that biological information could include pulse ox. I arguably should have included the cite as well to Sarantos, but I sort of implicitly applied in the combination.

Q. Sorry. I think I accidentally put myself on mute.

Do you agree -- let me rephrase.

Would a person of ordinary skill agree that oxygen saturation comprises heart rate sensing at different wavelengths?

A. A person skilled in the art would be familiar, circa 2015, to know how to use multiple wavelengths to get oxygen saturation.

Q. But is it heart rate sensing at different wavelengths?

A. As I already mentioned, you can get heart rate from each one separately. So it's -- it's -- heart rate is in there, but you're not using the heart rate per se on the oxygen saturation. You're using the relative ratio of the -- the wavelengths.

Q. And as I think you've said earlier today, heart rate is a different thing than oxygen saturation, correct?

A. I believe that's what we talked about earlier.

Q. So just measuring heart rate using different wavelengths of light, that doesn't get you to oxygen saturation by itself already; is that correct?

A. If you're -- so heart rate by itself, heart rate does not giving you oxygen saturation.

Q. Now, looking at Paragraph 48 in your Declaration.

MR. KIANG: Can we have that on the screen, please?

BY MR. KIANG:

Q. So in Paragraph 48, you say, "To the extent not disclosed by Iwamiya, a POSITA would have been motivated to determine oxygen saturation using Iwamiya's physiological sensor, based on the teachings of Sarantos, in order to expand a range of physiological parameters measured by Iwamiya's sensor, thereby improving the functionality and utility of the sensor."

Right?

A. Yes.

Q. In this sentence, are you saying that you can use Iwamiya's sensor by itself to measure oxygen saturation?

A. What I say in the sentence is "To the extent not disclosed by Iwamiya, a POSITA would have been motivated to determine oxygen saturation using Iwamiya's physiological sensor, based on the teachings of Sarantos, in order to..." -- use multiple wavelengths -- "...to expand the range of physiological parameters measured by Iwamiya's sensor..."

Q. So are you saying you'd have to modify Iwamiya's physiological sensor in some way to -- to measure oxygen saturation?

A. Again, I talk about the combination. So the combination is what I'm talking about here of Iwamiya and Sarantos and using multiple wavelengths to -- can certainly get you the additional biological information of the pulse ox.

Q. Right. So when I -- when you say "combination," you mean you're taking Iwamiya's sensor and doing something to it based on Sarantos, correct?

MR. SMITH: Objection; form.

A. Correct. You have -- you have the combination. You have the sort of multiple wavelengths, for example, of -- of Iwamiya to enhance the functionality, as -- as I describe in -- that was Paragraph -- I guess Paragraph 70, for example.

"In the combination, Sarantos discloses including LED configured to emit different wavelengths..." such that "...motivated to include such LED in Iwamiya's sensor in order to enable the sensor to perform a larger number of physiological measurements..."

Q. And in the final sentence of this paragraph, you say, A person -- "A POSITA would have reasonably expected success in adapting Iwamiya's sensor to this purpose because wrist-worn pulse oximetry sensors, such as that described in Sarantos, were well known in the art."

Right?

A. Correct.

Q. What do you cite for that?

A. Apple-1005, Sarantos.

Q. Dr. Anthony, are you looking at something right now?

A. No. I answered the question.
Q. Oh, okay.
And does Sarantos say that wrist-worn -- wrist-worn pulse oximetry sensors were well-known in the art?
A. Well, Sarantos is certainly a wrist-worn sensor, so we're on Page 5 of Sarantos. It's a watch.
Q. So you're saying that wrist-worn pulse oximetry sensors were well-known in the art and the only basis for that statement is Sarantos itself, correct?
MR. SMITH: Objection; form.
A. It is one example of a wrist-worn sensor that can do pulse ox. You don't need to cite every reference, but it's one that -- and in the combination, certainly discusses about wrist-worn sensors in -- in the combination, you know, Sarantos enables pulse ox.
Q. Now, I want to ask you, specifically though, about wrist-worn pulse oximetry sensors that you say were well-known in the art.

Are you aware of any wrist-worn pulse oximetry sensors that existed before July 2015?

A. So as I allude to here, so Sarantos is one example of a wrist-worn sensor that enables pulse ox.

Q. Okay. And so, supposing that Sarantos describes such a sensor, do you know if such a -- if that device actually existed as of July 2015?

MR. SMITH: Objection; form. Relevance. Scope.

A. Again, in establishing my opinions here, you know, this is the -- there is a threshold of -- of bringing into reality, you know, an invention, so Sarantos is demonstrating, you know, in the art as using sort of a wrist-worn sensor to measure pulse ox.

BY MR. KIANG:

Q. But you don't know if this device that you say is described in Sarantos actually existed as of July 2015, correct?

MR. SMITH: Same objection.

A. The Sarantos device, I have not held a Sarantos device. But it doesn't mean that it's not enabled and known in the art.

BY MR. KIANG:

Q. And you don't cite anything other than Sarantos for this statement, right?

Dr. Anthony, are you looking at something right now?

A. I was looking at the other -- the other references that I cited just to point to other examples if I -- if they were in the other references. Certainly Sarantos describes --

Q. I'm looking at your Declaration right now --

A. I'm sorry?

Q. -- Paragraph 48, last sentence.

A. Right. You asked if there were other examples, and so I was looking --

Q. No. That's not the question I'm asking.

I'm asking did you cite anything

else other than Sarantos?

A. At that sentence right there, I did not. I may have cited other places through the Declaration. I was trying to take the opportunity to review.

Q. Sarantos is a patent that was originally assigned to Fitbit, correct?

A. Sarantos-Fitbit, correct.

Q. And are you familiar with Fitbit?

A. Yes.

Q. They make wearable devices, right?

A. They do.

Q. So if a device described in Sarantos that could measure pulse oximetry at the wrist actually existed before July 2015, that would have been a Fitbit device, right?

MR. SMITH: Objection; form. Argumentative. Scope. Relevance.

A. It's one possibility. You know, it's -- there are other companies that make devices, big and small, in research and commercial.

BY MR. KIANG:

Q. Are you aware of any Fitbit device released before July 2015 that measures oxygen saturation at the wrist?

MR. SMITH: Same objection.

A. I'd have to review the release dates of various products. But as I said, Sarantos here describes the -- the pulse ox sensor at the wrist.

BY MR. KIANG:

Q. Okay. Are you aware that Fitbit only first announced in 2020 that some of its wearable devices would be able to measure oxygen saturation?

MR. SMITH: Objection to form. Argumentative. Foundation.

A. Which likely means they had to exist at least a decade prior, if not longer. To -- generally, an innovation takes about 25 years to get out of the first demonstration to a product. So, you know, there's big lag between something -- where something is known in the --

the people skilled in the art and when there's something that is commercially available. I would not be surprised if it's a long timeline.

BY MR. KIANG:

Q. Do you have any basis for your opinion that it would have to have existed for a decade prior to its release?

MR. SMITH: Objection; form.

A. In my experience -- and this is an area that we talk a lot about in MIT -- the data that we have here generally suggests that it takes for any technology 25 years from first conception/demonstration to get a commercial product even though there is a lot of research and innovations along the way.

So I did not cite that here. It was not necessary in forming my opinions. But certainly, there's a lot of evidence that that is on average. Everything from the zipper, zipper took 25 years to get from its first demonstration.

On average, that is the -- seems to

be the -- the norm of the statistics that talk about how long it takes to bridge the valley of death between innovation where the first invention, demonstration and a robust commercial product after going through the hype cycle of overinflated expectations, demoralized disappointments, and then sort of reaching a steady state where there's commercial activity.

Q. So from the moment somebody has an idea about doing wrist-worn pulse oximetry to actually being able to build one that works, you're saying it would take about 25 years?

MR. SMITH: Objection; relevance.

A. I'm saying in general, it takes a long time. It doesn't mean it doesn't exist beforehand. But to get it to the point where there's mass availability and dealing with all the scale-up issues and manufacturing. Doesn't mean that it didn't exist prior in those prior 25 years and doesn't mean that -- and again, I'm talking generalities now.

I'm not -- you asked what was my

evidence you said in terms of talking about this. The normal, the mean of how technology gets out there is sort of roughly that time frame.

Q. Earlier today, we talked about Iwamiya having an optical filter 17.

Do you remember that?

A. I'm sorry. You broke up there, please.

Q. Yeah. Earlier today, we talked about Iwamiya having an optical filter 17.

Do you remember that?

A. Can you refer to me, my Declaration where it is so I can reorient myself.

Q. Yeah. Let's -- let's go to Paragraph 43 of your Declaration.

A. Okay.

Q. And here, you're talking about an optical filter 17, right?

A. You said Paragraph 43?

Q. Yeah, it's on the screen right now.

A. Oh, sorry. I have the wrong Dec.

Yes, so in 43, as I said, in the

combination, there's a light shielding frame. Iwamiya thoroughly describes the optical filter 17 that is mounted on the lower side of a light shielding frame 18 between the photodiodes and the tissue.

Q. And you relied on that optical filter 17 for your combination, right?

A. As I described in 44, you know, "...the optical filter 17 is configured to transmit light of a specific wavelength band of 900 nm or more...configured to allow at least a portion of the light reflected from the tissue to pass through the photodiodes."

Q. Let's go to Iwamiya. That's Tab 4, Exhibit 1004. And let's go to Column 8. And that Lines -- let's see -- 42 to 47.

That's talking about the optical filter 17, right?

A. 8 -- yeah, Line 40, starting at 42, "FIG. 8, the optical filter 17 is configured to transmit light of a specific wavelength band of 900 nm or more and shield length of a wavelength

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band of 900 nm or less, such that the light receiving unit 9 alleviates an influence from a measurement change due to external light, such as sunlight."

Q. So the optical filter filters out light that's below 900 nanometers, right?

A. The optical filter here is matched to the wavelength that is used.

Q. And it says right here shield wave -- "...shield light of a wavelength band of 900 nm or less..."

Right?

A. Correct.

Q. Do you agree that red light has a wavelength of about 660 nanometers?

A. Thereabouts.

Q. So this optical filter will shield light that's red, correct?

MR. SMITH: Objection form.

A. Well, a POSITA reading this would certainly understand that you're using wavelengths -- filters that correspond to the light that you're using for illumination. So in this case, we're using 940 as described in the paragraph above. So it would be -- you wouldn't want to have -- you want to maximize your signal so you use a filter that's matched to the wavelength -- the wavelengths that you're using.

Q. But this particular optical filter would filter out red light, correct?

A. As I just described, it's going to filter out things that are not the wavelength that's used and not being -- in this particular embodiment, it's not red. So -- but in the combination, you would use multiple and so a POSITA would know with those multiple wavelengths to also use the filters that are matched to the wavelengths to be used.

But in this particular embodiment, yes, it's using something matched to the 940 as described in the paragraph prior.

Q. All right. Where in your Declaration did you say that you would use a different optical filter?

A. A POSITA would certainly know to use wavelengths and filters that are matched to each other. And so in the combination, we use multiple LEDs, multiple wavelengths, and so you would use filters that are matched to the wavelengths that you used. That POSITA would find that very obvious.

Q. You didn't say that anywhere in your Declaration, correct?

A. Well, a POSITA would know to combine and a POSITA taking the learnings and teachings of -- in Iwamiya, sort of here's a filter that's matched to the wavelength. Using another wavelength, you would want to have a filter matched to another wavelength. So a skilled -- a person skilled in the art would find that obvious.

Q. Dr. Anthony, I don't think you've said that in your Declaration before, so it sounds like a new opinion.

Do you agree with that?

MR. SMITH: Objection; form.

Argumentative.

A. I don't believe it's a new opinion. It's something a person skilled in the art would know about using multiple wavelengths. I already alluded to multiple wavelengths. A person skilled in the art must find it. They would not even think about it almost. You would certainly use things that are matched to the wavelengths that you're using.

So it's not a new opinion. It's what a person skilled in the art would -- would know.

BY MR. KIANG:

Q. So if it's not a new opinion, where is it stated in your Declaration?

MR. SMITH: Objection; form. Argumentative.

A. It's a description -- you asked the question whether a POSITA would use -- I forget your question now. My apologies.

But you asked something about whether a person skilled in the art would use this filter for a different wavelength. The answer there is they would know to use a different wavelength -- a different filter for those different wavelengths.

BY MR. KIANG:

Q. And what you said just now is not in your Declaration, correct?

A. Many things I've said today are not in the Declaration. I've been trying to answer the questions.

Q. And this optical filter 17 that's described here in Iwamiya, Column 8, Lines 42 to 47, that optical filter would filter out red light, correct?

A. And a POSITA reading this more would broadly understand, as I've described, that that is a -- matched to the wavelength that is used. So, yes, this particular filter is not going to be appropriate for red, but a POSITA in the combination using other wavelengths would know that you match your filters to your wavelengths.

MR. KIANG: At this time, I'd like

the court reporter -- sorry -- the hot-seater to please pull up Tab 7. This was previously marked as Exhibit 1007.

(Tech complies.)

(Whereupon, Exhibit 1007, US Patent 6,483,976, was identified.)

BY MR. KIANG:

Q. Dr. Anthony, have you seen this before?

A. This is Shie. Okay. Yeah, this is Shie.

Q. Okay. And do you agree that Shie doesn't mention physiological monitoring?

MR. SMITH: Objection; form. Argumentative.

A. So Shie in particular -- and I was not establishing opinions on Shie by itself, but Shie in particular, for example, in Column 1, Line 15, "There are many types of optical elements useful for an endless number of current and new applications."

And then as I highlight in my

Declaration on Page 37 under Paragraph 30 -- 76 describing why a POSITA would look to Shie to understand, you know, with more detail how to apply the -- the light shape changing material that Shie offers in the combination with Sarantos.

Q. But Shie itself doesn't talk about physiological monitoring, correct?

A. Again, it was not establishing opinions on Shie by itself. Shie talks about optical elements, having an integral surface diffuser applicable in many current applications and new applications. And physiological monitoring is -- is one of those.

And a person skilled in the art looking to, as I say in Paragraph 76, to do that shape changing I would look to the -- the light shape changing materials is -- of Shie.

Q. Shie never mentions physiological monitoring as a potential application for any of these -- of this disclosure, correct?

A. As I said, there are many types --

being many types, an endless number it says of current and new applications.

So it's not limited to physiological. It's not limited to monitors. It's not limited to -- it's an endless number. Any place where you have optics, you know, it's -- or needing to control light, it's a person skilled in the art would know how to apply these teachings as they do in the combination with Sarantos.

Q. Does Sarantos ever mention using a light shape changing device -- or sorry -- a material to change the shape of light?

A. I'm sorry. Can you repeat the question?

Q. Does Sarantos ever mention using a material to change the shape of light that's emitted from the LEDs?

A. So as I describe here, and I'm not talking about Shie by itself.

But Shie in Sarantos or by itself, but Sarantos and Shie in combination, as in 76.

"...combination, Shie describes a diffuser that has a 'light diffusing and shaping advantages'...It would have been obvious to a POSITA to use the light shape changing material of Shie in the wristwatch sensor of Sarantos in between the LEDs...and the user's wrist...in order to change the shape of light...into a second shape projected on to the tissue...A POSITA would have been motivated to..." -- do that by -- "...in order to...direct the light emitted" -- "light emitted toward the tissue...to increase power efficiency..." -- get -- "...light closer to photodiodes, to increase accuracy..."

Illuminate larger areas.

"...decrease irregular readings caused by skin variation..."

As I describe in Paragraph 76.

Q. Would a person of ordinary skill be looking at Sarantos and Shie together because they were looking at Claim 1 of the '745 patent?

MR. SMITH: Objection; form. Argumentative.

A. No. A person skilled in the art knows the -- that you want to get good sort of illumination, you know, good signal-to-noise ratio, and would look at optical and electrical, and sort of techniques to improve that.

And so as I describe here a POSITA would be motivated to make that a more uniformly illuminated, largely illuminated, making the light directed to where it needs to be to increase power efficiency and increase overall quality.

BY MR. KIANG:

Q. Now, let's go back to your Declaration, Paragraph 76, which is on Page 37 to 38.

Now, I think you were just reading from this paragraph; is that right?

A. Correct.

Q. Now you said, in Paragraph 76 on the latter half of it, a person of skill, "A POSITA would have been motivated to use a light shape changing material, such as Shie's, in order to precisely direct the light emitted toward the tissue so as to increase power efficiency by shining light closing to photodiodes..."

Do you see that?

A. Yes.

Q. Do you agree that Sarantos doesn't say that?

A. I agree that a POSITA would have been motivated to use light shape changing materials in order to manifest the fact of improving quality, as I describe here, by doing these things that a POSITA would understand would improve power efficiency, increase accuracy, deal with variation in skin.

Q. Okay.

A. And light shape changing materials were known to be used for this purpose in the prior art. So a POSITA would have reasonably expected Shie's light shape changing material to work successfully in manifesting those change -- changes to Sarantos's sensor.

Q. What do you cite to support these

statements in Paragraph 76? The ones that you
were just reading from.
A. Well, certainly a POSITA would have
understood these things. And looks like I
probably have some mistakes there in -- in what
those numbers are.
Q. And what do you mean by "mistakes"?
A. I'm missing something that is giving
the -- a document.
Q. Do you know what that document is?
A. I have to re-review to figure out
which one that is.
Q. Do you know what a in-citation is?
A. Yeah. As the above, but it doesn't
look be like the Apple 105 [verbatim].
Q. Doesn't make sense to talk about
Paragraph 400 in Exhibit 1005, right?
A. I'm sorry. That did not come
through.
Q. Doesn't make sense to have a
reference to Paragraph 400 in Exhibit 1005,
right?

A. Correct.
Q. Sitting here today, do you have any idea what this referred to?
A. Yeah. I believe it's a mistake in the collaborative writing effort. So...
Q. So, no idea?
MR. SMITH: Objection; form.
A. Again, I believe it's a mistake in the collaborative writing effort.
BY MR. KIANG:
Q. So sitting here today, you do not know what this citation refers to, correct?
A. Again, it could be a mistake that I would have to re-review and figure out what went on.
Q. When you signed this Declaration, you reviewed the contents of this Declaration before you signed it, right?
A. That is correct.
Q. And when you reviewed this paragraph, did you have any questions about what this citation was referring to?

A. I obviously missed clarifying and then correcting this.

Q. Okay. So these statements about what a person of ordinary skill would have been motivated to do, you know, based on, as you say, precisely directing the light toward the tissue, increase accuracy of measurements, something about obscuring the LED appearance from the user, there's nothing cited here, correct?

MR. SMITH: Objection; form. Argumentative.

A. There's something cited here, but I'm pointing to someplace incorrect. And so, again, it's a mistake in what this reference is pointing to.

MR. SMITH: And, Counsel, we've been going -- Counsel, we've been going for about an hour, so when you get a chance to take a break.

MR. KIANG: After I finish my line of questioning.

MR. SMITH: That's -- that's fine.

MR. KIANG: Unless -- unless the witness would like one right now.

THE WITNESS: No. You're fine.

MR. KIANG: Okay.

BY MR. KIANG:

Q. Would it surprise you to learn that this citation doesn't refer to any evidence in the IPR record?

MR. SMITH: Objection; form. Argumentative.

A. Again, I -- it's a mistake. So my -- my bad for not catching this in my review. But even without it referenced there, a person skilled in the art would certainly know to create better illumination properties for reducing signals to noise.

BY MR. KIANG:

Q. And what's your basis for that?

A. My understanding of what a POSITA is and would know.

Q. Okay. And do you agree that Sarantos doesn't talk about any of these supposed motivations?

A. A person skilled in the art familiar with physiological -- optical physiological monitoring knows the issues associated with stray light, motion, lack of illumination, uniformity. So a person skilled in the art would know that such improvements would be beneficial to improving overall quality.

Q. Would a person of ordinary skill have known that as of July 2015?

A. Yes.

Q. Why?

A. It was well-known throughout the history of physiological monitoring, you know, pulse ox systems all the way back to, like, 1940s and Mendelson I think it was. In terms of before we cut the wire of physiological monitoring, the issues with stray light and good illumination and anybody that does signal to -- anybody that does sensors, you know, you want to give your best signal possible. And if your signalling mechanism is light, you want to make sure that you are maximizing doing things you need to do to maximize the -- the signal that you're -- you're trying to monitor.

Q. What about obscuring the LED's appearance from the user? There's nothing cited to support that, correct?

A. One more time. Sorry.

Q. You said here obscure the LED's appearance from a user, right?

A. Yes, that is at the end of a long list of other things that would be beneficial, yes.

Q. Sarantos doesn't talk about that, right?

A. I will need to re-review Sarantos to make sure that that is the case.

Q. Shie doesn't talk about that, correct?

A. I would need to re-review them and make sure that's the case.

Q. If they had said something obscuring the LED's appearance from the user, wouldn't you have cited it here?

MR. SMITH: Objection; form.

Argumentative.

A. Again, this reference here is -- is clearly problematic and a mistake, so.

And just as a general comment, certainly a person skilled in the art of physiological monitoring knows you don't want to scare people with technology. So having things that are obscured from the user would not be surprising thing for a POSITA to want to do.

Let me re-review here.

Q. Personally be scared by the appearance of a LED?

A. Just the under -- just the workings of technology. You don't always want to -- let's see.

So your question is whether Sarantos or Iwamiya sort of talked about the -- obscuring the LED appearance?

Q. Yeah.

Sarantos doesn't talk about

obscuring the LED's appearance, right?

A. Well, for example, in Column 2 sort of -- sort of refers to it. That's not the quote here, but "...the back face may include a thin window, and the window regions may be sub-regions that are defined by the photo-detector elements. In some other or additional such implementations, each photodetector element may be offset from the corresponding transparent window by a corresponding gap..."

That would have the effect of obscuring them a little bit.

Q. But you didn't cite that here in your Declaration, correct?

A. I did not, but you asked whether it talked about it at all in Sarantos, and so now that is what I'll reviewing.

And, again, in Column 4 around Line 35, "In some other additional such implementations, each photodetector element may be offset from the...transparent window...by a gap in the direction...gap may be free of optical

light guides."
Q. So there's window and a LED -- a photodetector. That's not the LED, correct?
A. Photodetector is not the LED, correct.
Q. And what were you pointing at in Column 2?
A. Line -- let's see. Line -- in other "additional implementations, each photodetector element may be offset from the corresponding window..."
Q. What line are you talking about?
A. It's Line 61 -- 60, 61 -- 61.
Q. Okay. So I'm looking at Sarantos, which is Exhibit 1005. We're looking -- you were pointing me at Column 2, Line 50 -- this paragraph that starts at Line 58 to 65; is that right?
That's not talking about an LED, right?
A. Correct, that's a photodetector.
MR. KIANG: All right. I think now

is a good time for a break.

MR. SMITH: All right.

THE TECH: Okay. Going off the record. The time is 4:25.

AUTOMATED MESSAGE: Recording stopped.

(Recess taken.)

AUTOMATED MESSAGE: Recording in progress.

THE TECH: We are back on the record. The time is 4:38.

BY MR. KIANG:

Q. All right. Dr. Anthony, did you speak to anybody during the break about the substance of your testimony today?

A. No.

Q. Let's turn to Paragraph 77 of your Declaration. We're still looking at the 1291 Declaration.

MR. KIANG: Can we also have the next page up on the screen as well.

BY MR. KIANG:

Q. Okay. So in Paragraph 77, you're addressing Limitation 1.3, which talks about a plurality of photodiodes, correct?

A. Correct.

Q. And you've pointed to what you say are plurality of photodiodes in Sarantos, specifically in Figure 22, correct?

A. Correct, Figure 22 of 1005, which is Sarantos, correct.

Q. And there's -- there's two photodetector elements 2212 in Figure 22; is that correct?

A. As shown in the cross-section slice through -- they cross -- slices through generally two.

Q. So that's -- okay.

So those are two distinct photodetectors, correct?

A. So it's a cross-section cutting through again a plane cut-through, you know, what it would actually be in 3D. It could be in that -- surrounding that center. It could be

two. It could be three. It could be four.
Q. But at least two, right?
A. At least two.
MR. KIANG: Let's turn to -- could I have the hot-seater please bring up Exhibit 1005, Sarantos. And let's go to Figure 25, which is on Page 17.
(Tech complies.)
BY MR. KIANG:
Q. And you've seen Figure 25, right?
A. Correct.
Q. And this shows a single photodetector 2512; is that right?
MR. SMITH: Objection; form.
A. So this is one embodiment. Figure 25 describes an annular photodetector element 2512 and a light source 2508.
You know, another embodiment, for example, is shown in Figure 18, which shows there are two LEDs in the center there and three elements around. So there are multiple embodiments. This is but one that shows a

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singular -- seems to show one in the center in one singular monolithic one and others show two in the center or -- or three or four or more around the periphery.

Q. So in Figure 25, there's just one photodetector, correct?

A. So Figure 25 is described as depicting an example of an annular photodetector element 2512 with a light source 2508 in the middle. So it's describing a light source.

It's -- in the description here, it is probably -- it looks like it might be a little vague in terms of what the light source, whether it be a single element -- you know, a light source can be multiple light bulbs or three or four or five light bulbs.

But this is more -- if you compare this figure to some of the other figures, you know, this is more of the illumination region. And, for example, it's explicit in, for example, Figure 18 where there's multiple elements.

So it's unclear, I think, in the

description whether it's a single element or the light source --

Q. I will stop you there. I think you might have misunderstood my question. I was just talking about the photodetector, not the light-emitting sources.

A. Right. In this embodiment, it seems to be describing as an annular photodetector element. In others, it's described as a hexagonal and multi-elements pieced-wise linear in earlier embodiments.

MR. KIANG: Counsel, could you please give me a couple of minutes for a break?

MR. SMITH: Yeah, no problem.

THE TECH: Okay. Going off the record. The time is 4:46.

AUTOMATED MESSAGE: Recording stopped.

(Discussion held off the record.)

AUTOMATED MESSAGE: Recording in progress.

THE TECH: We are back on the record. The time is 4:48.
BY MR. KIANG:
Q. Sorry. Before we took that break, I think we were talking about Figure 25, and I think you said this is just a single annular photodetector; is that correct?
A. As described in Column 19, "FIG. 25 depicts an example of an annular photodetector with a light source in the middle, in accordance with an example implementation."
And I was pointing out the other implementations that had multiple elements, the hexagonal one as other embodiments.
Q. So in Figure 22, there's two photodetectors, right?
A. In Figure 22 it's unclear if it's two photodetectors. It's a cross-section through and so that slice could be through the singular annular or it could be through the embodiments where it's hexagonal. It could be a slice through the embodiment where it's two or four as

well, or three for that matter.

Q. Regardless of whether it's two, it's a plurality of photodiodes, correct?

A. Correct. In a case where it's annular, it could be one if it's one homogenous one. If it's multiple, it's a plurality.

Q. Figure 25 is a different embodiment than Figure 22, correct?

A. Well, Figures 22 through 24 depict cross-sections of simple representations of various PPG sensors. So it's not necessarily different, at least in that description.

I need to read more here but it could be multiple. It could be singular annular one, but it's certainly one and/or more.

Q. But you opined that Figure 22 shows at least a plurality, right? That's more than one?

A. Correct. In the embodiments for that have multiple, yes.

Q. Yeah. All right. I'd like to turn now to your second Declaration. This is for

IPR -- the 1465 IPR.

(Whereupon, Exhibit 1003, Declaration of Dr. Brian W. Anthony, Ph.D., was identified.)

MR. KIANG: And let's see. So I have on the screen, it looks look the hot-seater has pulled up on the screen Exhibit 1003 from IPR 2022-1465.

(Tech complies.)

BY MR. KIANG:

Q. Dr. Anthony, have you seen this before?

A. Yes. That appears to be the cover page from my second Declaration.

Q. Okay. I'm just going to go through some of the other stuff we did this morning.

Let's take a look at Paragraph 11 on Page 8 and also Page 9; so it looks like it continues a little to Page 10.

But in any case, does Paragraph 11 provide a complete and accurate listing of the materials that you considered for your

Declaration?

A. Yes. Unless there were things I missed here and that were cited with reference in the document.

Q. So if there was something that you missed in Paragraph 11, it would be cited somewhere else in your Declaration, correct?

A. Correct.

Q. Let's turn now to Page 13 and have a look at the section called "Level of Ordinary Skill in the Art."

You've applied the same level of ordinary skill in the art for the second Declaration that you applied in the first Declaration, correct?

A. That is correct.

Q. And also on this page, starting at Paragraph 21, just Paragraph 21, you have another claim construction section; is that correct?

A. Correct.

Q. And for this Declaration, you also haven't provided any constructions on any

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particular terms, correct?
A. That is correct.
Q. Now, do you understand in IPR2022-01465 that Apple is only seeking to invalidate certain dependent claims of the '745 patent?
A. Sorry. I missed the numbers. Are we --
Q. Okay. Sorry.
In this 1465 Declaration, that's for this IPR2022-01465, is it your understanding that Apple is only seeking to invalidate certain dependent claims of the '745 patent?
A. Well, for example, I mean I give my opinion around the combination on Page 19 why -- for why Claim 1, which is a dependent -- or an independent. Sorry.
Q. Maybe my question is a little bit more too technical -- technical on the legal side, so I'll just move past that.
You've presented opinions in this Declaration concerning the independent Claims 1,

15, and 20, correct?
A. Correct.
Q. And are your opinions and your analyses about those claims the same as your opinions that you presented in your first Declaration for the 1291 IPR?
A. I -- there may have been some additional discussion, but they should substantially be the same.
Q. Okay. Are you -- sitting here today, are you aware of any differences between your analyses of Claims 1, 15 and 20 in this 1465 Declaration versus your opinions and analyses of Claims 1, 15 and 20 in the 1291 Declaration?
A. Nothing substantially different.
Q. Okay. Let's turn to Paragraph 28 of your Declaration, which is on, let's see, Paragraph 28, yeah, Page 18. All right.
Do you see in the middle of that paragraph --
A. I'm sorry. Which paragraph, 28?
Q. Yeah, Paragraph 28.

A. Okay.

Q. -- it says, "'A LSD can be made to collect incoming light and either (1) distribute it over a circular area from a fraction of a degree to over 100°, or (2) send it into an almost unlimited range of elliptical angles.'"

A. Yes.

Q. What is an elliptical angle?

A. So, as described in Column 1, so, the LSD can be make to collect incoming light and either distributed over a circular area, so circularly symmetric where the angular subtense could be a fraction of a degree to over 100°, or, you know, a nonsymmetric circle, or an ellipse, right, would be asymmetric in its angle of illumination.

So you can have a different angle in one principal axis versus the other principal axis.

Q. And is that how a person of ordinary skill would understand that term "elliptical angle"?

A. Yes. It's described here as well. For example, you know, so it's describing sort of an asymmetric sort of angular subtense. So reading it in context would -- a person skilled in the art would understand what it meant.

Q. Let's go to Paragraph 53 of your Declaration.

A. I'm sorry. Which one?

Q. 53.

A. 5-3?

Q. Yep. First and second wavelengths, right?

So this is -- Paragraph 53 is your analysis of Claim 2. And it's largely the same as your analysis that you presented in your first Declaration, right, as to Claim 27?

A. Well, in the discussion for here for Claim 2, I have significantly more discussion underneath that than the -- under 27, which is Paragraph 104 in the earlier Dec.

But here, yes, we're just -- the combination discloses LED configured for

different wavelengths.
Q. So in this Paragraph 53, are you talking about combining Iwamiya with Sarantos so you can add oxygen saturation?
A. I'm -- I'm sorry. Can you repeat that?
Q. In this Paragraph 53 in your 1465 Declaration, are you providing an opinion that you add -- or that you would combine Iwamiya with Sarantos to add the second wavelength so that you can measure oxygen saturation?
A. Yes. That's as I've described here. Additional physiological monitoring signals.
Q. All right. Let's turn to Paragraph 59 of your Declaration. And this is talking about Claim 6.
And do you see in the middle, sort of in the middle of this paragraph, there is a sentence that starts "By disposing"?
A. Yes.
Q. Okay. Sounds like -- looks like you have an opinion here that "By disposing the

plural light receiving units 9 in an annular or ring-shaped arrangement around the circumference, the plural light receiving units 9 are thereby arranged in the spatial configuration corresponding to the annular or ring-shaped portion of the tissue bounded by the reflection layers of the annular light guide 7."

Does Iwamiya talk about putting the light receiving units 9 in annular or ring-shaped arrangement?

MR. SMITH: Objection; form.

A. So talking about the combination, even though I only cite here the 1004, which is the Iwamiya. So in the combination, we disclose plural light receiving units disposed around the ring-shaped region.

Q. Do you have any opinion in this Declaration why a person of ordinary skill would do that?

Let me rephrase.

Do you have any opinion in this Declaration why a person of ordinary skill would want to dispose plural light receiving units 9 in an annular or ring-shaped arrangement in Iwamiya?

A. Sorry. Repeat -- please repeat that?

MR. KIANG: Let me -- please bring up Exhibit 1004 and go to Page 5 which has Figure 4 on it. And please rotate that.

(Tech complies.)

BY MR. KIANG:

Q. So your opinion was looking at Figure 4 of Iwamiya, correct?

Perhaps I should say Figures 2 through 4 of Iwamiya.

A. So indeed I'm -- I'm pointing to Figures 2 and 4 as I annotate on -- 2 through 4 as I annotate on Pages 23 and 24.

Q. Okay. So if you have plural light receiving units 9 in an annular or ring-shaped arrangement, as you've said here in figure -- in Paragraph 59, would that mean that there's a center portion in that annular or ring-shaped arrangement where there is no light receiving

unit?
A. I'm sorry. Can you -- can you ask that question again?
Q. Yeah.
In Paragraph 59, you talk about "disposing the plural light receiving units 9 in an annular or ring-shaped arrangement," right?
A. Correct.
Q. And in that arrangement, there would be an empty spot in the middle of that -- of those light receiving units, right?
A. Well, as described here, by disposing plural lights around the ring shaped, you know, the lights are around the ring and corresponding to an annular or the ring-shaped portion of the tissue.
Q. So there would be a spot kind of in the middle of these light receiving units that there is no light receiving unit, correct?
A. If we're only arranging them around an annulus, a ring, then you would have your detectors there and something else in the center,

yeah.

Q. So in the center of those light receiving units, there would potentially be an empty spot, right, where light would not be --

A. Or the -- the emitter, for example.

Q. Say that again?

A. Or the emitter, for example, or a series of emitters.

Q. Okay. Well, looking at Figure 4, and Figures 2 through 4 of Iwamiya, right?

A. Are we talking about -- we're talking about the -- I'm sorry. My apologies.

Q. Yeah. Iwamiya, the emitters 6 are to the side of the light receiving unit 9, correct?

A. In Iwamiya, the figure that you have up, the -- the detector is in the center, labeled, I think, 9, and the detectors that are -- oh, sorry -- the emitters are 6 and the detector is 9. And in Sarantos, it is the other way around.

Q. Now, in Paragraph 59 when you talk

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about this arrangement, this annular or ring-shaped arrangement of light receiving units, there would be kind of this empty spot, right, in the middle of those light receiving units?

A. I guess I'm confused by what you're saying in terms of "empty spot." The detectors -- yeah.

Q. All right. Let's look at Figure 4 on the screen, right?

A. Correct.

Q. And this shows a single light receiving unit 9, right?

Do you see that single light receiving unit 9?

A. Yes, in this cross-section 9 is the receiving unit and 6 is the emitters.

Q. Right. So in your opinion on -- in Paragraph 59, are you talking about changing what's shown here in Figure 4 where it's a single light-receiving unit and replacing it with a ring of light-receiving units 9 that are kind of in that same spot?

A. So, again, I talk about the combination, and, you know, the -- the ways that in -- in or -- sorry -- in Iwamiya, it's detector on the outside -- no, sorry -- it's emitter on the outside, detector in the middle. And Sarantos, it's emitter on the middle, detector on the outside.

Persons skilled in the art would know that you can do it either way, depending on your design considerations. And so in the combination, as I point you here, we would put the receiving units on a optical center around the annular region.

Q. In the combination that you've set forth in your Declaration, where would those light receiving units 9 be? Are they still within this light-shielding frame 18?

A. So the -- the -- in Iwamiya, the emitters are in -- on the outside detector in the center. And then Sarantos is the other way around. In the combination, a person skilled in the art would know that they could be flipped.

In this combination, the light-receiving units would be arranged in a optical axis corresponding to the annular region on the ring.

Q. So would those light-receiving units still be between the light-emitting unit 6 in your proposed combination?

A. Would they be between what? Sorry.

Q. Would they be between the light-emitting unit 6?

A. Would the -- sorry. Would the detectors be between the light unit?

Q. Yes. That's what I'm asking.

A. So the material configured to be positioned between the light-emitting diodes would still be between, as -- it's not that the -- the LEDs are between. It's the materials configured to be between the emitter and the detector.

Q. That's not quite what I'm asking. But it sounds like it's not very clear what the combination is.

A. No, I think it's more --

MR. SMITH: Objection; form.
Argumentative.
BY MR. KIANG:
Q. So in this proposed combination of Iwamiya and Sarantos where you're saying that there is a plurality of light-receiving units 9, right? More than one?
A. Yes, yes.
Q. Are all of those light-receiving units going to be inside of this space that's bounded by the light-shielding frame 18, or are you thinking that they're put somewhere else?
A. The shield separates the emitter from the detector still in this combination.
Q. Okay. But where are the detectors?
A. So as I say, the plural -- let's see. By disposing the plural light receiving units in an annular ring arrangement around the circumference, the receiving units are arranged in a spatial configuration configured to the annular ring of the tissue bounded by the reflection layer of the annular light guide.

Q. Okay. So what is the circumference you're talking about?
A. The -- the ring around which the -- the -- the elements are nominally placed, the circumference of the ring.
Q. What ring?
A. The spatial configuration of how the elements, the receiving elements are centered about a -- about the circumference.
Q. Okay. Earlier you said that in Iwamiya, it has this configuration where its emitter is on the outside, detector in the middle, right? And then you said Sarantos has detectors on the outside and emitter in the middle, correct?
A. Correct.
Q. In this proposed combination of Iwamiya and Sarantos, where are the photodetector -- photodetectors?
A. So as I say in Paragraph 59, "...plural light receiving units are in an annular or ring-shaped arrangement around the

circumference, the plural light receiving units are thereby arranged in a spatial configuration corresponding to the annular or ring-shaped portion of the tissue bounded by the reflection layers of the annular light bed."

Q. Okay. And so in -- what you've just said, are the plurality of photo -- are the plurality of light-receiving units 9, are they going to be in the middle of the light emitters, or are they going to be outside of the light emitters?

A. I see. So in this combination, we would likely have the -- in a ring, the receivers and transmit in the center.

Q. All right. Could you say that again? I don't -- didn't quite understand your answer.

A. So Sarantos, for example, flips the sort of the -- the direction. So a person skilled in the art knows that you would -- you could have emitter inside, transmitter outside or vice versa.

And in this arrangement, one possible configuration would be to have the -- the receivers around the ring and the transmitter in the center.

Q. What's the transmitter?

A. Emitter, LED.

Q. Okay. So are you saying you would put the emitters, the light emitters 6, from Iwamiya and put them in the middle? And then you'd have light receiving units 9 that are outside of those light emitters?

A. You could also have combinations where they were on the outside as well still within a ring. So the exact -- the exact sort of implementation, you want nice good circular symmetry and good illumination. You can flip the geometry as you have it flipped in Sarantos and have emitter in the center and detectors in the ring. You could also have a larger ring of transmitters and a smaller ring of the detectors.

Q. What's the combination that you are actually presenting here in your Declaration?

All right. Let me ask you a different question. Is what you've just told me specifically for your analysis of Claim 6, or is it in general for all of your Iwamiya and Sarantos combination opinions?

A. Sorry. Say that -- please say that again.

Q. So you've been trying to describe to me this combination of Iwamiya and Sarantos. And I'm just wondering, was this just for Claim 6 in Paragraph 59 of your Declaration or?

A. What I was describing here for Claim 6 was describing how the plural light receiving units are arranged and describing Claim 6.

Q. Okay. So beyond Claim 6, that's not the combination you're presenting?

A. Well, Claim 6 is the specific embodiment where it's the device of Claim 1 where the plurality of photodiodes, and Claim 6 is the dependent claim on 1. And there are no other dependent claims upon Claim 6.

So my analysis here is on Claim 6 --

THE WITNESS: When we're at a good stop, I could use a quick bio break. But we can keep going.

MR. KIANG: Quick break. Five minutes?

THE WITNESS: That's fine. Yep.

THE TECH: Okay. Going off the record. The time is 5:31.

AUTOMATED MESSAGE: Recording stopped.

(Recess taken.)

AUTOMATED MESSAGE: Recording in progress.

THE TECH: We are back on the record. The time is 5:35.

BY MR. KIANG:

Q. Dr. Anthony, I want to go back to Paragraphs 41 of your Declaration.

MR. KIANG: Actually, let's just have Pages 26 and 27 up on the screen.

THE TECH: Sorry. My -- okay. It's

working. Never mind.

BY MR. KIANG:

Q. So this is your analysis of Claim 1, correct?

A. Correct.

Q. And this is the Iwamiya and Sarantos combination?

A. Yes.

Q. And so there is a figure on 27, on Page 27, looks like a highlighted or annotated version of Figure 4 of Iwamiya, correct?

A. Correct.

Q. And you've highlighted 9 in this figure, and you pointed to it and called it "Photodiodes 9," right?

A. Correct.

Q. So at least in your analysis of Claim 1, the -- you're saying that the plurality of photodiodes would be where they are shown here in Figure 4, correct?

A. Correct.

Q. All right. And so for Claim 6,

then, you're saying instead of what you've shown here in Claim 1, you're now envisioning the photodiodes would be outside of the emitters; is that correct?

MR. SMITH: Objection; form.
Mischaracterizing prior testimony.

A. I think what I was describing is you can have two scenarios. You could have a ring in a ring, or you could have where the emitter's on the outside and the detector is in the ring. Or you could also imagine a scenario where you have the detector -- sorry -- emitter in the center and a ring on the outside.

BY MR. KIANG:

Q. Okay.

A. What we're talking here is the -- the orientation -- the positioning of the detectors being about a ring, an annular ring.

Q. And so going back to Paragraph 59, specifically when you're talking about Claim 6 --

A. Paragraph 59?

Q. Yeah.

A. Okay.

Q. -- are you saying that in Paragraph 59 for Claim 6 that these photodiodes are no longer going to be in the middle between these two light emitters and they are, instead, going to be on the opposite of the light emitters?

MR. SMITH: Objection; form. Argumentative.

A. No. I was describing you could have either scenario. You could have them in the same configure where it's inside and outside or outside and inside.

BY MR. KIANG:

Q. All right. Which is the one you're relying on for your opinions?

A. Well, here I'm describing that the -- the plural light receiving units are arranged in an annular ring about a circumference.

Q. Okay. And in your Declaration, you don't really talk about having these light receiving units rearranged so that they are outside of the light emitting units 6, correct?

A. I talk about the combination. And so a person skilled in the art looking at the combination could envision having them in either the inside and outside or outside and inside where you have two rings that are still in the same orientation or that you could flip them around. But here I'm talking about the annular orientation of the receiving units.

Q. I want to move on now to Paragraph 100 of your 1465 Declaration. And this is part of your analysis of Claim 21.

MR. KIANG: And could we show Page 48 as well on the screen?

(Tech complies.)

BY MR. KIANG:

Q. So Claim 21, you have the system of Claim 20, wherein the system is configured to determine the state of wellness of a user based on the determined physiological parameter, right?

A. Yes.

Q. And on Paragraph 100, you say,

"Based on my review, a POSITA would have understood that the blood oxygen saturation level and heart rate are each measures of a user's 'wellness,' and that the system therefore determines a state of wellness of the user by determining either or both of the user's blood oxygen saturation or heart rate."

Right?

A. Correct. And then I continue. "Wellness is a concept that encompasses many facets of...the well-being..." and many -- many physiological measurements.

Q. All right. Do you cite anything to support your opinions here?

A. I cite what a POSITA would have understood.

Q. Where is that cited?

A. Well, I -- my comment is "A POSITA would have understood that the blood oxygen saturation level and heart rate are each measures of a user's 'wellness,' and that the system therefore determines a state of wellness...by determining either or both of the user's blood oxygenation saturation or heart rate."

And the POSITA, furthermore, would have understood "wellness is a concept that can encompass many facets of a person's being..." including many physiological measurements.

Q. So is it your opinion that by measuring blood oxygen saturation or heart rate or both that that, in itself, is a determination of a state of wellness?

A. They are measures of a user's wellness. And any singular thing, depending on the state of health of the person, how that data is used, you know, there are many contributors to wellness; but they are aspects of being able to contribute to measures of a user's wellness.

We use many vital signs. Each contribute to a measure of the user's wellness.

Q. So in your opinion, for the combination of Iwamiya and Sarantos to satisfy Claim 21, the combination just has to determine oxygen saturation, correct?

MR. SMITH: Objection; form. Argumentative.

A. As I was describing here, they would have understood that blood oxygenation or blood saturation, heart rate are each measures. There are multiple measures; they are not the only ones.

But they are measures of a user's wellness and can be used to estimate and track changes of the user's wellness.

Q. Turn to Paragraph 104 of your Declaration on Page 51.

All right. And you say in the last sentence of this paragraph, "By the relatively relied Critical Date of the '745 Patent (July 2, 2015), it was well known in the field that additional insights could be gained from reviewing trends of such data beyond that which could be gleaned from static measurements of physiological parameters obtained at a single point in time."

Right?

A. Correct.
Q. And what do you cite there? Sorry. What do you cite for that?
A. Exhibit 1022.
MR. KIANG: Okay. Could I have the hot-seater please bring up, I think, Tab 15.
(Whereupon, Exhibit 1022, Methods and Approaches of Future Studies article, was identified.)
MR. KIANG: And this is previously marked as Exhibit 1022.
BY MR. KIANG:
Q. Dr. Anthony, do you recognize this?
A. That is "Methods and Approaches of Future Studies," 1022, yes.
MR. SMITH: And that exhibit is available also via the download link; is that right?
MR. KIANG: It should be.
MR. SMITH: Okay.
THE WITNESS: Let me go there. Hold on. Hold on. I don't want to share the

screen. Okay.

BY MR. KIANG:

Q. Do you have that in front of you?

A. I do.

Q. Is this what you cited to support your statement in Paragraph 104?

A. "Methods and Approaches of Future Studies."

"Methods and Approaches of Future Studies," yes.

Q. Okay. And this looks like it's some article from World Futures Society; is that right?

A. Could you just watch that over?

Q. And I'm looking at the top of this exhibit. It says something. "This was downloaded and greatly abridged from the World Futures Society."

Do you see that?

A. Yes.

Q. What is the World Futures Society?

A. It's a publication from which this

was downloaded.
Q. Sorry. I don't think that was quite clear on the transcript. What did you say?
A. The -- the place where this was downloaded from.
Q. Other than that, do you know what World Futures Society is?
A. I'd have to go back and look at my notes to describe in detail what the World Futures Society is.
Q. Are you a member of the World Futures Society?
A. I am not.
Q. Is the World Futures Society something that a person of ordinary skill would be a member of?
A. There are many organizations and this is what one reference talks about the benefits of trends, that, you know, the World Futures Society, you also need to be a member to be able to understand what's written here.
Q. Did you find this article yourself?

A. I don't recall whether this was one that I found or one that was recommended to me by counsel.

Q. Do you know when this article was published?

A. I don't have that date in front of me.

The benefit of -- of physiological monitoring and cutting the wire and using wellness devices, you know, the benefit that we have compared to making measurements in the hospital where you get single episodic measurements where you're suffering from white coat hypertension. You know, the long promise for years and the whole reason we started, for example, the Medical Electronics Device Realization Center was to -- was recognizing the fact wearable electronics allows us to collect sort of continuous measurements in the context of daily living and to potentially even sort of sacrifice episodic precision on its individual measurement for the benefit of having those measurements over time.

So this is but one reference that was a pretty well established -- it's the whole reason that we started decades ago the MEDRC.

Q. Let's go to the second page of this document, and you see the "Trend Analysis" on this page.

And do you see this kind of graph that's also on the second page?

A. Yes.

Q. It's talking about things like life expectancy, natural resources, world oil production, food pollution, industrial output, population.

Does any of this have anything to do with physiological monitoring?

A. These are alluding to the fact that trend analysis trending over time is a method that everybody uses. And historically frankly, we have not used it in medical devices because they were locked into what you could get in the hospital.

And, again, the whole reason -- and there are many -- there's actually probably a talk from 15 years ago, if not longer, of me talking about the MEDRC and the benefit of longitudinal measurements, of serial measurements, of giving measurements over time and sacrificing some of the precision that you're able to get episodically with being able to get that continuously in the context of daily living.

So this is but one reference. A POSITA certainly in 2015 understood that one of the big promises of wearable physiological monitoring was to have that in the context of daily living, more continuous measurements of vital signs of many sorts. So the trend analysis is pretty synonymous in many ways with the benefit that we can get for wellness and health in using wearable physiological monitors.

Q. Why would a person of ordinary skill be looking at the World Futures Society?

A. Again, trend analysis has the benefit of being able to have cut the wire on physiological monitoring and wear devices. This is but one place that talks about it. There are many others that a POSITA would have -- would know the benefit of why continuous measurement gives you sort of a stronger signal of changing aspects of health and wellness.

Q. All right. Let's turn to Paragraph 203 of your Declaration.

A. Okay.

Q. Now, you've opined here that you -- someone would use a -- sorry -- a person of ordinary skill would use a cylindrical light-shaping material in Sarantos; is that correct?

A. This is Sarantos and the -- and (talking to self). Yeah, so the combination here is Sarantos, Shie, and Venkatraman.

Q. And you said here in Paragraph 203, "By directing the light in this manner, the photodiodes would capture more of the light signal and be able to better produce more reliable measurement information without requiring overly expensive, highly-sensitive detector elements," right?

A. Yes.

Q. And by "overly expensive, highly-sensitive detector elements," are you talking about the high aspect ratio photodiodes that were disclosed in Sarantos?

MR. SMITH: Objection; form. Argumentative.

A. You know, here, it's -- I'm directing light to increase the -- capture more light. So by getting light where it can be captured more, you need less -- you don't need detectors -- detectors that are as sensitive.

So the idea of giving light to where the detectors are, whether they be the high aspect ratio or other photodiodes, has the benefit of, you know, being able to get light to where it needs to be.

I'm just noting -- I apologize, but I do have an extremely hard stop in five minutes to go be -- to do child pickup, so my apologies.

Q. Yeah. I also apparently have a little bit of a family emergency too now so I also need to get going soon.

In this combination, are you suggesting that by using this cyclical light-shaping material with Sarantos that you would no longer need the high aspect photodetectors in Sarantos?

A. A POSITA would have been motivated to implement cyclical light-shaping to improve signal-to-noise ratio. High aspect ratio photodiodes can also do that. And in the end, we want to put the design attributes in place that gives us sufficient quality, given cost constraints and given use constraints. So it wouldn't eliminate the need, but it can augment it. There are tradeoffs.

Q. Are you aware of any -- are you aware of any physiological monitoring device that has ever used a cylindrical light-shaping material?

A. A person skilled in the art,

depending on their design constraints, would be very familiar -- is very familiar with the lenses of many shapes and sizes. A cylindrical lens is not something magic. It's just a cylindrical lens.

Q. You're not aware of any prior art that talks about a physiological monitoring device that uses a cylindrical light-shaping material in the form of the LEDs, correct?

MR. SMITH: Objection; form.

A. A person skilled in the art would know to use the appropriate LEDs and sensors and optics for the configuration design that there -- that they are in the constraints they're trying to do and ways to improve, including lenses and distribution of light in an appropriate way.

We've used annular lenses and -- and cylindrical lenses. A lens does not have to be a circularly symmetrical thing to be a lens.

BY MR. KIANG:

Q. None of the prior art that you've discussed in your Declaration talks about using a cylindrical lens in a physiological monitoring device, correct?

MR. SMITH: Objection; form. Argumentative.

A. Ones I described in 203, "...a POSITA would have been motivated to implement a cylindrical light-shaping material in order to better project light towards the portions of the wrist tissue nearest the...photodiodes" that are directing light.

The photodiodes capture more light, appears better reliable measurements without requiring additionally expensive photodetector elements.

"In particular, the cylindrical light-shaping material would be...advantageous to spread the light towards photodiodes that are not arranged in a circular configuration but are instead...opposite each other on opposite sides of the sensor."

So it depends. You know, the lens you use, if you want to get to the light to where you just choose the sensors, so again, the same way you would use different filters depending on the wavelengths you use, you use different optics depending on the arrangement of the emitter and detectors you choose to use.

MR. KIANG: All right. I'll pass the witness.

MR. SMITH: And I have no questions.

MR. KIANG: All right.

MR. SMITH: One minute early, Dr. Anthony.

THE WITNESS: Thank you for that. My wife and my kids thank you. So thank you, everybody. And I'm going to run.

MR. KIANG: Thank you, Dr. Anthony, for your time.

THE WITNESS: Thank you.

THE TECH: Going off the record, this deposition is concluded at 5:59.

AUTOMATED MESSAGE: Recording stopped.

(Time noted: 5:59 p.m. EDT.)

CERTIFICATE OF SHORTHAND REPORTER-NOTARY PUBLIC

I, Amanda Gorrono, the officer before whom the foregoing deposition was taken, do hereby certify that the foregoing transcript is a true and correct record of the testimony given; that said testimony was taken by me stenographically and thereafter reduced to typewriting under my direction; and that I am neither counsel for, related to, nor employed by any of the parties to this case and have no interest, financial or otherwise, in its outcome.

IN WITNESS WHEREOF, I have hereunto set my hand this 24th day of March, 2023.

AMANDA GORRONO, CLR
CLR NO: 052005 - 01
Notary Public in and for
The State of New York
County of Suffolk
My Commission No. 01G06041701
Expires: 01/07/2027

Brian W. Anthony, Ph.D., c/o
Fish & Richardson P.C.
1717 Main Street, Suite 5000
Dallas, TX 75201

Case: Apple, Inc. v. Masimo Corp.
Date of deposition: March 24, 2023
Deponent: Brian W. Anthony, Ph.D.

Please be advised that the transcript in the above referenced matter is now complete and ready for signature. The deponent may come to this office to sign the transcript, a copy may be purchased for the witness to review and sign, or the deponent and/or counsel may waive the option of signing. Please advise us of the option selected. Please forward the errata sheet and the original signed signature page to counsel noticing the deposition, noting the applicable time period allowed for such by the governing Rules of Procedure. If you have any questions, please do not hesitate to call our office at (202)-232-0646.

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Case: Apple, Inc. v. Masimo Corp.
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Deposition Date: March 24, 2023

I do hereby acknowledge that I have read and examined the foregoing pages of the transcript of my deposition and that:

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Deposition Date: March 24, 2023

Page No. Line No. Change

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Massi E. Kiani	
U.S. Patent No.:	6,771,994	Attorney Docket No.: 50095-0005IP1
Issue Date:	August 3, 2004	
Appl. Serial No.:	10/374,303	
Filing Date:	February 24, 2003	
Title:	PULSE OXIMETER PROBE-OFF DETECTION SYSTEM	

DECLARATION OF DR. BRIAN W. ANTHONY

I, Brian W. Anthony, of Cambridge, MA, declare that:

I. QUALIFICATIONS AND BACKGROUND INFORMATION

1. My name is Dr. Brian W. Anthony. I am an Associate Principal Research Scientist at the Institute of Medical Engineering & Science at Massachusetts Institute of Technology (MIT). I am also a Principal Research Scientist at MIT's Mechanical Engineering department, Director of the Master of Engineering in Advanced Manufacturing and Design Program at MIT, a Co-Director of the Medical Electronic Device Realization Center of the Institute of Medical Engineering & Science, and Associate Director of MIT.nano. My current *curriculum vitae* is attached and some highlights follow.

2. I earned my B.S. in Engineering (1994) from Carnegie Mellon University. I earned my M.S. (1998) and Ph.D. (2006) in Engineering from MIT. My research focused on high-performance computation, signal processing, and electro-mechanical system design.

Anthony
Exhibit 1
(3-24-23)
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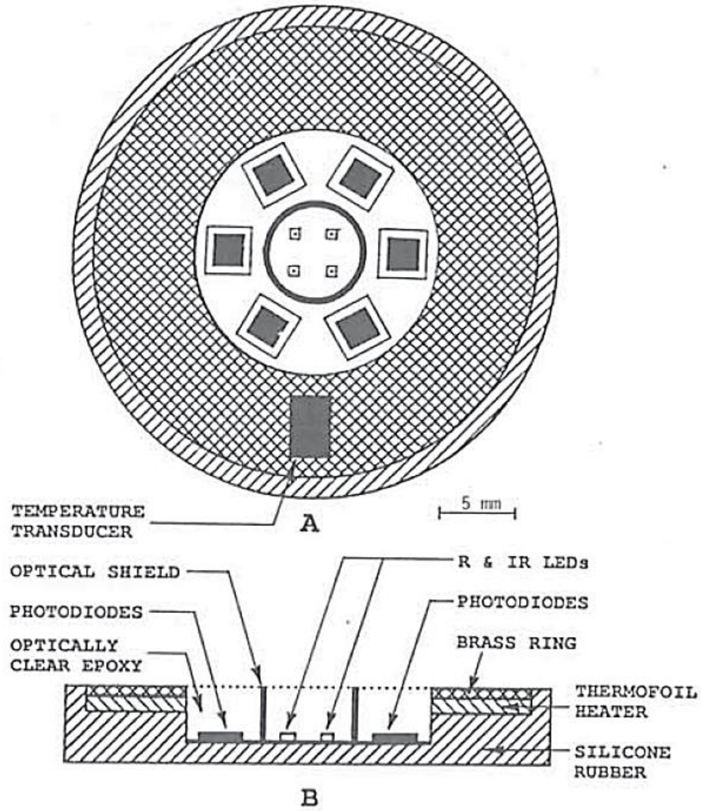

Fig 1. (A) Frontal and (B) side views of the heated skin reflectance pulse oximeter sensor. See text for explanation. R & IR LEDs = *red and infrared light-emitting diodes.*

23. The use of optical sensors to detect physiological parameters, including photoplethysmography, has also been known for decades. Optical techniques are commonly used in medical monitoring systems such as pulse oximetry systems that measure a person's pulse rate and blood oxygen saturation. APPLE-1013 at 769-76, 1346-55 (discussing oximetry and other applications).

24. Photoplethysmography works by directing light into a person's tissue and measuring the light that is reflected back from or transmitted through the tissue. APPLE-1013 at 764. Different components of blood or tissue absorb

different wavelengths of light. By measuring how much light is absorbed by the tissue and how the absorption changes over time, a device can calculate parameters that are related to the properties of the tissue or blood.

25. For example, hemoglobin (the protein molecule in blood that carries oxygen to cells) reflects more red light when it is more oxygenated than when it is deoxygenated; it absorbs more red light when it is deoxygenated. APPLE-1013 at 769. Hemoglobin reflects the same amount of infrared (IR) light whether oxygenated or deoxygenated. APPLE-1013 at 769. If a device measures the absorbed red and IR light multiple times per second, the device can determine several things: (i) the ratio of oxygenated to deoxygenated hemoglobin (oxygen saturation), and (ii) how the volume of blood in the tissue changes over time, allowing detection of a person's pulse. APPLE-1013 at 769, 771.

26. Photoplethysmography is an optical technique, and it uses basic optical components or building blocks. The "basic building blocks" of optical sensor systems include lenses, mirrors, reflective surfaces, filters, beam splitters, light sources, fiber optics, light detectors, and other passive components and various active components to convert light signals to electrical signals. APPLE-1013 at 765.

XI. CONCLUSION

I currently hold the opinions set forth in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of the Title 18 of the United States Code.

Dated: 8/31/2020 By: ______________________

Dr. Brian W. Anthony

US009392946B1

(12) **United States Patent**
Sarantos et al.

(10) **Patent No.: US 9,392,946 B1**
(45) **Date of Patent: Jul. 19, 2016**

(54) **HEART RATE SENSOR WITH HIGH-ASPECT-RATIO PHOTODETECTOR ELEMENT**

(71) Applicant: **Fitbit, Inc.**, San Francisco, CA (US)

(72) Inventors: **Chris H. Sarantos**, San Francisco, CA (US); **Peter W. Richards**, San Francisco, CA (US)

(73) Assignee: **Fitbit, Inc.**, San Francisco, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/724,750**

(22) Filed: **May 28, 2015**

(51) **Int. Cl.**
A61B 5/024 (2006.01)
A61B 5/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A61B 5/02427*** (2013.01); ***A61B 5/02438*** (2013.01); ***A61B 5/681*** (2013.01)

(58) **Field of Classification Search**
CPC . A61B 5/02427; A61B 5/02438; A61B 5/681
See application file for complete search history.

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Primary Examiner — Bo J Peng
(74) *Attorney, Agent, or Firm* — Weaver Austin Villeneuve & Sampson LLP

(57) **ABSTRACT**

Heart rate sensors including high-aspect-ratio photodetector elements are discussed herein. Such high-aspect-ratio photodetector elements may provide improved signal-strength-to-power-consumption performance for heart rate sensors incorporating such photodetector elements as compared with heart rate sensors incorporating, for example, square photodetector elements.

30 Claims, 14 Drawing Sheets

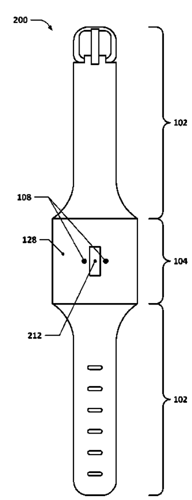

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Exhibit 2
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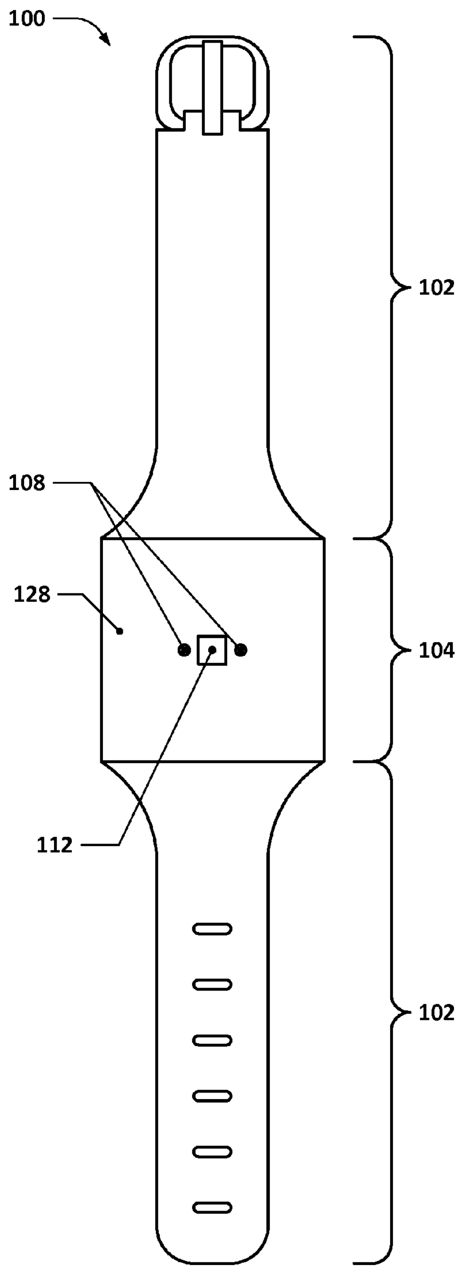

FIG. 1
(Prior Art)

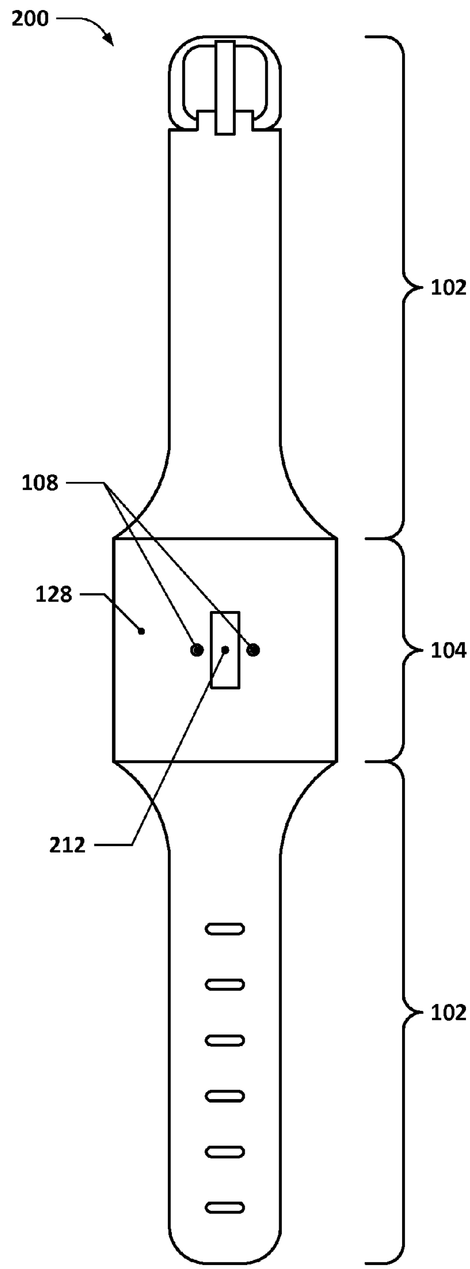

FIG. 2

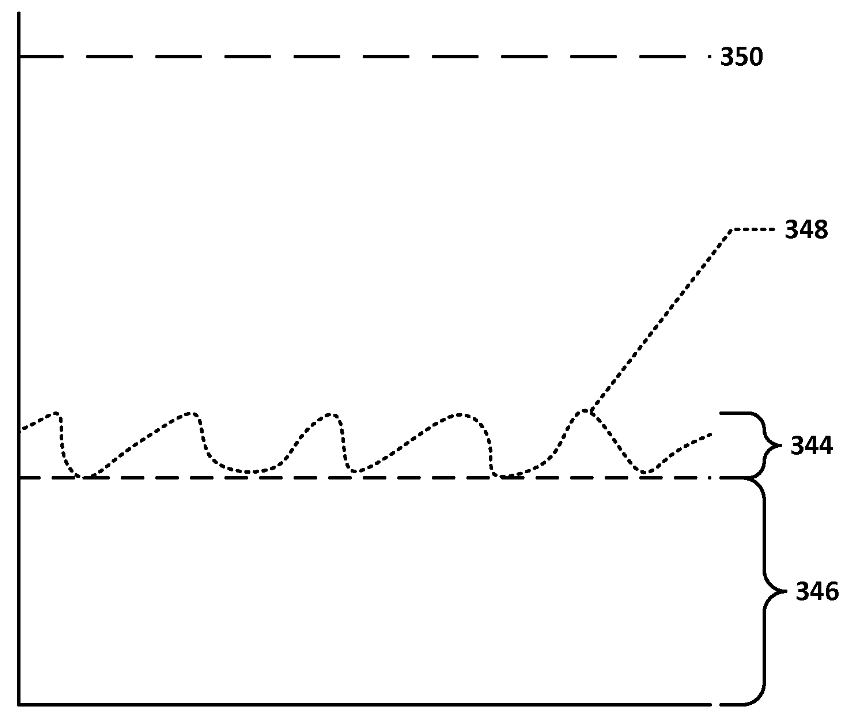

FIG. 3

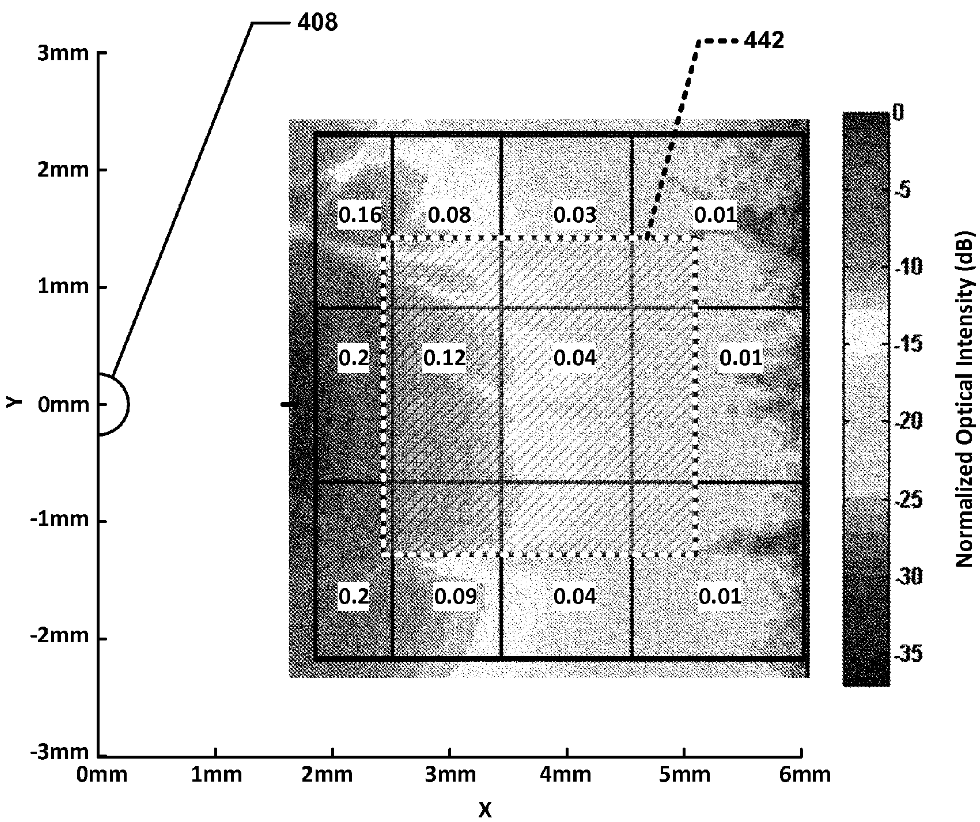

FIG. 4

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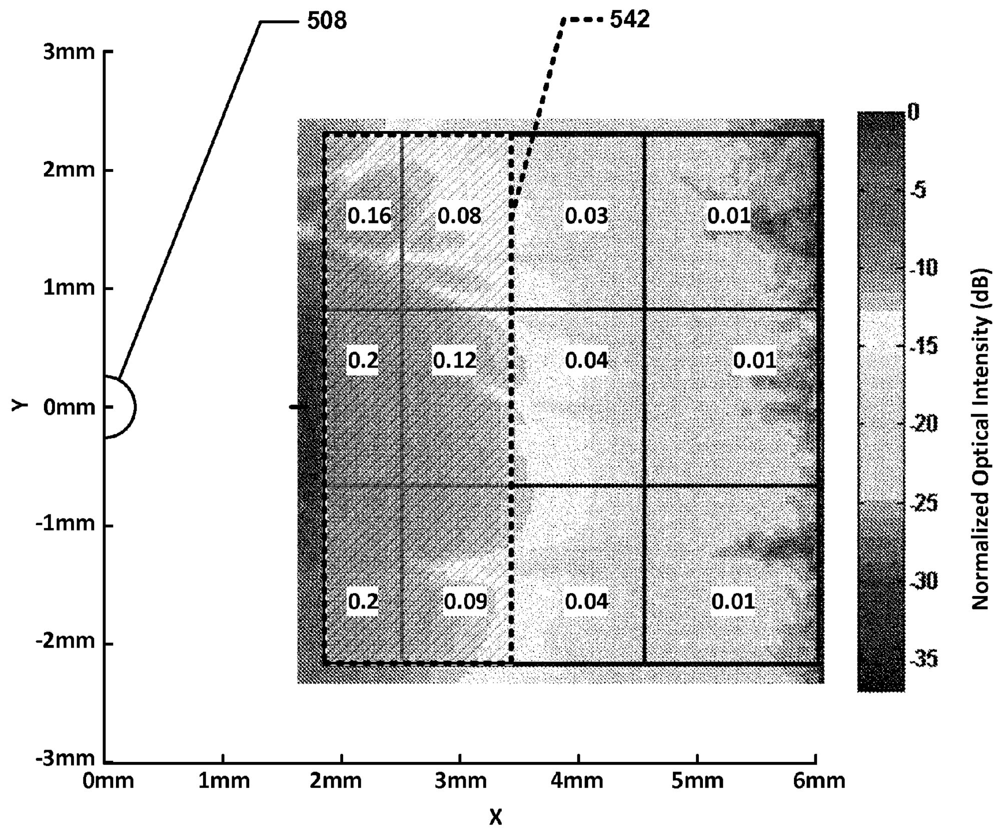

FIG. 5

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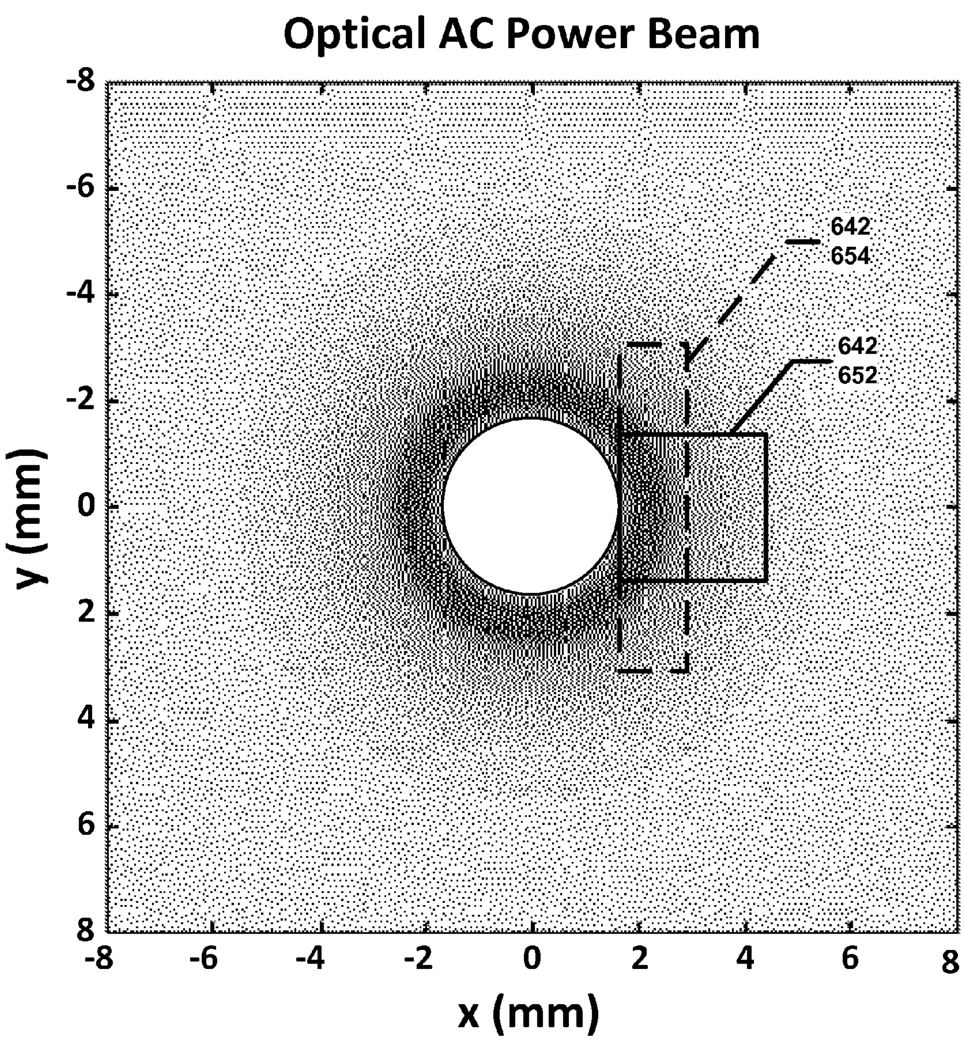

FIG. 6

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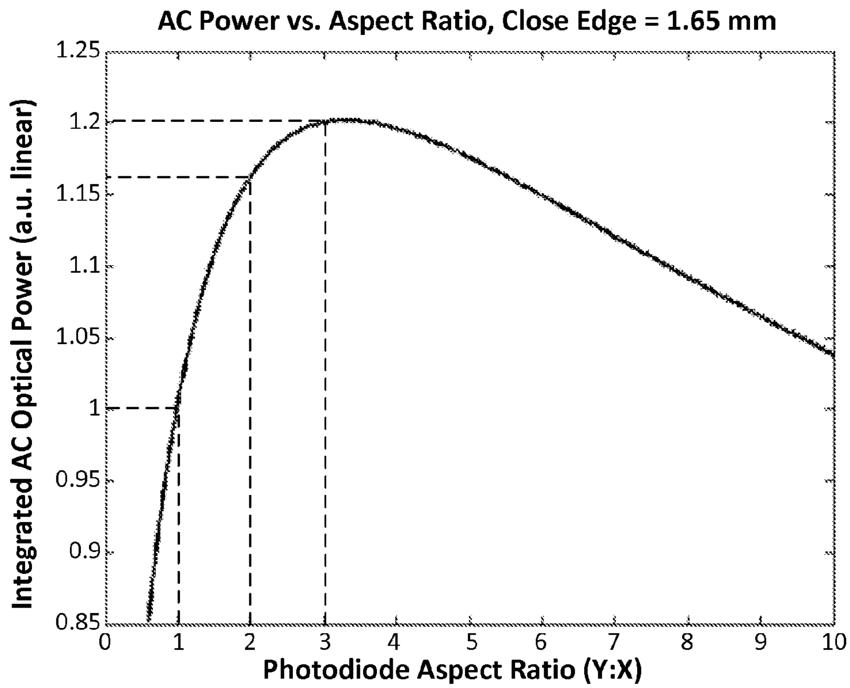

FIG. 7

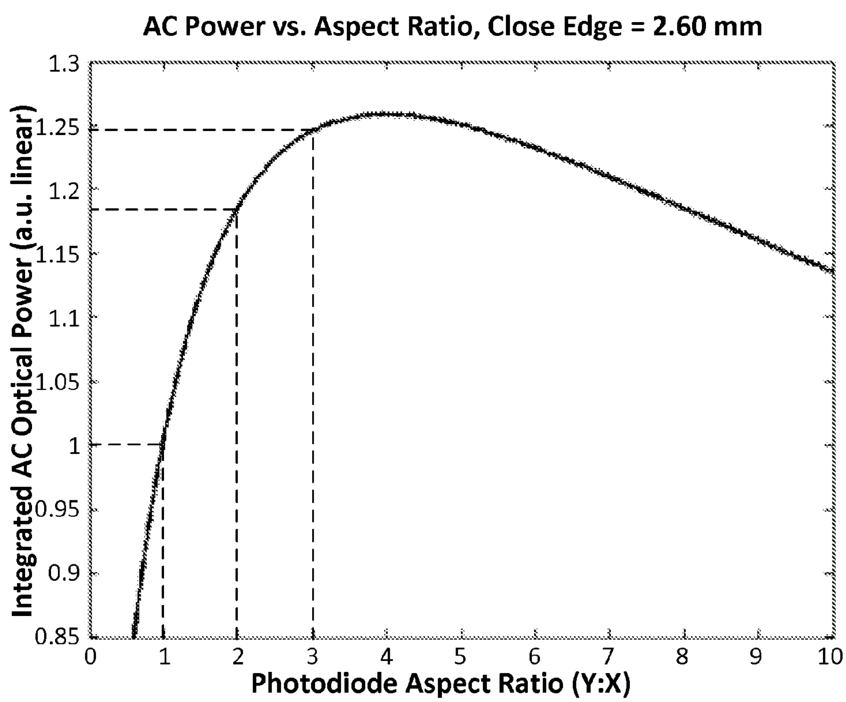

FIG. 8

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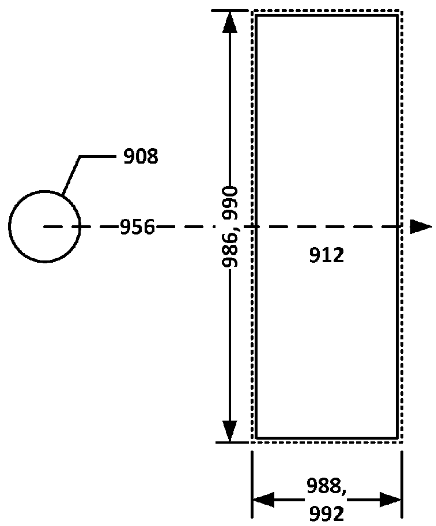

FIG. 9

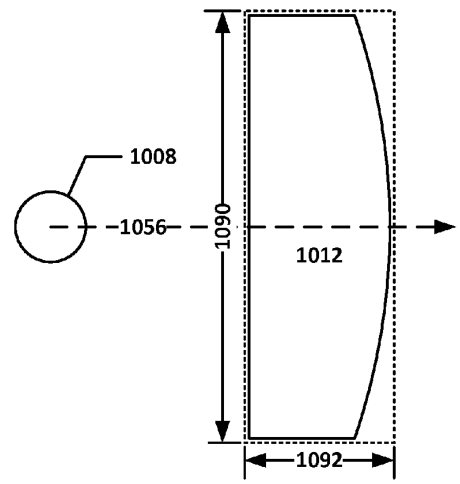

FIG. 10

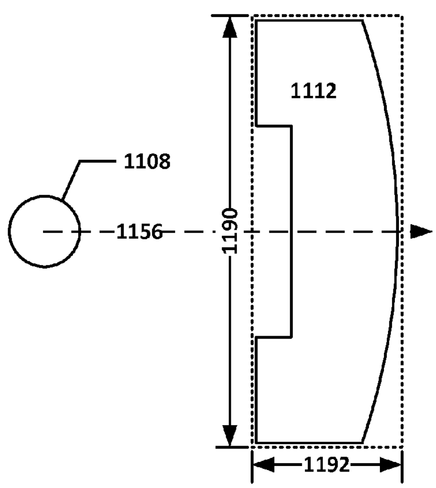

FIG. 11

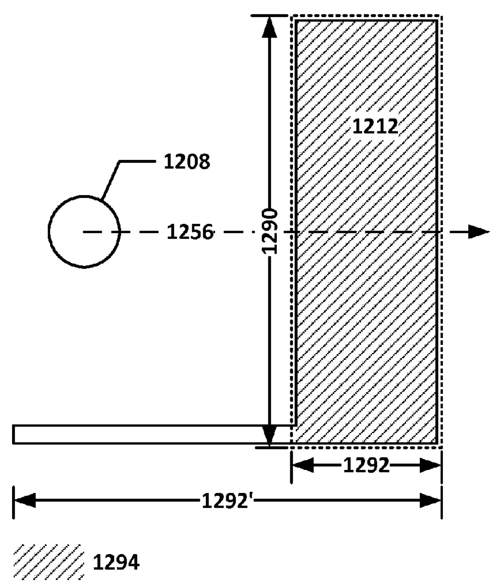

FIG. 12

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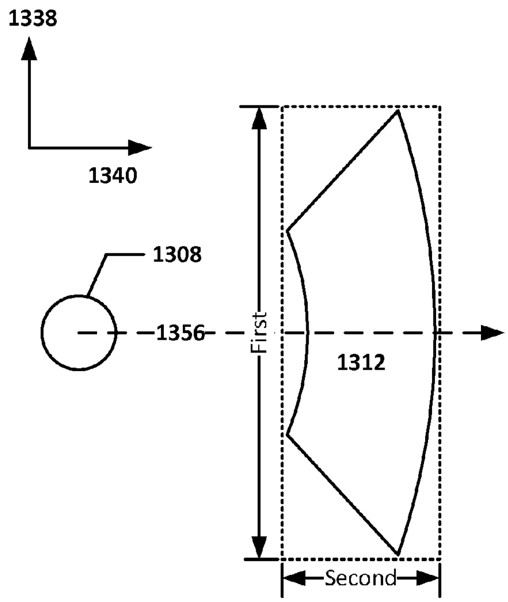

FIG. 13

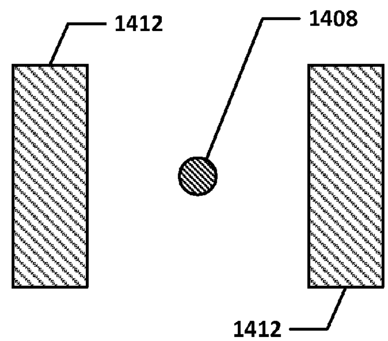

FIG. 14

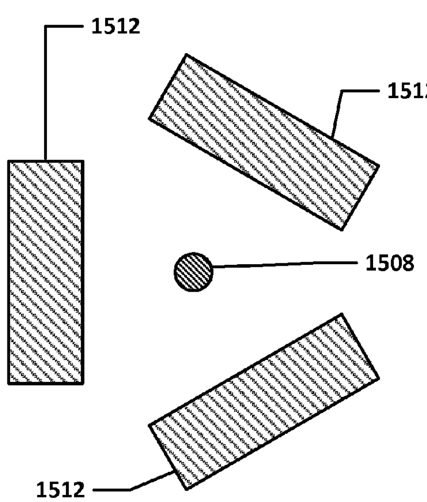

FIG. 15

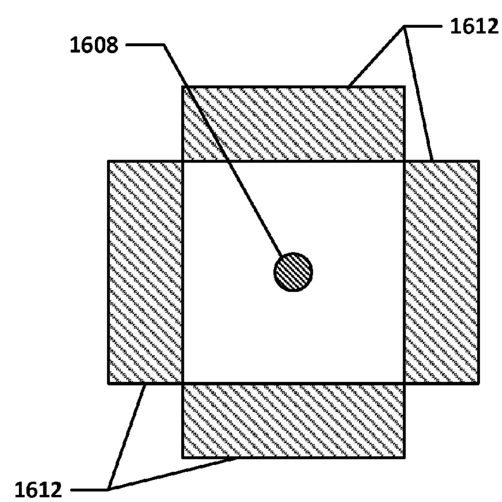

FIG. 16

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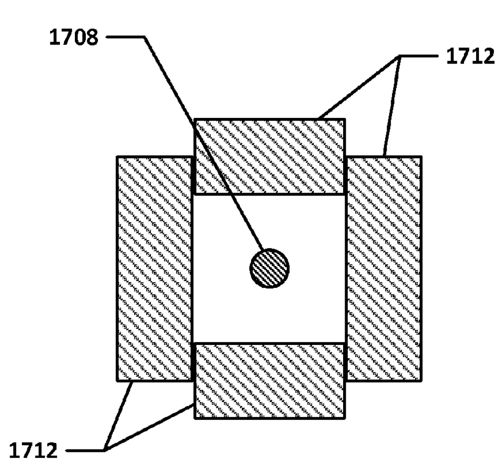

FIG. 17

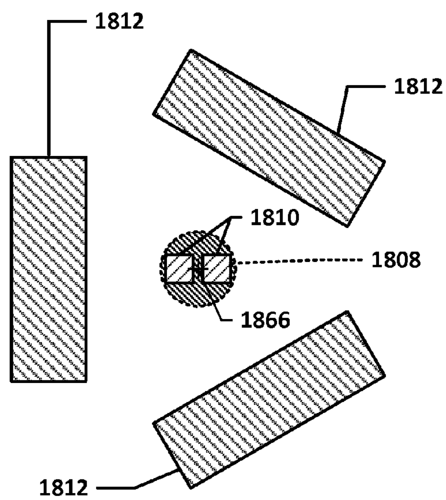

FIG. 18

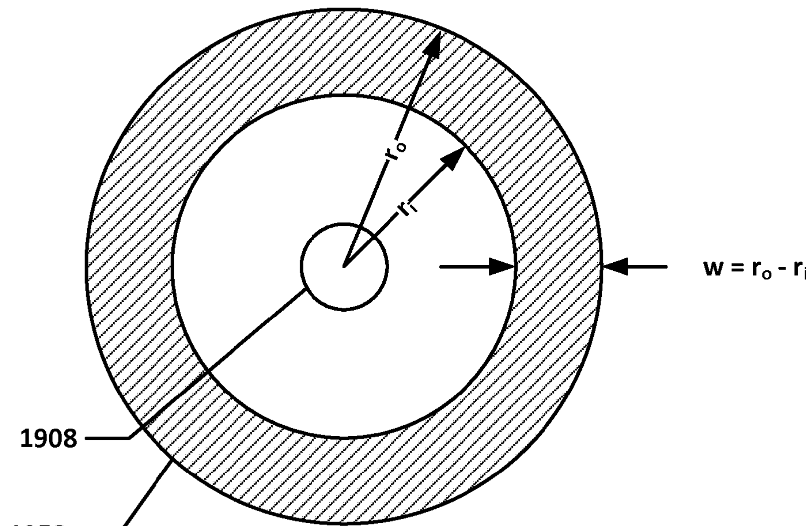
r_o
r_i
w = r_o - r_i
1908
1958

FIG. 19

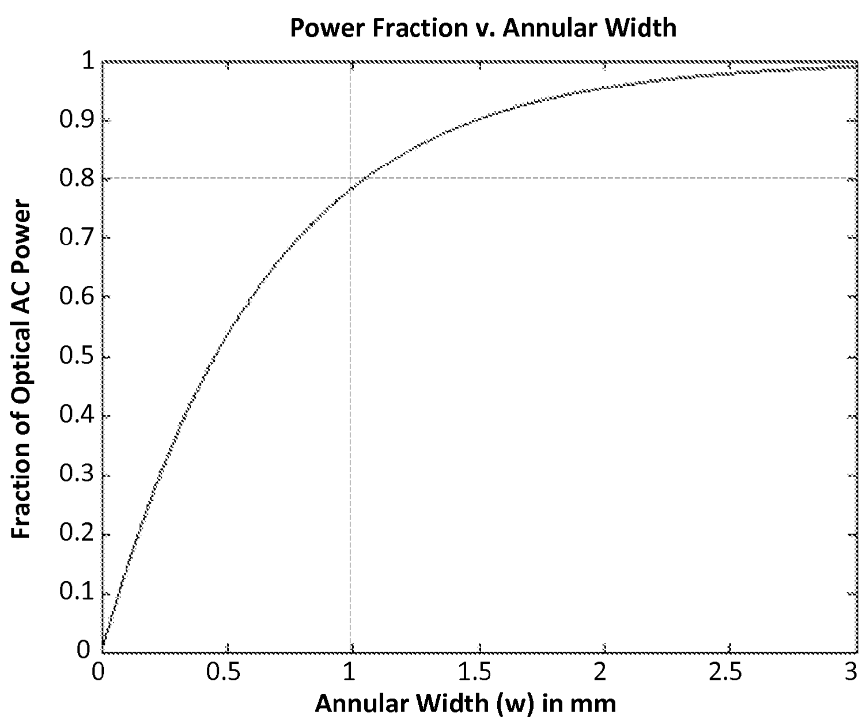
Power Fraction v. Annular Width
Fraction of Optical AC Power
Annular Width (w) in mm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5
2
2.5
3

FIG. 20

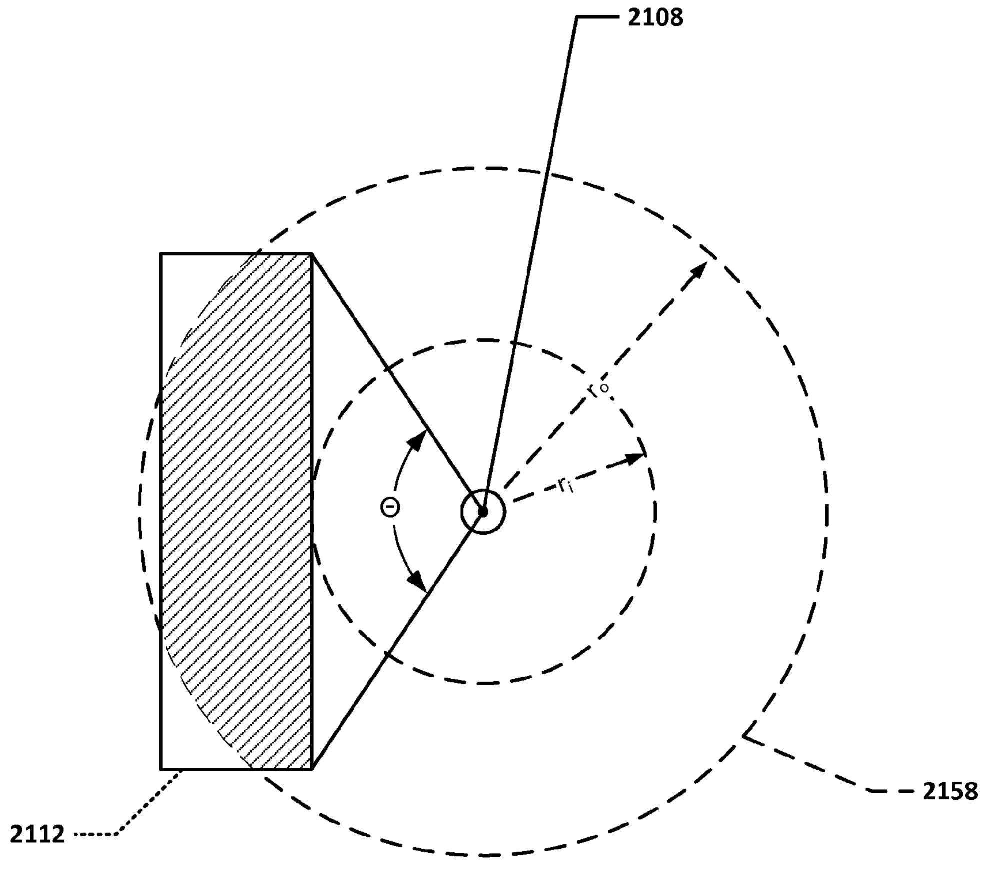

FIG. 21

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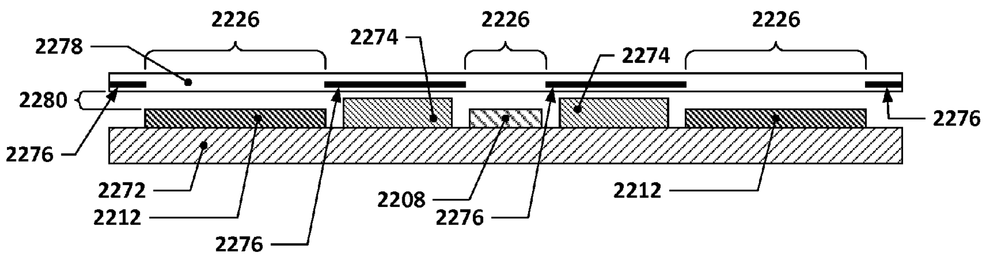

FIG. 22

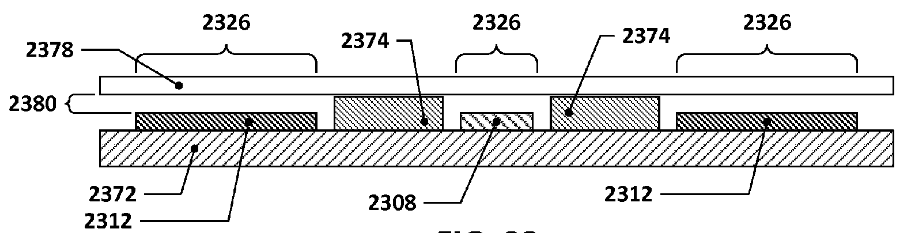

FIG. 23

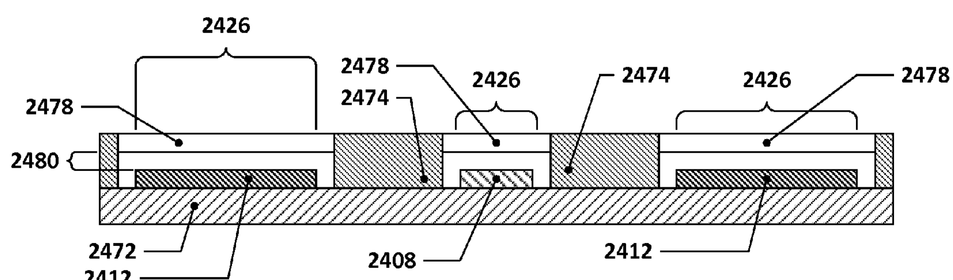

FIG. 24

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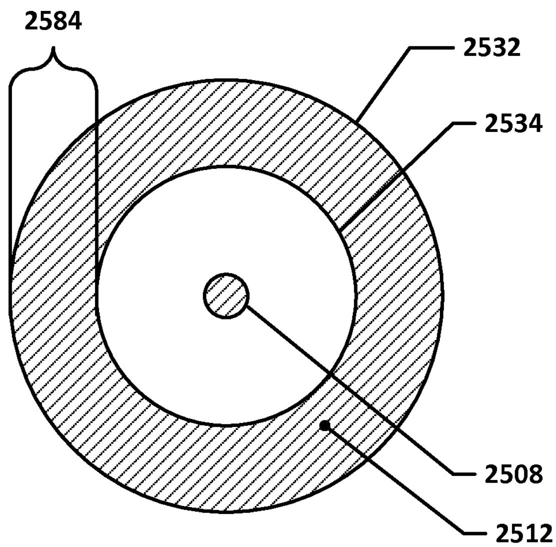

FIG. 25

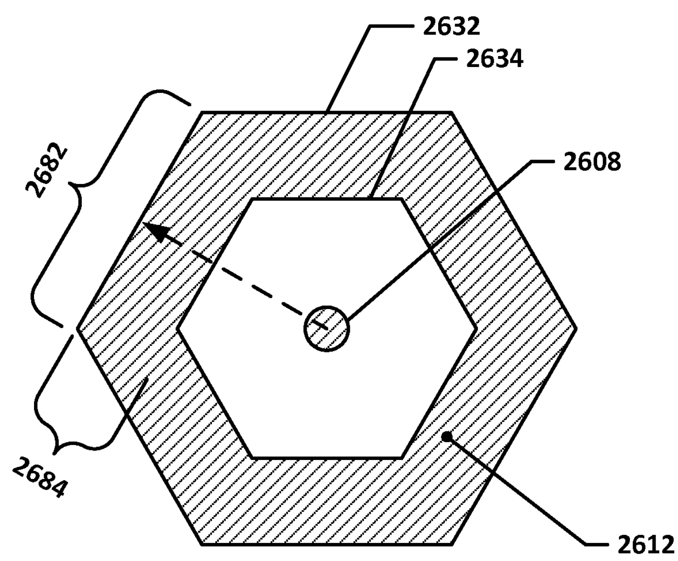

FIG. 26

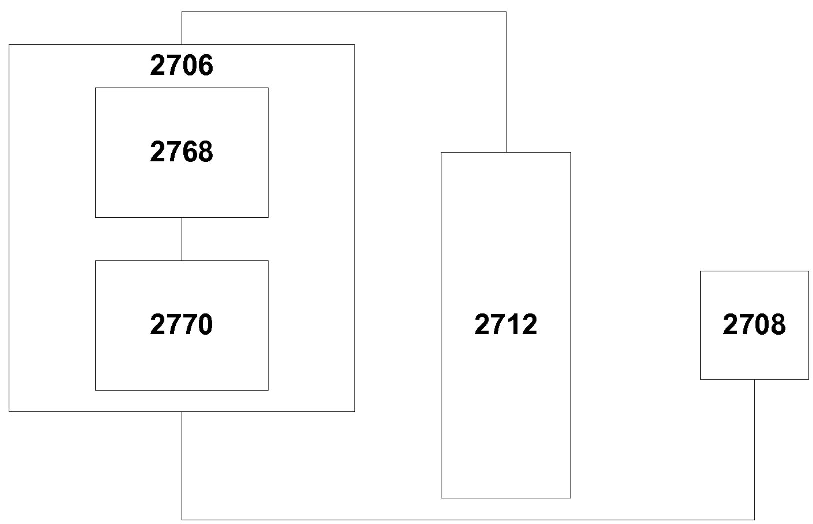

FIG. 27

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HEART RATE SENSOR WITH HIGH-ASPECT-RATIO PHOTODETECTOR ELEMENT

BACKGROUND

Heart rate may be measured using any of a variety of different sensors, including, for example, electrode-based sensors, such as EKG sensors, and optical sensors, such as photoplethysmographic (PPG) sensors. PPG sensors typically include a light source and a photodetector that are placed adjacent to a person's skin. The light source and photodetector are typically arranged so that light from the light source cannot reach the photodetector directly. However, when the PPG sensor is placed adjacent to a person's skin, light from the light source may diffuse into the person's flesh and then be emitted back out of the person's flesh such that the photodetector can detect it. The amount of such light that is emitted from the person's flesh may vary as a function of heart rate, since the amount of blood present in the flesh varies as a function of heart rate and the amount of light that is emitted from the person's flesh, in turn, varies as a function of the amount of blood present.

The assignee of this application, Fitbit, Inc., makes wearable fitness monitoring devices, some of which, such as the Charge HR™ and the Surge™, incorporate PPG sensors that include two high-brightness, green light-emitting diodes (LEDs) that are spaced approximately 8 mm apart, as well as a 2 mm square photodetector element located midway between the LEDs. Various other companies that make wearable fitness monitoring devices utilize a similar architecture. For example, the Basis Peak™ incorporates two green LEDs with a square photodetector element located midway between them, as does the Motorola Moto 360™.

FIG. **1** depicts a simplified representation of a prior-art wristband-type wearable fitness monitor **100** that incorporates a PPG sensor. The wearable fitness monitor **100**, in this example, includes a housing **104** with two straps **102** attached; the straps **102** may be used to fasten the housing **104** to a person's forearm, in much the same manner as a watch (indeed, many such devices may incorporate timekeeping functionality as well). The PPG sensor, in this example, includes two light sources **108**, with a photodetector element **112** interposed midway between them on a back face **128** of the housing **104**; the photodetector element **112** in this example has a photosensitive area with a square aspect ratio. When the wearable fitness monitor **100** is worn by a person in a manner similar to a wristwatch, the back face **128** may be pressed against the person's skin, allowing the light sources **108** to illuminate the person's skin. The photodetector element **112** may then measure the amount of that light that is then emanated back out of the person's skin. Control logic (not pictured) within the housing **104** may then calculate the person's heart rate based on fluctuations in the amount of light measured by the photodetector element **112**.

SUMMARY

Details of one or more implementations of the subject matter described in this specification are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages will become apparent from the description, the drawings, and the claims. Note that the relative dimensions of the following figures may not be drawn to scale unless specifically indicated as being scaled drawings.

In some implementations, an apparatus having a light source and one or more discrete photodetector elements may be provided. Each photodetector element may have a first edge having a first length and may also have a first width in a direction perpendicular to the first edge. The apparatus may also include control logic, which may be communicatively connected with the light source and each photodetector element and configured to cause the light source to emit light, obtain one or more measured light intensity measurements from the one or more photodetector elements, and determine a heart rate measurement based, at least in part, on the one or more light intensity measurements. In such implementations, the ratio of the first length to the first width of each photodetector may be substantially between 2:1 to 5:1.

In some such implementations, the first edge of each photodetector element may be perpendicular or transverse to an axis radiating out from a center of the light source.

In some implementations of the apparatus, the light source may include a plurality of light-emitting devices.

In some such implementations, the plurality of light-emitting devices may include at least two light-emitting devices that predominantly emit light of different wavelengths. In some further or alternative such implementations, there may be a plurality of photodetector elements arranged in a pattern, and the plurality of light-emitting devices may be collocated at a center point of the pattern of photodetector elements. In some such implementations, each photodetector element in the pattern may be equidistant from the center of the light source and/or evenly spaced within the pattern.

In some implementations of the apparatus, the ratio of the first length to the first width of each photodetector element may be substantially between 2:1 to 3.5:1. In some other implementations of the apparatus, the ratio of the first length to the first width of each photodetector element may be substantially between 3.5:1 to 5:1.

In some implementations of the apparatus, each photodetector element may have a first length between 1 mm and 5 mm and a first width between 0.5 mm and 2 mm, with the ratio of the first length to the first width substantially between 2:1 to 5:1, and each such photodetector element may be positioned such that an edge of the photodetector element closest to the light source is between 1 mm and 4 mm from the light source.

In some implementations of the apparatus, there may be a pattern of photodetector elements that includes three or four photodetector elements that are equidistantly spaced about the light source.

In some implementations of the apparatus, the apparatus may also include a housing having a back face that includes one or more transparent window regions through which light may enter the apparatus. In such implementations, each photodetector element is positioned such that that photodetector element is overlapped by a corresponding one of the one or more transparent window regions, and the housing may be configured such that the back face is adjacent to the skin of a person wearing the apparatus when the apparatus is worn by that person.

In some such implementations of the apparatus, the back face may include a thin window, and the window regions may be sub-regions of the window that are defined by the photodetector elements. In some other or additional such implementations, each photodetector element may be offset from the corresponding transparent window region by a corresponding gap in a direction normal to the photodetector element, and the gap may be free of optical light guides.

In some implementations of the apparatus, each photodetector element may, in addition to the first edge, have an

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arcuate second edge opposite the first edge. The arcuate second edge may have a maximum distance from the first edge, when measured along a direction perpendicular to the first edge, that is equal to the first width.

In some implementations, an apparatus may be provided that includes a first light source and a second light source, as well as a photodetector element interposed between the first light source and the second light source. The apparatus may also include control logic that is communicatively connected with the first and second light sources and the photodetector element and that is configured to cause the first light source and the second light source to emit light, obtain measured light intensity measurements from the photodetector element, and determine a heart rate measurement based, at least in part, on the light intensity measurements. In such implementations, the photodetector element may be rectangular in shape, have a first edge with a first length, and have a second edge, perpendicular to the first edge, with a second length. Furthermore, in such implementations, the ratio of the first length to the second length may be substantially between 2:1 to 5:1.

In some such implementations, the first edge of each photodetector element may be perpendicular or transverse to an axis spanning between a center of the first light source and a center of the second light source.

In some other or additional such implementations, the apparatus may include a housing having a back face that includes a transparent window region that overlaps the photodetector element and two further window regions that are each associated with a different one of the first light source and the second light source and that allow light from the associated light source to pass through the back face. In such implementations, the first light source and the second light source may be the only light sources in the apparatus configured to emit light through the back face, and the housing may be configured such that the back face is adjacent to the skin of a person wearing the apparatus when the apparatus is worn by that person.

In some implementations of the apparatus, the photodetector element may be equidistant from the first light source and the second light source.

In some implementations, an apparatus may be provided that includes a light source and one or more photodetectors, each photodetector having a photosensitive area. In such implementations, at least 90% of the photosensitive area of the photodetector is defined by a first dimension along a first axis and a second dimension along a second axis perpendicular to the first axis. The apparatus may also, in such implementations, include control logic that is communicatively connected with the light source and each photodetector and that is configured to cause the light source to emit light, obtain one or more measured light intensity measurements from the one or more photodetectors, and determine a heart rate measurement based, at least in part, on the one or more light intensity measurements. In such implementations, the ratio of the first dimension to the second dimension may be substantially between 2:1 to 5:1.

In some implementations of the apparatus, the light source may include a plurality of light-emitting devices. In some such implementations, the plurality of light-emitting devices may include at least two light-emitting devices that predominantly emit light of different wavelengths. In some further or alternative such implementations, there may be a plurality of photodetector elements arranged in a pattern, and the plurality of light-emitting devices may be collocated at a center point of the pattern of photodetector elements. In some such implementations, each photodetector element in the pattern may be equidistant from the center of the light source and/or evenly spaced within the pattern.

In some implementations of the apparatus, the ratio of the first length to the first width of each photodetector element may be substantially between 2:1 to 3.5:1. In some other implementations of the apparatus, the ratio of the first length to the first width of each photodetector element may be substantially between 3.5:1 to 5:1.

In some implementations of the apparatus, each photodetector element may have a first length between 1 mm and 5 mm and a first width between 0.5 mm and 2 mm, with the ratio of the first length to the first width substantially between 2:1 to 5:1, and each such photodetector element may be positioned such that an edge of the photodetector element closest to the light source is between 1 mm and 4 mm from the light source.

In some implementations of the apparatus, there may be a pattern of photodetector elements that includes three or four photodetector elements that are equidistantly spaced about the light source.

In some implementations of the apparatus, the apparatus may also include a housing having a back face that includes one or more transparent window regions through which light may enter the apparatus. In such implementations, each photodetector element is positioned such that that photodetector element is overlapped by a corresponding one of the one or more transparent window regions, and the housing may be configured such that the back face is adjacent to the skin of a person wearing the apparatus when the apparatus is worn by that person.

In some such implementations of the apparatus, the back face may include a thin window, and the window regions may be sub-regions of the window that are defined by the photodetector elements. In some other or additional such implementations, each photodetector element may be offset from the corresponding transparent window region by a corresponding gap in a direction normal to the photodetector element, and the gap may be free of optical light guides.

In some implementations, an apparatus may be provided that includes a light source and at least one photodetector element. The apparatus may also include control logic that is communicatively connected with the light source and the photodetector element and that is configured to cause the light source to emit light, obtain at least one measured light intensity measurement from the at least one photodetector element, and determine a heart rate measurement based, at least in part, on the at least one light intensity measurement. In such implementations, the at least one photodetector element may subtend an angle at the center of the light source of substantially at least: 2·arctan

$$\left(\frac{1}{r_i}\right)$$

radians, where r_i is a measurement of a distance from the center of the light source to the photodetector element, at least 80% of the photodetector element covers an annular region centered on the center of the light source and defined by r_i and r_o, and r_o is greater than r_i by not more than 2 millimeters.

In some such implementations, the angle at the center of the light source subtended by the at least one photodetector element may be substantially at most: 2·arctan

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$$\left(\frac{2.5}{r_i}\right)$$

radians.

In some implementations, an apparatus may be provided that includes a light source configured to emit light predominantly having wavelengths in the 500 nm to 600 nm range, as well as a photodetector element having a central opening. The apparatus may also include control logic that is communicatively connected with the light source and the photodetector element and that is configured to cause the light source to emit light, obtain measured light intensity measurements from the photodetector element, and determine a heart rate measurement based, at least in part, on the light intensity measurements. In such implementations, the light source may be positioned so as to emit light through the central opening of the photodetector element, and the photodetector element may have a) an exterior periphery defined by a first boundary and b) a second boundary defining the central opening.

In some such implementations, the first boundary and the second boundary may form an annulus, the first boundary may be radially offset from the second boundary by a first distance, and the ratio of the circumference of the second boundary to the first distance may be between 9.5:1 to 11.5:1.

In some other or additional such implementations, the first boundary and the second boundary may form an annulus, the first boundary may have a diameter of between 3 to 5.5 mm, and the second boundary may have a diameter of between 1 to 2.5 mm.

In some implementations of the apparatus, the second boundary may be a regular polygon of N sides each having a second length, and for each of the N sides of the second boundary, the first boundary may be offset from that side of the second boundary by a first distance along a reference axis that originates at a center of the light source and passes through the midpoint of that side of the second boundary. In such implementations, the ratio of the second length to the first distance for each of the N sides may be between 2:1 to 5:1.

These and other implementations are described in further detail with reference to the Figures and the detailed description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The various implementations disclosed herein are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings, in which like reference numerals refer to similar elements.

FIG. **1** depicts a simplified representation of a prior-art wristband-type wearable fitness monitor that incorporates a PPG sensor.

FIG. **2** depicts a simplified representation of a wristband-type wearable fitness monitor that incorporates a PPG sensor that uses a non-square photodetector element, in accordance with an example implementation.

FIG. **3** is a theoretical plot of emitted light intensity and detected light intensity for an example PPG sensor that is used to obtain heart rate information from a person's flesh, in accordance with an example implementation.

FIG. **4** depicts a grey-scale plot of measured AC power intensity for light emanated from a rectangular region measuring approximately 4.5 mm wide by 5 mm tall on a person's arm near the wrist, in accordance with an example implementation.

FIG. **5** depicts the same light intensity image map of FIG. **4**, but with the outline of a high-aspect-ratio photodetector element added to the Figure, in accordance with an example implementation.

FIG. **6** depicts a simulation of the AC intensity or power of light that is emanated within a 16 mm by 16 mm region of skin as a result of light that is shined into the skin at the center of the region, in accordance with an example implementation.

FIG. **7** depicts a plot of measurable AC light power as a function of photodetector footprint aspect ratio with regard to the simulation shown in FIG. **6**, in accordance with an example implementation.

FIG. **8** depicts a plot of measurable AC light power as a function of photodetector footprint aspect ratio with regard to the simulation shown in FIG. **6**, but with the edge of the photodetector closest to the center of the light source offset from the light source center by 2.6 mm instead of 1.65 mm, in accordance with an example implementation.

FIG. **9** depicts a diagram of a high-aspect-ratio ("HAR") photodetector element that is rectilinear, in accordance with an example implementation.

FIG. **10** depicts a diagram of a HAR photodetector element that is generally rectangular, but that possesses some non-rectangular aspects, in accordance with an example implementation.

FIG. **11** depicts a diagram of a HAR photodetector element that is similar to the HAR photodetector element of FIG. **10**, but with a rectangular cutout along the first edge, in accordance with an example implementation.

FIG. **12** depicts a diagram of a HAR photodetector element that is similar to the HAR photodetector element of FIG. **9**, but one where the active area is generally rectangular yet has a "peninsula" that protrudes out from the rectangular area, in accordance with an example implementation.

FIG. **13** depicts a diagram of a HAR photodetector element that is arcuate in shape, in accordance with an example implementation.

FIGS. **14** through **17** depict several examples of implementations with multiple HAR photodetectors, in accordance with several example implementations.

FIG. **18** depicts an example of a PPG sensor photodetector layout as shown in FIG. **15** but with multiple light-emitting devices used in the light source, in accordance with an example implementation.

FIG. **19** shows an example light source and a surrounding annular region, in accordance with an example implementation.

FIG. **20** depicts a plot of the fraction of the light intensity that is emanated outside of an arbitrary inner radius r_i that would fall within the bounds of an annular region with an inner radius r_i and an annular width as indicated along the x-axis, in accordance with an example implementation.

FIG. **21** depicts a light source, HAR photodetector, and various reference annotations.

FIGS. **22** through **24** depict cross-sections of simplified representations of various PPG sensors, in accordance with various example implementations.

FIG. **25** depicts an example of an annular photodetector element with a light source in the middle, in accordance with an example implementation.

FIG. **26** depicts an example of a polygonal photodetector element with a light source in the middle, in accordance with an example implementation.

FIG. **27** depicts a high-level block diagram of a PPG sensor, in accordance with an example implementation.

DETAILED DESCRIPTION

The present disclosure relates to PPG sensors and, more particularly, to PPG sensors designed for use with wearable

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biometric monitoring devices (also referred to herein as "biometric tracking devices," "biometric tracking modules," "wearable fitness monitors," or the like). The present inventors have determined that the use of non-square photodetector elements in PPG sensors may provide a significant performance increase as compared with traditional PPG designs, which typically utilize square photodetector elements. The present inventors have also determined that such a performance increase may be obtained, if desired, while still maintaining essentially the same power consumption as a square photodetector element in a traditional PPG design.

FIG. **2** depicts a simplified representation of a wristband-type wearable fitness monitor **200** that incorporates a PPG sensor that uses a non-square photodetector element in accordance with an example implementation of the concepts arrived at by the present inventors and discussed below. The wearable fitness monitor **200**, in this example, shares many components in common with the prior art wearable fitness monitor **100**, including the control logic, the housing **104** and the straps **102**, the back face **128**, and the two light sources **108**. The wearable fitness monitor **200**, however, features a photodetector element **212** which has a non-square active area in place of the photodetector element **112**.

As discussed above, PPG sensors operate by shining light into a person's skin. This light diffuses through the person's flesh and a portion of this light is then emitted back out of the person's skin in close proximity to where the light was introduced into the flesh; the amount of light that is emitted back out of the person's flesh attenuates with increasing distance from the light source. This effect can be seen when one holds a bright penlight or other concentrated light source against one's skin; the flesh surrounding the area where the light source contacts the skin will glow red or orange from the diffused light. While imperceptible to the human eye, the amount of this light that is emanated from the person's skin will fluctuate in sync with the person's heart rate. As a person's heart beats, the person's blood vessels expand and contract in synch with the heart as the pumping of the heart exerts pressure on the person's blood which, in turn, results in cyclic pressure increases in the person's blood vessels. When a blood vessel expands, it allows more blood to flow into the vessel, which results in the amount of blood present in a given region of the person's flesh fluctuating in rhythm with the person's heart rate. This, in turn, results in fluctuations in the amount of light from the light source that is emanated back out of the flesh. The heart rate may then be determined by measuring the amount of light that emanates back out of the person's flesh via the above-described diffusion mechanism. Such measured light may have two components—a component that remains constant, i.e., the light that generally emanates from the skin regardless of heart rate, and a component that fluctuates with heart rate. The light that remains constant may be referred to herein as "DC," as it may be thought of as analogous in some respects to direct current since it remains relative constant over time. The light that fluctuates may be referred to herein as "AC," as it may be thought of as analogous to alternating current since it fluctuates relatively regularly over time. A typical heart rate might range from 50 beats per minute (BPM) to 200 bpm, and the AC component of light may have a frequency that maps to the heart rate frequency.

Generally speaking, the AC component of the detected light, which may be referred to herein as "AC optical power" or, more generally, simply as "light intensity," may be much smaller in magnitude than the DC component, as a large amount of the light that is diffused into the person's skin and then emanated out will still emanate regardless of the changes in the amount of blood present due to the heart beating. However, the AC component is of principle interest since it is what is indicative of heart rate.

FIG. **3** is a theoretical plot of emitted light intensity and detected light intensity for an example PPG sensor that is used to obtain heart rate information from a person's flesh, in accordance with an example implementation. It is to be understood that FIG. **3** is not to scale and does not depict actual data; it is merely intended to assist the reader in understanding the difference between the AC and DC components of a detected light signal. In FIG. **3**, the horizontal axis indicates time, and the vertical axis indicates light intensity. As can be seen, light is emitted into the person's flesh at a constant value **350** in this example. Light emanating from the person's skin is then measured by a photodetector element; this measured light intensity is depicted as data trace **348**. The data trace **348** may be split into a DC component **346**, which does not fluctuate with time, and an AC component **344**, which does fluctuate with time.

As noted above, a conventional PPG sensor may include a square photodetector element that is located near a light source (or, in many cases, near two or more light sources). The present inventors determined that such an arrangement was inefficient in terms of signal collection as a function of potential power consumption. For example, photodetectors are typically composed of a single photosensitive lateral area, e.g., the area of the photodetector that is parallel to the photodetector die top surface, that provides an output signal that indicates the total amount of light that is incident on the photosensitive cell at any given moment in time. The amount of power that such a photodetector consumes is directly tied to the size of the photosensitive area of the photodetector. The present inventors determined that, for a square photodetector element, a large percentage of the photodetector element may be located in positions where a much lower amount of AC light is emanated in comparison to locations where other portions of the photodetector element are located. This effect is discussed in more detail with respect to some of the Figures, as set forth below.

FIG. **4** depicts a grey-scale plot of measured AC power intensity for light emanated from a rectangular region measuring approximately 4.5 mm wide by 5 mm tall on a person's arm near the wrist, in accordance with an example implementation. A light source **408** is positioned at X=0 mm and Y=0 mm and shines light into the person's arm; the intensity of the light that is emanated back out is reflected in the shading in the image (the largest and smallest light intensities, due to the limitations of using black and white ink, appear similar—it is to be understood that the light intensity is greatest at the left side of the image and then falls off to the lowest intensities at the right edge of the image). The light source used in FIG. **4** was a 1.9 mm diameter green-wavelength LED, although the illumination beam that it produced was concentrated in an area smaller than that. FIG. **4** is based on actual image data taken with a human subject; as such, it includes various imperfections, such as hairs, that result in asymmetries in the light intensity detected. The light source that was used in this example emitted light that was predominantly in the 515 nm to 545 nm range, i.e., primarily green light.

The rectangular region has been divided into twelve rectangular bins; the number in each bin indicates the fraction of the overall AC light intensity (also referred to as the "power fraction") within the total bin area that is attributable to that particular bin. Thus, the bin in the lower left corner sees 20% of the total AC light intensity or power that is emitted from the totality of the twelve bins, whereas the bin immediately to the right of that bin only sees 9% of the total AC light intensity or power within that region.

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FIG. **4** also depicts the footprint **442** of a typical, square photodetector element at a spacing of approximately 2.5 mm from the light source center. As used herein, the terms "photodetector element," "active area," "active region," "photosensitive area," and "footprint" (with respect to a photodetector) all refer to the same portion of a photodetector, namely, the area of the photodetector that can actually detect light that is incident on the photodetector. It is to be understood that photodetectors may also include other components that are outside of the active area, such as interconnects, circuits, application-specific integrated circuits (ASICs), etc. that interact with the photodetector element in order to provide power or produce signal output. These other components are not to be considered to be part of the photodetector element. Thus, a photodetector with a 2 mm by 2 mm square photodetector element having a 1 mm by 2 mm ASIC located adjacent to one edge of the photodetector element might have an overall size of 3 mm by 2 mm, which would be rectangular, but the photodetector element of that photodetector would not be rectangular since the ASIC is not part of the photodetector element. It is also to be understood that reference herein to a "square" photodetector refers to a photodetector that has a square photodetector element, regardless of the aspect ratio that the entire photodetector has. Similarly, reference herein to a "rectangular" or "non-square" photodetector is to be understood as referring to a photodetector with a rectangular or non-square, respectively, photodetector element, regardless of whether the photodetector overall has a square shape.

Due to the aspect ratio and positioning of the square photodetector element, more than half of the active area is only able to measure light from the rightmost six bins, which represent only 14% of the available AC power in the overall bin area. The square photodetector element will not even collect all of the available light from those rightmost six bins since it only fully overlaps one of those rightmost six bins—only part of the light emanated from the remaining five bins of the rightmost six bins will be collectable by the square photodetector element. As shown, the square photodetector element may only be able to measure about 20% of the available light intensity that is emitted across all twelve bins.

Even if the square photodetector element is shifted to the left so that the edge closest to the light source is located at approximately 1.85 mm from the light source center, approximately 40% of the square photodetector element will still only be able to measure light from the rightmost six bins. In this case, the square photodetector element may collect roughly 50% of the AC optical power available in the 12 bins.

The present inventors have determined that a significant performance increase may be realized by deviating from the typical square (or nearly-square) aspect ratios that are used in photodetector elements of conventional PPG sensors. More specifically, the present inventors have determined that using a high-aspect-ratio photodetector element may provide a significant improvement in the amount of AC light measurable by a photodetector without incurring a significant power consumption penalty as compared with square photodetectors of the same active area. As used herein, the term "high-aspect-ratio" (or "HAR") photodetector refers to non-square photodetectors where at least 90% of the photodetector element active area, which may be referred to herein as the "active area of interest," has a maximum first dimension along a first axis that is at least twice as large as a maximum second dimension of the photodetector element along a second axis that is perpendicular or orthogonal to the first axis; the second axis is parallel to a ray emanating from the center of a light source used with the photodetector to form a PPG sensor, and the first axis is perpendicular to that ray. The maximum first dimension may be thought of as the distance between two lines that are both parallel to the ray emanating from the center of the light source and that pass through the opposing ends of the active area of interest that are furthest from the ray in directions perpendicular to the ray. The maximum second dimension, correspondingly, may be thought of as the distance between two lines that are both perpendicular to the ray emanating from the center of the light source and that pass through the opposing ends of the active area of interest that are furthest from and closest to the center of the light source. The "maximum first dimension" may also be referred to herein and in the claims as the "height" or "length" of a HAR photodetector, and the "maximum second dimension" may also be referred to herein and in the claims as the "base" or "width" of a HAR photodetector.

It is to be understood that while the examples discussed herein feature HAR photodetector elements with long axes that are perpendicular to rays extending out from a PPG sensor light source, similar performance benefits may be realized by utilizing similarly-sized photodetector elements that are not strictly perpendicular, e.g., ±10° from perpendicular. More generally, the concepts discussed herein may be practiced using HAR photodetector elements that are arranged with the long axis of such HAR photodetector elements being transverse to rays radiating outwards from the center of the light source.

FIG. **5** depicts the same light intensity image map of FIG. **4**, but with the outline of a high-aspect-ratio photodetector element added to the Figure, in accordance with an example implementation. The HAR photodetector element outline that is shown has a height-to-width aspect ratio of approximately 2.8 to 1, and completely overlaps with the leftmost six bins, which represent nearly 85% of the available AC power in the overall bin area. Thus, the HAR photodetector element shown in FIG. **5** is able to collect nearly four times as much light as the square photodetector element shown in FIG. **4**. The HAR photodetector is able to offer such improved light collection capabilities while still having substantially the same active area as the square photodetector of FIG. **4**. For example, a square photodetector element may have an active area of approximately 7 mm^2 and a HAR photodetector element may have an active area of approximately 7 mm^2. As a result, the power consumed by both the square photodetector and the HAR photodetector will be approximately equal since they have the same active area. Thus, the HAR photodetector in the example simulation shown in FIG. **5** offers a 300% improvement in collected AC power as compared with a traditional square photodetector implementation as set forth in FIG. **4**, while requiring effectively no additional power in order to attain such an improvement.

FIG. **6** depicts a simulation of the AC intensity or power of light that is emanated within a 16 mm by 16 mm region of skin as a result of light that is shined into the skin at the center of the region, in accordance with an example implementation. In FIG. **6**, there are two photodetector active area footprints **642** shown—one for a square photodetector footprint **652** and one for a HAR photodetector footprint **654**. Both have areas of 7.5 mm^2, which is the area of the photosensitive area of the square photodetector used in the Fitbit Charge HR™ and Surge™ products, and are positioned with the edge closest to the light source offset from the light source center by 1.65 mm. The stippling density in FIG. **6** provides an indication of relative intensity—the higher the stippling density, the higher the light intensity (the center region is not stippled since this area is, in effect, the region through which light is introduced into the skin, plus some buffer, and it is unsuitable for obtaining light intensity measurements). As can be seen, a much higher

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proportion the HAR photodetector footprint **654** overlaps with higher-density stippling/light intensity regions than is the case with the square photodetector footprint **652**.

FIG. **7** depicts a plot of measurable AC light power as a function of photodetector footprint aspect ratio with regard to the simulation shown in FIG. **6**, in accordance with an example implementation. The vertical axis represents the AC light power that is measurable by the photodetector, and the horizontal axis represents the aspect ratio of the photodetector; the vertical axis has been normalized such that a 1:1 aspect ratio photodetector provides a measurable AC light power value of 1. As can be seen, by utilizing a HAR photodetector, such as a photodetector with an aspect ratio of 2:1 or 3:1, the amount of AC light that is measurable by the HAR photodetector may be increased by up to 20% as compared with the square photodetector. This is a lower performance increase than was discussed above with respect to FIG. **5**, but is still significant in terms of power consumption efficiency of a PPG sensor. In the modeled scenario, a HAR photodetector with an aspect ratio of between 3:1 and 4:1 provides the highest performance in this respect. As used herein, the term "between," with reference to a range, is used to indicate a range that is inclusive of the upper and lower limits of the range. Thus, in the above example, aspect ratios of 3:1 and 4:1 would be included in the range of "between 3:1 and 4:1." This convention is used throughout this paper and in the claims. The same observation may be made with respect to the use of "to" to describe an implied range, e.g., "a ratio of 3:1 to 4:1" would mean "between 3:1 to 4:1" and 3:1 and 4:1 would be included in this range.

FIG. **8** depicts a plot of measurable AC light power as a function of photodetector footprint aspect ratio with regard to the simulation shown in FIG. **6**, but with the edge of the photodetector closest to the center of the light source offset from the light source center by 2.6 mm instead of 1.65 mm, in accordance with an example implementation. The vertical axis represents the AC light power that is measurable by the photodetector, and the horizontal axis represents the aspect ratio of the photodetector; the vertical axis has been normalized such that a 1:1 aspect ratio photodetector provides a measurable AC light power value of 1. As can be seen, a similar performance increase can be observed when using a HAR photodetector even at the increased spacing from the light source, although the performance increase is slightly more pronounced, e.g., up to ~27% for HAR photodetectors with aspect ratios of 3:1 to 5:1.

In view of the above, in some implementations, a PPG sensor may utilize one or more HAR photodetector elements having aspect ratios of between 2:1 and 5:1. In some implementations, a PPG sensor may utilize one or more HAR photodetector elements having ratios of between 2:1 and 7:2, and in some other implementations, a PPG sensor may utilize one or more HAR photodetector elements having ratios of between 7:2 to 5:1. It is to be understood that HAR photodetector elements may have proportions that fall substantially between the aspect ratios discussed herein, both prior to and after this point, e.g., HAR photodetector elements may also have dimensions within ±0.1 mm of dimensions that would satisfy such aspect ratios or have aspect ratios within ±10% of such aspect ratios, e.g., for a 2:1 to 5:1 aspect ratio range, HAR photodetector elements having aspect ratios of 1.8:1 or 5.5:1 may be considered as having aspect ratios substantially between aspect ratios between 2:1 and 5:1.

HAR photodetectors may have increased effectiveness when arranged and sized according to one or more guiding principles, as discussed in more detail below.

As mentioned earlier, at least 90% of the active or photosensitive area of a HAR photodetector may have a maximum first dimension along a first axis that is at least twice as large as a maximum second dimension of the active or photosensitive area along a second axis that is perpendicular or orthogonal to the first axis; the second axis is parallel to a ray emanating from the center of a light source used with the photodetector to form a PPG sensor, and the first axis is perpendicular to that ray. This concept is discussed in more detail below, with reference to several Figures.

FIG. **9** depicts a diagram of a HAR photodetector element **912** that is rectilinear, in accordance with an example implementation. As can be seen, the active area of the HAR photodetector element **912** is rectangular and has a first dimension **986** along an axis that is perpendicular to a ray **956** emanating from the center of a light source **908**, and a second dimension **988** along an axis that is parallel to the ray **956**; the first dimension **986** and the second dimension **988** are thus orthogonal to one another. The HAR photodetector element **912**, in this case, has a form factor where the active area as a whole has a first dimension **986** that is three times larger than the second dimension **988**, i.e., 100% of the active or photosensitive area of the HAR photodetector element **912** has a maximum first dimension that is at least twice (in this case, thrice) as large as the maximum second dimension.

In this particular example, the HAR photodetector element **912** is a rectangular element, which is the most efficient shape in terms of manufacturing yield, as such photodetector elements may be made by simply dicing a semiconductor wafer with the requisite semiconductor elements for the photodetector elements in a rectangular grid, much in the same manner that square photodetector elements are manufactured (just with a different dicing spacing).

HAR photodetectors, as described herein, may also take on HAR shapes other than simple rectangles. Several examples of such alternative photodetector elements are discussed in more detail below.

FIG. **10** depicts a diagram of a HAR photodetector element **1012** that is generally rectangular, but that possesses some non-rectangular aspects, in accordance with an example implementation. The HAR photodetector element **1012** may have a first edge that is closest to the light source **1008**, and an arcuate second edge that is opposite the first edge. If one considers the entire active area of the HAR photodetector element **1012**, it is apparent that the HAR photodetector element **1012** has an active area with a maximum first dimension **1090** and a maximum second dimension **1092**, which is the same as with the HAR photodetector element **912**. Thus, the depicted HAR photodetector element **1012** would also be considered to have an aspect ratio of 3:1.

FIG. **11** depicts a diagram of a HAR photodetector element **1112** that is similar to the HAR photodetector element of FIG. **10**, but with a rectangular cutout along the first edge, in accordance with an example implementation. While the active area of such a photodetector element differs from the photodetector elements of FIGS. **9** and **10**, the HAR photodetector element **1112** active area still has a maximum first dimension **1190** that is three times larger than a maximum second dimension **1192** of the active area.

FIG. **12** depicts a diagram of a HAR photodetector element **1212** that is similar to the HAR photodetector element of FIG. **9**, but one where the active area is generally rectangular yet has a "peninsula" that protrudes out from the rectangular area, in accordance with an example implementation. In this case, if one considers 100% of the active area of the photodetector, the maximum first dimension **1290** and the maximum second dimension **1292'** would technically be the same, which would

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result in an aspect ratio of 1:1. However, if the active area of the peninsula is omitted, the remaining 90% of the active area of the photodetector element **1212**, e.g., active area of interest **1294**, indicated by diagonal cross-hatching, has a maximum first dimension **1290** that is three times larger than the maximum second dimension **1292**. Accordingly, such a photodetector element **1212** may be considered to be a HAR photodetector element under the conditions described herein.

FIG. **13** depicts a diagram of a HAR photodetector element **1312** that is arcuate in shape, in accordance with an example implementation. In this case, the HAR photodetector element **1312** has an active area with a maximum first dimension that is also three times larger than the maximum second dimension.

To be clear, all of the examples of photodetector elements shown in FIGS. **9** through **13** may be classified as HAR photodetector elements since at least 90% of the active or photosensitive area of each of these photodetector elements has a maximum first dimension along a first axis, where the first axis is perpendicular to a ray emanating from the center of the light source of a PPG sensor, that is at least twice as large as a maximum second dimension of the active or photosensitive area along a second axis that is perpendicular or orthogonal to the first axis. There are, of course, other shapes and examples of photodetector elements that may be considered to be HAR photodetector elements, commensurate with the above discussion.

Generally speaking, while only one light source and one photodetector element are needed in order to construct a PPG sensor, including multiple light sources or light-emitting devices and/or multiple photodetector elements may offer increased sensitivity, but at the expense of increased power consumption.

If multiple light-emitting devices are used, they may, for example, be spaced apart from one another, as shown in FIGS. **1** and **2**, or may be closely grouped. In some implementations, all such light sources may be the same type of light source. In some other implementations, however, different types of light sources may be used for some or all of the light sources. For example, it may be desirable to utilize an LED that predominantly emits light in the green light spectrum for the purposes of detecting heart rate since the fluctuations in the light that is emitted back out of the person's skin may be more pronounced in the green light spectrum. At the same time, photoplethysmographic techniques may also be used to measure other physiological parameters besides heart rate, such as blood oxygenation levels. It may, in such situations, be desirable to utilize an LED that predominantly emits light in the red or infrared spectrum for such purposes. Thus, it may be desirable to include separate light-emitting devices that are each able to emit different wavelengths of light; each light-emitting device may be used to supply light for a different type of photoplethysmographic measurement. In some implementations, these light-emitting devices or light sources may be distributed across the PPG sensor face—for example, the light source **108** on the left side of FIG. **2** may be a green-wavelength LED, and the light source **108** on the right side of FIG. **2** may be a red- or infrared-wavelength LED. In some other implementations, light emitting devices may be closely clustered together, e.g., within a millimeter or two or less of each other; in such implementations, the clustered light-emitting devices may be viewed as a single light source with a center point that is, for example, associated with the centroid of the light intensity distribution of the cluster of light-emitting devices when all of the light-emitting devices in the cluster are emitting light simultaneously or that is associated with the averaged location of all of the light-emitting devices in the cluster. For light sources with single light-emitting devices, the center of the light source is to be understood as corresponding to a point generally associated with the centroid of the light intensity distribution of that light-emitting device, e.g., typically the center of the LED. It is to be understood that the term "light-emitting device," as used herein, refers to a single, discrete light-emitting device, such as a single LED or a laser diode, and that the term "light source," as used herein, refers to one or more light-emitting devices that are generally treated as a unit, e.g., that are close enough together that an observer would not be able to discern a gap between the light-emitting devices in a group of light-emitting devices when the light-emitting devices in the group are all emitting light simultaneously and the observer is approximately two to three feet from the light-emitting devices (this assumes that the light-emitting devices are emitting light in a spectrum visible to the observer; for light-emitting devices that emit light in a non-visible spectrum, e.g., infrared, such an evaluation may be based on whether gaps between such light-emitting devices would be visible at a distance of two to three feet if such light-emitting devices instead emitted visible light).

Conventional PPG sensors featuring square photodetector elements, such as the example shown in FIG. **1**, may utilize two light sources that bracket the photodetector element so that the fall-off in illumination intensity that is evident in FIG. **4** may be mitigated—in such an arrangement, the light intensity along the left edge of the depicted area of FIG. **4** may be mirrored along the right edge of the depicted area, resulting in a valley of lower-intensity light near the middle of the square photodetector, but with both the left and right edges of the square photodetector seeing increased light intensity. This, however, requires that two LEDs be powered, instead of one, effectively doubling the power consumption attributable to the light sources.

The present inventors have determined that utilizing a HAR photodetector element, in some cases, can present a much more power-efficient technique for achieving increased sensor performance than the conventional approach of including multiple light sources, as a HAR photodetector element and single light source may achieve performance that is comparable or superior to the performance of a square photodetector with multiple light sources—thus avoiding the use of the extra light source (and avoiding the extra power consumption it would incur).

The present inventors have also determined that further increases in PPG sensor performance may be attained, in some cases, by arranging multiple HAR photodetectors in an array or pattern about a light source. Since the same light source may provide light to multiple HAR photodetectors, there is little or no additional power consumption attributable to the light source in such implementations as compared with implementations having only one photodetector element. The use of such HAR photodetector elements may also increase the signal to ambient noise ratio of the PPG sensor.

FIGS. **14** through **16** depict several examples of implementations with multiple HAR photodetectors, in accordance with several example implementations. In FIG. **14**, two HAR photodetector elements **1412** are shown with a light source **1408** interposed midway between them. In FIG. **15**, three HAR photodetector elements **1512** are shown in a circular array centered on a light source **1508**. Similarly, in FIG. **16**, four HAR photodetector elements **1612** are arranged in a circular array about a light source **1608**. It is not necessary for the HAR photodetector elements in such patterns or arrays to be equidistantly-spaced, as is shown in the implementations of FIGS. **14**, **15**, and **16**. For example, a three-element array

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may be formed by removing one of the photodetector elements **1612** from the array shown in FIG. **16**. It is also not necessary for the photodetector elements within such a pattern or array to all be the same size and shape. For example, the upper and lower photodetector elements **1612** in FIG. **16** might have aspect ratios of 5:1, and the left and right HAR photodetector elements **1612** in FIG. **16** might have aspect ratios of 3:1 (which is the actual aspect ratio depicted). FIG. **17** depicts another example arrangement of photodetector elements. In FIG. **17**, the upper and lower HAR photodetector elements **1612** may have aspect ratios of 2:1, and the left and right HAR photodetector elements **1612** may have aspect ratios of 3:1; in some such implementations, the shorter photodetector elements, e.g., the 2:1 aspect ratio photodetector elements **1712** in the depicted example, may be positioned with the midpoints of their shorter edges generally located along a line spanning between the short edges of the longer photodetector elements, e.g., the 3:1 aspect ratio photodetector elements **1712** in the depicted example. In some PPG implementations involving multiple HAR photodetector elements, the HAR photodetector elements may occupy more than 50% of an annular region about the light source that has an annular width of 1 mm.

FIG. **18** depicts an example of a PPG sensor photodetector layout as shown in FIG. **15** but with multiple light-emitting devices used in the light source, in accordance with an example implementation. As discussed earlier herein, a PPG sensor may utilize one or more light sources, each of which may include one or more light-emitting devices. As can be seen, the light source **1808** includes two light-emitting devices **1810**, which may, for example, be surface-mount LEDs, one emitting primarily green-wavelength light and the other emitting primarily red-wavelength light. The two light-emitting devices **1810** may define a center point **1866** located midway between them, and may, in combination, be viewed as forming a light source **1808**. It is to be understood that the light-emitting devices **1810** may be operated independently and may not be powered on simultaneously during actual use. As a result, the array of photodetector elements **1812** may not appear to be centered on the center of either light-emitting device **1810** when that light-emitting device **1810** is on, but the array of photodetector elements **1812** may, nonetheless, be considered to be centered on the light source **1808**.

The present inventors have further determined that HAR photodetector elements, in at least some implementations, may be sized such that their width or the second maximum dimension of at least 90% of the active area of the HAR photodetector element is between approximately 0.5 mm and 1 mm; there may be some deviation from this range in some of these implementations, such as HAR photodetector elements where this dimension ranges between 0.45 mm and 1.1 mm.

Generally speaking, the light intensity for light emanating from a person's skin from a PPG light source falls off in an axially symmetric manner with increasing distance from the center of the light source (this assumes a single light source PPG sensor). Accordingly, the light source may be surrounded by a plurality of concentric, annular regions that each correspond with a different average light intensity. The present inventors analyzed the characteristics of such annular regions and determined that, regardless of the inner radius of a particular annular region, approximately 80% of the available power or intensity of the emanated light available outside of the inner radius of the annular region occurs within 1 mm of the inner radius. Thus, any particular annular region with an annular width of approximately 1 mm will see approximately 80% of the light intensity/power that is available outside of the inner radius of that annular region. For clarity, the "annular width" (w) of an annular region is equal to the outer radius (r_o) of the annular region minus the inner radius (r_i) of the annular region. This is illustrated in FIG. **19**, which shows a light source **1908** and a surrounding annular region **1958**, in accordance with an example implementation; the inner radius r_i, the outer radius r_o, and the annular width of the annular region **1958** are indicated. FIG. **20** depicts a plot of the fraction of the light intensity that is emanated outside of an arbitrary inner radius r_i that would fall within the bounds of an annular region with an inner radius r_i and an annular width as indicated along the x-axis, in accordance with an example implementation. As can be seen, approximately 80% of the available light intensity falls outside the inner radius r_i and within 1 mm of the inner radius r_i.

The present inventors determined that, given the high concentration of emanated light intensity within this 1 mm zone, sizing HAR photodetectors so as to have approximately a 1 mm width or less or such that the second dimension referenced above is approximately 1 mm or less may, in some implementations, offer enhanced performance in a PPG sensor.

In some implementations, HAR photodetector elements may be sized and arranged to satisfy certain geometric constraints. For example, in some implementations, the size of the HAR photodetector element may be constrained by certain geometric relationships, as described further below with respect to FIG. **21**. FIG. **21** depicts a light source, HAR photodetector, and various reference annotations. In FIG. **21**, a HAR photodetector element **2112** is shown positioned at a distance r_i from a light source **2108**. An annular region **2158** having an inner radius of r_i and an outer radius of r_o may be centered on the light source **2108**. Generally speaking, the difference between r_i and r_o for the annular region **2158** in such implementations may be less than or equal to 2 mm. In addition to the relationship between r_i and r_o set forth above, the HAR photodetector element **2112** may subtend an angle θ at the light source center, as shown. In such circumstances, the HAR photodetector may be sized such that a) there is at least 80% overlap between the annular region **2158** and the HAR photodetector element **2112** (the overlap is indicated in FIG. **21** by diagonal cross-hatching; approximately 86% of the HAR photodetector **2112** in this example overlaps with the annular region **2158**) and b) the angle θ is at least:

$$2 \cdot \arctan\left(\frac{1}{r_i}\right) \text{radians}$$

In some further implementations, the HAR photodetector **2112** may be further sized such that the angle θ is not more than:

$$2 \cdot \arctan\left(\frac{2.5}{r_i}\right) \text{radians}$$

FIGS. **22** through **24** depict cross-sections of simplified representations of various PPG sensors, in accordance with various example implementations. Similar components in each of FIGS. **22** through **24** are indicated by numeric indicators having the last two digits in common, and may only be described once with respect to FIG. **22**; this description is also applicable, however, to the corresponding elements in FIGS. **23** and **24**.

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In FIG. **22**, a substrate **2272** supports two HAR photodetector elements **2212** that are positioned on either side of a light source **2208**. A window **2278** is offset from the substrate **2272**. The window **2278**, in this implementation, is made from a translucent or transparent material, such as transparent acrylic, with an in-mold label **2276** embedded within it. The in-mold label **2276** may be black or otherwise rendered opaque to light to prevent light from entering or exiting the PPG sensor through the window **2278** except through window regions **2226**. In other implementations, other masking techniques, such as a painted or silk-screened mask applied to the window **2278**, may be used. Regardless of which technique is used, the in-mold label **2276** or the masking may prevent stray light from other sources, e.g., ambient light, from reaching the HAR photodetector elements **2212** and affecting the heart rate signal obtained by the PPG sensor. The window **2278** may be held against a person's skin, e.g., by being held in place with a strap, when heart rate measurements are obtained to allow light from the light source **2208** to shine through its associated window region **2226** and into the person's skin, where the light then diffuses into the surrounding flesh and is then emitted back out of the person's skin and into the HAR photodetector elements **2212** through the respective window regions **2226** associated with the HAR photodetector elements **2212**.

In order to reduce the chance that light from the light source **2208** will reach either of the HAR photodetector elements **2212** without first being diffused through the person's skin, the light source **2208** may be separated from the HAR photodetector elements **2212** within the PPG sensor by walls **2274**, which may extend to the window **2278** or may stop short of the window **2278**. In some implementations, an adhesive gap filler, e.g., black silicone, may be used to bridge any gap remaining between the walls **2274** and the window **2278**. A gap **2280** may exist between the window **2278** and the HAR photodetector elements **2212** in some implementations, although in other implementations, this gap may be eliminated and the HAR photodetector element **2212** may be butted up against the window **2278**. The walls **2274** may prevent light from the light source **2208** from reaching the HAR photodetector elements **2212** by following paths completely within the housing of the PPG sensor. As can be seen, the window regions **2226** through which the light reaches the HAR photodetector elements **2212** each overlap their respective HAR photodetector elements **2212**. In the depicted example, the window regions **2226** are mutually coextensive with their respective HAR photodetector elements **2212**, although in other implementations, the window regions **2226** may be smaller or larger than their respective HAR photodetector elements **2212**, e.g., to accommodate assembly tolerance mismatch.

FIG. **23** depicts a PPG sensor implementation that is similar to the PPG sensor of FIG. **22** except that the window **2378** does not include any masking, for example, in the form of an in-mold label, such as in-mold label **2276**. In FIG. **23**, the walls **2374** also extend closer to the window **2378**. In FIG. **23**, the window **2378** is optically transparent across the entire depicted span.

FIG. **24** depicts a PPG sensor implementation that is similar to the PPG sensor implementation of FIGS. **22** and **23**, except that the contiguous windows **2278** and **2328** have been replaced with discrete windows **2478**. In this implementation, each window **2478** may have its own window region **2426** that overlaps with a different one of the light source **2408** or the HAR photodetector elements **2412**. In such implementations, the windows **2478** may be glued or otherwise held in place within a frame that may supply the walls **2474**. Alternatively, the windows **2478** may be formed by filling the recesses formed by the walls **2474** and other surrounding structure with a clear, flowable material, such as epoxy, and then allowing the flowable material to cure and harden. In such implementations, the gap **2480** may not exist since the flowable material may encapsulate the HAR photodetector elements **2412**.

Regardless of the particular manner in which the window regions **2226**, **2326**, or **2426** are provided, the window regions overlap with the HAR photodetector elements such that light that enters the PPG sensor via the window regions generally takes a direct route to the HAR photodetector element, as compared with a route that involves forcing the light to travel in a direction parallel to the window, as may be done with various types of optical light guides. The phrase "optical light guide," as used herein with respect to PPG sensors, refers to particular types of optical structures that redirect or transport the light that enters through a surface within a first region of the surface such that a majority of that light is transported in a direction generally transverse to the surface to an area overlapped by a second region of the surface that is offset from the first region along the surface. Optical light guides, as the term is used herein, are not to be confused with other optical structures, such as microlens arrays or lenses that may be placed over a HAR photodetector element to improve collection efficiency, optical windows that may slightly refract light that passes through the windows but that do not transport or redirect light in a significant manner in directions transverse to the surface, optical filters that may simply filter light of certain wavelengths, etc. In some implementations of the PPG sensors discussed herein, there is no need for optical light guides since the HAR photodetector elements are generally overlapped by the window regions.

The above concepts have been discussed primarily with respect to light sources that emit green light, e.g., wavelengths in the range of 500 nm to 550 nm, although it is contemplated that the photodetector element concepts discussed herein may see similar performance with light sources that emit light predominantly in the 500 nm to 600 nm range, which includes yellow light as well as some light orange light. Light sources emitting light in the green spectrum are particularly well-suited for photoplethysmographic techniques for measuring heart rate. In contrast, other photoplethysmographic techniques, such as techniques for measuring blood oxygenation levels, may be most effective using light of dramatically different wavelengths, such as in the red wavelengths, e.g., 660 nm, or in the infrared spectrum. The aspect ratios and dimensional values discussed herein are tailored based on the green/yellow light spectrum and are not tailored for use in other spectrums, such as the red or infrared spectra.

While the concepts discussed herein are thought to be applicable to a variety of different sizes of photodetectors, the concepts are particularly applicable to PPG implementations for wearable fitness monitoring devices. Generally speaking, such devices, which are often designed to be worn as bracelets or wristbands, have a small housing that has a limited area that is in contact with a persons' skin. As a result, there are practical upper limits in such implementations on how the light source(s) and photodetector element(s) of a PPG sensor may be arranged and sized. Typically speaking, the light source(s) and photodetector element(s) of such implementations may be arranged such that the photodetector element(s) are positioned with the edge closest to the light source located between 1 mm to 4 mm from the center or edge of the light source. However, it is to be understood that implementations discussed herein may be used in products that achieve closer

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or farther spacing from the light source center, such as spacing closer than 1 mm or farther than 4 mm.

In some implementations, the HAR photodetector elements that may be used in a PPG may be positioned with the edge closest to the light source of the PPG sensor offset from the center of the light source by between 1 mm and 4 mm and may be sized such that they have a maximum first dimension substantially between 1 mm and 5 mm and a maximum second dimension substantially between 0.05 mm and 2 mm, while being consistent with the aspect ratio of the maximum first dimension to the maximum second dimension being substantially between 2:1 to 5:1.

While the photodetector element may be positioned with its closest edge further than 4 mm from the center of the light source, doing so may prove counterproductive, as a higher-intensity light source may be needed to ensure that sufficient light is diffused across the increased distance in order to obtain a sufficiently strong signal at the photodetector. As a higher-intensity light source will generally consume additional power, such a compromise may be undesirable in a wearable fitness monitor context.

In addition to the HAR photodetectors discussed herein, performance increases over square-photodetector-based PPGs for heart rate measurement may be realized through the use of non-HAR and non-square photodetector elements that generally encircle the light source and that have a central opening in the middle for the light source to shine through. Generally speaking, such photodetector elements may have an exterior periphery that is defined by a first boundary, and a second boundary, within the first boundary, that defines the central opening. FIGS. **25** and **26** depict two example implementations of such PPG sensors.

FIG. **25** depicts an example of an annular photodetector element **2512** with a light source **2508** in the middle, in accordance with an example implementation. The annular photodetector element **2512** may have an exterior periphery defined by a first boundary **2532** and a central opening defined by a second boundary **2534**; the first boundary **2532** and the second boundary **2534** may be offset from one another by a first distance **2584** along a radius of the annular area. The light source **2508** may be a green wavelength light source that predominantly emits light between 500 nm and 550 nm or between 500 nm and 600 nm in wavelength. Such a photodetector element **2512** may be sized such that the ratio of the circumference of the second boundary **2534** to the first distance **2584** is between 9.5:1 and 11.5:1. In some implementations, the annular photodetector element **2512** may be sized such that the first boundary has a diameter of between 3 mm to 5.5 mm and the second boundary has a diameter of between 1 mm to 2.5 mm. These parameters are believed to provide good light-gathering performance for heart rate measurement purposes when used with green-wavelength light.

FIG. **26** depicts an example of a polygonal photodetector element **2612** with a light source **2608** in the middle, in accordance with an example implementation. As with the annular photodetector element **2512**, the polygonal photodetector element **2612** may have an exterior periphery defined by a first boundary **2632** and a central opening defined by a second boundary **2634**. In this case, however, the first boundary **2632** and the second boundary **2634** are both polygonal in nature, e.g., a six-sided polygon. Other polygonal shapes may be used for other implementations, such as triangular shapes, square shapes, pentagonal shapes, septagonal shapes, octagonal shapes, and so on, i.e., N-sided polygons. The edges of the first boundary **2632** and the second boundary **2634** may be offset from one another by a first distance **2684** along an axis perpendicular to the edges. In such implementations, each side of the polygon forming the second boundary **2634** may have a second length **2682**, and the ratio of the second length **2682** to the first distance **2684** may be between 2:1 to 5:1. These parameters are believed to provide good light-gathering performance for heart rate measurement purposes when used with green-wavelength light.

It is to be understood that reference herein to "control logic" refers to hardware and/or software that may be used to provide certain functionality, such as controlling when the light source(s) of a PPG is on or off, controlling the intensity with which the light source(s) is illuminated, collecting data from one or more photodetectors, and analyzing at least the data collected from the one or more photodetectors in order to determine a measurement of a person's heart rate. Control logic may include, for example, one or more processors and a memory that stores computer-executable instructions for controlling the one or more processors to provide such functionality. The control logic may also include various circuit elements that may provide aspects of such functionality without need for computer-executable instructions stored in memory. In some implementations, the control logic may be provided, at least in part, by an application-specific integrated circuit (ASIC).

FIG. **27** depicts a high-level block diagram of a PPG sensor, in accordance with an example implementation. In FIG. **27**, control logic **2706** is shown, which includes a processor **2768** and a memory **2770**, which are operatively coupled with one another. The control logic is operatively coupled with a light source **2708** and a photodetector element **2712**. The control logic **2706** may thus cause the light source **2708** to emit light at desired times, and may receive a signal indicative of an amount of detected light from the photodetector element **2712**.

There are many inventions described and illustrated herein. While certain implementations, features, attributes and advantages of the inventions have been described and illustrated, it should be understood that many others, as well as different and/or similar implementations, features, attributes and advantages of the present inventions, are apparent from the description and illustrations. As such, the above implementations of the inventions are merely exemplary. They are not intended to be exhaustive or to limit the inventions to the precise forms, techniques, materials and/or configurations disclosed. Many modifications and variations are possible in light of this disclosure. It is to be understood that other implementations may be utilized and operational changes may be made without departing from the scope of the present inventions. As such, the scope of the inventions is not limited solely to the description above because the description of the above implementations has been presented for the purposes of illustration and description.

In particular, it is to be understood that any of the implementations discussed above with respect to a single photodetector element spaced apart from a light source may also be implemented using a plurality of photodetector elements arranged about the light source, as discussed with respect to various other implementations discussed herein.

Furthermore, it is to be understood that the use of the term "substantially" herein, unless otherwise defined with respect to a specific context, with respect to a numeric quantity or otherwise quantifiable relationship, e.g., perpendicularity or parallelism, is to be understood as indicating that quantity ±10%. Thus, for example, lines that are substantially perpendicular to one another may be at angles between 81° and 99° to one another. In a further example, dimensions that are substantially between 1 mm and 3 mm, for example, may range from 0.9 mm to 3.3 mm. In another example, an angle

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that is substantially in the range of 1 to 1.1 radians may be between 0.9 radians and 1.21 radians.

Importantly, the present invention is neither limited to any single aspect nor implementation, nor to any combinations and/or permutations of such aspects and/or implementations. Moreover, each of the aspects of the present invention, and/or implementations thereof, may be employed alone or in combination with one or more of the other aspects and/or implementations thereof. For the sake of brevity, many of those permutations and combinations will not be discussed and/or illustrated separately herein.

What is claimed is:

1. An apparatus comprising:

a light source;

one or more discrete photodetector elements, each photodetector element having:

a first edge having a first length, and

a first width in a direction perpendicular to the first edge; and

control logic, the control logic communicatively connected with the light source and each photodetector element and configured to:

cause the light source to emit light,

obtain one or more measured light intensity measurements from the one or more photodetector elements, and

determine a heart rate measurement based, at least in part, on the one or more light intensity measurements,

wherein the ratio of the first length to the first width of each photodetector is substantially between 2:1 to 5:1.

2. The apparatus of claim **1**, wherein:

the first edge of each photodetector element is perpendicular to an axis radiating out from a center of the light source.

3. The apparatus of claim **1**, wherein:

the first edge of each photodetector element is transverse to an axis radiating out from a center of the light source.

4. The apparatus of claim **1**, wherein:

the light source includes a plurality of light-emitting devices.

5. The apparatus of claim **4**, wherein:

the plurality of light-emitting devices includes at least two light-emitting devices that predominantly emit light of different wavelengths.

6. The apparatus of claim **4**, wherein:

there are a plurality of photodetector elements arranged in a pattern, and

the plurality of light-emitting devices is collocated at a center point of the pattern of photodetector elements.

7. The apparatus of claim **6**, wherein the ratio of the first length to the first width of each photodetector element is substantially between 2:1 to 3.5:1.

8. The apparatus of claim **1**, wherein the ratio of the first length to the first width of each photodetector element is substantially between 3.5:1 to 5:1.

9. The apparatus of claim **1**, wherein each photodetector element:

has a first length between 1 mm and 5 mm and a first width between 0.5 mm and 2 mm, with the ratio of the first length to the first width substantially between 2:1 to 5:1, and

is positioned such that an edge of the photodetector element closest to the light source is between 1 mm and 4 mm from the light source.

10. The apparatus of claim **9**, wherein the pattern of photodetector elements includes three photodetector elements that are equidistantly spaced about the light source.

11. The apparatus of claim **1**, further comprising:

a housing having a back face that includes one or more transparent window regions through which light may enter the apparatus, wherein:

each photodetector element is positioned such that that photodetector element is overlapped by a corresponding one of the one or more transparent window regions, and

the housing is configured such that the back face is adjacent to the skin of a person wearing the apparatus when the apparatus is worn by that person.

12. The apparatus of claim **11**, wherein:

the back face includes a thin window, and

the window regions are sub-regions of the window that are defined by the photodetector elements.

13. The apparatus of claim **11**, wherein:

each photodetector element is offset from the corresponding transparent window region by a corresponding gap in a direction normal to the photodetector element, and

the gap is free of optical light guides.

14. The apparatus of claim **1**, wherein each photodetector element has, in addition to the first edge, an arcuate second edge opposite the first edge, wherein the arcuate second edge has a maximum distance from the first edge, when measured along a direction perpendicular to the first edge, that is equal to the first width.

15. An apparatus comprising:

a first light source;

a second light source;

a photodetector element interposed between the first light source and the second light source; and

control logic, the control logic communicatively connected with the first light source, the second light source, and the photodetector element and configured to:

cause the first light source and the second light source to emit light,

obtain measured light intensity measurements from the photodetector element, and

determine a heart rate measurement based, at least in part, on the light intensity measurements,

wherein:

the photodetector element is rectangular in shape, has a first edge with a first length, and has a second edge, perpendicular to the first edge, with a second length, and

the ratio of the first length to the second length is substantially between 2:1 to 5:1.

16. The apparatus of claim **15**, wherein:

the first edge of each photodetector element is perpendicular to an axis spanning between a center of the first light source and a center of the second light source.

17. The apparatus of claim **15**, wherein:

the first edge of each photodetector element is transverse to an axis spanning between a center of the first light source and a center of the second light source.

18. The apparatus of claim **15**, further comprising

a housing having a back face that includes a transparent window region that overlaps the photodetector element and two further window regions that are each associated with a different one of the first light source and the second light source and that allow light from the associated light source to pass through the back face, wherein:

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the first light source and the second light source are the only light sources in the apparatus configured to emit light through the back face, and

the housing is configured such that the back face is adjacent to the skin of a person wearing the apparatus when the apparatus is worn by that person.

19. The apparatus of claim **15**, wherein the photodetector element is equidistant from the first light source and the second light source.

20. An apparatus comprising:

a light source;

one or more photodetectors, each photodetector having a photosensitive area, wherein at least 90% of the photosensitive area is defined by a first dimension along a first axis and a second dimension along a second axis perpendicular to the first axis; and

control logic, the control logic communicatively connected with the light source and each photodetector and configured to:

cause the light source to emit light,

obtain one or more measured light intensity measurements from the one or more photodetectors, and

determine a heart rate measurement based, at least in part, on the one or more light intensity measurements, wherein, for each photodetector:

the ratio of the first dimension to the second dimension is substantially between 2:1 to 5:1.

21. The apparatus of claim **20**, wherein:

the light source includes a plurality of light-emitting devices, and

the plurality of light-emitting devices includes at least two light-emitting devices that predominantly emit light of different wavelengths.

22. The apparatus of claim **20**, wherein:

the one or more photodetectors includes a plurality of photodetectors arranged in a pattern, and

the light source is located at a center point of the pattern of photodetectors.

23. The apparatus of claim **20**, wherein the ratio of the first dimension to the second dimension of each photodetector is substantially between 2:1 to 3.5:1.

24. The apparatus of claim **20**, wherein the ratio of the first dimension to the second dimension of each photodetector is substantially between 3.5:1 to 5:1.

25. The apparatus of claim **20**, wherein:

the one or more photodetectors includes a plurality of photodetectors arranged in a pattern, and

the center of the photosensitive area of each photodetector in the pattern is equidistant from the center of the light source.

26. The apparatus of claim **25**, wherein:

the first dimension associated with each photodetector is between 3 mm and 5 mm and the second dimension associated with each photodetector is between 1 mm and 2 mm, consistent with the ratio of the first dimension to the second dimension being between 2:1 to 5:1, and

each photodetector is positioned such that an edge of the photosensitive area for that photodetector that is closest to the light source is between 1 mm and 4 mm from the center of the light source.

27. The apparatus of claim **26**, wherein the pattern of photodetectors includes four photodetectors that are equidistantly spaced about the light source.

28. The apparatus of claim **20**, further comprising:

a housing having a back face that includes one or more thin, transparent window regions, wherein:

each photodetector is positioned such that the photosensitive area of that photodetector is overlapped by a corresponding one of the transparent window regions, and

the housing is configured such that the back face is adjacent to the skin of a person wearing the apparatus when the apparatus is worn by that person.

29. The apparatus of claim **28**, wherein:

the back face includes a thin window, and

the window regions are sub-regions of the window that are defined by the photosensitive areas of the one or more photodetectors.

30. The apparatus of claim **28**, wherein:

the photosensitive area of each photodetector is offset from the corresponding transparent window region by a corresponding gap in a direction normal to the photodetector, and

the gap is free of optical light guides.

* * * * *

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Ammar Al-Ali		
U.S. Patent No.:	10,687,745	Attorney Docket No.:	50095-0045IP1
Issue Date:	June 23, 2020		
Appl. Serial No.:	16/835,772		
Filing Date:	March 31, 2020		
Title:	PHYSIOLOGICAL MONITORING DEVICES, SYSTEMS, AND METHODS		

DECLARATION OF DR. BRIAN W. ANTHONY

Anthony
Exhibit 3
(3-24-23)
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I, Brian W. Anthony, of Cambridge, MA, declare that:

1. My name is Dr. Brian W. Anthony. I am an Associate Principal Research Scientist at the Institute of Medical Engineering & Science at Massachusetts Institute of Technology (MIT). I am also a Principal Research Scientist at MIT's Mechanical Engineering department, Director of the Master of Engineering in Advanced Manufacturing and Design Program at MIT, Director of Health Technology at the MIT Center for Clinical and Translational Research, a Co-Director of the Medical Electronic Device Realization Center of the Institute of Medical Engineering & Science, and Associate Director of MIT.nano. My current *curriculum vitae* is attached and some highlights follow.

2. I earned my B.S. in Engineering (1994) from Carnegie Mellon University. I earned my M.S. (1998) and Ph.D. (2006) in Engineering from MIT. My research focused on high-performance computation, signal processing, and electro-mechanical system design.

3. In 1997, I co-founded Xcitex Inc., a company that specialized in video-acquisition and motion-analysis software. I served as the Chief Technology Officer and directed and managed product development until 2006. Our first demo product was an optical ring for human motion measurement used to capture user hand motion in order to control the user's interaction with a computer. Many of the structural elements of our optical ring addressed the same system issues as

those described and claimed in the patent at issue. For example, our optical ring included multiple light emitting diodes, multiple photodetectors, techniques for modulation and synchronization, and noise reduction algorithms. We estimated human hand-motion based on how that motion changed the detected light. In our application, we did not try to eliminate motion artifact, we tried to measure it. In developing our ring, we considered well-known problems such as ambient light and noise. Motion Integrated Data Acquisition System (MiDAS) was our flagship video and data acquisition product which relied upon precise synchronization of multiple clocks for optical sensor and video acquisition, data acquisition, and external illumination.

4. I joined MIT in 2006 and was the Director of the Master of Engineering in Advance Manufacturing and Design Program for over ten years. The degree program covers four main components: Manufacturing Physics, Manufacturing Systems, Product Design, and Business Fundamentals. Many of the courses, projects, and papers my students undertake involve technologies relevant to the patent at issue, for example, sensor devices including non-invasive optical biosensors.

5. In 2011, I co-founded MIT's Medical Electronic Device Realization Center ("MEDRC") and currently serve as co-director. The MEDRC aims to create and deploy revolutionary medical technologies by collaborating with

clinicians, the microelectronics, and medical devices industries. We combine expertise in computation; communications; optical, electrical, and ultrasound sensing technologies; and consumer electronics. We focus on the usability and productivity of medical devices using, for example, image and signal processing combined with intelligent computer systems to enhance practitioners' diagnostic intuition. Our research portfolio includes low power integrated circuits and systems, big data, micro electro-mechanical systems, bioelectronics, sensors, and microfluidics. Specific areas of innovation include wearable, non-invasive and minimally invasive optical biosensor devices, medical imaging, laboratory instrumentation, and the data communication from these devices and instruments to healthcare providers and caregivers. My experience with these devices is directly applicable to the technology in the patent at issue.

6. I am currently the Co-Director of the Device Realization Lab at the Medical Electronic Device Realization Center at the Institute of Medical Engineering & Science at MIT. The Device Realization Lab designs instruments and techniques to sense and control physical systems. Medical devices and manufacturing inspection systems are a particular focus. We develop and combine electromechanical systems, complex algorithms, and computation systems to create instruments and measurement solutions for problems that are otherwise intractable.

7. The research of the Device Realization Lab focuses on product development interests cross the boundaries of computer vision, acoustic and ultrasonic imaging, large-scale computation and simulation, optimization, metrology, autonomous systems, and robotics. We use computation, and computer science, as methodology for attacking complex instrumentation problems. My work combines mathematical modeling, simulation, optimization, and experimental observations, to develop instruments and measurement solutions.

8. My record of professional service includes recognitions from several professional organizations in my field of expertise.

9. I am a named inventor on 10 issued U.S. patents. Most but not all of these patents involve physiological monitoring and other measurement technologies.

10. I have published approximately 100 papers, and have received a number of best paper and distinguished paper awards. A number of papers that I have published relate to physiological monitoring and other measurement and instrumentation technologies.

11. I have been retained on behalf of Apple Inc. to offer technical opinions relating to U.S. Patent No. 10,687,745 (“the ’745 patent,” APPLE-1001) and prior art references relating to its subject matter. I have reviewed the ’745 Patent and relevant excerpts of the prosecution history of the ’745 Patent

(EX1002). I have also reviewed the following prior art references and materials, in addition to other materials I cite in my declaration:

- APPLE-1004: U.S. Pat. No. 8,670,819 ("Iwamiya")
- APPLE-1005: U.S. Pat. No. 9,392,946 ("Sarantos")
- APPLE-1006: U.S. Pub. No. 2014/0275854 ("Venkataraman")
- APPLE-1007: U.S. Pat. No. 6,483,976 ("Shie")
- APPLE-1008: U.S. Pat. No. 6,801,799 ("Mendelson-799")
- APPLE-1009: U.S. Pub. No. 2015/0018647 ("Mandel")
- APPLE-1010: U.S. Pub. No. 2009/0275810 ("Ayers")
- APPLE-1011: PCT. Pub. No. 2011/051888 ("Ackermans")
- APPLE-1012: U.S. Pat. No. 6,158,245 ("Savant")
- APPLE-1013: Design of Pulse Oximeters, J.G. Webster; Institution of Physics Publishing, 1997 ("Webster")
- APPLE-1014: U.S. Pub. No. 2009/0054112 ("Cybart")
- APPLE-1015: U.S. Pat. No. 5,893,364 ("Haar")
- APPLE-1016: U.S. Pat. No. 5,952,084 ("Anderson")

12. Counsel has informed me that I should consider these materials through the lens of one of ordinary skill in the art related to the '745 patent at the time of the earliest possible priority date of the '745 patent, and I have done so during my review of these materials. The '745 patent claims priority to an

application filed July 2, 2015 (the "Critical Date"). Counsel has informed me that this Critical Date represents the earliest priority date to which the challenged claims of '745 patent are possibly entitled, and I have therefore used that Critical Date in my analysis below.

13. I have no financial interest in the party or in the outcome of this proceeding. I am being compensated for my work as an expert on an hourly basis. My compensation is not dependent on the outcome of these proceedings or the content of my opinions.

14. In writing this Declaration, I have considered the following: my own knowledge and experience, including my work experience in the fields of mechanical engineering, computer science, biomedical engineering, and electrical engineering; my experience in teaching those subjects; and my experience in working with others involved in those fields. In addition, I have analyzed various publications and materials, in addition to other materials I cite in my declaration.

15. My opinions, as explained below, are based on my education, experience, and expertise in the fields relating to the '745 patent. Unless otherwise stated, my testimony below refers to the knowledge of one of ordinary skill in the fields as of the Critical Date, or before. Any figures that appear within this document have been prepared with the assistance of Counsel and reflect my understanding of the '745 patent and the prior art discussed below.

I. Background

16. The ’745 patent, entitled “Advanced Pulse Oximetry Sensor,” describes a “non-invasive, optical-based physiological monitoring system[.]” APPLE-1001, Face, Abstract.

17. Independent claim 1 of the ’745 patent is generally representative:

> 18. 1. A physiological monitoring device comprising:
>
> 19. a plurality of light-emitting diodes configured to emit light in a first shape;
>
> 20. a material configured to be positioned between the plurality of light-emitting diodes and tissue on a wrist of a user when the physiological monitoring device is in use, the material configured to change the first shape into a second shape by which the light emitted from one or more of the plurality of light-emitting diodes is projected towards the tissue;
>
> 21. a plurality of photodiodes configured to detect at least a portion of the light after the at least the portion of the light passes through the tissue, the plurality of photodiodes further configured to output at least one signal responsive to the detected light;
>
> 22. a surface comprising a dark-colored coating, the surface configured to be positioned between the plurality of photodiodes and

the tissue when the physiological monitoring device is in use, wherein an opening defined in the dark-colored coating is configured to allow at least a portion of light reflected from the tissue to pass through the surface;

23. a light block configured to prevent at least a portion of the light emitted from the plurality of light-emitting diodes from reaching the plurality of photodiodes without first reaching the tissue; and

24. a processor configured to receive and process the outputted at least one signal and determine a physiological parameter of the user responsive to the outputted at least one signal.

II. Level of Ordinary Skill in the Art

25. Based on the foregoing and upon my experience in this area, a person of ordinary skill in the relevant art as of the Critical Date (a "POSITA") would have been a person with a working knowledge of physiological monitoring technologies. The person would have had a Bachelor of Science degree in an academic discipline emphasizing the design of electrical, computer, or software technologies, in combination with training or at least one to two years of related work experience with capture and processing of data or information, including but not limited to physiological monitoring technologies. Alternatively, the person

could have also had a Master of Science degree in a relevant academic discipline with less than a year of related work experience in the same discipline.

26. Based on my experiences, I have a good understanding of the capabilities of a POSITA. Indeed, I have taught, participated in organizations, and worked closely with many such persons over the course of my career.

27. I have performed my analysis through the lens of a POSITA as of the Critical Date.

III. Interpretations of the ’745 Patent Claims at Issue

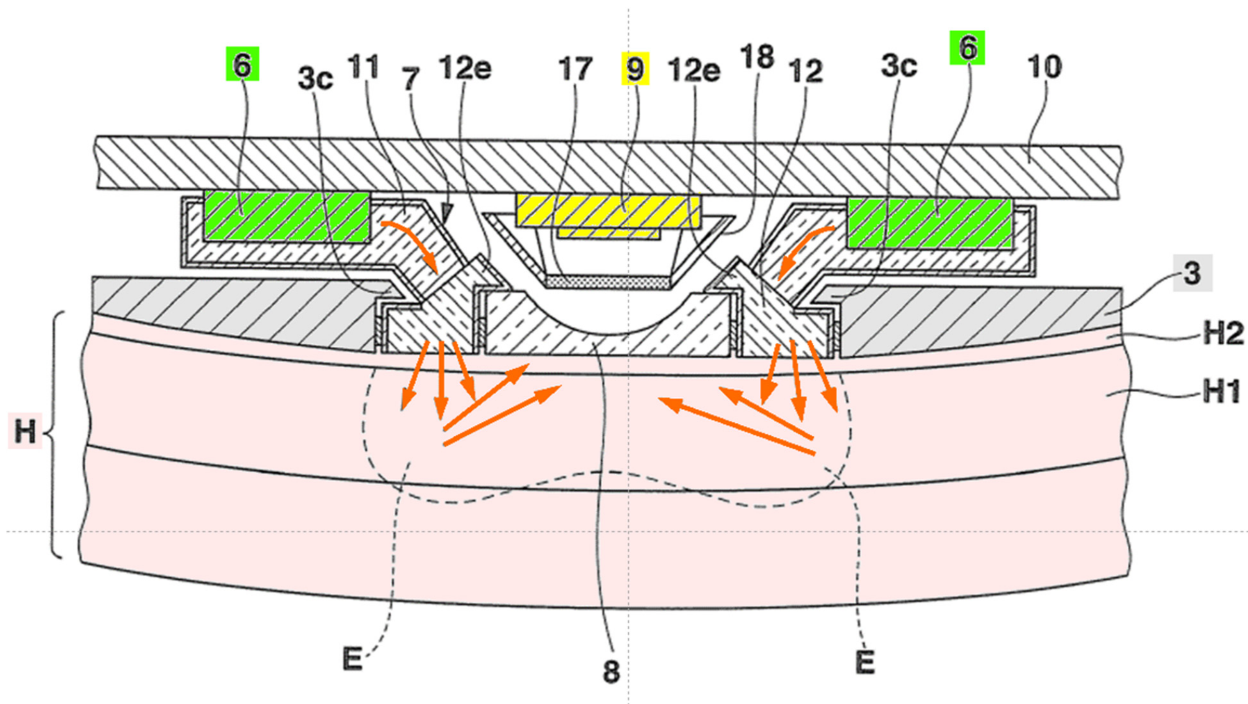
28. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should generally be interpreted according to their “ordinary and customary meaning.” *See Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (Fed. Cir. 2005) (en banc). I understand that “the ordinary and customary meaning of a claim term is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention.” *Id*. at 1313. I also understand that the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification. *Id*.

IV. Prior Art Analysis

A. Ground 1A: Claims 1 and 9 are obvious over Iwamiya in view of Sarantos

1. Overview of Iwamiya

29. Iwamiya discloses an "optical biological information detecting apparatus" which is a physiological monitoring device. APPLE-1004, Abstract. For example, Iwamiya describes that the "optical biological information detecting apparatus" is provided in "a central portion of the back cover" of "a wristwatch" (*i.e.*, facing the wearer's wrist). APPLE-1004, 5:54-66, FIG. 1. As shown in the following annotated FIG. 4 from Iwamiya, the device includes LEDs 6 (shown in green) that emit light (orange) that is refected by the tissue of the wearer's wrist (pink) and detected by photodiodes 9 (yellow).



APPLE-1004, Detail of FIG. 4 (annotated)

2. Overview of Sarantos

30. Sarantos describes a "wristband-type wearable fitness monitor" that measures "physiological parameters" of the wearer, such as the person's "heart rate" and "blood oxygenation levels." APPLE-1005, 2:5-14, 5:55-59, 7:12-14, 13:39-47. The monitor performs these measurements using a photoplethysmographic (PPG) sensor, which includes one or more light sources (e.g., LEDs) and an array of photodetectors. *Id.*, 1:9-10, 43-47, 7:12-16, 15:23-43. Sarantos describes that when the monitor "is worn by a person in a manner similar to a wristwatch, the back face" of the monitor "may be pressed against the person's skin, allowing the light sources" of the PPG sensor "to illuminate the person's skin." *Id.*, 1:48-51, 7:12-23. The light "diffuses through the person's flesh and a portion of this light is then emitted back" (i.e., reflected) "out of the person's skin in close proximity to where the light was introduced into the flesh." *Id.*, 7:24-28. The photodetector array of the PPG sensor measures the "intensity" of this reflected light, and provides signals representing the intensity to "control logic" of the monitoring device. APPLE-1005, 2:5-14, 7:12-23, 13:39-47. The control logic can then calculate different physiological parameters based on characteristics of the reflected light signal. *Id.*, 1:54-56, 7:12-23. For example, the person's heart rate can be calculated based on "fluctuations in the amount of light from the light

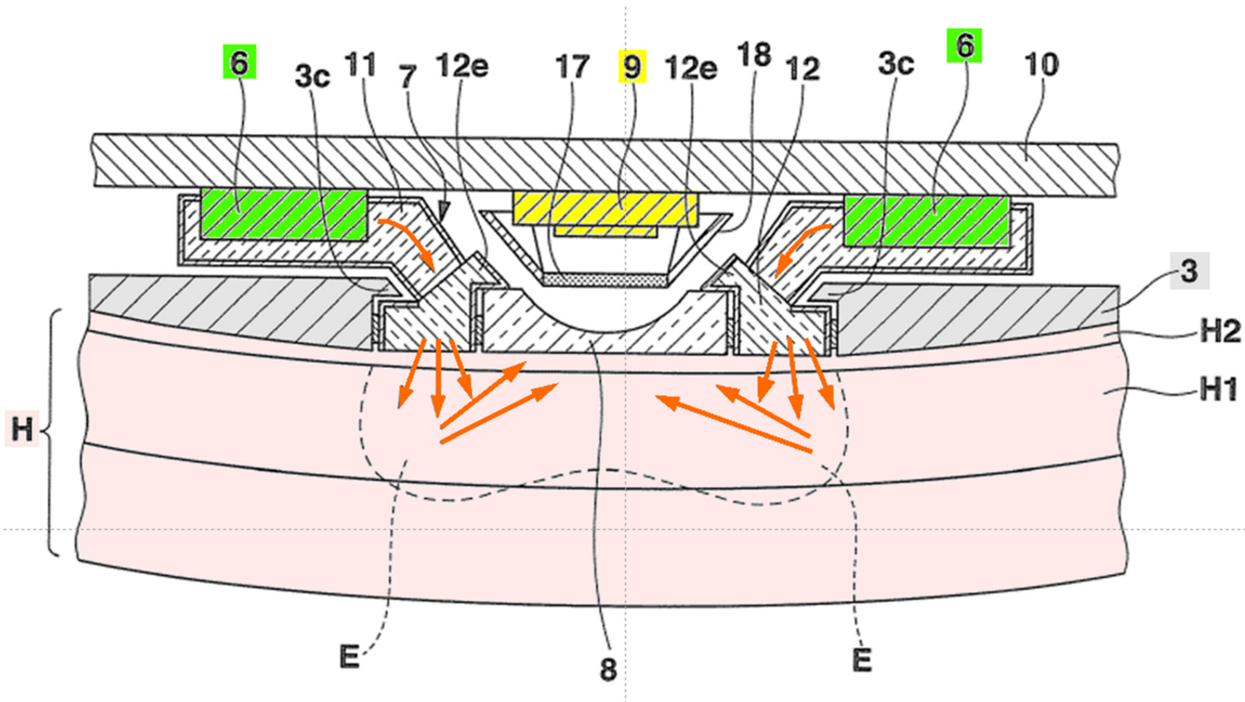
source that is emanated back out of the flesh" that correspond fluctuations in blood volume associated with each beat of the person's heart. *Id*., 7:23-60.

3. Analysis

(a) Claim 1

[1.0] A physiological monitoring device comprising:

31. In the combination, Iwamiya discloses an "optical biological information detecting apparatus" which is a physiological monitoring device. APPLE-1004, Abstract. For example, Iwamiya describes that the "optical biological information detecting apparatus" is provided in "a central portion of the back cover" of "a wristwatch" (*i.e.*, facing the wearer's wrist). APPLE-1004, 5:54-66, FIG. 1. As shown in the following annotated FIG. 4 from Iwamiya, the device includes LEDs 6 (shown in green) that emit light (orange) that is refected by the tissue of the wearer's wrist (pink) and detected by photodiodes 9 (yellow).

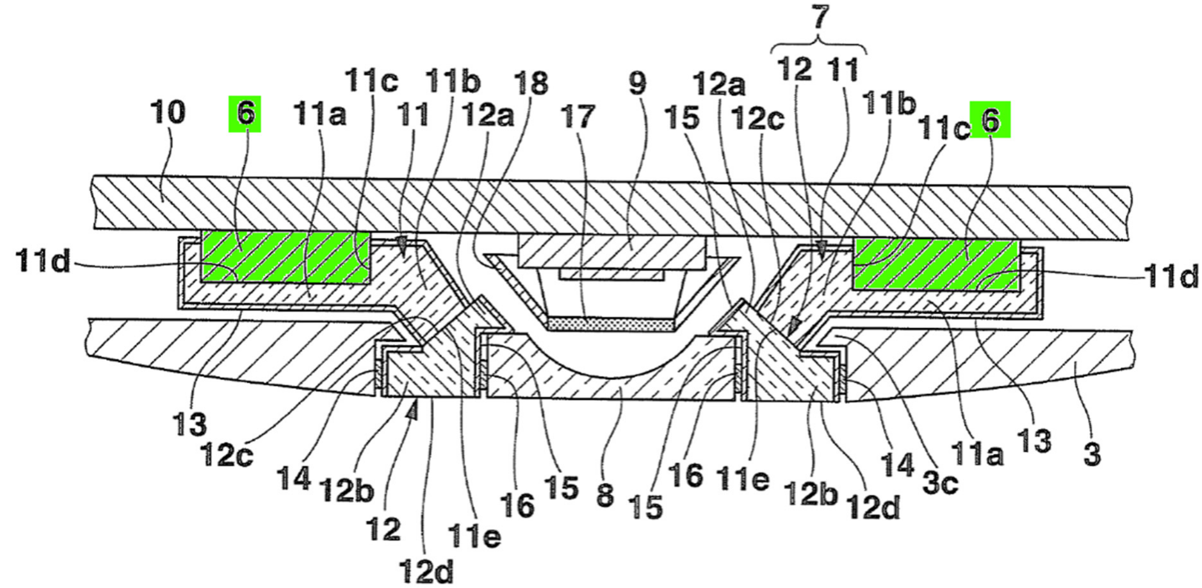


APPLE-1004, Detail of FIG. 4 (annotated)

32. Accordingly, the combination of Iwamiya and Sarantos renders obvious a "physiological monitoring device."

[1.1] a plurality of light-emitting diodes configured to emit light in a first shape;

33. In the combination, Iwamiya discloses "light emitting units 6" that are each "composed of a light emitting diode (LED)." APPLE-1004, 6:7-11, 6:32-39. The light emitting units 6 are shown in green in the following annotated FIG. 3 from Iwamiya:



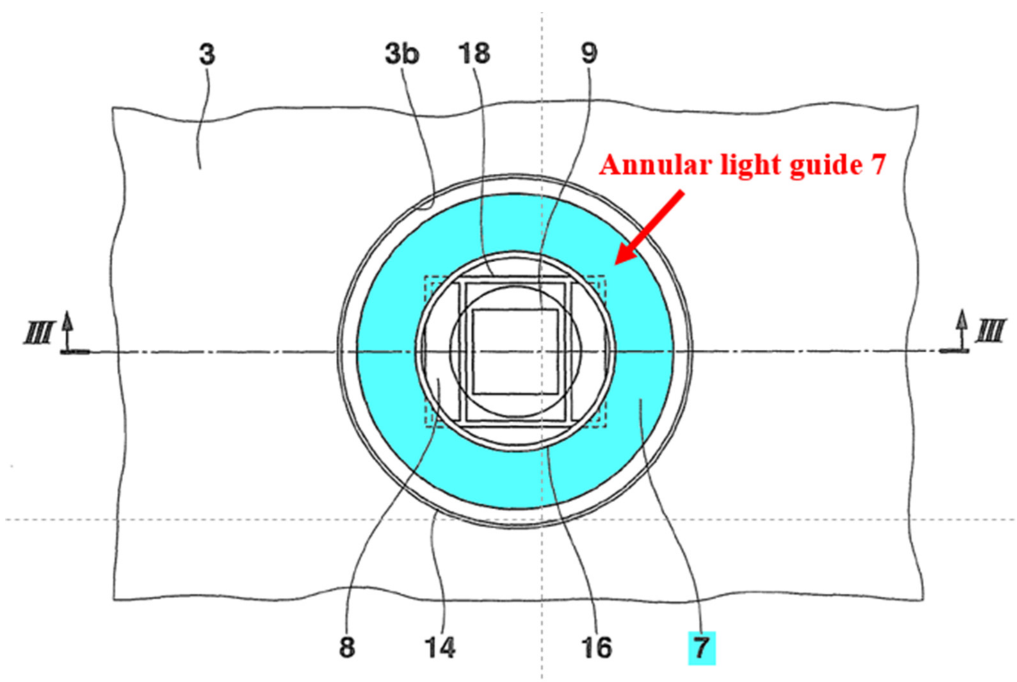
APPLE-1004, Detail of FIG. 3 (annotated)

34. The light emitting units 6 "emit observation light of a specific wavelength band to optically observe a skin tissue of a human body." *Id.*, 6:7-11. The emitted observation light is in a first shape characterized by the specific location of each light emitting unit, *e.g.*, the "3 o'clock" and "9 o'clock" positions as shown in FIGS. 3 and 4 of Iwamiya. *See id.*, 6:7-11, FIGS. 3-4.

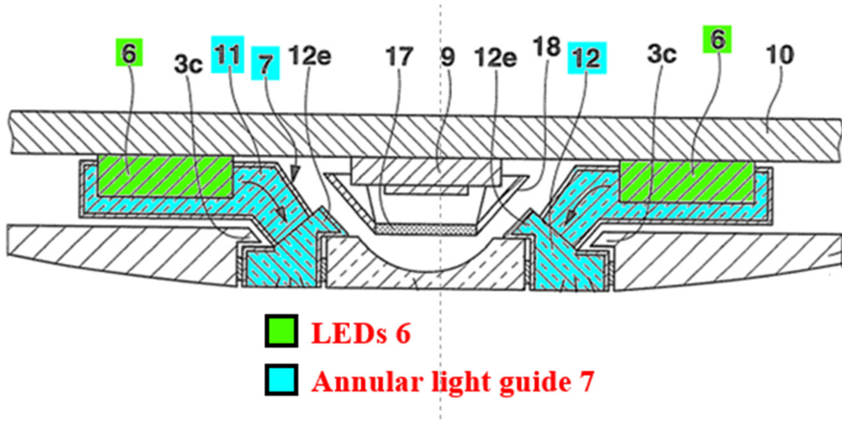
[1.2] a material configured to be positioned between the plurality of light-emitting diodes and tissue on a wrist of a user when the physiological monitoring device is in use, the material configured to change the first shape into a second shape by which the light emitted from one or more of the plurality of light-emitting diodes is projected towards the tissue;

35. In the combination, Iwamiya describes that the physiological sensor includes "an annular light guide unit 7 that guides the observation light emitted from the light emitting units 6 and annularly diffuses and irradiates the observation

light with respect to a skin H." APPLE-1004, 6:7-14, Fig. 4. The annular light guide unit 7 includes "a light guiding ring portion 11" formed "using a material such as transparent glass or a transparent resin with a high light transmitting property." *Id.*, 6:40-45. The annular light guide unit 7 also includes "a diffusion/irradiation ring portion 12" that is "formed in almost a ring shape, using a clouded or milky resin with a light diffusing property." *Id.*, 6:40-42, 7:4-6. The following annotated FIGS. 2 and 4 from Iwamiya show top and cross-section views of physical monitoring device the annular light guide unit 7 (annotated in teal).

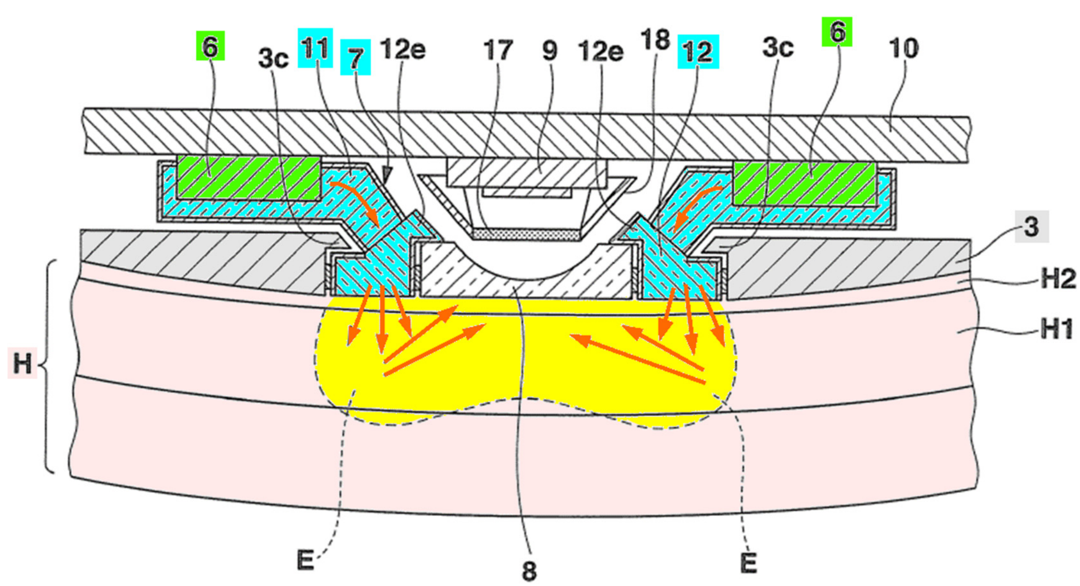


APPLE-1004, Detail of FIG. 2 (annotated)



APPLE-1004, Detail of FIG. 4 (annotated)

36. Annular light guide unit 7 changes the shape of the light emitted from individual light emitting units 6 to an annular shape (a second shape) and causes the light to irradiate an annular portion of tissue. *Id.*, 11:55-12:36. As shown in the following annotated FIG. 4 from Iwamiya, the light from the light emitting units (the orange arrows) irradiates "an irradiation area E" in the user tissue "having a ring shape" (shown in yellow). *Id.*, 7:61-65:



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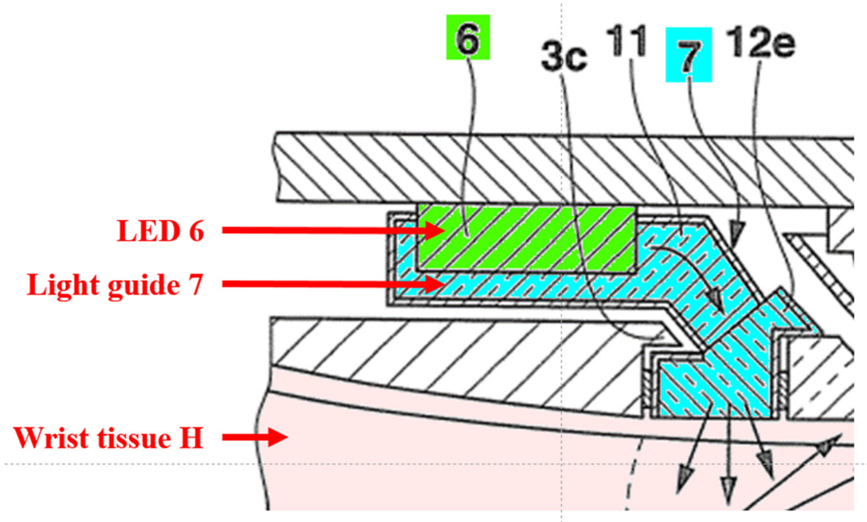
APPLE-1004, Detail of FIG. 4 (annotated)

37. As previously discussed (*see* [1.0], *supra*), Iwamiya's physiological sensor in Figure 4 is a wristwatch. *See, e.g.,* APPLE-1004, 6:22-31. Therefore, annular light guide unit 7 is positioned between light emitting units 6 and tissue on the wrist, as shown in annotated FIG. 4 below:



APPLE-1004, Detail of FIG. 4 (annotated)

[1.3] a plurality of photodiodes configured to detect at least a portion of the light after the at least the portion of the light passes through the tissue, the plurality of photodiodes further configured to output at least one signal responsive to the detected light;

38. In the combination, Iwamiya describes that the physical monitoring device includes a plurality of photodiodes. APPLE-1004, 14:36-41 (disclosing "plural light receiving units 9"), 8:20-23 (stating that each unit is "composed of a silicon photo diode"). The photodiodes are configured to detect light after the light passes through tissue and output a signal responsive to the detected light, which is

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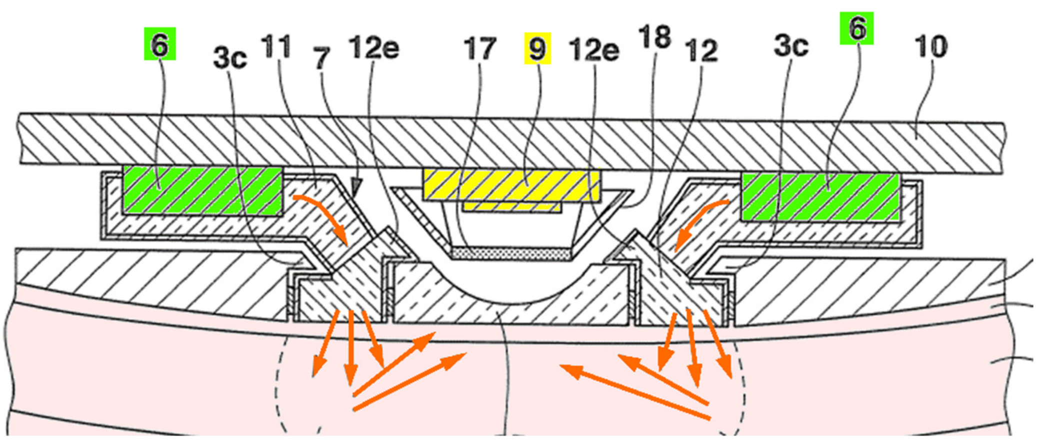
used to determine a physiological parameter of a user. *See* APPLE-1004, 9:28-32 ("the observation light emitted from the light emitting unit 6 is irradiated onto the skin H and the scattered light thereof is received by the light receiving unit 9" which "outputs a current signal according to the amount of received light"), 8:61-9:7 (describing "convert[ing] a current signal output from the light receiving unit 9" into a "voltage signal" and then displaying resulting biological information).

39. The following annotated FIG. 4 from Iwamiya shows that the light (shown as orange arrows) emitted by the light emission units 6 (in green) is reflected by the tissue H (in pink) and received by the photodiodes 9 (in yellow).

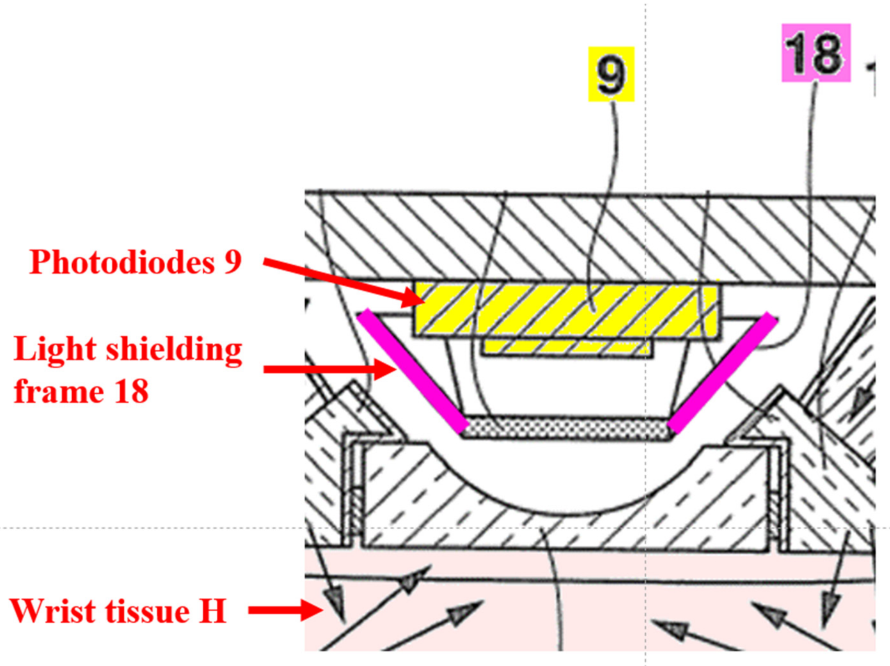


APPLE-1004, Detail of FIG. 4 (annotated)

[1.4] a surface comprising a dark-colored coating, the surface configured to be positioned between the plurality of photodiodes and the tissue when the physiological monitoring device is in use,

40. In the combination, Iwamiya describes a "light shielding frame 18" surrounding the photodiodes 9. APPLE-1004, 8:38-47, FIG. 4. As shown in FIG.

4 from Iwamiya, the light shielding frame 18 (shown in pink) is positioned between the photodiodes 9 (in yellow) and the tissue (in pink):



APPLE-1004, Detail of FIG. 4 (annotated)

41. Also in the combination, Sarantos discloses a wrist-worn reflectance-based physiological sensor that has a dark-colored coating 2276 to block light. APPLE-1005, 5:55-58, Fig. 22. Saranto's also discloses that light source 2208 emits light through a window into a user's skin, wherein the light is reflected from the skin and back to the sensor and detected by photodetector elements 2212. APPLE-1005, 17:16-25. The light travels through openings 2226 in the dark-colored coating 2276 applied to window 2278. *Id*.. Specifically, Sarantos discloses that "in-mold label 2276 may be black or otherwise rendered opaque to light to prevent light from entering or exiting the PPG sensor through the window 2278

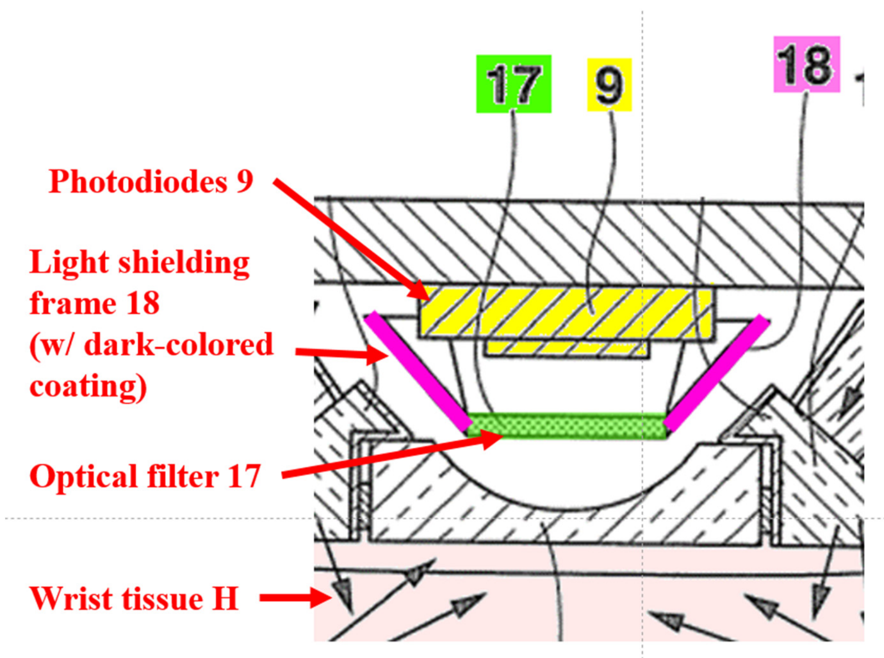
except through window regions 2226." APPLE-1005, 17:1-16. Sarantos explains that various masking techniques may be used to block stray light from reaching the photodetector elements 2212, including "a painted or silk-screened mask" applied to the window 2278. *Id*.

42. A POSITA would have been motivated to employ an in-mold label or other black or opaque material as disclosed by Sarantos in the light shielding frame 18 of Iwamiya to serve the purpose indicated by the component's name: shielding the photodiodes 9 from stray light (one of the dominant noise sources), and thereby ensuring accuracy of the sensor. *See, e.g.,* APPLE-1004, 8:38-47, FIG. 4; APPLE-1005, 5:55-58, 17:1-25, FIG. 22. A POSITA would have understood that a dark-colored coating, such as that described by Sarantos, would have served this purpose by not only blocking light but also by limiting reflections, which could lead to stray light being incident on the photodiodes 9. It also would have been obvious to a POSITA to use a dark-colored coating for light shielding frame 18 because dark-colored coatings and materials were well-known to effectively block light. *See, e.g.,* APPLE-1005, 17:1-10. A POSITA would have known that a light shielding frame 18 or holder portion 43 as disclosed by Iwamiya can be of various proportions, and a thin surface is a coating. *See id.* Because using dark-colored coatings in light blocks was so well-known, and Iwamiya and Sarantos are both wrist-worn reflectance-based physiological sensors, a POSITA would have

reasonably understood the combination of Iwamiya with Sarantos to be successful with no unexpected results. *Id.*

[1.5] wherein an opening defined in the dark-colored coating is configured to allow at least a portion of light reflected from the tissue to pass through the surface;

43. As previously discussed (*see* [1.4]), in the combination, the "light shielding frame 18" of Iwamiya employs a dark-colored coating, such as that described by Sarantos. Iwamiya further describes an "an optical filter 17" that "is mounted on the lower side of a light shielding frame 18" between the photodiodes 9 and the tissue H. APPLE-1004, 8:39-42. This configuration is shown in the following detail of FIG. 4 from Iwamiya:

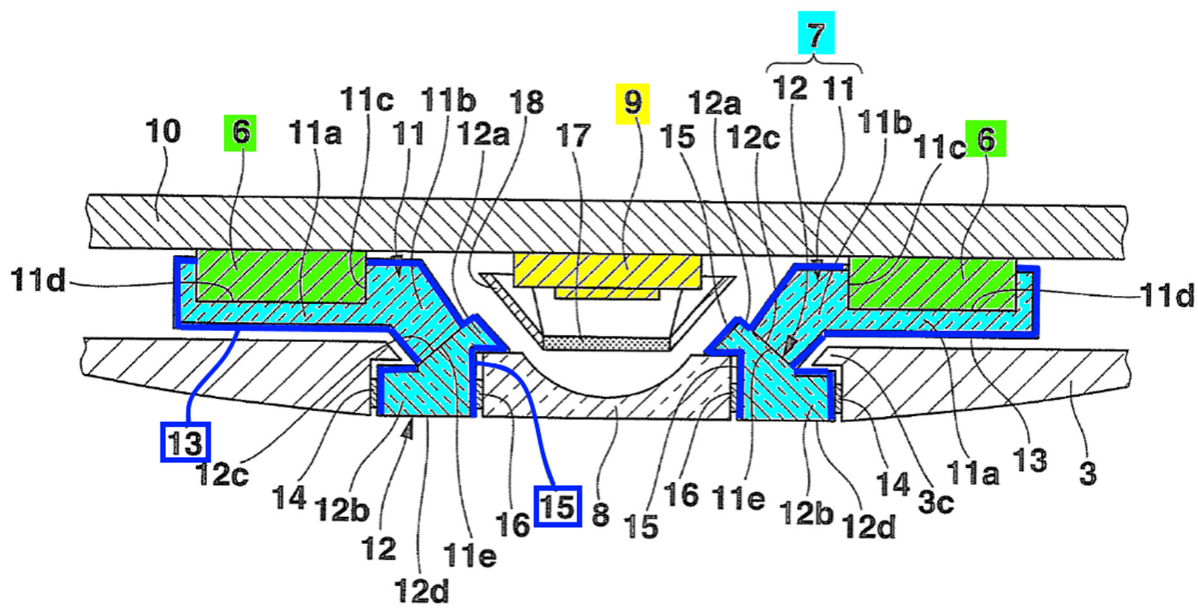


APPLE-1004, Detail of FIG. 4 (annotated)

44. Iwamiya describes that the "optical filter 17 is configured to transmit light of a specific wavelength band of 900 nm or more," and thus is configured to allow at least a portion of light reflected from the tissue to pass through to the photodiodes 9. APPLE-1004, 8:42-44.

[1.6] a light block configured to prevent at least a portion of the light emitted from the plurality of light-emitting diodes from reaching the plurality of photodiodes without first reaching the tissue; and

In the combination, FIG. 3 of Iwamiya shows reflection layers 13 and 15 (annotated in dark blue) that prevent light within annular light guide 7 from leaking outside of the annular light guide. APPLE-1004, 6:62-7:3, 7:41-49, FIG. 3:



APPLE-1004, Detail of FIG. 3 (annotated)

45. By preventing the light from leaking outside of the light guide 7, the reflection layers 13 and 15 act as light blocks that prevent light emitted from light

emitting unit 6 from directly reaching the photodiodes 9 without first reaching the tissue. APPLE-1004, 6:62-7:3, 7:41-49, FIG. 3.

[1.7] a processor configured to receive and process the outputted at least one signal and determine a physiological parameter of the user responsive to the outputted at least one signal.

46. In the combination, Iwamiya discloses a central processing unit (CPU) 20 that controls the disclosed biological information detecting apparatus. APPLE-1004, 8:61- 9:7. The CPU receives a current signal from the photodiodes of Iwamiya, processes it into a voltage signal, and then determines and displays a physiological parameter of the user, such as a heart rate, based on the signal. APPLE-1004, 8:61-9:7, 9:36-43.

(b) Claim 9

[9.0] The physiological monitoring device of claim 1, wherein the physiological parameter comprises oxygen saturation.

47. In the combination, Iwamiya discloses a sensor that detects "biological information," which includes oxygen saturation, and provides the example of a "pulse wave" or heart rate, wherein oxygen saturation comprises heart rate sensing at different wavelengths. APPLE-1004, 8:61-9:7.

48. Also in the combination, Sarantos discloses measuring blood oxygenation levels. APPLE-1005, 13:40-14:22. To the extent not disclosed by Iwamiya, a POSITA would have been motivated to determine oxygen saturation using Iwamiya's physiological sensor, based on the teachings of Sarantos, in order

to expand the range of physiological parameters measured by Iwamiya's sensor, thereby improving the functionality and utility of the sensor. *See, e.g.,* APPLE-1005, 13:40-14:22. A POSITA would have reasonably expected success in adapting Iwamiya's sensor to this purpose because wrist-worn pulse oximetry sensors, such as that described in Sarantos, were well-known in the art. *See, e.g.,* APPLE-1005, 13:40-14:22, FIG. 2.

B. Ground 1B: Claims 15, 18, 20, and 27 are obvious over Iwamiya and Sarantos in view of Venkatraman

1. Overview of Venkatraman

49. Venkatraman teaches a portable biometric monitoring device with a touchscreen display that can be worn on the wrist like a watch. APPLE-1006, 12:16-21, 15:19-26, 52:23-53:18. In particular, Venkatraman describes a "biometric monitoring device[] ... adapted to be worn or carried on the body of a user ... including [an] optical heart rate monitor" designed to "be a wrist-worn or arm-mounted accessory such as a watch or bracelet." APPLE-1006, 37:29-33. Venkatraman's monitoring device is "small in size so as to be unobtrusive for the wearer" and "designed to be able to be worn without discomfort for long periods of time and to not interfere with normal daily activity." APPLE-1006, 14:28-36. Venkatraman device also includes a digital display with "uses capacitive touch detection" to display data acquired or stored locally on the wristwatch. APPLE-1006, 53:19-55:51.

50. Venkatraman further discloses transmitting information wirelessly from its monitoring device to a secondary device such as a smartphone. APPLE-1006, 31:1-16, 57:20-53. Venkatraman also discloses that such a configuration allows the secondary device to act as a user interface for the wrist-worn wearable physiological device. APPLE-1006, 57:42-44. Venkatraman further discloses that the secondary device (*i.e.*, smartphone) can show various metrics regarding the user's health, and receive inputs through a touch-screen display. APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

2. Analysis

(a) Claim 15

[15.0] A physiological monitoring device comprising:

51. *See* [1.0].

[15.1] a plurality of light-emitting diodes configured to emit light proximate a wrist of a user;

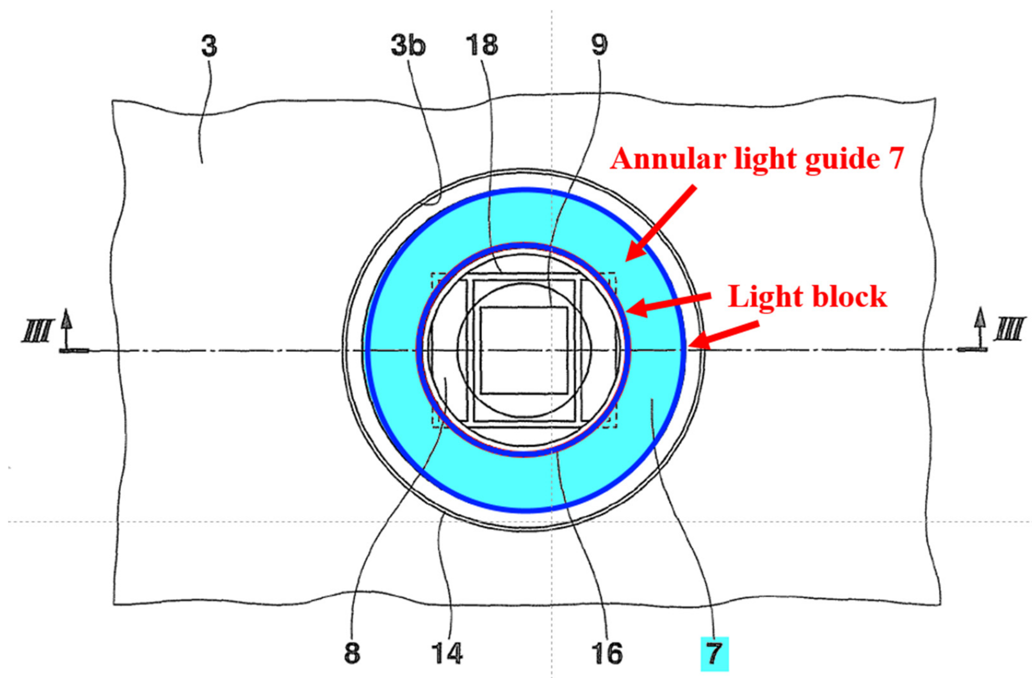
52. As previously discussed (*see* [1.0]-[1.1]), in the combination, Iwamiya's physiological sensor shown in Figure 4 is a wristwatch. APPLE-1004, 5:54-67, 6:22-31. Therefore, light emitting units 6 emit light proximate a user's wrist. *Id*..

[15.2] a light diffusing material configured to be positioned between the plurality of light-emitting diodes and a tissue measurement site on the wrist of the user when the physiological monitoring device is in use;

53. *See* [1.2].

[15.3] a light block having a circular shape;

54. As discussed above regarding claim element [1.6] with reference to Figures 3 and 4 of Iwamiya, reflection layers 13 and 15 are a light block. APPLE-1004, 6:62-7:3; *see* [1.6], *supra*. Figure 2 of Iwamiya shows reflection layers 13 and 15 each having a circular shape as they are formed on outer surfaces of light guiding ring portion 11 and diffusion/irradiation ring portion 12, respectively, which together form annular light guide unit 7. APPLE-1004, 6:62-7:3, 7:41-49, FIGS. 2-4:



APPLE-1004, Detail of FIG. 2 (annotated)

[15.4] a plurality of photodiodes configured to detect at least a portion of the light emitted from the plurality of light-emitting diodes after the light passes through the light diffusing material and a portion of the tissue measurement site encircled by the light block, wherein the plurality of photodiodes are arranged in an array having a spatial configuration corresponding to a shape of the portion of the tissue measurement site encircled by the light block

55. As previously discussed (*see* [1.3]), in the combination, Iwamiya describes that light emitted from light emitting units 6 travels through light diffusing material (annular light guide unit 7) and then passes into skin tissue that is encircled by the light block (reflection layers 13 and 15). APPLE-1004, 6:7-14, 12:3-17, FIGS. 3-4. Reflection layers 13 and 15, which form the light block, encircle a portion of patient tissue, shown in Iwamiya FIG. 4 as irradiation area E. APPLE-1004, FIGS. 3-4.

56. Iwamiya describes that the physiological monitoring device includes a plurality of photodiodes configured to detect light reflected by the encircled tissue. APPLE-1004, 6:7-14, 8:20-23, 12:3-17, 14:36-41, FIGS. 3-4. The photodiodes "may be two-dimensionally disposed in the places positioned at the side opposite to the skin H in the scattered light taking unit 8." APPLE-1004, 14:36-39. "In this case, the plural light receiving units 9 are preferably disposed on the same circumference centered on an optical axis of the scattered light taking unit 8." APPLE-1004, 14:39-41. A POSITA would thus have understood that the photodiodes described in Iwamiya are arranged in an array having a spatial

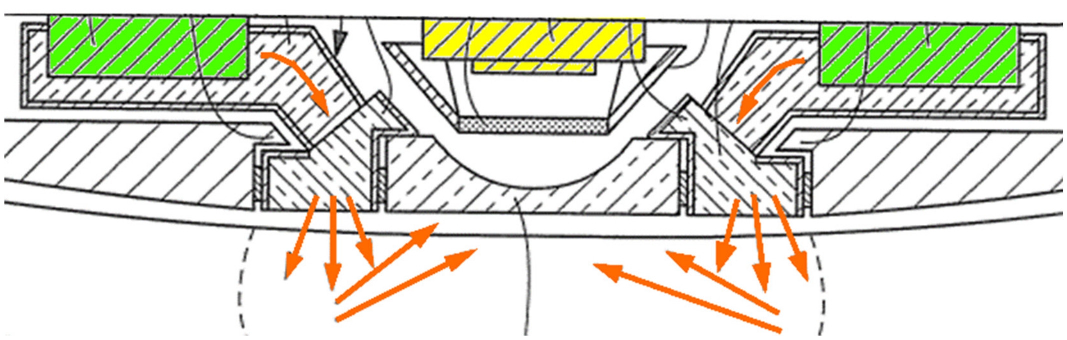
configuration corresponding to a shape of the portion of the tissue measurement site encircled by the light block. *See, e.g.,* APPLE-1004, 14:36-41, FIGS. 2-4.

[15.5] wherein the plurality of photodiodes are further configured to output at least one signal responsive to the detected light, and

57. *See* [1.3].

[15.6] wherein the plurality of light-emitting diodes and the plurality of photodiodes are arranged in a reflectance measurement configuration;

58. In the combination, Iwamiya discloses multiple LEDs and a plurality of photodiodes wherein light is shone into tissue and reflected back to the photodiodes. APPLE-1004, 6:7-21, 13:49-64, FIG. 4. This configuration is shown in FIG. 4 of Iwamiya, which shows the LEDs in green, the photodiodes in yellow, and the reflected light in orange:



APPLE-1004, Detail of FIG. 4 (annotated)

59. A POSITA would have understood the configuration shown in FIG. 4 of Iwamiya to be a reflectance measurement configuration. *See, e.g.,* APPLE-1013, 87-88, Figure 7.2.

[15.7] wherein the light block is configured to optically isolate the plurality of light-emitting diodes from the plurality of photodiodes by preventing at least a portion of light emitted from the plurality of light-emitting diodes from reaching the plurality of photodiodes without first reaching the portion of the tissue measurement site;

60. *See* [1.6].

[15.8] a processor configured to receive and process the outputted at least one signal and determine a physiological parameter of the user responsive to the outputted at least one signal; and

61. *See* [1.7].

[15.9] wherein the physiological monitoring device is configured to transmit physiological parameter data to a separate processor.

62. In the combination, Venkatraman discloses a non-invasive light-based wrist-worn physiological monitoring device, like Iwamiya's, that wirelessly transmits physiological parameter data to a separate processor, such as a smartphone. APPLE-1006, 31:1-16. A POSITA would have been motivated to transmit information from Iwamiya's wrist-worn wearable device, which has limited display space and processing power, to a secondary device like a smart phone, as taught by Venkatraman in order to increase the functionality of the system without significantly increasing the power consumption of Iwamiya's sensor. *See, e.g.,* APPLE-1004, 5:54-66, FIG. 1; APPLE-1006, 31:1-16, 37:41-63, 55:29-51, 57:20-58:9; APPLE-1011, 10:23-27;. For example, a POSITA would understand that it is important for wearable sensors, such as that described in Iwamiya, to avoid "power-consuming" features, such as large amounts of data

processing or elaborate graphical displays, because such added features may necessitate "a power supply unit with a sufficient battery capacity and an according heavy weight." *See, e.g.,* APPLE-1004, 5:54-66, FIG. 1; APPLE-1011, 10:23-27. By wirelessly "transmitting … measured physiological parameters to a monitor station," such as the smartphone taught by Venkatraman, additional features can be realized, such as the calculation additional metrics regarding the user's health, without the need to increase the battery capacity, and therefore weight, of Iwamiya's sensor. *See, e.g.*, APPLE-1004, 5:54-66, FIG. 1; APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9; APPLE-1011, 10:23-27.

63. Further, a POSITA would have found it obvious to modify Iwamiya based on Venkatraman because doing so entails the use of known solutions to improve similar systems and methods in the same way. Here, "when a patent 'simply arranges old elements with each performing the same function it had been known to perform' and yields no more than one would expect from such an arrangement, the combination is obvious." *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 417 (2007). A POSITA would have recognized that applying Venkatraman's teachings of transmitting physiological parameters wirelessly to a smartphone to Iwamiya's system would have led to the predictable result, taught by Venkatraman, of a smartphone displaying information based on the received physiological

parameters. APPLE-1004, 5:54-66, FIG. 1; APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

64. Accordingly, for at least these reasons, a POSITA would have been motivated and found it obvious to implement the combination of Iwamiya and Venkatraman as described above. Such a modification would have been routine and straightforward to a POSITA, and it would have been clear that such a combination would predictably work and provide the expected functionality, because Venkatraman describes a physiological monitoring device that operated in the proposed manner. *See, e.g.*, APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

(b) Claim 18

[18.0] The physiological monitoring device of claim 15, wherein the physiological parameter comprises oxygen saturation.

65. *See* Ground 1A, [9.0].

(c) Claim 20

Limitaions [20.0] – [20.8]

66. *See* [15.0] – [15.8].

[20.9] a processing device configured to wirelessly receive physiological parameter data from the physiological monitoring device, wherein the processing device comprises a user interface, a storage device, and a network interface configured to wirelessly communicate with the physiological monitoring device, and

67. As previously discussed (*see* [15.9], *supra*), in the combination, Venkatraman discloses a wrist-worn wearable physiological device and

transmitting information wirelessly from that device to a secondary device such as a smartphone. APPLE-1006, 31:1-16, 57:20-53. Venkatraman also discloses that such a configuration allows the secondary device to act as a user interface to the wrist-worn wearable physiological device. APPLE-1006, 57:42-44. Venkatraman further discloses that the secondary device (i.e., smartphone) can show various metrics regarding the user's health, and receive inputs through a touch-screen display. APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

68. As previously discussed (*see* [15.9], *supra*), a POSITA would have been motivated to transmit information from Iwamiya's wrist-worn wearable device, which has limited display space and processing power, to a secondary device like a smart phone, as taught by Venkatraman in order to increase the functionality of the system without significantly increasing the power consumption of Iwamiya's sensor.

69.

(d) Claim 27

[27.0] The system of claim 20, wherein at least one of the plurality of light-emitting diodes is configured to emit light of a first wavelength and at least one of the plurality of light-emitting diodes is configured to emit light of a second wavelength, the second wavelength being different than the first wavelength.

70. In the combination, Sarantos discloses including LEDs configured to emit different wavelengths of light, such as red and infrared, in a physiological monitoring device. APPLE-1005, 13:40-53. A POSITA would have been

motivated to include such LEDs in Iwamiya's sensor in order to enable the sensor to perform a larger number of physiological measurements, thereby increasing the functionality of the sensor. *See* APPLE-1005, 13:40-53. For example, as described in Sarantos, a POSITA would have found it "desirable to include separate light-emitting devices that are each able to emit different wavelengths of light" in the physiological monitoring device because "each light emitting device may be used to supply light for a different type of photoplethysmographic measurement," thereby increasing and improving the functionality of Iwamiya's sensor. APPLE-1005, 13:40-53. A POSITA would have reasonably expected success in implementing this combination, because Sarantos describes a physiological monitoring device including multiple LEDs of different wavelengths. APPLE-1005, 13:40-53.

C. Ground 2A: Claims 1, 9, 15, and 18 are obvious over Sarantos in view of Shie

1. Overview of Shie

71. Shie describes a diffuser that has a "light diffusing and shaping advantages" and changes a first shape of light into a second shape. APPLE-1007, 6:61-7:7. The diffuser includes a "plurality of surface micro-structures" that "are designed to homogenize light passing through" the diffuser "to produce a predetermined pattern of smoothly varying, non-discontinuous light exiting the" diffuser. APPLE-1007, Abstract. Shie describes that the exiting light "is therefore

altered according to both the macro-optical characteristic of the" diffuser "as well as the homogenizing characteristics of the micro-structures." *Id*.

2. Analysis

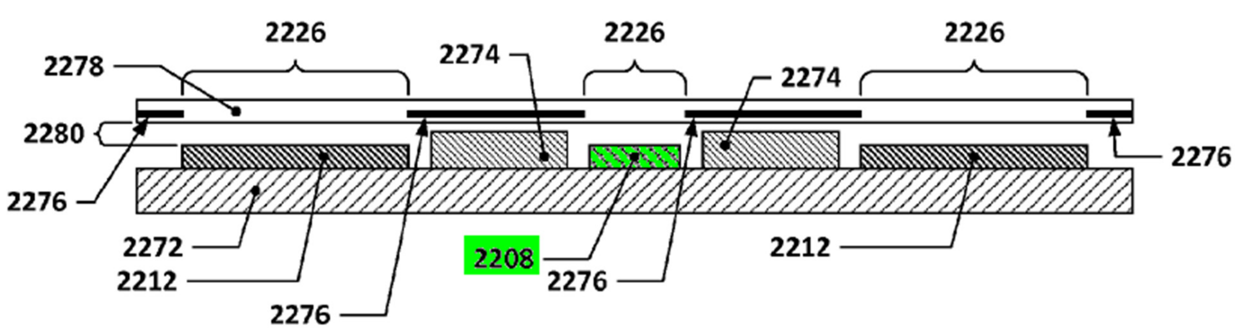
(a) Claim 1

[1.0] A physiological monitoring device comprising:

72. In the combination, Sarantos discloses a "wristband-type wearable fitness monitor" including a photoplethysmography (PPG) sensor, which is a physiological monitoring device. APPLE-1005, 7:12-16.

[1.1] a plurality of light-emitting diodes configured to emit light in a first shape;

73. In the combination, Sarantos describes a sensor that uses a plurality of LEDs. APPLE-1005, 2:18-19, 13:34-53. The light emitted from the LEDs is in a first shape, the first shape being characterized by the specific location of each light emitting device, *e.g.*, at light source 2208 (annotated in green) in FIG. 22 of Sarantos:

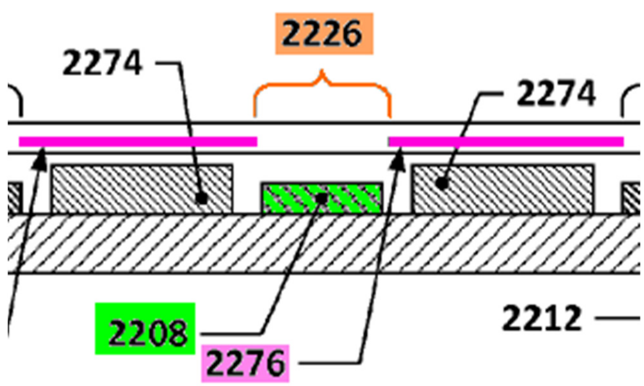


APPLE-1005, Detail of FIG. 22 (annotated)

74. Therefore, Sarantos discloses a plurality of light-emitting diodes configured to emit light in a first shape.

[1.2] a material configured to be positioned between the plurality of light-emitting diodes and tissue on a wrist of a user when the physiological monitoring device is in use, the material configured to change the first shape into a second shape by which the light emitted from one or more of the plurality of light-emitting diodes is projected towards the tissue;

75. In the combination, Sarantos' FIG. 22 depicts LEDs 2208 (annotated in green below) that shine through a window 2226 (orange) defined by in-mold labels 2274 (pink). APPLE-1005, 17:1-25, Fig. 22:



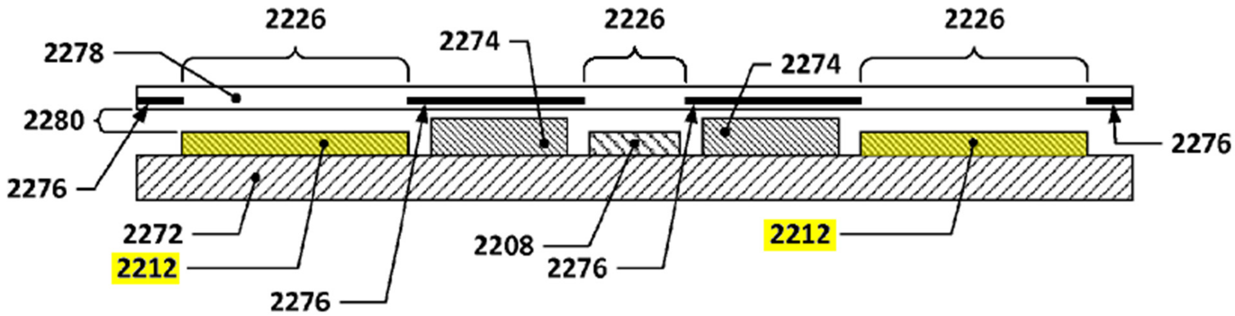
APPLE-1005, Detail of FIG. 22 (annotated).

76. Also in the combination, Shie describes a diffuser that has a "light diffusing and shaping advantages" and changes a first shape of light into a second shape. APPLE-1007, 6:61-7:7. It would have been obvious to a POSITA to use the light shape changing material of Shie in the wristwatch sensor of Sarantos in between LEDs 2208 and the user's wrist tissue, shown in Fig. 22 above, in order to change the shape of light emitted by LEDs 2208 into a second shape projected onto

the tissue. APPLE-1005, 7:12-16, Fig. 22. A POSITA would have been motivated to use a light shape changing material, such as Shie's, in order to precisely direct the light emitted toward the tissue so as to increase power efficiency by shining light closer to photodiodes, to increase accuracy of measurements by directing light towards a larger area to decrease irregular readings caused by moles or other aberrations on the skin, and/or to obscure the LED's appearance from a user. Light shape changing materials were known to be used for such purposes in the prior art, so a POSITA would have reasonably expected Shie's light shape changing material to work successfully in Sarantos's sensor. Id. ¶¶ 400, 418, 425-28.

[1.3] a plurality of photodiodes configured to detect at least a portion of the light after the at least the portion of the light passes through the tissue, the plurality of photodiodes further configured to output at least one signal responsive to the detected light;

77. In the combination, Sarantos discloses a plurality of photodiodes (photodetector elements 2212) which are configured to detect light after the light passes through tissue. APPLE-1005, 17:1-3, FIG. 22. The following annotated FIG. 22 from Sarantos shows the plurality of photodiodes 2212 (annotated in yellow):

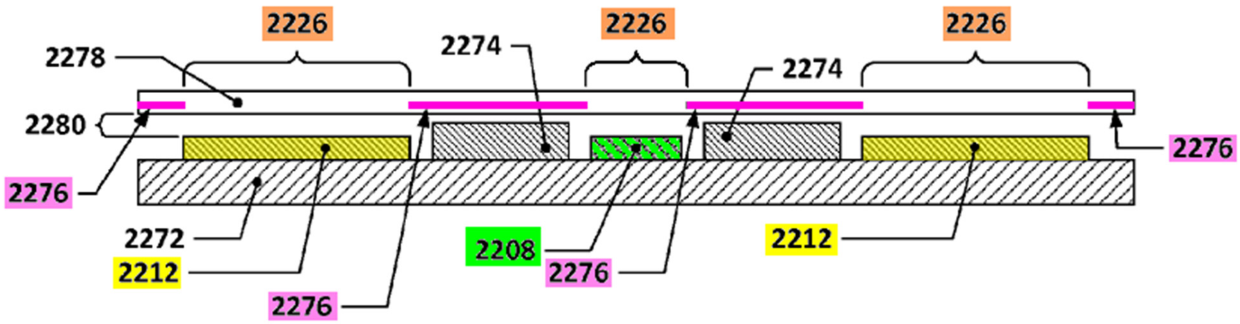


APPLE-1005, Detail of FIG. 22 (annotated)

78. The photodiodes are configured to detect light after the light passes through tissue. APPLE-1005, 17:16-25. The photodiodes then output a signal responsive to the detected light which is used to determine a physiological parameter of a user. APPLE-1005, 20:24-33.

[1.4] a surface comprising a dark-colored coating, the surface configured to be positioned between the plurality of photodiodes and the tissue when the physiological monitoring device is in use, wherein an opening defined in the dark-colored coating is configured to allow at least a portion of light reflected from the tissue to pass through the surface;

79. FIG. 22 of Sarantos depicts a surface with a dark-colored coating (window 2226 with in-mold label 2276) is positioned between the photodiodes 2212 and tissue of user's wrist, wherein openings 2226 in the dark-colored coating allow light reflected from the tissue to reach photodiodes 2212. APPLE-1005, FIG. 22. The following annotated FIG. 22 shows the windows 2226 (shown in orange), the in-mold labels 2276 (shown in pink), and the photodiodes 2212 (shown in yellow).

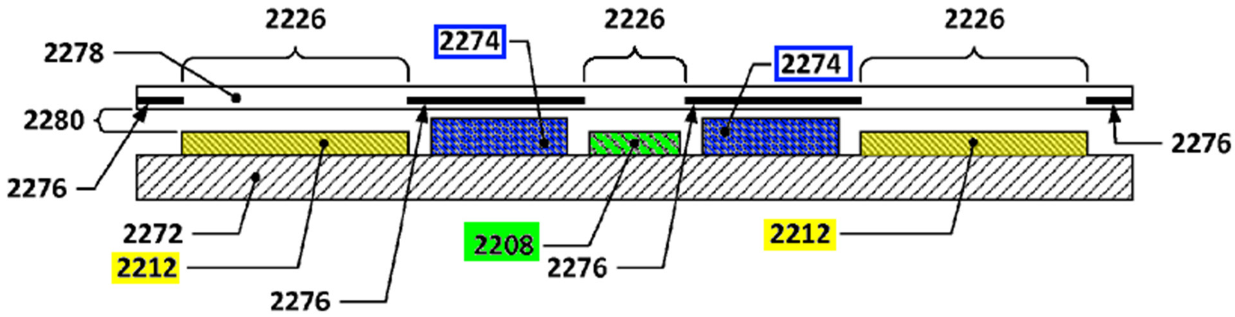


APPLE-1005, Detail of FIG. 22 (annotated)

80. Specifically, Sarantos discloses that the inmold label 2276 applied to window 2278 of Figure 22 can be black or opaque. APPLE-1005, 17:1-16. Sarantos explains that various types of surfaces with dark-colored coatings may be used to block stray light from reaching the photodetector elements 2212, including "a painted or silk-screened mask" applied to the window 2278. *Id.*.

[1.5] a light block configured to prevent at least a portion of the light emitted from the plurality of light-emitting diodes from reaching the plurality of photodiodes without first reaching the tissue; and

81. Sarantos discloses walls 2274 which serve as light blocks that prevent light emitted from light source 2208 from reaching photodetector elements 2212 without first passing through a user's tissue. APPLE-1005, 17:39-42. FIG. 22 from Sarantos shows the walls 2274, annotated in blue below:



APPLE-1005, Detail of FIG. 22 (annotated)

82. As shown in FIG. 22, the walls 2274 (blue) are positioned between the LEDs 2208 (green) and the photodiodes 2212 (yellow), and is thus configured to prevent at least a portion of the light emitted from the LEDs 2208 from reaching the plurality of photodiodes 2212 without first reaching the user's tissue. APPLE-1005, FIG. 22.

[1.6] a processor configured to receive and process the outputted at least one signal and determine a physiological parameter of the user responsive to the outputted at least one signal.

83. Sarantos discloses a processor 2768 that receives and processes signals from the photodetectors regarding the detected light reflected from the tissue of the user. APPLE-1005, 20:24-33. The processor then uses those signals to determine a measurement of the user's heart rate. Id. at 20:7-14.

(b) Claim 9

[9.0] The physiological monitoring device of claim 1, wherein the physiological parameter comprises oxygen saturation.

84. Sarantos also discloses the additional limitation of claim 9 requiring a sensor that measures oxygen saturation. APPLE-1005, 13:40-53 (disclosing measuring "blood oxygenation levels").

(c) Claim 15

[15.0] A physiological monitoring device comprising:

85. *See* [1.0].

[15.1] a plurality of light-emitting diodes configured to emit light proximate a wrist of a user;

86. *See* [1.1]. Because Sarantos's physiological sensor is a wristwatch, the LEDs emit light proximate a user's wrist. APPLE-1005, 7:12-25.

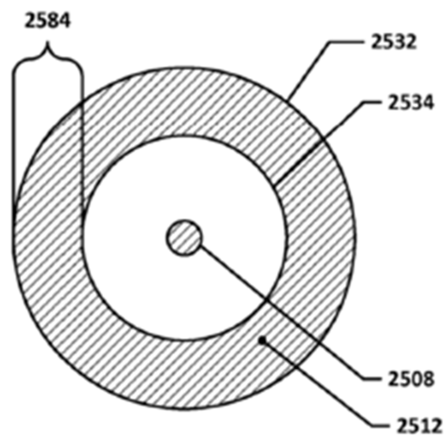
[15.2] a light diffusing material configured to be positioned between the plurality of light-emitting diodes and a tissue measurement site on the wrist of the user when the physiological monitoring device is in use;

87. *See* [1.2].

[15.3] a light block having a circular shape;

88. Sarantos Figure 22 discloses using a light block such as walls 2274 to prevent light from leaking between the LEDs and photodiodes before first reaching a user's tissue. APPLE-1005, 17:26-58, Fig. 22. Sarantos additionally discloses using annular photodetector elements, which would require the use of a circular

light block. *Id.*, 19:22-35, Fig. 25 (showing annular photodetector element 2512 with a light source 2508 in the middle).



89. FIG. 25

[15.4] a plurality of photodiodes configured to detect at least a portion of the light emitted from the plurality of light-emitting diodes after the light passes through the light diffusing material and a portion of the tissue measurement site encircled by the light block, wherein the plurality of photodiodes are arranged in an array having a spatial configuration corresponding to a shape of the portion of the tissue measurement site encircled by the light block,

90. A POSITA would have been motivated to incorporate the diffuser of Shie between LEDs 2208 and a user's tissue such that light emitted from LEDs 2208 travels through the light diffusing material of the diffuser and then passes into tissue that is encircled by the light block (walls 2274). APPLE-1005, 17:1-25; APPLE-1007, 6:61-7:7. Photodetector elements 2212 are positioned just outside of walls 2274. APPLE-1005, Fig. 22.

[15.5] wherein the plurality of photodiodes are further configured to output at least one signal responsive to the detected light, and

91. *See* [1.3].

[15.6] wherein the plurality of light-emitting diodes and the plurality of photodiodes are arranged in a reflectance measurement configuration;

92. Sarantos discloses multiple LEDs and a plurality of photodiodes wherein light is shone from the multiple LEDs into tissue and reflected back to the photodiodes. APPLE-1005, 17:1-4, 17:16-25, Fig 22. This is a reflectance measurement configuration.

[15.7] wherein the light block is configured to optically isolate the plurality of light-emitting diodes from the plurality of photodiodes by preventing at least a portion of light emitted from the plurality of light-emitting diodes from reaching the plurality of photodiodes without first reaching the portion of the tissue measurement site;

93. *See* [1.5], [15.3].

[15.8] a processor configured to receive and process the outputted at least one signal and determine a physiological parameter of the user responsive to the outputted at least one signal; and

94. *See* [1.6].

[15.9] wherein the physiological monitoring device is configured to transmit physiological parameter data to a separate processor.

95. Sarantos discloses "one or more processors and a memory" that are used to collect and analyze data collected from the photodetectors to determine a heart rate. Sarantos at 20:7-14, 20:14-18. In view of those disclosures, a POSITA would have found limitation [15I] obvious. A POSITA also would have found it obvious to transmit physiological parameter data from Sarantos's wrist-worn device to a separate processor such as a smartphone.

(d) Claim 18

[18.0] The physiological monitoring device of claim 15, wherein the physiological parameter comprises oxygen saturation.

96. *See* [9.0].

D. Ground 2B: Claims 15, 18, 20, 27 are obvious over Sarantos and Shie in view of Venkatraman

1. Analysis

(a) Claim 15

Limitations [15.0]-[15.8]

97. *See* Ground 2A, [15.0]-[15.8].

[15.9] wherein the physiological monitoring device is configured to transmit physiological parameter data to a separate processor.

98. Venkatraman discloses a noninvasive light-based wrist-worn physiological monitoring device, like Sarantos's, that wirelessly transmits physiological parameter data to a separate processor, such as a smartphone. APPLE-1006, 31:1-16; APPLE-1005, 7:12-16, FIG. 22. A POSITA would have been motivated to transmit information from Sarantos's wrist-worn wearable device, which has limited display space and processing power, to a secondary device like a smart phone, as taught by Venkatraman in order to increase the functionality of the system without significantly increasing the power consumption of Sarantos' sensor. *See, e.g.,* APPLE-1005, 7:12-16, FIG. 22; APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9; APPLE-1011, 10:23-27. For example, a POSITA would understand that it is important for wearable sensors, such as that described

in Sarantos, to avoid "power-consuming" features, such as large amounts of data processing or elaborate graphical displays, because such added features may necessitate "a power supply unit with a sufficient battery capacity and an according heavy weight." *See, e.g.,* APPLE-1005, 7:12-16, FIG. 22; APPLE-1011, 10:23-27. By wirelessly "transmitting … measured physiological parameters to a monitor station," such as the smartphone taught by Venkatraman, additional features can be realized, such as the calculation additional metrics regarding the user's health, without the need to increase the battery capacity, and therefore weight, of Sarantos' sensor. *See, e.g.*, APPLE-1011, 10:23-27; APPLE-1005, 7:12-16, FIG. 22; APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

99. Further, a POSITA would have found it obvious to modify Sarantos based on Venkatraman because doing so entails the use of known solutions to improve similar systems and methods in the same way. Here, "when a patent 'simply arranges old elements with each performing the same function it had been known to perform' and yields no more than one would expect from such an arrangement, the combination is obvious." *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 417 (2007). A POSITA would have recognized that applying Venkatraman's teachings of transmitting physiological parameters wirelessly to a smartphone to Sarantos' system would have led to the predictable result, taught by Venkatraman, of a smartphone displaying information based on the received physiological

parameters. APPLE-1005, 7:12-16, FIG. 22; APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

100. Accordingly, for at least these reasons, a POSITA would have been motivated and found it obvious to implement the combination of Sarantos and Venkatraman as described above. Such a modification would have been routine and straightforward to a POSITA, and it would have been clear that such a combination would predictably work and provide the expected functionality, because Venkatraman describes a physiological monitoring device that operated in the proposed manner. *See, e.g.*, APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

(b) Claim 18

[18.0] The physiological monitoring device of claim 15, wherein the physiological parameter comprises oxygen saturation

101. *See* Ground 2A, [9.0].

(c) Claim 20

Limitations [20.0]-[20.8]

102. See Ground 2A, [1.0]-[1.8]

[20.9] a processing device configured to wirelessly receive physiological parameter data from the physiological monitoring device, wherein the processing device comprises a user interface, a storage device, and a network interface configured to wirelessly communicate with the physiological monitoring device, and wherein the user interface includes a touch-screen display configured to present visual feedback responsive to the physiological parameter data.

103. In the combination, Venkatraman discloses a wrist-worn wearable physiological device and transmitting information wirelessly from that device to a secondary device such as a smartphone. APPLE-1006, 31:1-16, 57:20-53. Venkatraman also discloses that such a configuration allows the secondary device to act as a user interface to the wrist-worn wearable physiological device. APPLE-1006, 57:42-44. Venkatraman further discloses that the secondary device (i.e., smartphone) can show various metrics regarding the user's health, and receive inputs through a touch-screen display. APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9. A POSITA would have been motivated to wirelessly connect the wristband-type wearable fitness monitor of Sarantos to a secondary processing device having a user interface with a touch screen display as taught by Venkatraman in order to increase the functionality of the system by utilizing the superior display and processing capabilities of the secondary processing device, as described above. *See, e.g.,* APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9. A POSITA would have reasonably expected success in implementing this combination because Venkatraman describes a physiological monitoring device operating in the proposed manner. *See, e.g.,* APPLE-1006, 37:41-63, 55:29-51, 57:20-58:9.

(d) Claim 27

[27.0] The system of claim 20, wherein at least one of the plurality of light-emitting diodes is configured to emit light of a first wavelength and at least one of the plurality of light-emitting diodes is configured to emit light of a second wavelength, the second wavelength being different than the first wavelength.

104. In the combination, Sarantos discloses including LEDs configured to emit different wavelengths of light, such as red and infrared, in its physiological monitoring device. APPLE-1005, 13:40-53.

V. Legal Principles

A. Anticipation

105. I have been informed that a patent claim is invalid as anticipated under 35 U.S.C. § 102 if each and every element of a claim, as properly construed, is found either explicitly or inherently in a single prior art reference. Under the principles of inherency, if the prior art necessarily functions in accordance with, or includes the claimed limitations, it anticipates.

106. I have been informed that a claim is invalid under 35 U.S.C. § 102(a) if the claimed invention was known or used by others in the U.S., or was patented or published anywhere, before the applicant's invention. I further have been informed that a claim is invalid under 35 U.S.C. § 102(b) if the invention was patented or published anywhere, or was in public use, on sale, or offered for sale in this country, more than one year prior to the filing date of the patent application.

And a claim is invalid, as I have been informed, under 35 U.S.C. § 102(e), if an invention described by that claim was described in a U.S. patent granted on an application for a patent by another that was filed in the U.S. before the date of invention for such a claim.

B. Obviousness

107. I have been informed that a patent claim is invalid as "obvious" under 35 U.S.C. § 103 in light of one or more prior art references if it would have been obvious to a POSITA, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called "secondary considerations" of non-obviousness, which include: (i) "long felt need" for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) "copying" of the claimed invention by others.

108. I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason to modify the single prior art reference, or combine two or more references, in order to achieve the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference or references themselves, the knowledge or "common sense" of one skilled in the art,

or from the nature of the problem to be solved, and may be explicit or implicit from the prior art as a whole. I have been informed that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of the Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Dated: 7/22/2022 By: ______________________

Dr. Brian W. Anthony

Curriculum Vitae

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
School of Engineering Faculty Personnel Record

Date: October 20, 2021 Name: Brian W. Anthony

Department: Mechanical Engineering / Institute of Medical Engineering and Science

1. Date of Birth: July 1972
2. Citizenship: USA
3. Education:

School	Degree	Date
Carnegie Mellon University	BS	1994
MIT	SM	1998
MIT	PhD	2006

4. Title of Thesis for Most Advanced Degree:
   Video Based System Monitoring

5. Principal Fields of Interest:
   Computational Instrumentation, Medical Device Design and Manufacturing, Innovation and Product Realization, Ultrasound Imaging and Novel uses of Ultrasound

6. Name and Rank of Other Department Faculty in the Same Field:
   Harry Asada, Professor
   Ian Hunter, Professor
   Kamal Youcef-Toumi, Professor
   Charlie Sodini, Professor (EECS)

7. Non-MIT Experience (including military service):

Employer	Position	Beginning	Ending
LANL	Scientist	1992	1994
Independent Consultant	Consultant	1994	1998
Xcitex	CoFounder / CTO	1998	2005
Cooper Perkins	CTO	2005	2007
dRNOME	CoFounder	2011	2016

8. History of MIT Appointments:

Rank	Beginning	Ending
Lecturer, Sloan	2006	2009
Lecturer, MechE	2006	(present)
Research Scientist	2006	2013
Principal Research Scientist	2013	(present)
Director Singapore MIT Alliance – Manufacturing Systems and Technology		

Program (SMA-MST)	2006	2010
Director Master of Engineering in Manufacturing Program (MEngM)		
	2006	(present)
Faculty Lead for Education, MIT Skoltech Initiative	2011	2016
Deputy Director, MIT Skoltech Initiative	2014	2016
Associate Director, AIM Academy	2016	2017
Associate Director, MIT.nano	2017	
Faculty Lead for Industry Engagement, MechE	2018	

9. Consulting Record:

Firm	Beginning	Ending
Engagements greater than 3 months.		
Los Alamos National Labs		2000
Textron		2000
Federal Trade Commission		2000
FAA		2004
Kodak		2004
Redlake		2005
Olympus		2006
TIS	2009	2012
Photron	2009	2011
Cooper Perkins	2010	2012
IDEO	2012	---
Alcon	2012	---
Ximedica	2013	2014
Herman Miller	2014	2014
Novartis	2015	2015
Lenze	2015	2016
Apple	2017	

10. Professional Service

Activity	Beginning	Ending
MEngM Admissions Committee	2006	present
CDO Admissions Committee	2007	2008
Career Fair – SMA in Singapore, Org Chair	2007	2007
Career Fair – SMA/MIT in Singapore, Org Chair	2008	2008
Mfg. microFluidics Symp, Chair	2009	2010
SMART Proposal Lead on Med Devices	3/2010	9/2010
LMP Summit Co-Chair	2011	2011
MEDRC Workshop, Chair	2012	2012
Pilot IMI Proposal, MIT Lead	5/2012	6/2012
Additive mfg working group, Lead	6/2012	8/2012
MIT's role in reducing the cost of health care	2014	2015

Activity	Beginning	Ending
SPIE Conference Committee	2011	2018
SPIE Conference Committee	2012	2018
Co-Chair Education Workstream, AMP 2.0	2013	2014

11. Awards Received:

Award	Date
National Television Academy, Emmy for Innovative Technical Achievement. "Golf on CBS, SwingVision."	2005
BPLA Invented Here, Featured Honoree	2014

12. Current Organization Membership:

Organization	Offices Held
ASME	
IEEE	
SPIE	
AIUM (American Institute of Ultrasound in Medicine)	
Sigma Xi	

13. Patents and Patent Applications Pending:

1. US Patent 5606130 "Method for determining the octane rating of gasoline samples by observing corresponding acoustic resonances therein."
2. US Patent 6393384 "Apparatus and method for remote ultrasonic determination of thin material properties using signal correlation."
3. US Patent 6226081 "Optical height of fill detection system and associated methods."
4. US Patent 8,333,704, B. Anthony and M. Gilbertson, "Handheld Force-Controlled Ultrasound Probe," Dec 11, 2012
5. US Patent 8,328,725, B. Anthony and M. Gilbertson, "Ultrasound Probe," Dec 18, 2012
6. US Patent 8,382,671, B. Anthony and M. Gilbertson, "Handheld Ultrasound Probe," Feb 26, 2013
7. US Patent 9,121,705, B. Anthony and D. Ljubicic, "Sensor for Simultaneous Measurement of Thickness and Lateral Position of a transparent object," Sept 1, 2015
8. US Patent 9,456,800, Brian W. Anthony, Matthew W. Gilbertson, "Ultrasound scanning system", Oct 4, 2016
9. US Patent 10353191, Circular scanning technique for large area inspection, July 16, 2019.
10. MIT Case 14088, Force Controlled Ultrasound Probe, 16-Dec-09
11. MIT Case 14387, Deformation Estimation and Correction in Elastography with a Handheld Force Controlled Ultrasound Probe, 16-Jul-10
12. MIT Case 14422, High-Speed Profilometer for Manufacturing Inspection, 30-Jul-10
13. MIT Case 14966J, Force Measurement Ultrasound Probe for Sonographer Fatigue Monitoring, 10-Jun-11

14. MIT Case 15012, A 6-DOF Optical System for Freehand 3D Ultrasound, 05-Jul-11
15. MIT Case 15681J, Local Actuation and Control of Stamp Deformation in Microcontact Printing, 06-Jun-12
16. MIT Case 15782, Usability Improvements to a Handheld Force-Controlled Ultrasound Probe, 03-Aug-12
17. MIT Case 15884, Computer-Guided Restoration of Ultrasound Scan Poses by Optical Tracking, 01-Oct-12
18. MIT Case 16160, Quick-Release Mechanism for a Force-Measuring Ultrasound Probe, 22-Feb-13
19. MIT Case 16447, Force-correlated Quantitative Ultrasound Image Analysis, 02-Jul-13
20. MIT Case 17106J, Acoustic Characterization of Superficial Body Fluids, 07-May-14
21. MIT Case 17211J, Wireless Capsule Endoscopic Ultrasound, 24-Jun-14
22. MIT Case 17259K, A Concentric Circle Scanning Technique for Large Area Inspection, 09-Jul-14
23. MIT Case 17260K, Grid-Based Matching for Full-Field Large-Area Deformation Measurement, 09-Jul-14
24. MIT Case 17344, Recovery and Computer-Guided Restoration of Ultrasound Scan Poses Based on Human Skin Features, 21-Aug-14
25. MIT Case 17864J, Ultrasound-Based Individual Scatterer Detection Method Using Scatterer Motion Induced by Acoustic Radiation Force, 21-Apr-15
26. MIT Case 17865, Ultrasound-Based Absolute Scatterer Concentration Measurement Technique: Image Volume Estimation from Scatter Spread Function Extracted From the Image, 21-Apr-15
27. MIT Case 17990, Hydrogel Ultrasound Angle Wedge, 04-Jun-15
28. MIT Case 18074, Joint Camera-Ultrasound Data Acquisition for Limb Scanning, 13-Jul-15
29. MIT Case 18544, An Iterative RTM with a Priori Data to Estimate Bone Thickness Using a Cylindrically Scanning Ultrasound Tomography Scanner, 22-Feb-16
30. MIT Case 18545K, Block-Wise Inversion for the Soundspeed of Human Soft Tissue and Bone Using Ray Based Travel Time Tomographic Techniques, 22-Feb-16
31. MIT Case 18636, Concentric Ring-Based Point Pattern Matching of Skin Features, 05-Apr-16
32. MIT Case, Physical and Chemical Characterization of Aerosols with Photonic Waveguides, United States Patent Application 20190234850
33. (to be updated)

14. Professional Registration:

N/A.

15. Major New Products, Processes Designs, or Systems:

See next.

16. Major New Products, Processes Designs, or Systems:

The following is split between a) University Programs or Significant Initiatives, b) Products, and c) Companies.

A. Programs, Centers, or Significant Initiatives

MechE Alliance – Industry Immersion Project Program

The I2P Program provides MechE graduate students with an exclusive opportunity to gain real-world experience working on a 3-to-6 month industry project at a participating company while still enrolled at MIT. Project concepts are first proposed by the company, and then refined and improved by students and their faculty advisors to best suit their academic experience and career interests.

Living Lab in IMES

The Sekisui House at MIT will establish a multi-year and sustained collaboration around specific themes and needs, answer key questions—via targeted projects designed to collect clinically relevant evidence—and generate significant technology innovations. The program will be staffed and operated by clinicians, researchers, and technical instructors, while fostering educational and global exchange between disparate communities, all while highlighting efforts in medical and observational research. The broader MIT community will be engaged with annual workshops and calls for proposals, as well as nominations for faculty and students to join programs surrounding specific themes.

Immersion Lab – MIT.nano

The Immersion Lab is a two-story, state-of-the-art space for research in visualization, augmented and virtual reality (AR/VR), and the depiction and analysis of spatially related data. Housed in MIT.nano, the lab is an open-access research space. The Immersion Lab mission is to propel research and education at MIT by: Providing the community with an array of cutting-edge technologies to facilitate immersive experiences; Broadening interdisciplinary interest in immersive technologies at MIT and promoting collaborations in art, science, and technology; Supporting teaching in enhanced reality and mentoring MIT community members seeking to realize their projects using our facility; Bridging the domains of hardware and software—and encouraging cycles in which advances in one domain spark innovation in the other; Fueling experimentation and research in enhanced reality technologies through seed grants, shared equipment, symposia, and other resources.

MEngM

Former Director of the Master of Engineering in Manufacturing Program, and previously the director of the Singapore MIT Alliance - Manufacturing Systems and Technology Program since 2006. In these roles I have developed an education partnership program with small to multi-national corporations, defined and built the MEngM program and structure for the development and execution of company based projects. I place student groups into companies, teach professional engineering practice in the contact of industry based group projects, and broadly define and execute the operations of the MEngM degree program. Between 2007 and 2010, I raised over $900,000 from our partner companies to support program sponsored student fellowship and program operations.

MEDRC

Co-Founder, Co-Director of the Medical Electronic Device Realization Center (MEDRC). Along with Charlie Sodini, and Joel Voldman, I recruit large Medical Device manufacturing companies, lead research, and engage with the Med Tech community nationally and internationally.

The MEDRC establishes partnerships between the microelectronics industry, the medical devices industry, medical professionals, and MIT faculty, researchers and students to collaboratively achieve improvements in the cost and performance of medical electronic devices. The successful realization of such a vision also demands innovations in the usability and productivity of medical devices, and new technologies and approaches to manufacture devices. The MEDRC is a focal point for large business, for venture-funded startups, and for the medical community.

The unique research methodology of the MEDRC begins with the project definition. Research activities are jointly defined by faculty, physicians and clinicians, and industrial partners. Visiting scientists from microelectronic and medical device companies, physically resident at the Center, provide the industrial viewpoint in the project definitions and participate in the realization of the technology. Prototype systems are developed which are used in clinical tests early in the projects to help guide the research technology being developed in parallel.

To date we have raised significant funding and identified a visiting scientist from GE, Analog Devices, Maxim, Philips, Nihon Kohden, Novartis. Each company commits to $900,000 over 3 years.

MIT Skoltech Initiative

Deputy Director, and Lead Education, MIT Skoltech Initiative. I servied as the education faculty lead in the development of high level curriculum concept for SkolTech Master's degree programs, spanning across domains (space, nuclear, biomedicine, IT, and energy). We develop the education-team collaboration, build consensus on vision, objectives, and plans, and to create education programs for each domain.

AIM Academy

Associate Director of AIM Advance Integrated Photonics Manufacturing Academy. The AIM Photonics manufacturing institute is a public-private partnership that focuses the nation's premiere capabilities and expertise to capture critical global manufacturing leadership in Integrated Photonics technology that is essential to the U.S. economy. In this role I supported community, careers and investment for US world leadership in Integrated Photonics manufacturing. I lead development of a Masters program in Integrated Photonics Manufacturing and development of an Education Factory practice facility.

MIT.nano / SENSE.nano

Associated Director, MIT.nano.

Founding director of first center of excellence at MIT.nano, SENSE.nano. New sensors and sensing systems can provide previously unimaginable insight into the condition of the built and natural world and to positively impact man, machine, and environment. For example, new sensors can provide accessible sensing capabilities important to individual's health and wellness, such as recently-developed nanoparticle-embedded paper strips that can rapidly diagnose Zika, Ebola, and other diseases in a simple color-coded test. Massively distributed networks of sensors enable large-scale, global data collection important to agriculture and water distribution, environment monitoring, disaster recovery, disease outbreak detection and intervention, supply chain operations, and the operations of cities. Nano sciences and technologies offer unprecedented opportunities to realize designs for, and scale manufacturing of, the sensors and sensing technologies required to fundamentally understand and fight diverse challenges. MIT–with comprehensive excellence in engineering, business, earth science, electronics, computation, nanoscience, materials science, neuroscience, chemistry, physics, manufacturing, and biology–is poised to address the engineering, science, policy, and commercial challenges required to realize these grand, but nano, visions, to translate them to scale, and to positively impact society. MIT.nano is a world-class, nano-capable, shared laboratory facility and provides an open collaborative and cross-disciplinary nexus for advanced research, innovation, and education.

MIT Center for Clinical and Translation Research

Director of Clinical Technology.

The CCTR provides the facilities needed to conduct safe human research - in concert with colleagues in MIT Medical, the VPR Office of Research Compliance, and the Committee on the Use of Humans as Experimental Subjects (COUHES). The Center embodies a three-part mission: addressing critical needs in translational research within medicine, expanding central resources essential to MIT, and enabling external links to outside schools (Tufts University, Harvard University, Harvard Medical School), hospitals, and agencies (e.g. FDA).

Other Significant, formative, Initiatives

SMART Center - March through September 2010

I developed consensus around a theme, built the team of 10 investigators in Singapore and 10 investigators at MIT for a whitepaper and requested full center-proposal for SMART, entitled "*Realization (Design, Manufacturing, and Use) of Injectable Physiological Monitors – Enabling a Patient Centric Information Driven Healthcare Future.*" The research was motivated by addressing the need for unobtrusive, continuous, ambulatory, physiological monitoring of Congestive Heart Failure and Chronic Obstructive Pulmonary Disease patients. The 'state of health' information generated from these sensors can help reduce societal health care costs, improve quality of health care, increase quality lifespan, and lead to new understanding of the human physiology. Our proposal made it to the final round but was not selected. However these efforts lead to the creation of the MEDRC.

Pilot Innovation Manufacturing Institute (IMI) Proposal – May, June 2012

A team (University of Massachusetts Amherst, University of Connecticut, Massachusetts Institute of Technology, the Connecticut Center for Advanced Technology, the Pennsylvania State University, UMass Lowell, United Technologies Corporation, and the National Center for Manufacturing Sciences) proposed to form an independent, non-profit technical center of excellence to accelerate technological progress and innovation in additive manufacturing (AM), in response to the May 8, 2012 Air Force Research Laboratory Broad Agency Announcement (BAA-122-17-PKM) for the NNMI pilot. The NNMI Pilot Institute will demonstrate the value of the kind of collaborative problem-solving and asset-building that could occur on a broader scale with a nation-wide network of Institutes for Manufacturing Innovation. Federal government funding for the 2.5-year pilot program is $30M with a minimum of $30M in required cost sharing from industry, state government and universities.

In our center, The Advanced Direct Additive Manufacturing Institute (ADAM-I), we proposed to address key gap-bridging challenges in AM, including: rapid net shape production of structural metal, ceramic and polymer parts, and cost-effective manufacturing of large-area functional materials, components and devices.

Marty Schmidt and I spearheaded the MIT collaboration. We developed the business plan and financial sustainability model for the proposed center. I raised $3 million in matching fund commitments (10% of the total match commitment).

Flexible Hybrid Electronics Manufacturing Innovation Institute (NextFlex) – October 2015

MIT PI on winning proposal, including a team of : Marc Baldo, Duane Boning, Vladimir Bulovic, Karen K Gleason, David E Hardt, Anastasios John Hart, Sang-Gook Kim.

$150M national center with a mission to catalyze the development of an ecosystem for manufacturing new forms of electronics that integrate bulk ICs and printed devices with functions such as power, communications, fluidics, and bio-sensing in flexible systems that can bend, fold, stretch, and conform.

B. Products

Fuselage Crack Inspection System for FAA

In support of the Federal Aviation Administration National Aging Aircraft Research Program (NAARP) the state-of-the-art Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) Facility was established at the FAA William J. Hughes Technical Center. A fixture was designed to simulate the actual loads to which an aircraft fuselage structure is subjected while in flight. Data from tests using this fixture was used to experimentally validate analytical theories and methodologies to evaluate and predict the onset of Widespread Fatigue Damage (WFD). Crack growth data from testing was gathered from the Remote Control Crack Monitoring System.

I designed, built, and delivered The Remote Control Crack Monitoring System consisting of a pair of cameras with two different fields of view manipulative by with a large gantry robot. The cameras 'fly' over the fuselage surface to identify and track cracks using processed camera images to generate the feedback signal

Laser Wave for Textron

Textron Inc.'s LaserWave® products integrated advanced signal processing techniques, robust software algorithms, lasers, optics and ultrasonic technology. The LaserWave Instrument could measure material characteristics such as density, hardness, temperature, thickness, elastic constants and more. LaserWave was developed to measure the temperature of Silicon Wafers undergoing rapid thermal processing and evolved to become a general system for material characterization.

A pulse laser system is used to initiate a circular thermo-elastic Lamb wave. I developed propagation models describing the propagation of the collapsing circular, thermo-elastic, transient Lamb waves. I developed real-time inversion routines using a time-frequency wavelet decomposition to extract and identify group velocity mode shapes. The LaserWave products use models and algorithms that I developed to invert the measured temporal signals in order to estimate elastic constants and material thickness of thin layers.

This product line didn't fit Textron's business mode. They transferred the technology to Brown University.

MASIMO 2071
Apple v. Masimo
IPR2022-01291

http://investor.textron.com/newsroom/news-releases/press-release-details/2003/Textron-Donates-Laser-Technology-to-Brown-University-Research-Foundation/default.aspx

Motion Tools for Photron Inc

I designed Photron Motion Tools to operate high-speed PCI cameras. Photron Motion Tools provides users with manual and automatic tracking capabilities. By simply selecting the point of interest within the recorded image sequence, Motion Tools automatically tracks the points-motion within the sequence.

http://www.photron.com/index.php?cmd=product_general&product_id=17

i-Speed for Olympus

Capable of capturing images at speeds from 60 to 150,000 frames per second in 'normal' mode (down to 1 second/frame in 'timelapse' mode) i-SPEED cameras are an effective method of locating problems quickly and easily. The user can evaluate designs, increase productivity and reduce maintenance costs. Video images are digitally captured onto its onboard memory, where they can be written to compact flash card or downloaded via Ethernet connection to a laptop or PC.

I designed custom software to provide the operator with the ability to analyze and enhance images. Velocity and distance measurement can also be calculated. The i-SPEED Software Suite was designed to mirror the ease-of-use and high specification power of the camera range.

http://www.olympus-ims.com/en/ispeed-software/

Swing Vision for CBS

I designed and built the Swing Vision camera system, camera control system, camera mounts, the server architecture, and the analysis software. Two high-speed cameras record a golfer t-shot. A 2000 fps camera records the full view of the golfer. A 12500 frame per second camera is used to record the ball-club interaction. As the 2000 fps video is broadcast in slow motion, the 12500 fps video (gigabytes of raw video data) is **automatically** analyzed (in under 20 seconds). The ball is located, used for calibration, and tracked, the club is identified and tracked – all under highly variable condition (variable lighting from shadows, grass, occlusions, etc). The calculated speeds, back spin, and launch angle are sent to the broadcast truck. The results are broadcast in a graphic.

I won an Emmy for this system in 2005.

MiDAS - Xcitex

As Xcitex's first engineer, I developed the core of the flagship products - MiDAS and ProAnalyst. And as CTO and Vice-President of Xcitex, I developed and directed the development of products and solutions for the industrial and scientific video markets.

MiDAS is now the the standard for controlling, synchronizing, and automating digital high-speed and industrial video cameras. With thousands of installations worldwide, MiDAS software is used by researchers, production line engineers, scientists, doctors, and military range operators to convert their video cameras into easy-to-use motion capture systems.

MiDAS includes intelligent triggering, autonomous recording, synchronized video/data collection, large file organization tools. Features such as distance and velocity measurement calipers, auto-tracking, and video triggering are included.
http://xcitex.com/html/midas_description.php

ProAnalyst - Xcitex

As Xcitex's first engineer, I developed the core of the flagship products - MiDAS and ProAnalyst. And as CTO and Vice-President of Xcitex, I developed and directed the development of products and solutions for the industrial and scientific video markets.

ProAnalyst is a software package for automatically measuring moving objects with video. It is used extensively by NASA, engineers, broadcasters, researchers and athletes. ProAnalyst allows users to measure and track velocity, position, size, acceleration, location and other characteristics. Results can be instantly graphed and reviewed, compared against external data, and exported to a variety of output formats for further analysis or presentation purposes.

http://xcitex.com/html/proanalyst_description.php

C. Companies

Xcitex – CoFounder, formerly CTO, formerly Vice-President, Board of Directors

Xcitex was self-funded and grew through solid product development and consistent execution of our business strategy. As Xcitex's first engineer, I developed the core of the flagship products - MiDAS and Pro Analyst. I also describe these products in a document that I include as supplemental material. As CTO and Vice-President of Xcitex, I built the technical team, architected and directed the development of products and solutions for the industrial and scientific video markets. Our products alone fueled our growth from startup to dominant market leader.

dRNOME – CoFounder, Investor, Board of Director

CueVue is a cloud computing and storage service for the scientific video industry - enabling video content query and generalized motion analysis in video content management systems. We provide tools for managing, manipulating, archiving, and searching your scientific video. It removes the necessity for its customers to make heavy investments in expensive hardware and software solutions, removes the overhead required to manage high-volume video needs, and we back this with a service level guarantee.

Dynamic Time and Space Warping (DTSW), an algorithm that I developed for part of my doctoral work is core technology for CueVue - enabling video content query and generalized motion analysis in video content management systems.

dRNOME Inc. (CueVue.com – Launched in February 2011, sold technology in 2014). Our core technologies can be used to perform automated feature recognition of multiple streaming telemetry sources and to extract metadata and make this information available for ongoing operations, forensics, and security. Our products enable multi-camera real-time feature recognition, extraction & tagging automation.

Enumage – CoFounder, Investor, Board of Director

Specializing in Laser Ultrasound.

1. Books:

Smart Manufacturing On-line course, deployed 2019 and 2020

2. Papers in Referred Journals:

2.1. B. Anthony, A. Abbate, D. Klimek, P. Kotidis., "Analysis of Ultrasonic Waves in Arbitrarily Oriented or Rotating Anisotropic Thin Materials", Quantitative Nondestructive Evaluation. Vol 18. pgs 215 - 222. (1999).
2.2 A. Abbate, B. Anthony, D. Klimek, P. Kotidis., "Analysis of Dispersive Ultrasonic Signals by the Ridges of the Analysitc Wavelet Transform", Quantitative Nondestructive Evaluation. Vol 18. pgs 703 - 710. (1999).
2.3 Dan Klimek, Brian Anthony, Agostino Abbate, Petros Kotidis, "Laser Ultrasonic Instrumentation for Accurate Temperature Measurement of Silicon Wafers in Rapid Thermal Processing Systems", Rapid Thermal and Integrated Processing VII, Materials Research Society, Volume 525, pg 135. (1999)
2.4 Hardt, D.E., Anthony, B.W., Tor S.B., "A teaching factory for polymer microfabrication - μFac," International Journal of Nanomanufacturing, 2010, Vol. 6, No.1/2/3/4, pp. 137 - 151.
2.5 Shih-Yu Sun, Matthew Gilbertson, and Brian W. Anthony, "Probe Localization for Freehand 3D Ultrasound by Tracking Skin Features", Book Section, Medical Image Computing and Computer-Assisted Intervention - MICCAI 2014, Springer, 2014, Vol. 8674. Lecture Notes in Computer Science, Pages 365-372.
2.6 Xian Du, Brian W. Anthony, Nigel C. Kojimoto, “Grid-based matching for full-field large-area deformation measurement”, Optics and Lasers in Engineering, Volume 66, March 2015, Pages 307-319.
2.7 Xian Du, Nigel C. Kojimoto, Brian W. Anthony, “Concentric circular trajectory sampling for super-resolution and image mosaicing”, Journal of the Optical Society of America A, Volume 32, No. 2, February 2015, Pages 293-304.
2.8 M. Gilbertson, B. Anthony. "A Force and Position Control System for Freehand Ultrasound", IEEE Transactions on Robotics, Volume 31, Issue 4. 2015.
2.9 Andrey Kuzmin, Aaron Zakrzewski, Brian Anthony, Victor Lempitsky, "Multi-frame Elastography Using Handheld Force-Controlled Ultrasound Probe". Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Volume 62 , Issue 8, Pages 1486 – 1500, 2015.
2.10 Xian Du and Brian Anthony, "Concentric circle scanning system for large-area and high-precision imaging," Optics Express, Vol 23, Issue 15, Pages 20014-20029, 2015.
2.11 Du, X.., Anthony, B., “Controlled angular and radial scanning for super resolution concentric circular imaging,” Opt. Express 24(20), 22581, United States (2016).
2.12 Jimenez, X., Shukla, S. K., Ortega, I., Illana, F. J., Castro-González, C., Marti-Fuster, B., Butterworth, I., Arroyo, M., Anthony, B., et al., “Quantification of Very Low Concentrations of Leukocyte Suspensions In Vitro by High-Frequency Ultrasound,” Ultrasound Med. Biol. 42(7), 1568–1573, England (2016).
2.13 Koppaka, S., Shklyar, I., Rutkove, S. B., Darras, B. T., Anthony, B. W., Zaidman, C. M.., Wu, J. S., “Quantitative Ultrasound Assessment of Duchenne Muscular Dystrophy Using Edge Detection Analysis,” J. Ultrasound Med. 35(9), 1889–1897, United States (2016).
2.14 Lee, J., Boning, D., Anthony, B., "Measuring the Absolute Concentration of Microparticles in Suspension using High Frequency B-mode Ultrasound Imaging", Ultrasound in Medicine and Biology, 2018.
2.15 Correa-de-Araujo, R., Harris-Love, M., Miljkoviv, I., Fragala, M.S., Anthony, B.W., Manini, T., Newman, A.B., "The Need for Standardized Assessment of Muscle Quality in Skeletal Muscle

Function Deficit and Other Aging-Related Muscle Dysfunctions: A Symposium Report", Frontiers in Physiology, Section on Striated Muscle Physiology, 2017

2.16 Anthony, B, et al, "A Pilot Study to Precisely Quantify Forces Applied by Sonographers While Scanning: A Step Toward Reducing Ergonomic Injury", WORK: A Journal of Prevention, Assessment, and Rehabilitation, 2017

2.17 Zakrzewski, Aaron M., Anthony, Brian W., "Non-Invasive Blood Pressure Estimation Using Ultrasound and Simple Finite Element Models", IEEE Transactions on Biomedical Engineering, 2017

2,18 Anthony, B., Fitriana, "Computationally-Efficient Optimal Video-Comparison for Machine Monitoring and Process Control", Journal of Manufacturing Science and Engineering, 2017

2.19 Lee I, Du X, Anthony B. "Hair segmentation using adaptive threshold from edge and branch length measures," Computers in Biology Medicine, (2017).

2.20 Pigula-Tresansky AJ, Wu JS, Kapur K, Darras BT, Rutkove SB, Anthony BW. "Muscle compression improves reliability of ultrasound echo intensity," Muscle Nerve, 2017.

2.21 Xian Du, David Hardt, and Brian W. Anthony, "Real time imaging of invisible micron-scale monolayer patterns on a moving web using condensation figure," IEEE Transactions on Industry Electronics, (submitted, in review), 2017.

2.22 Brian W. Anthony, Xian Du, Ina Kundu, Judith Beaudoin, "Skin registration and point pattern matching of skin microrelief structure," (submitted, in revision), 2017.

2.23 Ozturk A, Grajo JR, Dhyani M, Anthony BW, Samir AE. Principles of ultrasound elastography. Abdominal Radiology. 2018.

2.24 Benjamin A, Zubajlo RE, Dhyani M, Samir AE, Thomenius KE, Grajo JR, Anthony, Brian W., "A Novel Approach to the Quantification of the Longitudinal Speed of Sound and its Potential for Tissue Characterization (Part I)", Journal of Ultrasound in Medicine and Biology, 2018

2.25 B. Anthony et al, "Experimental Validation of Longitudinal Speed of Sound Estimates in the Diagnosis of Hepatic Steatosis (Part II)", Journal of Ultrasound in medicine and biology, 2018

2.26 A. Ozturk et al., "Quantitative Hepatic Fat Quantification in NAFLD using Ultrasound-Based Techniques: A Review of Literature and their Diagnostic Performance," Ultrasound in Medicine and Biology, 2018

2.27 Zakrzewski, A. M., Huang, A. Y., Zubajlo, R. E., & Anthony, B. W. Real-Time Blood Pressure Estimation From Force-Measured Ultrasound. IEEE Transactions on Biomedical Engineering, 2018 (Nov 2018 cover article).

2.28 Singh, R., Su, P., Kimerling, L., Agarwal, A., & Anthony, B. W. "Towards On-chip Mid Infrared Photonic Aerosol Spectroscopy." Applied Physics Letters. (Accepted). 2018

2.29 Ranger, Bryan J., Feigin, M., Zhang, X., Moerman, Kevin M., Herr, H., Anthony, Brian W. "3D ultrasound imaging of residual limbs with camera-based motion compensation", Transactions on Neural Systems & Rehabilitation, (accepted) 2018.

2.30 Singh, R., Ma, D., Kimerling, L., Agarwal, A., & Anthony, B. W. "Chemical Characterization of Aerosol Particles Using On-chip Photonic Cavity Enhanced Spectroscopy". ACS Sensors. 2018

2.31 Feigin, M., Ranger, B., Anthony, B., "Probabilistic Framework for Maximal Consensus Image Registration with Application to Medical Ultrasound Imaging" IEEE Transactions on Biomedical Engineering, (submitted) 2019.

2.32 X. Du, D. Hardt, and B. Anthony, "Real Time Imaging of Invisible Micron-Scale Monolayer Patterns on a Moving Web Using Condensation Figures," IEEE Trans. Ind. Electron., pp. 1–1, 2019.

2.33 B. J. Ranger, M. Feigin, X. Zhang, K. M. Moerman, H. Herr, and B. W. Anthony, "3D Ultrasound Imaging of Residual Limbs With Camera-Based Motion Compensation," IEEE Trans. Neural Syst. Rehabil. Eng., vol. 27, no. 2, pp. 207–217, Feb. 2019.

2.34 M. Feigin-Almon, D. Freedman, and B. W. Anthony, "A Deep Learning Framework for Single-Sided Sound Speed Inversion in Medical Ultrasound," IEEE Trans. Biomed. Eng., pp. 1–1, 2019.

2.35 R. Singh, D. Ma, L. Kimerling, A. M. Agarwal, and B. W. Anthony, "Chemical Characterization of Aerosol Particles Using On-Chip Photonic Cavity Enhanced Spectroscopy," ACS Sensors, vol. 4, no. 3, pp. 571–577, Mar. 2019.
2.36 Xiang Zhang, Jonathan Fincke, Charles Wynn, Matthew Johnson, Robert Haupt, and Brian Anthony. Full Noncontact Laser Ultrasound: First Human Data. Nature, Light: Science & Applications. 2019 (Accepted)
2.37 M. Feigin, M. Zwecker, D. Freedman, and B. W. Anthony, "Detecting muscle activation using ultrasound speed of sound inversion with deep learning," Submitted Oct. 2019.
2.38 S. Kim, D. D. Kim, and B. Anthony, "Dynamic Control of a Fiber Manufacturing Process using Deep Reinforcement Learning," Submitted Nov. 2019.
2.39 R. Singh, Y. Nie, A. M. Agarwal, and B. W. Anthony, "Inverse Design of Photonic Metasurface Gratings for Beam Collimation in Opto-fluidic Sensing," Submitted Oct. 2019.

3. Proceedings of Refereed Conferences:

3.1. Dipen N. Sinha, Brian W. Anthony, David C. Lizon, "Swept Frequency Acoustic Interferometery Techniques for Chemical Weapons Verification and Monitoring", Third International Conference On-Site Analysis, (1995).
3.2. David E. Hardt, Brian W. Anthony and Shu Beng Tor, "A Teaching Factory for Polymer Microfabrication – muFac", Proc. 5th International Symposium on Nano-Manufacturing (ISNM), Athens, November 12-15, 2008.
3.3. Gilbertson, M., Anthony, B., and Sun, S.Y., "Handheld Force Controlled Ultrasound Probe", J. Med. Devices 4, 027540 (2010)
3.4. Ljubicic, D. M., Anthony, B., "Development of a high-speed profilometer for manufacturing inspection," Proceedings of SPIE Vol. 7767, 776705 (2010).
3.5. Sun, S., Anthony, B. W., Gilbertson, M. W., "Trajectory-based deformation correction in ultrasound images," Proceedings of SPIE Vol. 7629, 76290A (2010).
3.6. Anthony, B. W., Hardt, D. E., Hale, M., et al., "A research factory for polymer microdevices: muFac," Proceedings of SPIE Vol. 7593, 75930A (2010).
3.7. Gilbertson, M. W., Anthony, B. W., "Impedance-controlled ultrasound probe," Proceedings of SPIE Vol. 7968, 796816 (2011).
3.8. Ljubicic, D. M., Anthony, B. W., "3D high-speed profilometer for inspection of micro-manufactured transparent parts," Proceedings of SPIE Vol. 8082, 808211 (2011).
3.9. Anthony, B.W, Hardt, D.E., "Revitalizing US Manufacturing to Capitalize on Innovation – Through Education" 119th ASEE Annual Conference, San Antonio TX, June 10-13, (2012)
3.10. Anthony, B. W., Namvari, K., "Dimensional variation of polymer substrate electrode production," Proceedings of SPIE Vol. 8251, 82510G (2012).
3.11. Selvakumar, S., Linares, R., Oppenheimer, A., Anthony, B., "Variation analysis of flow rate delivered using a blister pump," Proceedings of SPIE Vol. 8251, 82510I (2012).
3.12. Donoghue, L., Anthony, B. W., "Design for manufacture of a micro-interdigitated electrode for impedance measurement in a biochemical assay," Proceedings of SPIE Vol. 8251, 82510Y (2012).
3.13. Holmes, J., Anthony, B. W., "Robustness and repeatability test of interdigitated electrodes on a polymer substrate in an aqueous environment," Proceedings of SPIE Vol. 8251, 825110 (2012).
3.14. Sun, S.-Y, Anthony, B. W. "Freehand 3D ultrasound volume imaging using a miniature-mobile 6-DOF camera tracking system". 2012 IEEE International Symposium on Biomedical Imaging (ISBI), 2-5 May, (2012).

3.15. Gilbertson, M.W., Anthony, B.A., 2012. "Ergonomic Controls Strategies for a Handheld Force-Controlled Ultrasound Probe," 2012 IEEE/RSJ Intelligent Robots and Systems (IROS) Conference. Vilamoura, Portugal. (2012)

3.16. Sun, S.-Y, Gilbertson, M., Anthony, B. W. “6-DoF Probe Tracking via Skin Mapping for Freehand 3D Ultrasound”. 2013 IEEE International Symposium on Biomedical Imaging (ISBI), (2013).

3.17. Sun, S.-Y, Gilbertson, M., Anthony, B. W. “Computer-Guided Ultrasound Probe Realignment by Optical Tracking”. 2013 IEEE International Symposium on Biomedical Imaging (ISBI), (2013).

3.18. Inamdar, T., Anthony, B. W., “Characterizing fluidic seals for on-board reagent delivery," Proceedings of SPIE (2013).

3.19. Zakrzewski, A., Anthony, B. W. “Quantitative Elastography and its Application to Blood Pressure Estimation: Theoretical and Experimental Results”. 2013 IEEE Engineering in Medicine and Biology Society (EMBS), (2013).

3.20. Gilbertson, M. Anthony, B.W., “An Ergonomic, Instrumented Ultrasound Probe for 6-Axis Force/Torque Measurement”. 2013 IEEE Engineering in Medicine and Biology Society (EMBS), (2013).

3.21. Dhyani, M, Gilbertson, M., Samir, A., Anthony, B.W., "Precise Quantification of Sonographic Forces: A First Step Toward Reducing Ergonomic Injury", 2014 AIUM Annual Convention, (2014).

3.22. Koppaka, S., Gilbertson, M., Wu, J., Rutkove, S., Anthony, B. W. “Assessing Duchenne Muscular Dystrophy With Force-controlled Ultrasound”. 2014 IEEE International Symposium on Biomedical Imaging (ISBI), (2014).

3.23. Koppaka, S., Gilbertson, M., Rutkove, S., Anthony, B. W. “Evaluating the Clinical Relevance of Force-correlated Ultrasound”. 2014 IEEE International Symposium on Biomedical Imaging (ISBI), (2014).

3.24. J. H. Lee, C. M. Schoellhammer, G. Traverso, D. Blankschtein, R. Langer, K. E. Thomenius, D. S. Boning, B. Anthony, "Towards Wireless Capsule Endoscopic Ultrasound (WCEU)," IEEE International Ultrasonics Symposium (IUS), Chicago, IL, 2014, pp. 734-7.

3.25. Zhang, Xiang; Fincke, Jonathan; Kuzmin, Andrey; Lempitsky, Victor; Anthony, Brian, "A single element 3D ultrasound tomography system," in Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE , vol., no., pp.5541-5544, 25-29 Aug. 2015.

3.26. Ranger, Bryan J.; Feigin, Micha; Pestrov, Nikita; Zhang, Xiang; Lempitsky, Victor; Herr, Hugh M.; Anthony, Brian W., "Motion compensation in a tomographic ultrasound imaging system: Toward volumetric scans of a limb for prosthetic socket design," in Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE , vol., no., pp.7204-7207, 25-29 Aug. 2015.

3.27. Lee, John H.; Jimenez, Javier; Xiang Zhang; Boning, Duane S.; Anthony, Brian W., "Ultrasound image-based absolute concentration measurement technique for materials with low scatterer concentration", IEEE International Ultrasonics Symposium (IUS), 2015.

3.28. Lee, John H.; Jimenez, Javier; Butterworth, Ian R.; Castro-Gonzalez, Carlos; Shukla, Shiva K.; Marti-Fuster, Berta; Elvira, Luis; Boning, Duane S.; Anthony, Brian W., "Measurement of very low concentration of microparticles in fluid by single particle detection using acoustic radiation force induced particle motion", IEEE International, Ultrasonics Symposium (IUS), 2015.

3.29. Anthony, B. W., “Enhanced ultrasound for advanced diagnostics, ultrasound tomography for volume limb imaging and prosthetic fitting,” Proc. SPIE 9790, N. Duric and B. Heyde, Eds., 97900Q (2016).

3.30. Fincke, J. R., Feigin, M., Prieto, G. A., Zhang, X.., Anthony, B., “Towards ultrasound travel time tomography for quantifying human limb geometry and material properties,” Proc. SPIE 9790, N. Duric and B. Heyde, Eds., 97901S (2016).

3.31. Kuzmin, A., Zhang, X., Finche, J., Feigin, M., Anthony, B. W.., Lempitsky, V., “Fast low-cost single element ultrasound reflectivity tomography using angular distribution analysis,” 2016 IEEE 13th Int. Symp. Biomed. Imaging, 1021–1024, IEEE (2016).

3.32. Pigula, A. J., Wu, J. S., Gilbertson, M. W., Darras, B. T., Rutkove, S. B.., Anthony, B. W., "Force-controlled ultrasound to measure passive mechanical properties of muscle in Duchenne muscular dystrophy," 2016 38th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc., 2865–2868, IEEE (2016).
3.33. Ranger, B. J., Feigin, M., Zhang, X., Mireault, A., Raskar, R., Herr, H. M.., Anthony, B. W., "3D optical imagery for motion compensation in a limb ultrasound system," Proc. SPIE 9790, N. Duric and B. Heyde, Eds., 97900R (2016).
3.34. Zhang, X., Fincke, J. R.., Anthony, B. W., "Single element ultrasonic imaging of limb geometry: an in-vivo study with comparison to MRI," Proc. SPIE 9790, 97901R–97901R–7 (2016).
3.35. Nguyen, M.M, Graule, M.A., Huang, A.Y, Shamdasani, V., Anthony, B.W., Xie, H., "Ultrasound shearwave elastography with force sensing – integration design and preliminary ex-vivo results.," Proc. Int. Tissue Elast. Conf. 2016 (2016).
3.36. Feigin M., Ranger, B.., Anthony, B., "Statistical Consensus Matching Framework for Image Registration," IEEE Int. Conf. Pattern Recognition, (2016).
3.37. Zakrzewski, A. M., Dhyani, M., Samir, A. E.., Anthony, B. W., "Non-Invasive, Non-Occlusive Blood Pressure Estimation Using Ultrasound: Clinical Results (I)," 38th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. (2016).
3.38. Anthony, et al, "Arterial Blood Pressure Estimation Using Ultrasound: Results on Healthy Volunteers and a Medicated Hypertensive Volunteer", 2017 39th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc., accepted (2017).
3.39. Anthony, et al, "Non-Invasive Diagnosis of Non-Alcoholic Fatty Liver Disease (NAFLD) using Ultrasound Image Echogenicity", 2017 39th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc., accepted (2017).
3.40. Anthony, et al, "Camera-tracking vs. image-based motion compensation in a tomographic limb ultrasound system", 2017 39th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc., (2017).
3.41. Fincke JR. Imaging cortical bone using the level-set method to regularize travel-time and full waveform tomography techniques. J Acoust Soc Am. Acoustical Society of America; (2017)
3.42. Yang H, Nguyen MM, Huang S-W, Shamdasani V, Xie H, Anthony BW. "Simulation, design, and implementation of external mechanical vibration for ultrasound shear wave elastography.", IEEE International Ultrasonics Symposium (IUS) IEEE; 2017.
3.43. A. Benjamin et al., "Non-invasive diagnosis of non-alcoholic fatty liver disease (NAFLD) using ultrasound image echogenicity," 2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Seogwipo, 2017,
3.44. H. Yang, A.Benjamin, B. Anthony, "Simulation of multi-source external mechanical vibration for shear wave elastography," The Journal of the Acoustical Society of America, 142, 2017
3.45. Singh, R., Ma, D., Agarwal, A., & Anthony, B. W. (2018). On-chip photonic particle senso. Presented at the SPIE BiOS, San Francisco, CA.
3.46. Kundu, I., & Anthony, B. W. . "Imaging the superficial vascular structure for mapping and identification." |SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring, Denver, Colorado. (2018)
3.47. Kundu, I., Du, X., & Anthony, B. W. (2018). "Imaging platforms for registering and analyzing the skin microrelief structure." Presented at the SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring, Denver, Colorado. (2018)
3.48. Zakrzewski, A. M., & Anthony, B. W. (2018). Pre-and-Post Exercise Blood Pressure Estimation from Force-Measured Ultrasound: First Results. Presented at the 2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Honolulu, HI.
3.49. Donk, F., Yang, H., & Anthony, B. W. (2018). Miniaturization of External Mechanical Vibration for Shear Wave Elastography Imaging. Presented at the 2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Honolulu, HI.
3.50. Chen, M., Li, Q., Karimian, N., Yeh, H., Duan, Y., Fontan, F., … Samir, A. E. (2018). Contrast-Enhanced Ultrasound to Quantify Perfusion in a Machine-Perfused Pig Liver. Presented at the 2018

40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Honolulu, HI.

3.51. Wang, Y. J., & Anthony, B. W. (2018). Characterization of wave fields using transient motion of microspheres under acoustic radiation force. Presented at the 21st International Symposium on Nonlinear Acoustics, Santa Fe, NM.

3.52. Yang, H., Carrascal, C., Xie, H., Shamdasani, V., Anthony, B.W., "Design and Experimental Validation of Miniature External Mechanical Vibrators towards Clinical Ultrasound Shear Wave Elastography", IUS, 2018.

3.53. Singh, Robin; Ma, Danhao; Kimerling, Lionel; Agarwal, Anuradha; Anthony, Brian, "Microscale photoacoustic spectroscopy using integrated photonics for lab-on-chip applications", Spie BIOS, (accepted), 2018.

3.54. J. B. Frontin and B. W. Anthony, "Quantifying Dermatology: Method and Device for User-Independent Ultrasound Measurement of Skin Thickness," in 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2019, pp. 5743–5748.

3.55. A. Benjamin et al., "Renal volume reconstruction using free-hand ultrasound scans," J. Acoust. Soc. Am., vol. 145, no. 3, pp. 1922–1922, Mar. 2019.

3.56. A. Y. Huang and B. W. Anthony, "An Instrumented Ultrasound Probe for Shear Wave Elastography With Uneven Force Distribution," in 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2019, pp. 6208–6211.

4. Other Major Publications:

4.1. Anthony, B.W.; Zarrouati, N.; Ljubicic, D. "Photogrammetric Based Inspection of Polymer Devices", Singapore MIT Alliance (SMA) Symposium January 2008.

4.2 Fitriani, Brian W. Anthony, "Multiscale Dynamic Time and Space Warping" SMA Symposium, January 21-22, 2009.

4.3 Anthony, B.W., "Video Analytics – Future is Fast and Distributed", Government Security News (GSN) Guide to Video Surveillance, September 2011. Invited guest column.

4b. Articles in Preparation:

4.4 Du, X., Anthony, B., "Rotational Manufacturing Inspection System: Design for Vibration Reduction", target:

4.5 Du, X., Anthony, B., "Local-Active-Rotational-Based Super Resolution", target: IEEE Transactions on Pattern Analysis and Machine Intelligence

4.6 Ljubicic, D., Anthony, B., "Sensor for Thickness and Lateral Position of a Transparent Web in a Roll-to-Roll Process", target: IEEE Sensors

4.7 Feigin M., Ranger B., Anthony B., "Statistical Maximal Consensus Framework for Image Registration with Application to Medical Ultrasound Imaging", pending submission to IEEE Transactions on Medical Imaging

5. Internal Memoranda and Progress Reports: List chronologically; number each item.

N/A

6. Invited Lectures (as of 2015):

June 2002, "High-speed software synchronizes images and data", Technology Interview. Vision Systems Design.

MASIMO 2071
Apple v. Masimo
IPR2022-01291

June 2003, 2003 “Highspeed Video and Data”, Brian W. Anthony, MIT High-Speed Photography and Videography for Motion Analysis: Systems and Techniques.

June 2003, 2004, 2005, 2006, “Overview of Machine Vision”, Brian W. Anthony, MIT High-Speed Photography and Videography for Motion Analysis: Systems and Techniques.

June 2006, “Video Event Analysis and Video Event Detection - Video Based System Monitoring”. Brian W. Anthony. CSAIL Machine Vision Colloquim.

July 24, 2008, "Computational Imaging Systems," Samsung Electro Mechanical Research, Korea.

May 5, 2009, "Video Instrumentation," LMP Seminar, MIT

January 5-7, 2011, "Automation of a Work Cell for Polymer Microdevice Production: Precise Alignment and Visual Quality Inspection ", The Second Conference on Advances in Microfluidics and Nanofluidics and Asian-Pacific International Symposium on Lab on Chip (AMN-APLOC 2011). Singapore.

February 11, 2011, "The MEDRC," MassMEDIC Board of Directors Meeting. Greenberg Traurig, International Place, Boston.

March 23-25 2011, "New Perspectives – similar problems", S2I2 Workshop on Collection Digitization, Field Museum, Chicago

June 20-22, 2011, "Design, Manufacturing, Information Technology, and Healthcare – enabling an information-driven healthcare future – industry, academia collaborations", Medical Device Manufacturing Summit, Red Rock Casino Resort & Spa, Las Vegas, NV.

July 6, 2011, “Design, Manufacturing, Information Technology, and Healthcare - enabling an information-driven healthcare future – industry, academia collaborations” Korean Institute of Science and Technology.

Nov 13-15, 2011, Invited Keynote Talk, "Medical Device Manufacturing - Helping to revitalize US manufacturing to capitalize on innovation," Medical Device Manufacturing Summit, Amelia Island, Florida

November 18, 2011, Invited Keynote Talk, "Computational Videography in Manufacturing," MIT Center for Biomedical Innovation’s Biomanufacturing Summit: Implementing Innovation in Biomanufacturing: The Hurdles and Opportunities, Bartos Theater, Building E15 MIT.

January 27, 2012, "The MEngM and MEDRC Models and Experiences," MassMEDIC's Workshop on Catalyzing Innovation through Industry/Academic Collaborations.

March 9, 2012, “Computational Enhanced Manufacturing Inspection Systems” Department of Manufacturing Engineering, Ann Arbor, Michigan

March 13, 2012, "Computational Instrumentation - designing systems at the intersection of mechanical engineering, electrical engineering, and computer science," LMP Seminar, MIT

March 15-16, 2012, "Industry, innovation, and entrepreneurship, in graduate education and research," SKTech Education Workshop, Moscow, Russia.

March 27-28 2012, Invited Keynote Talk, "The Inner Beauty of Computational Enhanced Systems," Technology Review EmTech India Conference, Bengaluru, India.

June 9, 2012, Invited Moderator, "American Transformations: the Next Industrial Revolution", MIT Graduate Alumni - Tech Reunions, MIT, Cambridge, MA.

May 22 2013, Invited Speaker, MIT Vienna Conference

June 16, 2013 , Invited Keynote Talk, "Lessons Learned from the MEDRC," EmTech China Conference, Shanghai, China.

November 13 2013, Invited Speaker, "Microfluidic Devices Manufacturing - Sensing and Instrumentation Challenges and Opportunities", Lab-on-a-chip Asia, Singapore

October 2013, Invited Speaker, “Have Russia’s Innovation Prospects Stalled or Are You Just Not Looking Hard Enough?”, US Russian Business Council (USRBC) Annual Meeting,

January 2015, Keynote, “Limb Imaging” Wayne State University and Karmanos

October 2015, “Medical Device Innovation”, Novartis Innovation Summit

(to be updarted)

Summary:

	Total	Completed	In Progress
Bachelor's	4	4	0
Master's	32	27	5
MEngM	16	16	0
Engineer's			
Doctoral			
As Supervisor	20	10	10
As Reader	4	3	1

Bachelor's Theses

Johnson, Michael B., "Design of a precise X-Y-Theta nanopositioning optical sensor", June 2009.

Syverud, Brian, "Robotic ultrasound manipulator: calibration of position and orientation measurement system", June 2009.

Chai, Lauren, "Design and Manufacture of arterial phantoms for ultrasound imaging", expected June 2012

Ramos, Javier, "Design of Force Measurement Probe", June 2012

Master's Theses

Fitriani, "Multiscale Dynamic Time and Space Warping", 2008

Zarrouati, Nadège, "A precision manipulation system for polymer microdevice production", 2010

Gilbertson, Matthew Wright, "Handheld force-controlled ultrasound probe", 2010

Sun, Shih-Yu, "Deformation correction in ultrasound imaging in an elastography framework", 2010

Zakrzewski , Aaron, "Multi-scale elastrography with application to real-time blood pressure estimation", 2013

Koppaka, Sisir, "Quantitative Ultrasound for DMD progression tracking", (in CDO) 2015

Zhang, Xiang (Shawn) , "3D Ultrasound scanning system for muscle deterioration monitoring, prosthetic fitting, and bone density monitoring", 2015

Primack, Willow. "Capacity Optimization of a Warehouse Flow Sortation System", LGO, 2015

Churchill, Hugh E., II, “Impact of lean implementation on cycle-time and efficiencies within Amazon soft-lines fulfilment”, LGO, 2015.

Sazdanoff, Nicholas, “Evaluation of Postponement for Improved Drug Product Supply Chain Stability”, LGO, 2015.

Kojimoto, Nigel Costello, "Ultrasonic Inspection Methods for Defect Detection and Process Control in Roll-to-Roll Flexible Electronics Manufacturing", 2015

Kundu, Ina Annesha, "Imaging platforms for detecting and analyzing skin features and Its stability: with applications in skin health and in using the skin as a body-relative position-encoding system", 2015

Conover Susan, “Prime Areas for Improvement in Skin Cancer Detection and How Technology Can Help”, SDM, 2015

Hess, Tylor, “System for small-volume high-frequency ultrasound, and quantitative optical molecular imaging assessment of biopsy samples”, 2016

Kang Qi Ian Lee, “Skin Feature Analysis”, CDO, 2016

Athena Yeh Huang, “New US Probes”, 2017

Alex Benjamin, “US Education Hardware”, CDO, 2017

Heng Yang, “Pulsed Elastography”, 2017

Rebecca Zubajlo, “US Clamp Probe”, 2017

Rishon Robert Benjamin, “Roll to roll polymer web inspection”, CDO, 2017

Samer Haidar, “Consumer Medical Device Supply Chain Strategy”, LGO, 2016

Mariam A Al-Meer, “Reducing Heart Failure Admissions through Improved Care Systems and Processes”, LGO, 2017

Michael Sandford, “Improving Speed-to-Market through 3D Printing”, LGO, 2017

Moritz Alexander Graule, “Dynamic SLAM”, 2017

Mingxiu Sun, “Education and Practice Factory”, 2018

Robin Singh. “Integrated Photonics”, 2018

Judy Beaudoin, “Quantifying Dermatology: User-Independent Ultrasound Measurement of Skin Thickness, 2018

Andrew Farenheit, “Manufacturing Fleet Flexibility” 2019

Chris DiAndreth, “Product Flow Optimization within the Downstream Supply Chain” 2019.

Manuel Martínez Puppo, "Replenishment in an Integrated Stock World", 2019.

Shirley Lu, "Fiber Manufacturing", expected 2020

Sangwoon Kim, "Deep learning in manufacturing", expected 2020.

MEng Theses

Su, Xiangyong, "Optimization of labor allocation at a syringe production facility: design proposals", September 2008.

Liaw, Sze Sen, "Optimization of labor allocation at a syringe production facility using computer simulation", September 2008.

Ng, Gar Yan, "Optimization of labor allocation at a syringe production facility: work study", September 2008.

Linares, Rodrigo, "Manufacturability of lab on a chip devices: tolerance analysis and requirements establishment", September 2010.

Selvakumar, Sivesh, "Manufacturing of Lab-On-a-Chip devices: variation analysis of liquid delivery using blister packs", September 2010.

Namvari, Kasra, "Manufacturability of lab-on-chip devices: dimensional variation analysis of electrode foils using visual technology", September 2011.

Donoghue, Linda, "Design of a micro-interdigitated electrode for impedance measurement performance in a biochemical assay", September 2011.

Holmes, Jacklyn, "Robustness and repeatability of interdigitated electrodes on a substrate tested in an aqueous environment", September 2011

Judge, Benjamin, "Electrode manufacturing for micro-fluidic devices", September 2012

Jain, Nikhil, "Blister pack manufacturing for micro-fluidic devices", September 2012

Inamdar, Tejas Satish, "Blister pack modeling for micro-fluidic devices", January 2013

Saber, Aabed Saud, "Electrode modeling for micro-fluidic devices", January 2013

Nguyen , Khanh Huy, "Microfluidic device manufacturing - tools", September 2013

Ragosta, Nicholas Hiroshi, "Microfluidic device manufacturing - inspection", September 2013

Kalsekar, Viren Sunil, "Microfluidic device manufacturing - process", September 2013

Elise Xue, "Deep-learning in ultrasound", June 2018

Engineer's Theses

N/A

Doctoral Theses, Supervisor

Ljubicic, Dean, “Design of high-speed inspection system for micro-fluidic device manufacturing”, MechE, January 2013

Gilbertson, Matthew Wright, “Human in the loop design and modeling of force controlled ultrasound probes”, MechE, May 2014

Sun, Shih-Yu, “Real-time visual and ultrasound simultaneous localization and mapping (SLAM)”, EECS, August 2014

Zakrzewski , Aaron, “Real-time multi-scale pressure enhanced elastrography”, MechE, 2017.

Roberts, Megan, “Advance manufacturing of flexible arrays for ultrasound probes”, MechE, 2018.

Lee, John, “Cell tracking and non-invasive ultrasound-based methods to diagnose neonatal and young infant meningitis”, EECS, 2015

Fincke, Jonathan Randall, "Ultrasonic quantification of human limbs (bone and tissue) using tomographic inversion techniques", 2018

Ranger, Bryan, “Prosthetic fitting”, HST, 2018

Ina Annesha Kundu, “Skin Imaging”, 2018

Rebecca Zubajlo, “Physical Measurement of Cells”, expected 2021

David Donghyun Kim, “Fiber Manufacturing Equipment”, expected 2020

Lauren Chai, “Radiation Force Manufacturing”, expected 2020

Jenny Wang, “Particle motion for acoustic radiation force characterization”, expected 2020

Anne Pigula, HST, “Image Based Biomarkers for Duchene Muscular Dystrophy”, expected 2020

Xiang Zhang, “Precision Tomography Platforms”, 2019

Alex Benjamin. “Volume Freehand Tomography”, expected 2020

Melinda Chen, “Liver Vascular Health Imaging”, expected 2020

Robin Singh, “Integrated Photonics Medical Sensors”, expected 2021

Alex Jaffe. EECS, “Venous and Blood Pressure in the extremities”, expected 2021

Yuwei Li, “Techniques for using AR/VR to measure physiological response”, expected 2022

Arjun Chandar, “Smart Manufacturing”, expected 2021

Doctoral Theses, Reader / Committee

Shi, Chuan, “Efficient Buffer Design Algorithms for Production Line Profit Maximization”, September 2011

Petrzelka, Joe, “On the contact fidelity and sensitivity of roll-based soft lithography”, June 2012

Smyth, Katherine, “Piezoelectric Micro-machined Ultrasonic Transducers for Medical Imaging”, October 2016

Athanasios G. Athanassiadis, “Optoacoustic Imaging”, 2019

Current Postdocs

Name	*Dates of Appointment*	*PhD Granting Institution*
Greg Ely	2019 -	MIT
Megan Roberts	2018 -	MIT
Shawn Zhang	2019 -	MIT

Previous Postdocs

Name	*Current Title*	*Current Employer*
Vannah, Bill	Scientist	Mary Free Bed Rehabilitation Hospital
Victor Lempitsky	Head of AI	Samsung
Javier J. Gonzalez	May 2013 – 2015	University of Madrid
Matthew Gilbertson	Senior Electro-Optical Engineer	Lockheed Martin
Xian, Du	Professor	UMass (2018)
David Ibarra	Professor	Monterery Tec
Micha Feigin	Research Scientist	MIT
Ian Butterworth	Biomedical Research Engineer	MIT
Carlos Castro-Gonzalez	Co-Founder and CEO	Leuko
Berta Martí Fuster	Head of Communications	Oncoheroes Biosciences
Bonghun (Bruce) Shin	Senior Scientist	University Waterloo