US010188299B2

(12) **United States Patent**
Islam

(10) **Patent No.: US 10,188,299 B2**
(45) **Date of Patent: *Jan. 29, 2019**

(54) **SYSTEM CONFIGURED FOR MEASURING PHYSIOLOGICAL PARAMETERS**

(71) Applicant: **OMNI MEDSCI, INC.**, Ann Arbor, MI (US)

(72) Inventor: **Mohammed N. Islam**, Ann Arbor, MI (US)

(73) Assignee: **Omni Medsci, Inc.**, Ann Arbor, MI (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.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/594,053**

(22) Filed: **May 12, 2017**

(65) **Prior Publication Data**

US 2017/0248567 A1 Aug. 31, 2017

Related U.S. Application Data

(63) Continuation of application No. 14/875,709, filed on Oct. 6, 2015, now Pat. No. 9,651,533, which is a (Continued)

(51) **Int. Cl.**
G01J 3/00 (2006.01)
A61B 5/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A61B 5/0088*** (2013.01); ***A61B 5/0013*** (2013.01); ***A61B 5/0022*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G01J 3/02; G01J 3/28; G01J 3/42; G01N 21/31; G01N 21/552
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,063,106 A 12/1977 Ashkin et al.
4,158,750 A 6/1979 Sakoe et al.
(Continued)

FOREIGN PATENT DOCUMENTS

DE 102010012987 A1 10/2010
EP 1148666 10/2001
(Continued)

OTHER PUBLICATIONS

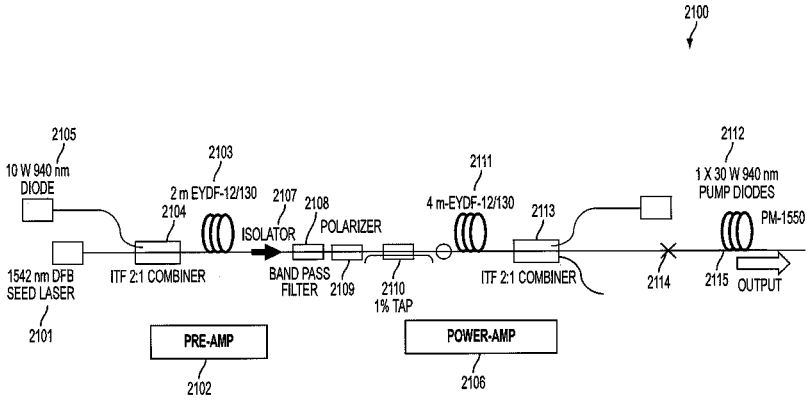
U.S. Appl. No. 61/350,673; titled: Opticoustic Sensor; Inventor: Massi Joe E. Kiani; filed Jun. 2, 2010.
(Continued)

Primary Examiner — Md M Rahman
(74) *Attorney, Agent, or Firm* — Brooks Kushman P.C.

(57) **ABSTRACT**

A wearable device for measuring physiological parameters includes a light source having a plurality of semiconductor light emitting diodes (LEDs) each configured to generate an output optical beam, wherein at least a portion of the one or more optical beam wavelengths is a near-infrared wavelength. The light source is configured to increase signal-to-noise ratio by increasing light intensity for at least one of the LEDs and by increasing a pulse rate of at least one of the LEDs. A lens is configured to receive the output optical beam and to deliver a lens output beam to tissue. A detection system generates an output signal in response to the lens output beam reflected from the tissue, wherein the detection system is configured to be synchronized to the light source, and is located a different distance from a first one of the LEDs than a second one of the LEDs.

20 Claims, 29 Drawing Sheets



Related U.S. Application Data

continuation of application No. 14/108,986, filed on Dec. 17, 2013, now Pat. No. 9,164,032.

(60) Provisional application No. 61/747,487, filed on Dec. 31, 2012.

(51) **Int. Cl.**

G16H 40/67	(2018.01)
A61B 5/145	(2006.01)
G01J 3/14	(2006.01)
A61B 5/1455	(2006.01)
G01N 33/15	(2006.01)
G01N 33/49	(2006.01)
G01J 3/10	(2006.01)
G01J 3/28	(2006.01)
G01N 33/44	(2006.01)
G01N 33/02	(2006.01)
G01N 21/3563	(2014.01)
G01N 21/39	(2006.01)
G01N 21/35	(2014.01)
G01N 21/88	(2006.01)
G01J 3/42	(2006.01)
G01J 3/02	(2006.01)
G06F 19/00	(2018.01)
G01J 3/453	(2006.01)
G01N 21/359	(2014.01)
G01J 3/18	(2006.01)
H01S 3/30	(2006.01)
G01M 3/38	(2006.01)
G01N 21/85	(2006.01)
G01N 21/95	(2006.01)
H01S 3/067	(2006.01)
H01S 3/00	(2006.01)
G01J 3/12	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/0075*** (2013.01); ***A61B 5/0086*** (2013.01); ***A61B 5/1455*** (2013.01); ***A61B 5/14532*** (2013.01); ***A61B 5/14546*** (2013.01); ***A61B 5/4547*** (2013.01); ***A61B 5/6801*** (2013.01); ***A61B 5/7257*** (2013.01); ***A61B 5/742*** (2013.01); ***A61B 5/7405*** (2013.01); ***G01J 3/0218*** (2013.01); ***G01J 3/108*** (2013.01); ***G01J 3/14*** (2013.01); ***G01J 3/28*** (2013.01); ***G01J 3/2823*** (2013.01); ***G01J 3/42*** (2013.01); ***G01J 3/453*** (2013.01); ***G01N 21/35*** (2013.01); ***G01N 21/359*** (2013.01); ***G01N 21/3563*** (2013.01); ***G01N 21/39*** (2013.01); ***G01N 21/88*** (2013.01); ***G01N 33/02*** (2013.01); ***G01N 33/025*** (2013.01); ***G01N 33/15*** (2013.01); ***G01N 33/442*** (2013.01); ***G01N 33/49*** (2013.01); ***G06F 19/00*** (2013.01); ***G16H 40/67*** (2018.01); *A61B 2562/0233* (2013.01); *A61B 2562/0238* (2013.01); *A61B 2562/146* (2013.01); *A61B 2576/02* (2013.01); *G01J 3/1838* (2013.01); *G01J 2003/104* (2013.01); *G01J 2003/1208* (2013.01); *G01J 2003/2826* (2013.01); *G01M 3/38* (2013.01); *G01N 21/85* (2013.01); *G01N 21/9508* (2013.01); *G01N 2021/3595* (2013.01); *G01N 2021/399* (2013.01); *G01N 2201/061* (2013.01); *G01N 2201/062* (2013.01); *G01N 2201/129* (2013.01); *H01S 3/0092* (2013.01); *H01S 3/06758* (2013.01); *H01S 3/302* (2013.01)

(58) **Field of Classification Search**

USPC 356/300

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,221,997	A	9/1980	Flemming
4,275,266	A	6/1981	Lasar
4,374,618	A	2/1983	Howard
4,403,605	A	9/1983	Tanikawa
4,462,080	A	7/1984	Johnstone et al.
4,516,207	A	5/1985	Moriyama et al.
4,523,884	A	6/1985	Clement et al.
4,605,080	A	8/1986	Lemelson
4,641,292	A	2/1987	Tunnell et al.
4,704,696	A	11/1987	Reimer et al.
4,728,974	A	3/1988	Nio et al.
4,762,455	A	8/1988	Coughlan et al.
4,776,016	A	10/1988	Hansen
4,958,910	A	9/1990	Taylor et al.
4,989,253	A	1/1991	Liang et al.
5,078,140	A	1/1992	Kwoh
5,084,880	A	1/1992	Esterowitz et al.
5,086,401	A	2/1992	Glassman et al.
5,134,620	A	7/1992	Huber
5,142,930	A	9/1992	Allen et al.
5,180,378	A	1/1993	Kung et al.
5,191,628	A	3/1993	Byron
5,218,655	A	6/1993	Mizrahi
5,230,023	A	7/1993	Nakano
5,246,004	A	9/1993	Clarke et al.
5,267,152	A	11/1993	Yang et al.
5,267,256	A	11/1993	Saruwatari et al.
5,267,323	A	11/1993	Kimura
5,300,097	A	4/1994	Lerner et al.
5,303,148	A	4/1994	Mattson et al.
5,305,427	A	4/1994	Nagata
5,313,306	A	5/1994	Kuban et al.
5,323,404	A	6/1994	Grubb
5,345,538	A	9/1994	Narayannan et al.
5,368,224	A	11/1994	Richardson et al.
5,400,165	A	3/1995	Gnauck et al.
5,408,409	A	4/1995	Glassman et al.
5,458,122	A	10/1995	Hethuin
5,544,654	A	8/1996	Murphy et al.
5,572,999	A	11/1996	Funda et al.
5,617,871	A	4/1997	Burrows
5,631,758	A	5/1997	Knox et al.
5,687,734	A	11/1997	Dempsey et al.
5,695,493	A	12/1997	Nakajima et al.
5,696,778	A	12/1997	MacPherson
5,704,351	A	1/1998	Mortara et al.
5,718,234	A	2/1998	Warden et al.
5,746,206	A	5/1998	Mannheimer
5,747,806	A	5/1998	Khalil
5,748,103	A	5/1998	Flach et al.
5,792,204	A	8/1998	Snell
5,795,300	A	8/1998	Bryars
5,812,978	A	9/1998	Nolan
5,855,550	A	1/1999	Lai et al.
5,862,803	A	1/1999	Besson et al.
5,867,305	A	2/1999	Waarts et al.
5,912,749	A	6/1999	Harstead et al.
5,919,134	A	7/1999	Diab
5,944,659	A	8/1999	Flach et al.
5,950,629	A	9/1999	Taylor et al.
5,957,854	A	9/1999	Besson et al.
5,970,457	A	10/1999	Brant et al.
6,014,249	A	1/2000	Fermann et al.
6,031,603	A	2/2000	Fine et al.
6,043,927	A	3/2000	Islam

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,185,535 B1 2/2001 Hedin et al.
6,200,309 B1 3/2001 Rice et al.
6,212,310 B1 4/2001 Waarts et al.
6,224,542 B1 5/2001 Chang et al.
6,246,707 B1 6/2001 Yin et al.
6,246,896 B1 6/2001 Dumoulin
6,273,858 B1 8/2001 Fox et al.
6,278,975 B1 8/2001 Brant et al.
6,281,471 B1 8/2001 Smart
6,285,897 B1 9/2001 Kilcoyne
6,289,238 B1 9/2001 Besson et al.
6,301,271 B1 10/2001 Sanders et al.
6,301,273 B1 10/2001 Sanders et al.
6,325,978 B1 12/2001 Labuda et al.
6,333,803 B1 12/2001 Kurotori et al.
6,337,462 B1 1/2002 Smart
6,340,806 B1 1/2002 Smart et al.
6,350,261 B1 2/2002 Domankevitz et al.
6,364,834 B1 4/2002 Reuss et al.
6,374,006 B1 4/2002 Islam et al.
6,381,391 B1 4/2002 Islam et al.
6,402,691 B1 6/2002 Peddicord et al.
6,407,853 B1 6/2002 Samson et al.
6,436,107 B1 8/2002 Wang et al.
6,441,747 B1 8/2002 Khair et al.
6,442,430 B1 8/2002 Ferek-Petric
6,443,890 B1 9/2002 Schulze et al.
6,450,172 B1 9/2002 Hartlaub et al.
6,453,201 B1 9/2002 Daum et al.
6,454,705 B1 9/2002 Cosentino et al.
6,458,120 B1 10/2002 Shen et al.
6,462,500 B1 10/2002 L'Hegarat et al.
6,463,361 B1 10/2002 Wang et al.
6,480,656 B1 11/2002 Islam et al.
6,512,936 B1 1/2003 Monfre
6,534,012 B1 4/2003 Viswanathan
6,549,702 B2 4/2003 Islam et al.
6,567,431 B2 5/2003 Tabirian et al.
6,587,702 B1 7/2003 Ruchti
6,603,910 B2 8/2003 Islam et al.
6,605,080 B1 8/2003 Altshuler et al.
6,611,643 B2 8/2003 Birk
6,619,835 B2 9/2003 Kita
6,625,180 B2 9/2003 Bufetov et al.
6,631,025 B2 10/2003 Islam et al.
6,640,117 B2 10/2003 Makarewicz
6,659,947 B1 12/2003 Carter et al.
6,659,999 B1 12/2003 Anderson et al.
6,701,170 B2 3/2004 Stetson
6,708,048 B1 3/2004 Chance
6,731,967 B1 5/2004 Turcott
6,738,652 B2 5/2004 Mattu
6,760,148 B2 7/2004 Islam
6,773,922 B2 8/2004 Jeng
6,788,965 B2 9/2004 Ruchti
6,802,811 B1 10/2004 Slepian
6,816,241 B2 11/2004 Grubisic
6,847,336 B1 1/2005 Lemelson
6,864,978 B1 3/2005 Hazen
6,885,498 B2 4/2005 Islam
6,885,683 B1 4/2005 Fermann et al.
6,916,096 B2 7/2005 Eberl et al.
6,943,936 B2 9/2005 Islam et al.
6,990,364 B2 1/2006 Ruchti
7,010,336 B2 3/2006 Lorenz
7,027,467 B2 4/2006 Baev et al.
7,060,061 B2 6/2006 Altshuler et al.
7,105,823 B2 9/2006 Abrahamsson et al.
7,133,710 B2 11/2006 Acosta
7,167,300 B2 1/2007 Fermann et al.
7,184,148 B2 2/2007 Alphonse
7,209,657 B1 4/2007 Islam
7,233,816 B2 6/2007 Blank
7,294,105 B1 11/2007 Islam
7,299,080 B2 11/2007 Acosta
7,317,938 B2 1/2008 Lorenz
7,332,784 B2 2/2008 Mills et al.
7,356,364 B1 4/2008 Bullock et al.
7,395,158 B2 7/2008 Monfre
7,433,116 B1 10/2008 Islam
7,468,036 B1 12/2008 Rulkov et al.
7,519,253 B2 4/2009 Islam
7,519,406 B2 4/2009 Blank
7,620,674 B2 11/2009 Ruchti
7,648,463 B1 1/2010 Elhag et al.
7,697,966 B2 4/2010 Monfre
7,771,320 B2 8/2010 Riley et al.
7,787,503 B2 8/2010 Wadsworth
7,787,924 B2 8/2010 Acosta
7,800,818 B2 9/2010 Mattsson
7,807,718 B2 10/2010 Hashim
7,848,605 B2 12/2010 Ridder et al.
7,890,158 B2 2/2011 Rowe et al.
8,000,574 B2 8/2011 Buchter
8,145,286 B2 3/2012 Arai
8,157,730 B2 4/2012 LeBoeuf et al.
8,158,493 B2 4/2012 Shah et al.
8,172,761 B1 5/2012 Rulkov et al.
8,180,422 B2 5/2012 Rebec
8,180,591 B2 5/2012 Yuen et al.
8,213,007 B2 7/2012 Wang et al.
8,310,336 B2 11/2012 Muhsin et al.
8,315,682 B2 11/2012 Such et al.
8,430,310 B1 4/2013 Ho et al.
8,463,576 B2 6/2013 Yuen et al.
8,472,108 B2 6/2013 Islam
8,475,367 B1 7/2013 Yuen et al.
8,509,882 B2 8/2013 Albert et al.
RE44,875 E 4/2014 Kiani et al.
8,755,871 B2 6/2014 Weng et al.
8,788,002 B2 7/2014 LeBoeuf et al.
8,945,017 B2 2/2015 Venkatraman et al.
8,948,832 B2 2/2015 Hong et al.
8,954,135 B2 2/2015 Yuen et al.
9,142,117 B2 9/2015 Muhsin et al.
9,179,876 B2 11/2015 Ochs et al.
9,192,329 B2 11/2015 Al-Ali
9,241,676 B2 1/2016 Lisogurski et al.
9,326,712 B1 5/2016 Kiani
9,596,990 B2 3/2017 Park et al.
9,651,533 B2 5/2017 Islam
9,675,250 B2 6/2017 Tverskoy
9,757,040 B2 9/2017 Islam
9,820,658 B2 11/2017 Tran
9,861,286 B1 1/2018 Islam
9,885,698 B2 2/2018 Islam
2002/0013518 A1 1/2002 West et al.
2002/0019584 A1 2/2002 Schulze et al.
2002/0032468 A1 3/2002 Hill et al.
2002/0082612 A1 6/2002 Moll et al.
2002/0109621 A1 8/2002 Khair et al.
2002/0115914 A1 8/2002 Russ
2002/0128846 A1 9/2002 Miller
2002/0178003 A1 11/2002 Gehrke et al.
2003/0022126 A1 1/2003 Buchalla
2004/0174914 A1 9/2004 Fukatsu
2004/0240037 A1 12/2004 Harter
2005/0049468 A1 3/2005 Carlson et al.
2005/0111500 A1 5/2005 Harter et al.
2005/0133691 A1 6/2005 Doppke et al.
2005/0209516 A1 9/2005 Fraden
2006/0198397 A1 9/2006 Korolev et al.
2006/0223032 A1 10/2006 Fried
2006/0245461 A1 11/2006 Islam
2006/0268393 A1 11/2006 Islam
2006/0281982 A1 12/2006 Grata et al.
2006/0283931 A1 12/2006 Polli et al.
2007/0021670 A1 1/2007 Mandelis et al.
2007/0078348 A1 4/2007 Holman
2008/0086318 A1 4/2008 Gilley et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0105605	A1	4/2009	Abreu
2009/0204110	A1	8/2009	Islam
2009/0244288	A1	10/2009	Fujimoto et al.
2009/0287067	A1	11/2009	Dorogusker et al.
2010/0046067	A1	2/2010	Fermann et al.
2010/0160794	A1	6/2010	Banet et al.
2010/0217102	A1	8/2010	LeBoeuf et al.
2010/0322490	A1	12/2010	Pan
2010/0331637	A1	12/2010	Ting
2011/0040197	A1	2/2011	Welch et al.
2011/0143364	A1	6/2011	Kim
2011/0208015	A1	8/2011	Welch et al.
2011/0237911	A1	9/2011	Lamego et al.
2011/0267688	A1	11/2011	Kleppe et al.
2011/0282167	A1	11/2011	Ridder et al.
2011/0292376	A1	12/2011	Kukushkin et al.
2012/0013722	A1	1/2012	Wong
2012/0203077	A1	8/2012	He et al.
2012/0239013	A1	9/2012	Islam
2012/0245439	A1	9/2012	Andre et al.
2012/0310062	A1	12/2012	Li et al.
2012/0316455	A1	12/2012	Rahman et al.
2013/0274569	A1	10/2013	Islam
2013/0281795	A1	10/2013	Varadan
2013/0303921	A1	11/2013	Chu et al.
2013/0327966	A1	12/2013	Fidler et al.
2014/0078510	A1	3/2014	Rubio Guivernau et al.
2014/0081100	A1	3/2014	Muhsin et al.
2014/0236021	A1	8/2014	Islam
2014/0249427	A1	9/2014	Liu
2014/0275852	A1	9/2014	Hong et al.
2014/0275854	A1	9/2014	Venkatraman et al.
2015/0011851	A1	1/2015	Mehta et al.
2016/0045118	A1	2/2016	Kiani

FOREIGN PATENT DOCUMENTS

JP	2005270544	A	10/2005
WO	WO09715240		5/1997
WO	WO97049340		12/1997
WO	WO01150959		7/2001
WO	200189362		11/2001
WO	200227640		4/2002
WO	200228123		4/2002
WO	2005013843	A2	2/2005
WO	2007061772	A2	5/2007
WO	2009130464	A1	10/2009
WO	WO2013012938	A1	1/2013
WO	WO2015084376	A1	6/2015

OTHER PUBLICATIONS

International Search Report and Written Opinion for International Application No. PCT/US2013/075700 dated Apr. 24, 2014.

International Preliminary Report on Patentability for International Application No. PCT/US2013/075700 dated Jul. 9, 2015.

Ooi ET, Zhang XQ, Chen JH, Soh PH, Ng K, Yeo JH, "Non-invasive glucose measurement using multiple laser diodes," Optical Diagnostic and Sensing VII, edited by Gerard L. Cote, Alexander V. Priezzhev, Proc. of SPIE vol. 6445, 64450K , (2007).

Schulz, I., J. Putzger, A. Niklas, M. Brandt, A. Jager, A. Hardt, S. Knorzer, K.A. Hiller, S. Loffler, G. Schmalz, S.N. Danilov, S. Giglberger, M. Hirmer, S.D. Ganichev, G. Monkman, "PPG signal acquisition and analysis on in vitro tooth model for dental pulp vitality assessment," ARC Submission 16, (2012).

Drexler, C., Hirmer, M., Danilov, S., Giglberger, S., Putzger, J., Niklas, A., Jager, A., Hiller, K., Loffler, S., Schmalz, G., Redlich, B., Schulz, I., Monkman, G., Ganichev, S. "Infrared spectroscopy for clinical diagnosis of dental pulp vitality." Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), 2012 37th International Conference on. IEEE (2012).

Susanne, Schmalz, Gottfried, Redlich, Britta, Schulz, Irene, Monkman, Gareth, Ganichev, Sergey. "Spectroscopic Study of Human Teeth and Blood from Visible to Terahertz Frequencies for Clinical Diagnosis of Dental Pulp Vitality." Journal of Infrared, Millimeter, and Terahertz Waves 33.3 (2012): 366-375.

Na, J, J.H. Baek, S.Y. Ryu, C. Lee, B.H. Lee, "Tomographic imaging of incipient dental-caries using optical coherence tomography and comparison with various modalities," Optical Review, vol. 16, No. 4, pp. 426-431 (2009).

Extended European Search Report for European Application No. 17155541.0 dated May 24, 2017.

Pan, Yingtian, et al., "Hand-held arthroscopic optical coherence tomography for in vivo high-resolution imaging of articular cartilage", Journal of Biomedical Optics 8(4), Oct. 2003, pp. 648-654.

Xie, Tuqiang, et al., "Endoscopic optical coherence tomography with a modified microelectromechanical systems mirror for detection of bladder cancers", Applied Optics, vol. 42, No. 31, Nov. 1, 2003, pp. 6422-6426.

Dubois, A., et al., "Three-dimensional cellular-level imaging using full-field optical coherence tomography", Physics in Medicine and Biology, Phys. Med. Biol. 49, 2004, pp. 1227-1234.

Park, Jesung, et al., "Analysis of birefringent image in the retinal nerve fiber layer by polarization sensitive optical coherence tomography", Ophthalmic Technologies XIV, Proceedings of SPIE, vol. 5314, 2004, pp. 188-194.

Unterhuber, A., et al., "Advances in broad bandwidth light sources for ultrahigh resolution optical coherence tomography", Physics in Medicine and Biology, Phys. Med. Biol. 49, 2004, pp. 1235-1246.

Drexler, Wolfgang, "Ultrahigh-resolution optical coherence tomography", Journal of Biomedical Optics, vol. 9, No. 1, Jan./Feb. 2004, pp. 47-74.

Schmitt, Joseph, et al., "Intravascular Optical Coherence Tomography Opens a Window Onto Coronary Artery Disease", Optics & Photonics News, Feb. 2004, pp. 20-25.

Nassif, N.A., et al., "In vivo high-resolution video-rate spectral-domain optical coherence tomography of the human retina and optic nerve", Optics Express, vol. 12, No. 3, Feb. 9, 2004, pp. 367-376.

Choi, Seung-Ho, et al., "Observation of Optical Precursors in Water", Physical Review Letters, vol. 92, No. 19, May 14, 2004, pp. 193903-1-193903-.3.

Pierce, Mark C., et al., "Advances in Optical Coherence Tomography imaging for Dermatology", Optical Coherence Tomography Advances, The Journal of Investigative Dermatology, Sep. 3, 2004, pp. 458-463.

"State-Specific Trends in Chronic Kidney Failure—United States, 1990-2001", Morbidity and Mortality Weekly Report, Department of Health and Human Services Centers for Disease Control and Prevention, vol. 53, No. 39, copied from internet: file://C:\Documents and Settings\eturlo\Desktop\State-Specific Trends in Chronic Kidney . . . Feb. 12, 2010, Oct. 8, 2004, pp. 918-920.

I.B. Ads, A.A.E. Wagie, N.B. Mariun, A.B.E. Jammal, "An Internet-based blood pressure monitoring system for patients," Journal of Telemedicine and Telecare, 2001, pp. 51-53.

R.H. Istepanian, B. Woodward, P.A. Bales, S. Chen, B. Luk, "The comparative performance of mobile telemediCal systems based on the IS-54 and GSM cellular telephone standards," Journal of Telemedicine and Telecare, 1999, pp. 97-104.

Shaw, et al, IR Supercontinuum Generation in As—Se Photonic Crystal Fiber, Optical Society of America, Copyright 2005, 3 pages.

PCT/US06/44451, Notification of Transmittal of the International Search Report and the Written Opinion of the International Searching Authority, or the Declaration, Nov. 29, 2007, 12 pages.

G.S. Edwards et al., "Free-electron-laser-based biophysical and biomedical instrumentation," American Institute of Physics, vol. 74, No. 7, Jul. 2003, pp. 3207-3245.

Computer Motion, Inc., "501(k) Summary—ZEUS® MicroWrist™ Surgical System and Accessories," Sep. 24, 2002, 6 pages.

Computer Motion, Inc. "HERMES™ O.R. Control Center—510(k) Summary of Safety and Effectiveness," Oct. 11, 2002, 5 pages.

K.M. Joos, et al. "Optic Nerve Sheath Fenestration with a Novel

(56) **References Cited**

OTHER PUBLICATIONS

J. Sanghera, I. Aggarwal, "IR Fiber Optics at NRL," undated, 10 pages.
J. Sanghera, L.B. Shaw, I.D. Aggarwal, "Applications of chalcogenide glass optical fibers," Academic of Science, 2003, pp. 1-11.
B. Rigas, P.T.T. Wong, "Human Colon Adenocarcinoma Cell Lines Display Infrared Spectroscopic Features," Cancer Research, Jan. 1, 1992, pp. 84-88.
G. Edwards, et al., "Comparison of OPA and Mark-III FEL for Tissue Ablation at 6.45 Microns," Department of Physics and Free Electron Laser Laboratory, Duke University, 2002, 7 pages.
Glenn Edwards, "Biomedical and potential clinical applications for pulsed lasers operating near 6.45 um," Society of Photo-Optical Instrumentation Engineers, 1995, 2 pages.
Passat, "Solid-State Lasers and Optical Components," Jul. 14, 2003, 5 pages.
P.A. Thielen and L.B. Shaw, et al., "Small-core As—Se fiber for Raman amplification," Optics LETI-ERS, vol. 28, No. 16, Aug. 15, 2003, 3 pages.
R.Rox Anderson, et al., "Selective Photothermolysis: Precise Microsurgery by Selective Absorption of Pulsed Radiation," Department of Dermatology, Harvard Medical School, Science, vol. 220, Apr. 29, 1983, 4 pages.
U.S. Appl. No. 10/652,276, "System and Method for Voice Control of Medical devices," by Mohammed N. Islam, abandoned filed Aug. 29, 2003.
U.S. Appl. No. 10/757,341, "System and Method for Voice Control of Medical devices," by Mohammed N. Islam, issued filed Jan. 13, 2004.
U.S. Appl. No. 12/206,432, "System and Method for Voice Control of Medical Devices," by Mohammed N. Islam, pending filed Sep. 8, 2008.
U.S. Patent and Trademark Office, Office Action for U.S. Appl. No. 12/206,432, filed Sep. 8, 2008, Mohammed N, Islam, dated Mar. 12, 2009.
U.S. Patent and Trademark Office, Notice of Allowance and Fee(s) Due for U.S. Appl. No. 12/206,432, filed Sep. 8, 2008, Mohammed N. Islam, dated Aug. 28, 2009.
Sun, Y., C.F. Booker, S. Kumari, R.N. Day, M. Davidson, A. Periasamy, "Characterization of an orange acceptor fluorescent protein for sensitized spectral fluorescence resonant energy transfer microscopy using a white-light laser," Journal of Biomedical Optics, vol. 14, No. 5, paper 054009 (2009).
Borlinghaus, R., "Colours Count: how the challenge of fluorescence was solved in confocal microscopy," in Modern Research and Educational Topics in Microscopy, A. Mendez-Vilas and J. Diaz, eds, pp. 890-899, Formatex (2007).
Borlinghaus, R., "The White Confocal: Continuous Spectral Tuning in Excitation and Emission," in Optical Fluorescence Microscopy, A. Diaspro (Ed), Chapter 2, pp. 37-54, ISBN 978-3-642-15174-3, Springer-Verlag, Berlin (2011).
Borlinghaus, R.T., L. Kuschel, "White Light Laser: The Ultimate Source for Confocal Microscopy," http://www.leica-microsystems.com/science-lab/white-light-laser (Jun. 27, 2012).
Ziegler, U., A.G. Bittermann, M. Hoechli, "Introduction to Confocal Laser Scanning Microscopy (LEICA)," www.zmb.unizh.ch, May 29, 2013.
Hazen, K.H., M.A. Arnold, G.W. Small, "Measurement of glucose and other analytes in undiluted human serum with near-infrared transmission spectroscopy," Analytica Chimica Acta, vol. 371, pp. 255-267 (1998).
Malin, S.F., T.L. Ruchti, T.B. Blank, S.N. Thennadil, S.L. Monfre, "Noninvasive prediction of glucose by near-infrared diffuse reflectance spectroscopy," Clinical Chemistry, vol. 45, No. 9, pp. 1651-1658 (1999).
Thennadil, S.N., J.L. Rennert, B.J. Wenzel, K.H. Hazen, T.L. Ruchti, M.B. Block, "Comparison of glucose concentration in interstitial fluid, and capillary and venous blood during rapid Troy, T.L., S.N. Thennadil, "Optical properties of human skin in the near infrared wavelength range of 1000 to 2200nm," Journal of Biomedical Optics, vol. 6, No. 2, pp. 167-176, (2001).
Blank, T.B., T.L. Ruchti, A.D. Lorenz, S.L. Monfre, M.R. Makarewicz, M. Mattu, K.H. Hazen, "Clinical results from a non-invasive blood glucose monitor," Optical Diagnostics and Sensing of Biological Fluids and Glucose and Cholesterol Monitoring II, A.V. Priezzhev and G.L. Cote, Editors, Proceedings of SPIE, vol. 4624, pp. 1019 (2002).
Yeh, S-J, C.F. Hanna, O.S. Khalil, "Monitoring blood glucose changes in cutaneous tissue by temperature-modulated localized reflectance measurements," Clinical Chemistry, vol. 49, No. 6, pp. 924-934 (2003).
Marbach, R., T. Koschinsky, F.A. Gries, H.M. Heise, "Noninvasive blood glucose assay by near-infrared diffuse reflectance spectroscopy of the human inner lip," Applied Spectroscopy, vol. 47, No. 7, pp. 875-881 (1993).
Enejder, A.M.K., T.G. Scecina, J. Oh, M. Hunter, W.C. Shih, S. Sasic, G.L. Horowitz, M.S. Feld, "Raman spectroscopy for noninvasive glucose measurements," Journal of Biomedical Optics, vol. 10, No. 3, 031114 (2005).
Olesberg, J.T., L. Liu, V.V. Zee, M.A. Arnold, "In vivo near-infrared spectroscopy of rat skin tissue with varying blood glucose levels," Analytic Chemistry, vol. 78, No. 1, pp. 215-223 (2006).
Olesberg, J.T., M.A. Arnold, C. Mermelstein, J. Schmitz, J. Wagner, "Tunable laser diode system for noninvasive blood glucose measurements," Applied Spectroscopy, vol. 59, No. 12, pp. 1480-1484 (2005).
Harman-Boehm, I. A. Gal, A.M. Raykhman, J.D. Zahn, E Naidis, Y. Mayzel, "Noninvasive glucose monitoring: a novel approach," Journal of Diabetes Science and Technology, vol. 3, No. 2 pp. 253-260 (2009).
Kim-K.D., G.S. Son, S.S. Lim, S.S. Lee, "Measurement of glucose level exploiting a relative optical absorption at discrete probe wavelengths," Japanese Journal of Applied Physics, vol. 48, 077001 (2009).
Smith, J.L., "The Pursuit of Noninvasive Glucose: Hunting the Deceitful Turkey," 2nd Edition, pp. 1-141 (2011).
Pezzaniti, J.L., T.W. Jeng, L. McDowell, G.M. Oosta, "Preliminary investigation of near-infrared spectroscopic measurements of urea, creatinine, glucose, protein and ketone in urine," Clinical Biochemistry, vol. 34, pp. 239-246 (2001).
Lussi, A., R. Hibst, R. Paulus, "Diagnodent: An optical method for caries detection," Journal of Dental Research, vol. 83, special issue C, pp. C80-C83 (2004).
Reese, E.L, E.E. Fisher, D.A. Horowitz, "Photoelectric densitometry of the circulation of the human dental pulp," The Journal of the Baltimore College of Dental Surgery, vol. 26, No. 1, pp. 6-18 (1971).
Zakian, C., I. Pretty, R. Ellwood, "Near-infrared hyperspectral imaging of teeth for dental caries detection," Journal of Biomedical Optics, vol. 16, No. 6, 064047 (2009).
Belikov, A.V., A.V. Skripnik, K.V. Shatilova, "Study of the dynamics of the absorption spectra of human tooth enamel and dentine under heating and ablation by submillisecond pulse radiation of an erbium laser with a generation wavelength of 2.79 um," Optics and Spectroscopy, vol. 109, No. 2, pp. 211-216 (2010).
Karlsson, L. "Caries detection methods based on changes in optical properties between healthy and carious tissue," International Journal of Dentistry, vol. 2010, Article ID 270729, 9 pages (2010).
Fried, D. M. Staninec, C.L. Darling, "Near-infrared imaging of dental decay at 1310nm," Journal of Laser Dentistry, vol. 18, No. 1, pp. 8-16 (2010).
Burmen, M. P. Usenik, A. Fidler, F. Pernus, B. Likar, "A construction of standardized near infrared hyper-spectral teeth database—a first step in the development of reliable diagnostic tool for quantification and early detection of caries," Lasers in Dentistry XVII, edited by P. Rechmann, D. Fried, Proceedings of SPIE, vol. 7884, Paper 78840E (2011).
Maia, A., L. Karlsson, W. Margulis, A. Gomes, "Evaluation of two imaging techniques: near-infrared transillumination and dental radio-

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS
Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS
Sync your system to PACER to automate legal marketing.