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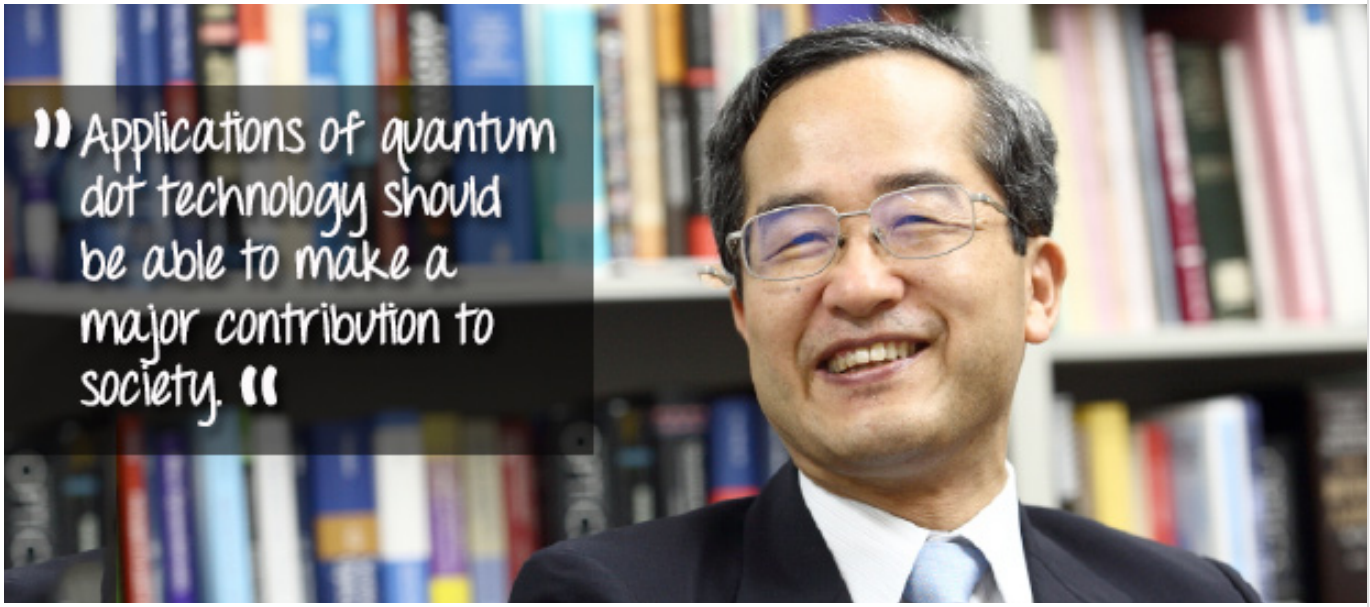

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Q&A with Yasuhiko Arakawa

Last updated on October 7th, 2014

From computers to home electronics, automobiles to infrastructure management. Have you ever thought about how our lives might be totally transformed in the not so distant future?

The potential for such a transformation may lie in an intriguingly named material, the “quantum dot.” With its capacity to emit photons very efficiently, it harbors infinite possibilities.

Meet our eighth “Tech Hero,” University of Tokyo Professor Yasuhiko Arakawa, a preeminent figure in the field of quantum dot research.

What is a “quantum dot”?

Professor Arakawa’s research lab is neat and orderly. It belies the stereotype of the cluttered and chaotic scientist’s lab, and seems more like an architect or industrial designer’s workspace. Most striking about the Prof. on first meeting is his logical and quick-witted conversation. He manages to explain the somewhat esoteric structure of quantum dots and their huge potential, with concise simplicity.

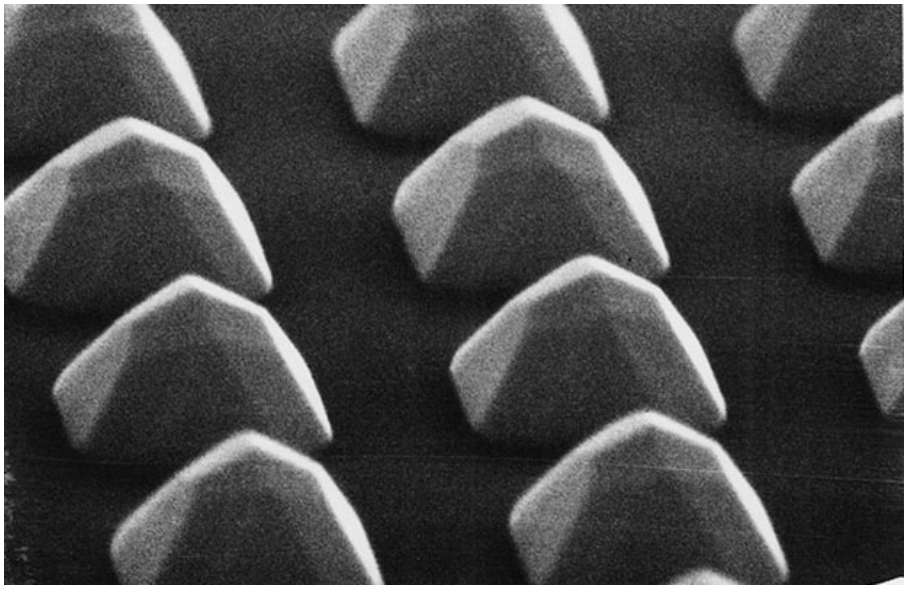
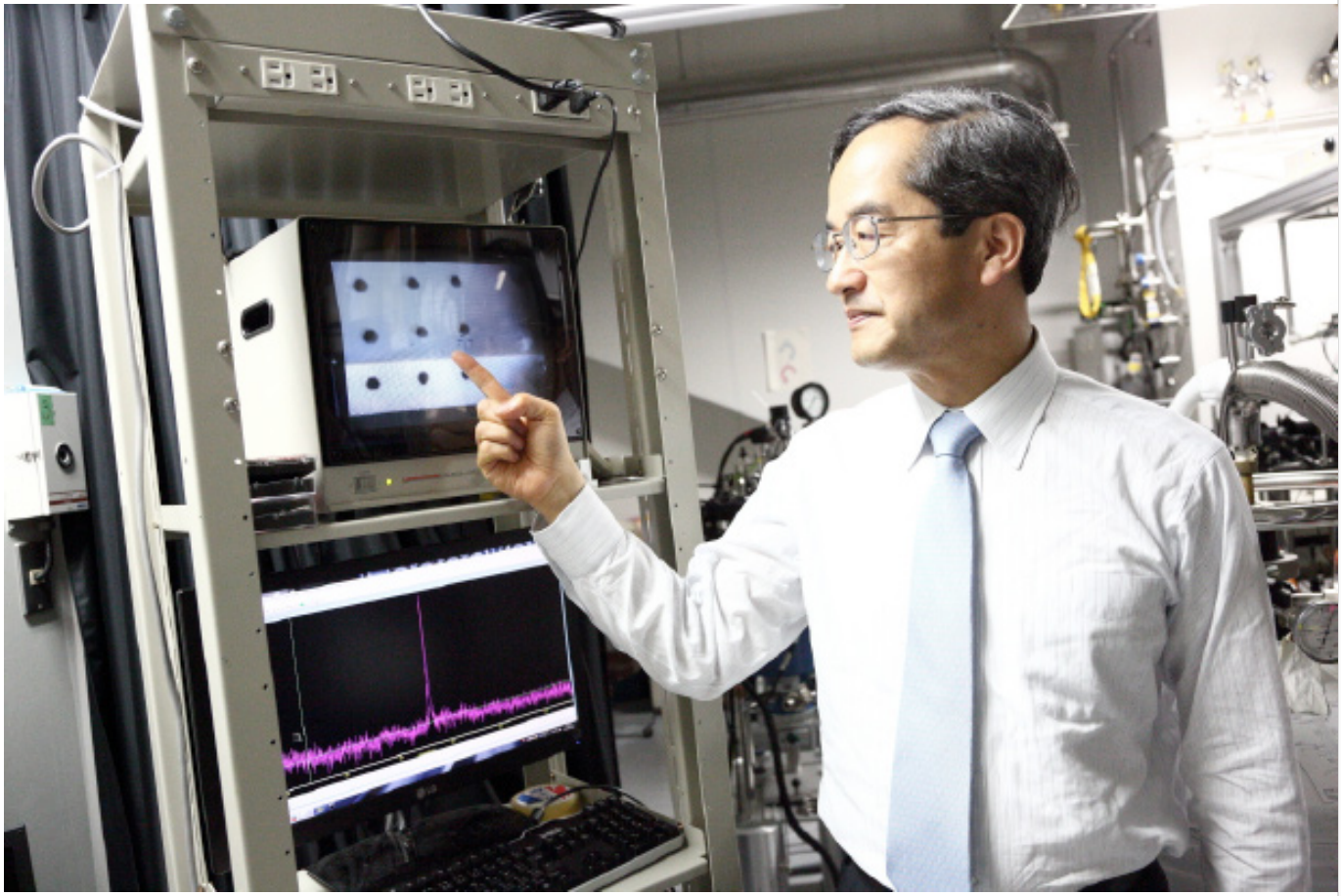


Image of “Quantum Dot”



“A quantum dot is what you get when you take a single free-moving electron, and use cutting-edge nanotechnology to confine it in an immobile state (as if it were an artificial atom), in a tiny three-dimensional space of only around 10 nanometers (1 nanometer = 1/100,000,000th of a meter). The dots are confined in countless box-like structures which are made by inducing crystal growth in materials such as gallium and indium. This causes electrons to behave in a completely atypical way. Put simply, each individual quantum, which is the smallest unit in electrons and light, can be controlled as a unit of data. You could compare it to having children who were running around in the playground all compete to sit down on a chair placed there. The idea is that once the children are seated, their energy can then be efficiently directed to schoolwork.”

“We first proposed the concept in 1982, but it wasn’t until 1990 that it actually became possible to produce quantum dots, and scientists could freely manipulate electrons. By modifying the size and shape of quantum dots, we can now use the energy from a multitude of electrons locked up in the dots to emit light simultaneously, and even produce ultra-high performance and low-power consumption “semiconductor lasers” with minimal temperature sensitivity.”

> light sources for broadband, and that quantum mechanics principles can also be applied to develop new devices for telecommunications and computers that we can't even imagine right now. Applications of quantum dot technology should be able to make a major contribution to society."

A palm-sized supercomputer?

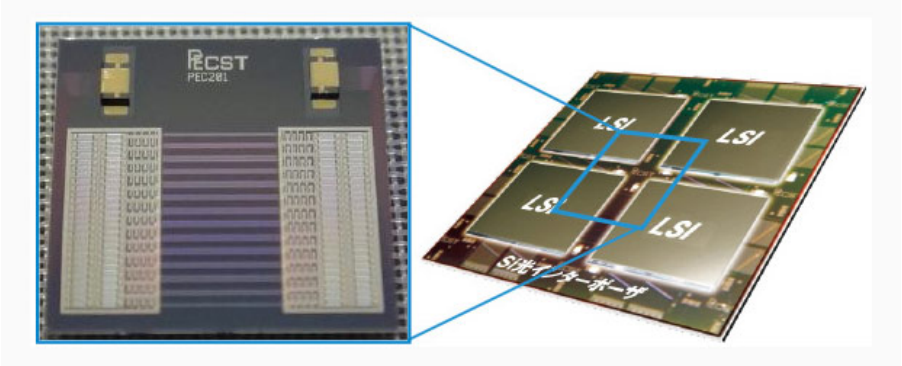
A key project for Professor Arakawa currently is building the technological base for creating a current day supercomputer-equivalent that can fit in the palm of your hand by 2035. The challenge requires light to be used in wiring between the multiple LSI (large-scale integrated circuits) embedded in the integrated circuit systems, so then light, not electrons, will transmit signals. The result will be ultra-high speed data transmission between the chips, but it requires everything to be connected seamlessly, which is not possible with today's wiring technology.

LSI chips generate substantial heat. If light is used instead of electrons for interconnect, the light sources and other photonic devices placed near the LSI chips is needed to be tolerant against the heat. Semiconductor lasers using the quantum dots are likely to be needed for the light source because of its temperature insensitivity and low-power consumption.

Working under the Japanese government's Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST), Professor Arakawa has developed a 5mm x 5mm silicon photonic integrated circuit substrate. With the substrate that uses photons to transmit signals between LSI chips, data is still processed inside the LSI with electrons as before, but the processed signal is sent by laser light with the high density photonic wires, then returned to its electron state and placed into the neighboring LSI.

In 2013, his team achieved the world–record high transmission bandwidth density of 30 terabits per second per 1cm² on a Silicon photonic integrated circuit system, three times their 10 terabit target set for the end of 2014 in the project.

A brave new world offering palm-sized supercomputers is coming into view, as Professor Arakawa ably leads the research to make it possible.



Silicon photonic integrated circuit (~5mm x 5mm) which is a part of photonic and electronic convergent systems.

Other devices that can be operated using photonics are also needed to complete the supercomputer project, and research on these is also in progress.

> "My aim to bring about convergence of photonics and electronics in LSI is underway."

In 2014, Professor Arakawa has developed a photonic integrated circuit substrate that can operate even at high temperatures, using quantum dot laser light sources instead of the traditional semiconductor lasers. The aim was to create the photonic integrated circuit that can handle an entire current-day high performance server on the one chip. He has also already produced a silicon photonic integrated circuit substrate, which integrates various devices in a silicon substrate form and uses a quantum dot laser light source.

Professor Arakawa is forging the way forward with his development of new generation photonics-electronics devices that meet the needs of our ever-changing post-industrial society.

A logical child

Professor Arakawa says he first thought of academia as a career when he read Galileo's life story as a small kid. But he wasn't so much a fan of science experiments.

> "Science class experiments at elementary and junior high schools were tinny, and didn't interest me so much. Plants and insects did nothing for me either. Kids into electronics usually liked vacuum tube radios, but I wasn't so much into them. I suppose I like theory. I'm not interested in doing experiments for their own sake. I liked coming up with a hypothesis, and doing an experiment to prove it. So I didn't really come to actually like doing experiments until physics class in high school. Even when I read about famous scientists in history, I was less interested in what they did, compared what they thought and how they lived."

He was a boy with a bent for logic. It seems the makings of the sharp academic were there from an early age.

Do it tough sometimes

But the Professor Arakawa is more than just a sharp-minded scholar.

> "Our work is like climbing a mountain in the darkness. You sometimes hit dead-ends. And then you stray from the path. But if you fall over, you can't let it be for nothing. You need to learn something from your failures. 'Collect a flower when you fall.' That kind of strong fighting spirits a valuable asset. Also, sometimes when you climb one mountain, another one can come into view. You can't hesitate then. Even if you've just

the rough at times, too.

> “Intuition can be important, too. Sometimes I let myself be guided by my intuition.”

Arakawa spends his days off reading fiction, watching movies, and sometimes going to the training gym. He says he leaves work at the lab, and tries to relax as much as possible. Logic is not the be-all and end-all. Arakawa’s logical mind no doubt helped him realize that.

Captivated by the elegance of logic

Why is he so focused on logical thinking?

> “I like to remove ambiguity as well as to look at the bird's-eye view of things. I believe a good science accompanies an elegance in logic,” he says.

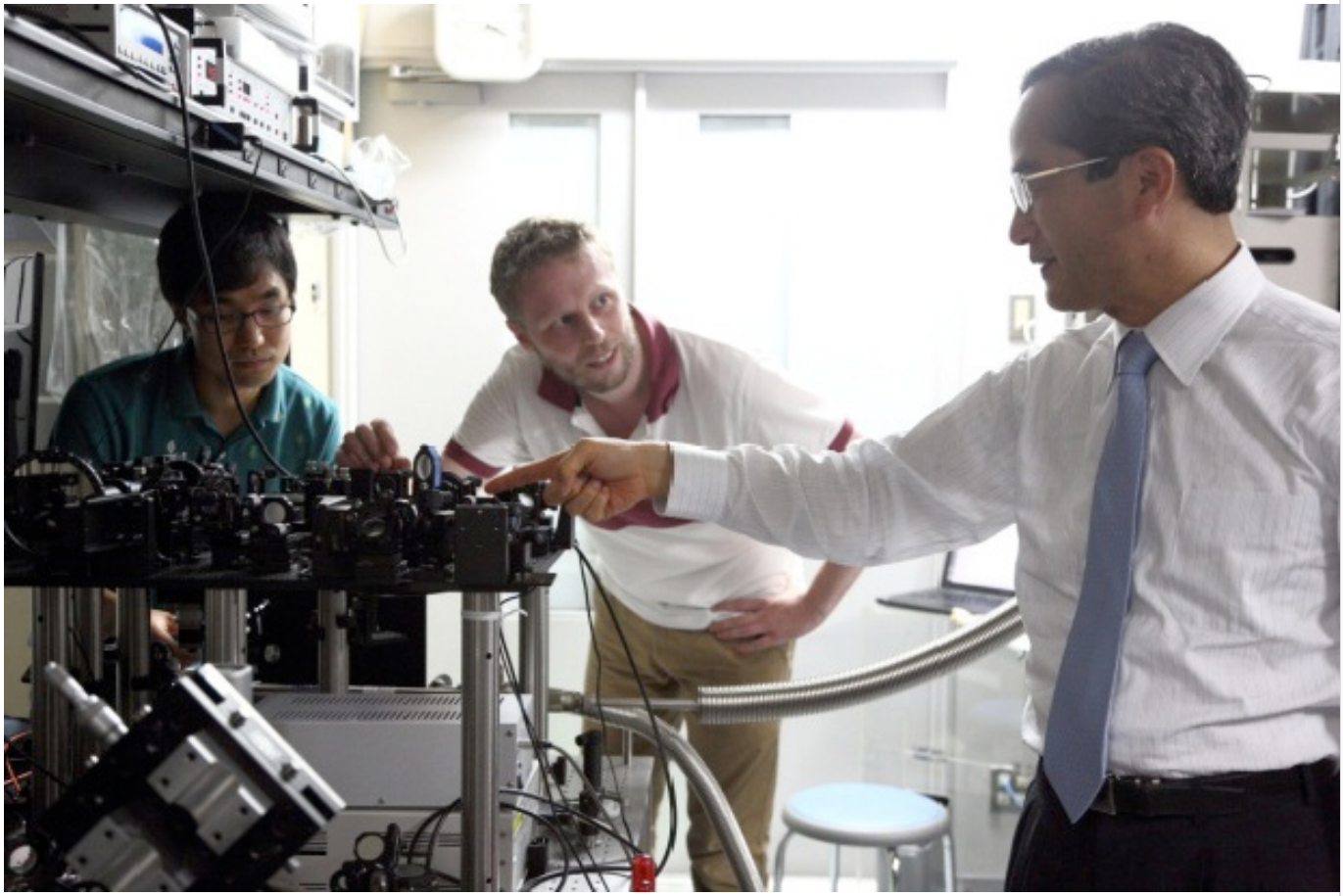
So Professor Arakawa sees beauty in the elegance of the science. He says he was hooked on Japanese-style archery when he was in high school. It is a martial art with a simple, spare aesthetic.

> “Even when I proposed the concept of quantum dots for semiconductor lasers, I was happier that I had found a logic that no other researcher had discovered than at the thought of what impact it might have on the world.”

An as yet undiscovered logic to Professor Arakawa is like finding a new kind of beauty unknown to the world. He is fascinated by the beauty of logic. It is intriguing that the motivation for Professor Arakawa’s pursuit of logic is beauty, a sense that cannot be explained by logic.

Quantum dot applications - the future

> “Quantum dots have infinite potential.”



Solar cells with exceptional conversion efficiency, maximum security quantum cryptography systems that house data on a single photon, quantum telecommunications, and key devices for quantum computers that can complete massive calculations and simulations within quantum dots. The possibilities are endless.

With the spread of quantum dot use in multiple fields, our lives too will change. Starting from driverless cars, high performance robots, and airplanes flying on autopilot that can respond to emergencies using instantaneous simulation, we face a future where our science fiction-based dreams could actually become reality.

It may seem far-fetched. But with an eminently logical mind pursuing the most efficient route, Professor Arakawa’s work could deliver this future to us sooner than we think. With the limitless potential of quantum dots, just imagine what kind of future that might be.

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