NICT NEWS

National Institute of Information and Communications Technology

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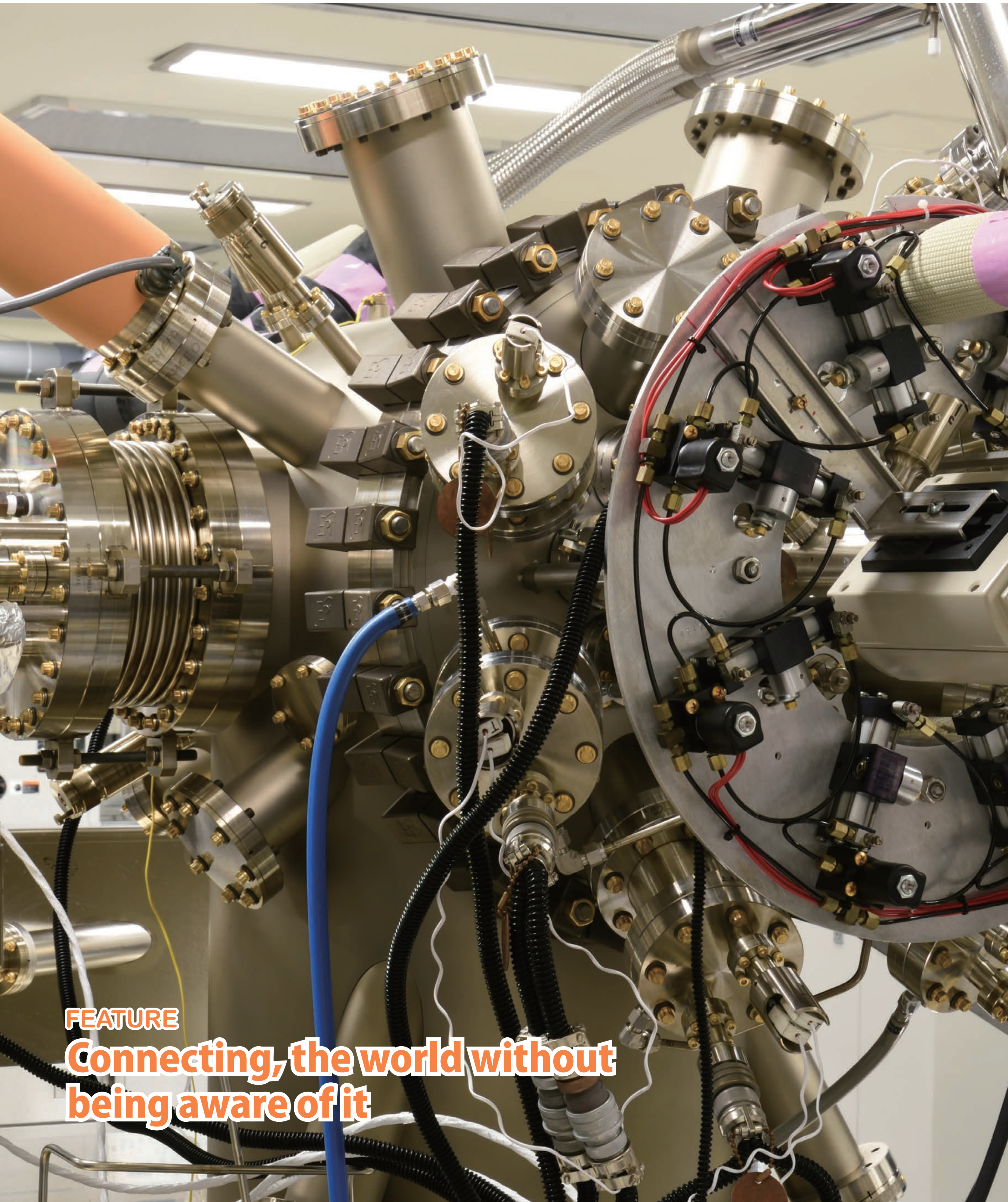

FEATURE

Connecting, the world without being aware of it

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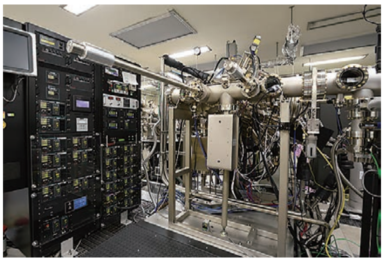
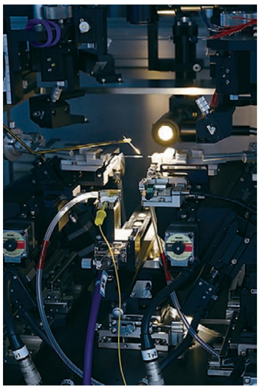




FEATURE

TOPICS

Cover photo: "Molecular beam epitaxy equipment"
This equipment can form semiconductor crystals while controlling their structure at the atomic scale. Nano-scale semiconductor crystals provide us with the ultimate level of control of the characteristics of light and electricity and are yielding advances in opto-electronic device technologies essential in information and communications.

INTERVIEW

The future of "Dedicated moderate range communication" will be constructed with optical access device and system technology

Naokatsu YAMAMOTO
Research Manager, Network Science and Convergence Device Technology Laboratory, Network System Research Institute / Director, Advanced ICT Device Lab

After completing a doctoral course and working as an assistant professor at university, Yamamoto joined the Communications Research Laboratory (currently NICT) in 2001. He engages in research including quantum dot photonic devices, a heterogeneous integration technology for convergence of photonics and electronics, and a dedicated moderate range communication technology. In 2013, he also became a visiting professor in Tokyo Denki University. Ph. D. (Engineering).

In today's world, information networks are working their way into every nook and cranny of people's lives. Demand for capacity and reliability is increasing as the role of these networks increases, and achieving it will make networks even more important. Optical access device and system technology will provide important support for these networks in the future. We spoke with Dr. Naokatsu YAMAMOTO, Research Manager of the Network Science and Convergence Device Technology Laboratory, Network System Research Institute and Director of the Advanced ICT Device Laboratory, regarding current and future prospects and the research organization.

What is "Optical access device and system technology?"

— "Optical" technologies have a major role in current ICT technology, but what part of that does "Optical access device and system technology" refer to?

Yamamoto: In an overall view of networks, the so-called backbone is the "core network". The part closer to users, which branches off of the core network and directly exchanges data with us over short and medium distances, is called the "access network".

As I mentioned, the core network is the backbone and must handle large volumes of data, so it is actively being converted to optical technology. These days, however, the size of the content itself is also increasing, so the speed and capacity of access networks closer to users must also be. This requires R&D on fundamental technologies supporting them. This is the area of our R&D on optical access device and system technology.

— Optical communication has the image of "high speed and large capacity." It used to be a core network technology, but is it right to understand that as the amount of information we use everyday increases, it is also needed to cover access networks closer to users?

Yamamoto: That's right. However, with access networks and other medium range data communication, wireless technology, such as the mobile phones we all use, plays an import-

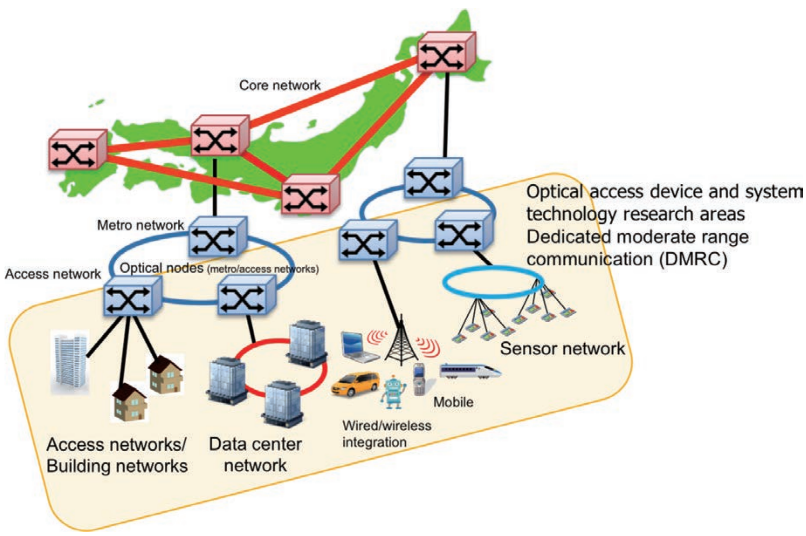


Figure 1　Research areas of optical access device and system technology

INTERVIEW

The future of "Dedicated moderate range communication" will be constructed with optical access device and system technology

ant role in addition to optical. As such, even though we call it optical access device and system technology, we cannot do without R&D on convergence of advanced optical and wireless technologies.

Optical is suitable for high-speed transmission of large amounts of information, but wireless is also very good for flexibility and freedom of use. Common themes regarding access networks include "integrated use of optical and wireless" and "wired/wireless convergence." Our R&D also promotes such concepts.

Two main research themes

— Specifically, what themes is the optical access device and system technology research group pursuing?

Yamamoto: Our project has two main targets. One is parallel photonics technology, and the other is 100 G-access network technology.

Parallel photonics technology aims to achieve overall large volume transmission by increasing speed and integration of device functions, while maximizing parallel operation of multiple device functions. To achieve such transmission technology requires advanced integration of optical circuits with high frequency electrical circuits. There is a limit to what individual devices and circuits can do, but with advanced parallelization of optical and high frequency components at the device level, performance of transmitters, receivers and switches can be greatly increased. This is the goal of parallel photonics technology.

Of course, as parallelism increases, we also work to reduce size. With access network technology, it is important that we can use devices like mobile phones and household appliances freely, so devices must be made smaller. However, squeezing multiple circuits into a small device and using both optical and high-frequencies in such a small space is bound to produce problems with electromagnetic cross talk (crossed lines, interference). Suppression of cross talk is a major issue in parallel photonics technology. On the other hand, many kinds of materials must be used within a very small space to achieve advanced control of optical and high frequencies. As such, functional materials must be used appropriately, and technologies to create, process, and implement excellent materials are also important.

In contrast to parallel photonics technology, which deals with device fundamentals, 100 G-access network technology looks into system development. Till now, radio and optical technologies were considered separately, depending on the situation; using radio for wireless and optical transmitters and receivers for optical communications. We believe that wired and wireless systems will converge in the future, and communication will occur with no particular awareness of the medium, whether optical or radio waves. To achieve this and also increase the capacity of wireless communication will require technologies for high frequencies, such as millimeter and terahertz waves; convergence of optical and high frequency technologies at the system level; and use of both digital and analog techniques, such as high speed waveform transmission. We expect to achieve data transmission exceeding 100 Gbps per end user using these techniques, which is 100 to 1,000 times the capacity generally available now.

We are also expecting to integrate devices based on the parallel photonics technology I discussed above into this 100 G-access network system technology.

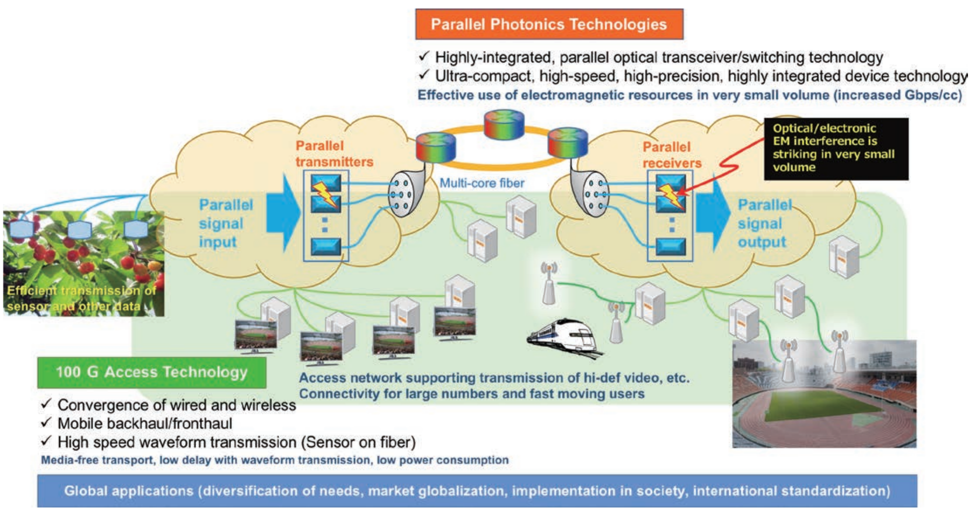


Figure 2 Two main R&D themes for optical access device and system technology

From fundamental technologies to applications and deployment in society

— Are there any particular applications from current R&D that are around the corner in real industry or society?

Yamamoto: One example is use of devices and system technologies developed for data communications to radar applications. In primary domestic airports, we are currently field testing a linear cell radar system that uses high resolution sensing technology. This radar detects small foreign objects on runways. In testing, radar equipment is installed along the side of runways and can identify metal objects dropped on the runway as small as several centimeters. Each radar head is connected by optical fiber, and converts optical signals to high-frequency signals using ultra-high-speed opto-electric convergence device technologies that we have developed.

Another example is development of a high-speed access technology for high-speed railways, although research is still at the elemental technology stage. This system uses terminals

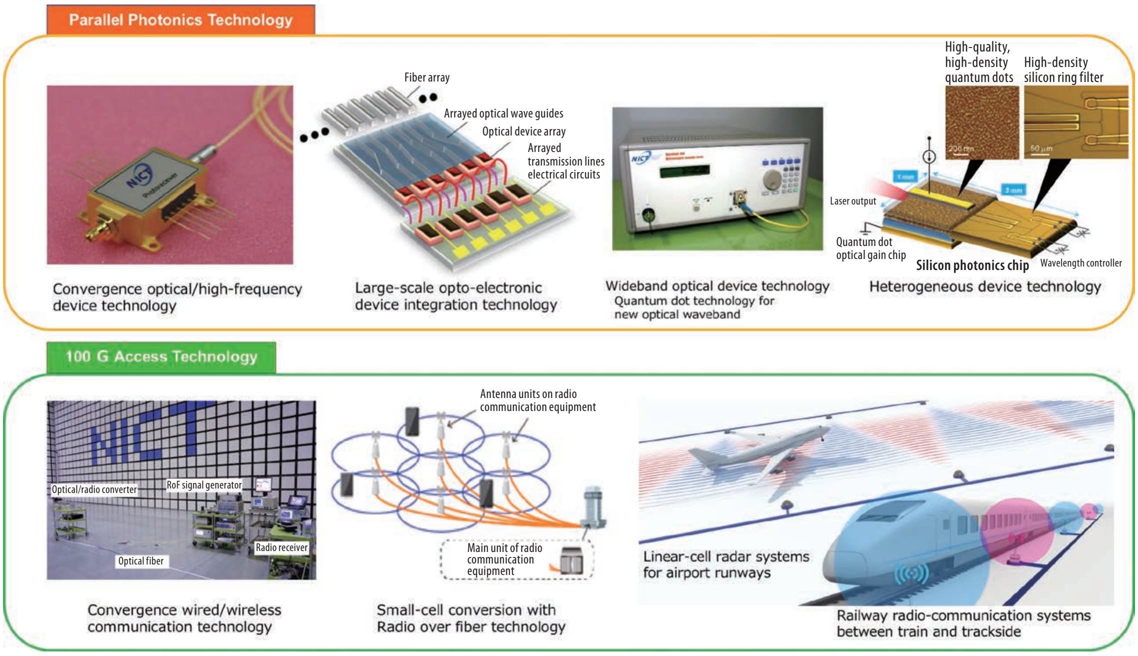


Figure 3　Convergence of optical/high-frequency device technologies and the expected outcomes

on an optical fiber stretched along the track and provides an uninterrupted connection for trains travelling at high speed. It uses millimeter-wave wireless communication with technology that converts between optical and millimeter-wave signals. Optical/high-frequency convergence device and system technologies are also important here, as with the radar system mentioned earlier.

This is being done as a Ministry of Internal Affairs and Communications project, so NICT is handling basic, elemental research on devices and system architecture, while promoting development of new infrastructure technologies in cooperation between industry and government, including with various organizations and facilities.

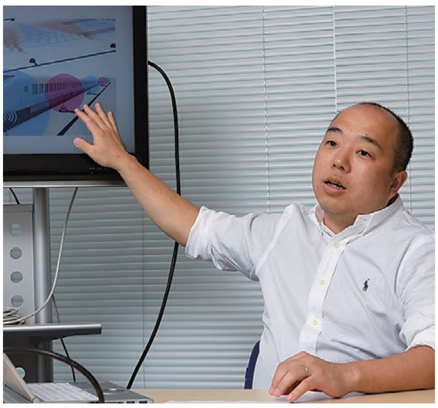
Besides these, we are also developing a wavelength tunable semiconductor quantum-dot laser device technology that is extremely small and operates in a new, ultra-wideband optical communication band (1.0-1.3 μm). This was originally intended for use in extremely compact ultra-wideband optical communication devices but may also have applications in bio-sensing and medical diagnostics.

Promoting integrated research along the three prongs: materials, devices, and systems

── From what you're saying, R&D involves convergence of various technologies, and exploiting them in the future will go beyond just telecommunications, won't it?

Yamamoto: That's right. Our group includes researchers from the field of materials as well as from the fields of devices and systems. That is one of our strengths and is an attractive point.

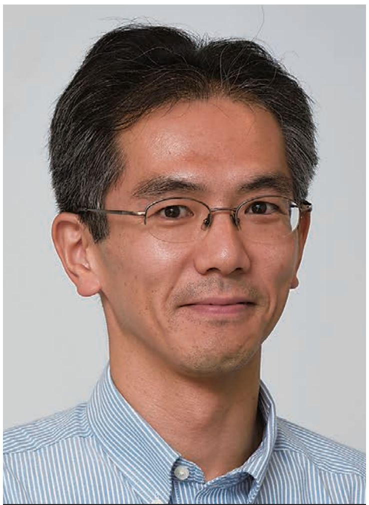
Often, when people of just a single specialty gather together, they only notice things within their field. For example, people specializing in devices only pursue device functionality and do not think about systems, while systems people only design systems using existing devices. As both devices and systems become more commoditized, this inhibits creation of new industries and any significant paradigm shifts. However, our group conducts research with researchers from different cultures, who are able to communicate with questions like "If we had X, we would be able to do Y, wouldn't we?" and "Is it possible to create Z?," so we can expect to see convergence of technologies from different fields. I think this sort of research system will become even more important in the future. Our optical access device and system technology research theme can be summarized as "optical and wireless convergence," which of course, must involve convergence of people's knowledge. If we also work on convergence of knowledge through international cooperation among industry, academia, and government, we can expect to expand the technologies cultivated for optical access and device systems into broader fields, beyond information and communications, such as radar, imaging, sensing, and medical applications.



With such group strengths, we can hope to contribute to society with new developments, by promoting fundamental and advanced research on technologies in each of these fields, and can look forward to convergence of these technologies.

Highly integrated optoelectronics platform for parallel photonics

Establishing high performance optoelectronic devices with nanotechnology



Kouichi AKAHANE
Senior Researcher
Network Science and Convergence Device Technology Laboratory
Network System Research Institute

While at university from 1999 to 2002, received a Research Fellowship for Young Scientists from the Japan Society for the Promotion of Science. Joined the Communications Research Laboratory (currently NICT) in April, 2002. Currently engaged in research on semiconductor crystal growth, nano-structure fabrication technologies, semiconductor lasers, and semiconductor optical amplifiers. Ph.D. (Engineering).

We are conducting research and development on platform technologies important for data communication access over short to medium ranges in particular; focusing research on material and device technology to make high-volume information and communications technology simpler and easier to use. Optical fiber communications require various technical elements, including high-performance light sources, modulators, transmission paths, and detectors. Beyond (wired) optical communication, it also needs to be integrated with wireless communications, to build networks that can be used without concern for the boundaries between these technologies.

As such, it is becoming urgent to realize an ideal device platform technology, able to integrate multiple functions densely into small spaces, providing compact, advanced functionality and high performance, and utilizing both high frequency and optical technologies. The Network Science and Convergence Device Technology Laboratory is conducting R&D to achieve this, implementing devices that integrate maximal functionality in minimal space, and creating a platform technology called parallel photonics, for building networks. Some of the results from this R&D are introduced below.

Great improvements in optical device performance through nanotechnology

More complex and advanced functionality can be implemented and applied to high-volume information and communications by integrating large numbers of optoelectronic devices into very small spaces. However, many individual devices operating cooperatively and simultaneously can generate heat, which can degrade performance. For example, the output of semiconductor lasers drops significantly at high temperatures.

In our laboratory, we are conducting research to modify and improve characteristics of materials using nanotechnology, as a possible solution to difficulties that are anticipated, as functionality is increasingly integrated in the future. Semiconductor quantum dots (Figure 1) are extremely small structures, on the scale of nanometers, whose optical and electrical properties, such as emission wavelength or electron energy level, can be controlled by controlling size, strain, and shape at the atomic level.

We are developing high density quantum dot fabrication techniques unique to NICT and not seen anywhere else in the world using molecular beam epitaxy in our Advanced ICT Device Lab. Quantum dot semiconductor lasers made with this technology have lasing threshold current and efficiency that hardly vary with temperature (Figure 2, right). We can expect dramatic increases in the performance of optoelectronic devices by using quantum dot technology to improve the fundamental capabilities of the materials.

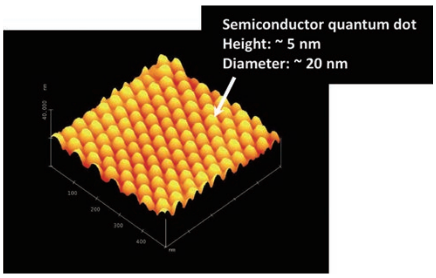


Figure 1 Overhead view of semiconductor quantum dots. An array of many quantum dots has been formed in a 500 nm × 500 nm area. Each quantum dot emits light.

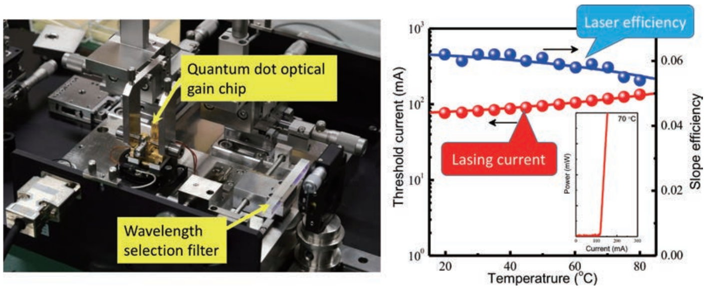


Figure 2 Variable-wavelength light source test system with a quantum dot optical gain chip (left) and a graph showing how laser driving current and efficiency are not greatly affected by temperature (right). Inset shows laser operation at a high temperature of 70 ˚C.

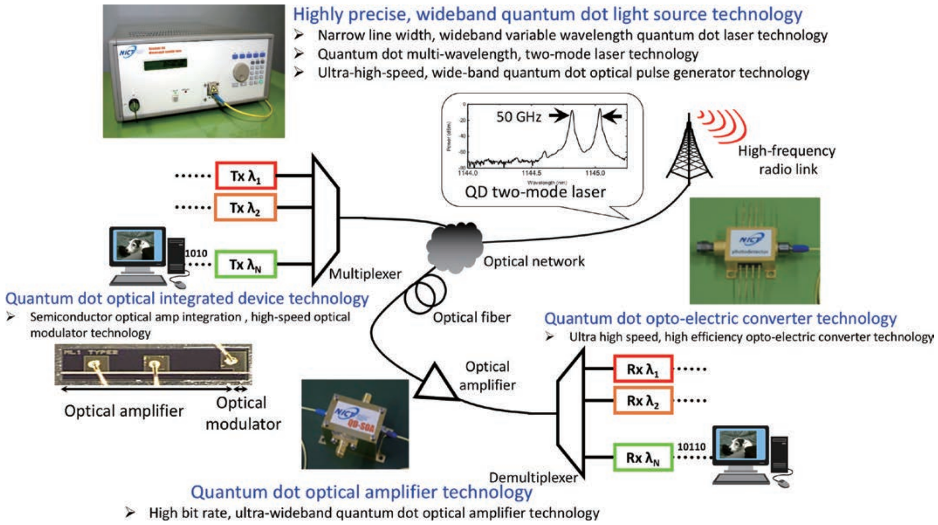


Figure 3 Device platform technologies with semiconductor quantum dots as a core material and technology in the field of information and communications.
Expansion into domains of short and medium range optical networks and convergence of optical and high-frequency communications.

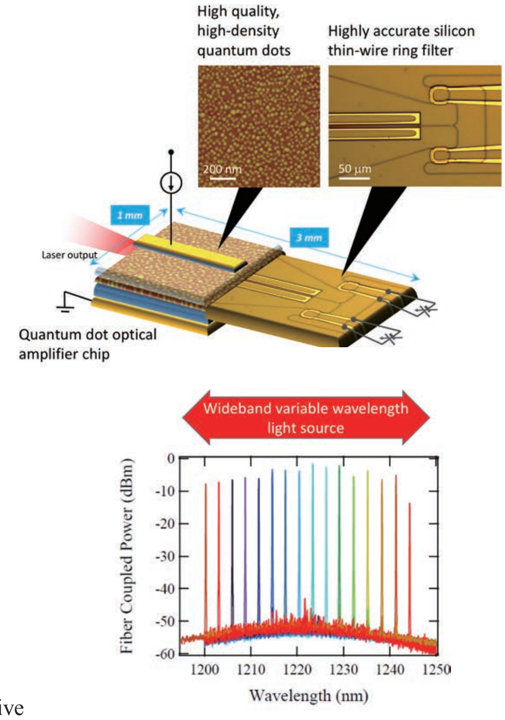


Figure 4 A quantum dot variable wavelength light source of only a few mm (above) and its variable wavelength characteristics (below). Holds promise for expansion in heterogeneous technologies that maximally exploit the characteristics of differing materials, and parallel photonics technologies, which gather multiple functions into very small spaces.

Development of semiconductor quantum dot technologies for optical/high-frequency integrated access networks

In addition to improving temperature tolerance in opto-electronic devices, semiconductor quantum dot technology created from nanotechnology also exhibits characteristics essential for data communications such as ultra-wideband optical amplification and responsiveness that can handle high-speed data signals. Figure 3 illustrates a typical wavelength multiplexed optical communication path which introduces various devices that we have developed. The wide-band characteristics of quantum dot technology are important for wavelength multiplexed communication and for flexible network architectures. A variable wavelength light source with narrow line width, which operates over a wide band, is a very important component for coherent optical communications. Further, since individual quantum dots behave almost independently, for the most part, a light source able to emit multiple wavelengths at the same time could be created using a single quantum dot chip.

It has been difficult to produce multiple-wavelength emission using conventional technology, but this QD property can be used to develop light sources that emit two wavelengths at the same time. Thus, a quantum dot two-mode laser, with the difference between the two frequencies set to around 100 GHz, in the millimeter wave or THz band, could be used to transmit millimeter-wave and THz high-frequency signals by optical fiber (Figure 2). In this way, a two-mode light source can be used to distribute high-frequency wireless signals by optical fiber. We are also conducting R&D on ultra-high-speed semiconductor amplifiers able to handle 100 Gbps-class signals, compact monolithic integrated optical modulator devices, and fast-response, highly-sensitive opto-electric converters using quantum dots as the core material.

In our lab, we are developing quantum dot optical device technologies for the 1 μm band (Thousand band) and the 1.3 μm band (Original band), in addition to the 1.55 μm communication band, and we expect to be able to use new wavelengths such as the T and O bands for short and medium distance data communication, which is not strongly affected by optical fiber transmission losses. We are also pursuing R&D through collaboration among industry, academia, and government. Most of the quantum dot optical device technologies shown in Figure 3 are contributing to expanding industry and implementation in society through technology transfer.

Right material, right place: Multi-function integration through heterogeneous technology

An important mission of our laboratory is to integrate optical and high-frequency technologies, and to conduct research on compact, high-performance opto-electronic device platform technologies. Till now, individual devices such as lasers and optical amplifiers were created as separate modules, but parallel photonics will become mainstream going forward, with multiple devices collected into very small spaces, arranged and operated in parallel to realize advanced functionality and high capacity communication. To begin achieving this through collaboration between academia and government, we have developed a quantum dot variable-wavelength light source reduced to the size of a grain of rice, compared to earlier devices which were hand-held size. The key developments here were use of a highly accurate silicon photonics processing technology for the wavelength selection structure, and use of quantum dot technology for an optical amplifier with wideband characteristics. In other words, we have established a heterogeneous technology that uses the right materials for the right purposes, drawing out the optimal characteristics from the materials and structure, and have used it to develop a wideband variable wavelength light source. We have verified that, although it is only several millimeters in size, the device is able to change frequency freely over a very wide bandwidth. We expect to expand this bandwidth and increase power output even further through various optimization experiments in the future.

Integrated optoelectronics platform for parallel photonics

Parallel photonics technology, which concentrates multiple functions into small spaces and uses them to build efficient networks, will be a platform for implementing compact transmitter and receiver devices in the future. It will be important to integrate optical and high frequency technologies within devices for parallel photonics, and to incorporate heterogeneous technologies that actively maximize use of the optical and electrical characteristics of different materials (Figure 4). The parallel photonics concept is a platform for integrated opto-electric device technology. It is expected to be fundamental to high-capacity data communications and many other technical fields, such as sensing and medicine, in the future.

Research and development of high speed photonics devices for access networks

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Dr. Toshimasa UMEZAWA received B.E. and M.E. degrees in electronics in 1984 and 1986, respectively. From 1987 to 2011, he was at Yokogawa Electric Corporation, and was a Visiting Scholar in the Department of Applied Physics, Stanford University. In 2011, he joined NICT. His current research interests are E/O devices, photonic integrated circuits, and millimeter-wave photonics. Ph.D.(Engineering)

The NICT Network System Research Institute conducts a broad range of research, mainly on photonics technologies, from the physical to higher layers. In this article, we introduce some of this research on high speed photonic devices for optical fiber wired/wireless communication being done in the Network Science and Convergence Device Technology Laboratory, including opto-electronic integrated devices and parallel photonics research, as well as R&D on optical devices for a high-speed mobile backbone technology using the millimeter-wave band.

Research on opto-electronic integrated devices

Radio over Fiber (RoF) technology for optical access systems is expected to play an important role in the future, and data transmission exceeding 100 Gbps over a single fiber is already possible in fixed fiber communication. For this reason, one desirable system would be to bring signals close to user end-points using high-speed optical cables, and thereafter use wireless distribution with simple, low-cost remote antenna units. Optical transmitters and receivers play a major role in this RoF technology, and NICT is researching high-speed millimeter-wave opto-electronic devices for development of optical access systems.

Many high-speed transmitters and receivers for optical communication have been reported, but few devices have been developed with both high efficiency and high output in high-frequency bands over 100 GHz. We have developed high-speed photodetectors operating over 100 GHz using InP materials with high electron mobility. These devices employ a structure separating the photo-absorption process from the electron drift process, which does not produce holes after photo-absorption. Also, by using special conditions in the semiconductor thin-film layer, we succeeded in achieving greater than 100 GHz bandwidth even under unbiased conditions. We also advanced integration of a high-speed photodetector with a high speed high-electron-mobility-transistor amplifier circuit to increase conversion efficiency from optical input to radio signal output over 100 GHz (Figure 1, 2). Besides communications applications, these technologies can be applied for airport runway radar alert systems. We plan to continue work improving output and efficiency in the future.

Research on parallel photonics (parallel opto-electronic circuit integration)

Mobile and optical communication traffic continues to increase each year, and there is ongoing research on technologies to deal with it, including wavelength multiplexing techniques, multi-value modulation techniques such as PAM and QAM, and spatial multiplexing techniques such as multi-core and multi-mode fiber. As a result, spectral efficiencies exceeding 6 bit/s/Hz on a single optical fiber have

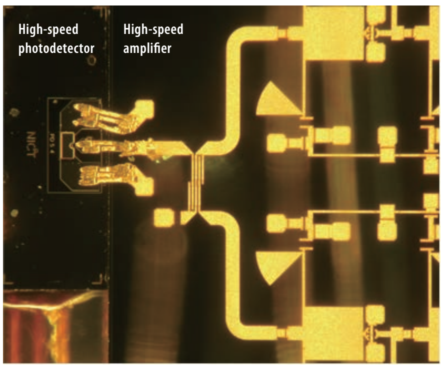


Figure 1 Integration of ultra-high-speed opto-electronics

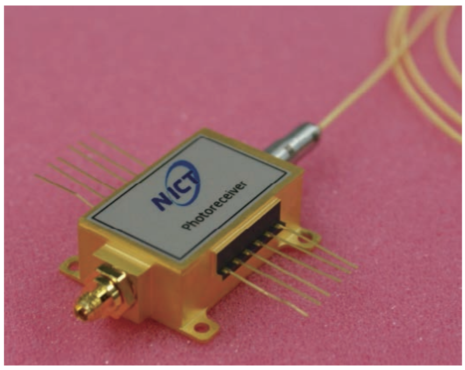


Figure 2 Integrated opto-electronic module (photo-receiver)

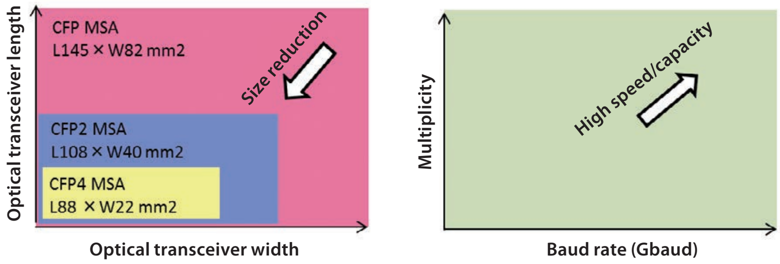


Figure 3 Trends in optical transceiver size (left), trends in optical communication speed (right)

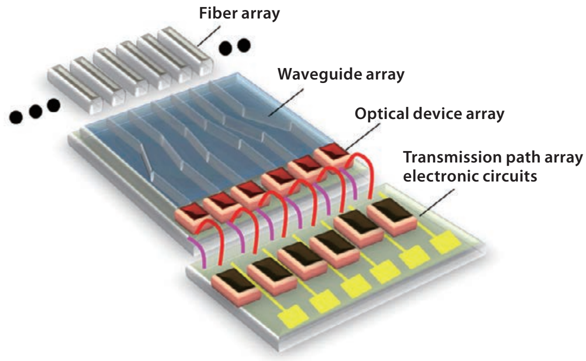


Figure 4 Schematic view of high-density opto-electronic integration

been reported recently, and with it, research on peta-byte-class optical transmission is being done, with spatial multiplexing techniques also being employed. In hardware, demand for further size and power reductions will continue, and reduction of transceiver sizes by approximately 80% compared to current ones will be needed (Figure 3). As such, highly integrated, compact optical and electrical circuits will also be needed.

To keep error rates low when designing devices for multi-level QAM and other high-spectral-efficiency modulation, electrical cross-talk had to be considered. Similarly, we predict both optical and electrical cross-talk will need to be considered with highly integrated opto-electrical circuits, as symbol rates increase. In recent research on optical device integration, there has been research on optical and electrical circuit integration using compound and Si semiconductor technology as a base. As modulation multiplicity increases in future circuits, we expect device design will also need to be resistant to cross-talk (Figure 4, 5).

We have clarified this issue, and reported on ways to reduce electrical cross-talk, such as establishing an air layer next to an optical waveguide, at international conferences. In the future, we plan to design and test opto-electronic circuits on a small scale and experimentally check for issues with parallel opto-electronic circuits.

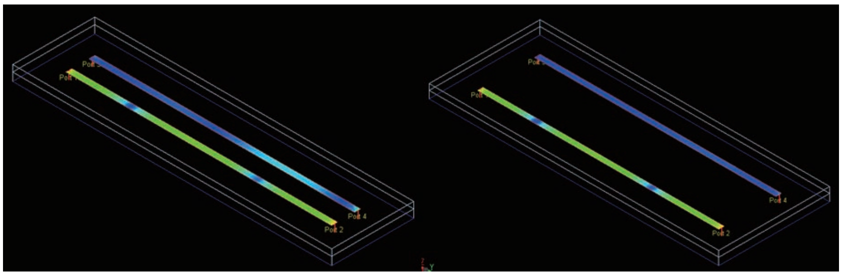


Figure 5 Simulation of electrical cross-talk between high-frequency transmission lines (Left: densely placed lines. Right: less densely placed lines. More electrical cross-talk is seen for densely placed lines.)

High-speed mobile backhaul technology R&D using the millimeter-wave band

On high-speed railways, some 1,000 passengers can be travelling together on a high speed train, so public networks have difficulty providing them with satisfying connection speeds using their existing mobile communication systems. The need for a stable broadband environment on high-speed trains is expected to increase, so we are researching platform technologies to implement broadband connections for high-speed vehicles, combining the existing optical fiber network installed along the railway with 90 GHz millimeter-wave band radio resources that have excellent directivity and bandwidth (Figure 6).

Specifically, to implement high-speed communication in trains travelling at over 200 km/h required research on RoF technology, development of optical-to-electrical conversion technology, and research on technologies for high-capacity multi-value decoding and optical signal distribution networks. For high-performance optical modulation technology in particular, we are researching integration of opto-electronic devices with high-speed electrical devices, optical-optical integration technologies with devices such as optical amplifiers and photoreceiver, and integration with Si photonics circuits (a part of this research is conducted under contract with the Ministry of Internal Affairs and Communications).

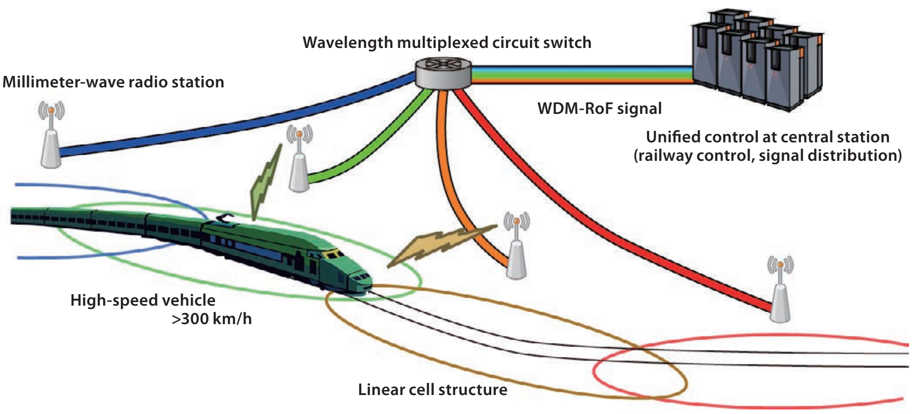
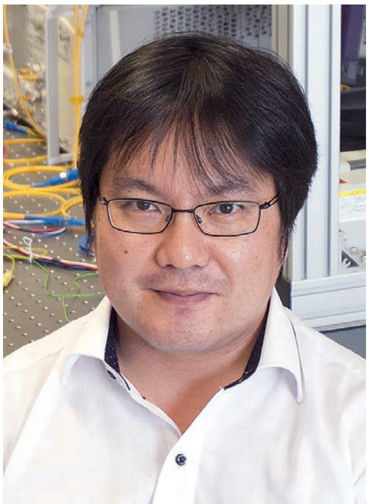


Figure 6 Conceptual diagram of backhaul technology for high-speed mobile communications using the millimeter-wave band

Transparent waveform transport technology

Future optical access network technology for seamless convergence of wired and wireless systems



Atsushi KANNO
Senior Researcher
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After joining the Institute of Science and Engineering at university as a postdoctoral fellow, he joined NICT in 2007. He has conducted research in areas of high-speed optical modulation, millimeter-wave and terahertz-wave radio over fiber technologies for communication and imaging. Ph. D. (Science).

Use of both optical fiber connections to homes and mobile communications such as 4G, as ways of connecting to the Internet, is spreading and both wired and wireless technologies are implementing broadband connections exceeding 100 Mbps. Furthermore, new communication technologies for convergence of wired and wireless communication are needed to implement networks that are easy to use and resilient to disasters. NICT is further developing optical fiber communication technology for high-speed communication as well as realization of seamless connection between wired (optical fiber) and wireless networks using Radio over Fiber (RoF) technology.

Seamless transport of wired and wireless waveforms

Generally, the signal formats for optical fiber communication and wireless communication are completely different. Wireless communication systems emit radio waves into public space, so they must suppress interference with other radio systems, and the bandwidth they can use is several GHz at most. On the other hand, optical signals are confined to the optical fiber in optical fiber communication, so there is no concern for interference on other systems, and bandwidths over 10 GHz can be used. Therefore, simple modulation schemes (on-off keying, etc.) that are fast but have low spectral efficiency have been used in optical fiber communication. Recent demands to increase transmission capacity require an increase of spectral efficiency even in optical fiber communication. This means that the signal waveforms for optical fiber communication are becoming more similar to those used in wireless communication. The latest optical fiber communication technologies are implementing the multi-level modulation schemes similar to schemes used in wireless communication, and thus, it is now possible to directly generate radio-quality/radio-friendly signals using optical technologies. Advanced photomixing technology helps realize direct conversion from optical to wireless signals. In other words, "Waveform transport" technology that can deliver signal waveforms without regard to the transmission medium, whether wired or wireless, by generating, transporting, converting, and receiving wireless signals using optical technology, has been realized.

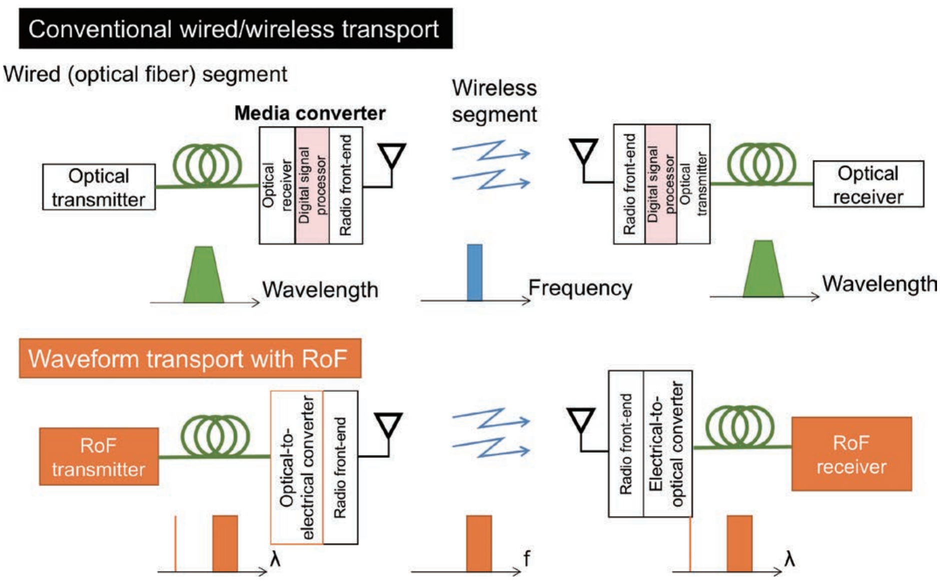


Figure 1 **Differences between conventional transport, converting signals between wired (optical fiber) and wireless, and waveform transport. Digital signal processing in the media converter is excluded, and the waveform itself is transported end-to-end**

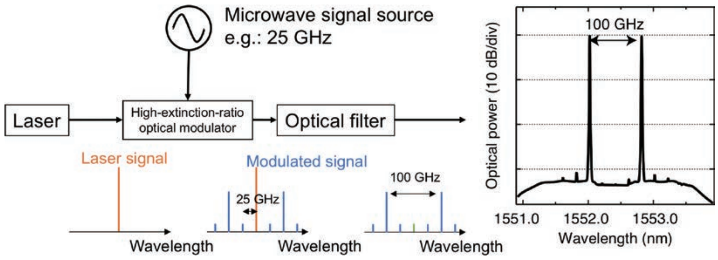


Figure 2 Generation of an optical two-tone signal with a frequency separation of 100 GHz using a high-precision optical modulator

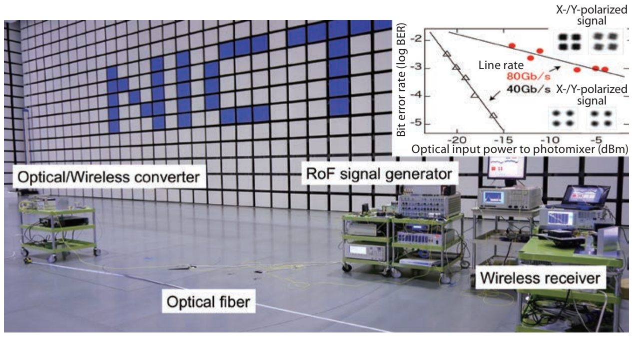


Figure 3 Ultra-high-speed RoF signal transmission using seamless optical/wireless convergence technology and an example of bit-error rates obtained

This is called Radio over Fiber (RoF) technology (Figure 1). High-frequency and broadband signals, which could not be delivered easily by only electronics and wireless technology, can now be transported by the fundamental broadband nature of optical signals.

Wired/wireless seamless convergence using waveform transport technology

The RoF signal generated by an optical transmitter can also be used for a wireless transmission using waveform transport technology. NICT is developing a fiber-wireless system using the millimeter-wave band for high-speed wireless communication directly connected to an optical fiber network. The key technologies are a two-tone optical signal generator to generate the millimeter-wave signal using optical technology, an optical multi-level modulator to encode data on the optical signal, a photomixer that converts the optical signal into a millimeter-wave signal, and a universal reception/demodulation algorithm for receiving and demodulating the signal, whether wired (optical fiber) or wireless. The optical two-tone signal generator is implemented using high-precision optical modulation technology, which provides a stable signal with low frequency fluctuation (Figure 2). The signal generation technique is also used for standard signal sources in radio astronomy and other fields. The universal receiver algorithm implements both optical and millimeter-wave wireless signal demodulation by using broadband coherent detection techniques, which are adopted from an advanced optical fiber communication technology. Using millimeter-wave band MIMO technology with waveform transport, we have achieved signal transmission at over 50 Gbps on the millimeter-wave wireless segment (Figure 3). We hope to realize wireless communication exceeding 100 Gbps, as is achieved with optical fiber communication, through this waveform transport technology.

Millimeter-wave sensing using waveform transport based on an RoF network

RoF signals can be used to distribute any radio signal over an optical fiber network. For example, a possible application is to transport precise signals such as radar signal from central office to remote radar terminals using an optical fiber network. In conventional radar systems, each radar head is equipped with a high-precision signal generator to make precision measurements. This raises cost, energy consumption and footprint issues, making it difficult to implement distributed radar systems with many radar heads. Of course, to detect small objects, short-wavelength (high frequency) radar signals must be used, such as millimeter-wave-band signals. However, millimeter-wave signals are attenuated quickly in the atmosphere and cannot propagate as far as the microwave-band signals used in mobile communication, so a larger number of remote transceivers are needed to survey a large area. In this scenario, waveform transport technology is useful to transport millimeter-wave radar signals to the radar heads. The cost of a remote radar head can be reduced greatly by using an RoF network to deliver precise signals from signal generators to multiple transceivers at remote locations. A high-precision radar system is also feasible by using precise radar signal generator equipment in a central office. A 96-GHz-band millimeter-wave radar system connected by an RoF network and using high-precision optical modulation technology developed by NICT is currently being tested in collaboration with other research institutes, in practical testing of a foreign object debris detection system for airport runways.

Communication without regard to the medium

In future society with the network connection speeds exceeding 1 Gbps, users will connect to networks anytime and anywhere, without selecting a connection technique whether wired or wireless; it will not be necessary to inform the users of the connection medium. Waveform transport technology, which implements seamless convergence in the physical layer, can be applied to next-generation ultra-high-speed communication, and also imaging technologies for implementing safety and security, radio astronomy, and big-science infrastructure (Figure 4). We will continue to advance R&D, actively collaborating with various domestic and international research institutes and enterprises.

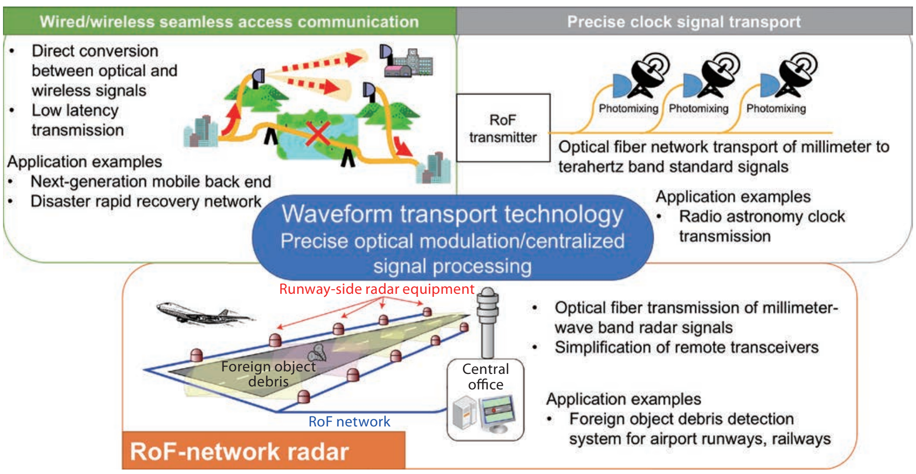
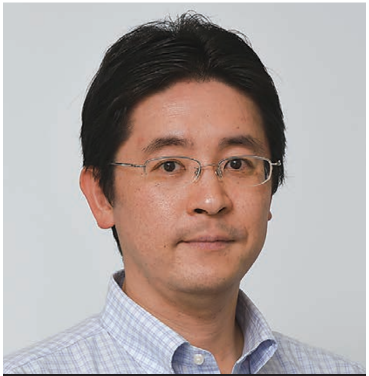


Figure 4 Application fields for waveform transport technology

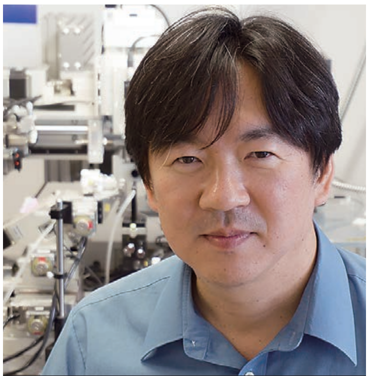
Standardization activities on "Radio over Fiber"

Toward the realization of a bridge linking radio and optical communication systems



Toshiaki KURI
Chief Planning Manager, Strategic Planning Office, Strategic Planning Department / Research Manager, Network Science and Convergence Device Technology Laboratory, Network System Research Institute

After completing a doctoral course, Kuri joined the Communications Research Laboratory (currently NICT) in 1996. He engages in research including radio-over-fiber systems and optical communication systems. Ph.D. (Engineering).



Tetsuya KAWANISHI
Research Executive Director, Network System Research Institute

After completing a doctoral course and working as a research fellow at Kyoto University Venture Business Laboratory, Kawanishi joined Communications Research Laboratory (currently NICT) in 1998. He engages in research including optical modulation devices, millimeter-wave/microwave photonics, and high-speed optical transmission technology. In 2004, he was a visiting researcher at University of California, San Diego. In 2015, he joined the Faculty of Science and Engineering, Waseda University. He has been named an IEEE Elevated Fellow. Ph.D. (Engineering).

Radio over fiber is becoming more important around the world, bridging the gap between wireless and wired communication systems and showing promise for use in 5G wireless communication systems, IoT, and M2M technologies. This article introduces Network System Research Institute activities with the ITU-T, the IEC, and the ASTAP on international standardization of radio over fiber implementations.

What is "Radio over Fiber" ?

Today, wireless communication terminals such as smartphones and tablets are common, so even when away from home or office, access to Internet services is available. The radio waves used for such wireless communication spread in three dimensions through space, but become weaker with propagation distance. Also, for the data to be received correctly, the signal must be stronger than a certain level, depending on the surrounding conditions. Generally with telecommunications, data is transported with the propagation of electrical energy, so to improve wireless services and transmit more information during the same amount of time, either stronger radio waves must be emitted from the antenna, or the distance between the user's terminal and the telecommunications carrier's wireless equipment (the service area) must be reduced. The battery life of wireless terminals is limited, so reducing the size of the service area is a good option, but it also requires the telecommunications carrier to install more equipment. One possible solution to this is to gather the main part of the equipment that creates the radio signals in one location, and to place only the antenna part, which emits the signals into space, near the users (Figure 1). Radio over fiber technology can be used for this. An electrical-to-optical converter generates an optical signal containing the radio-wave information created by the main wireless unit, this optical signal is transmitted to the antenna over an optical fiber having extremely low attenuation, and the

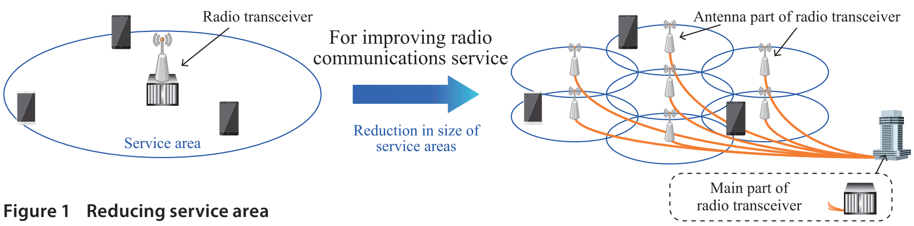


Figure 1 Reducing service area

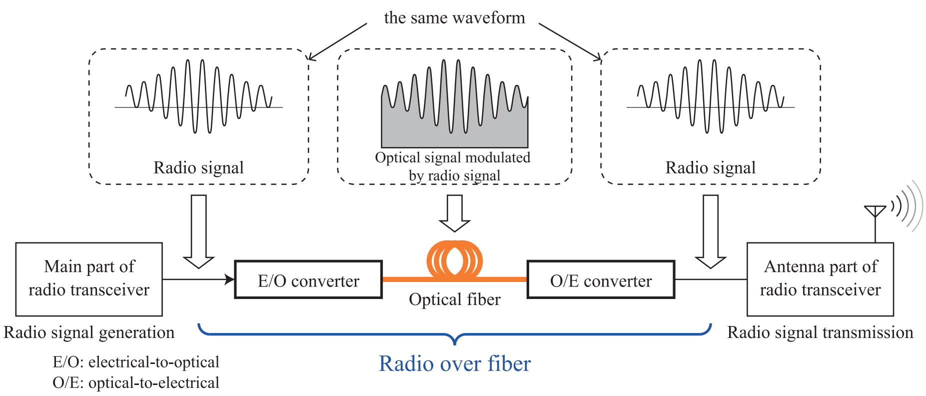


Figure 2 Overview of radio over fiber

signal is recovered at the destination using an optical-to-electrical converter (Figure 2). This technology is already used for mobile phones and terrestrial digital television broadcasting systems to cover areas where the signals do not easily reach, such as tunnels, underground shopping centers, mountainous areas, and the upper floors of tall buildings (See NICT News 2013 No. 9, pp. 5-6).

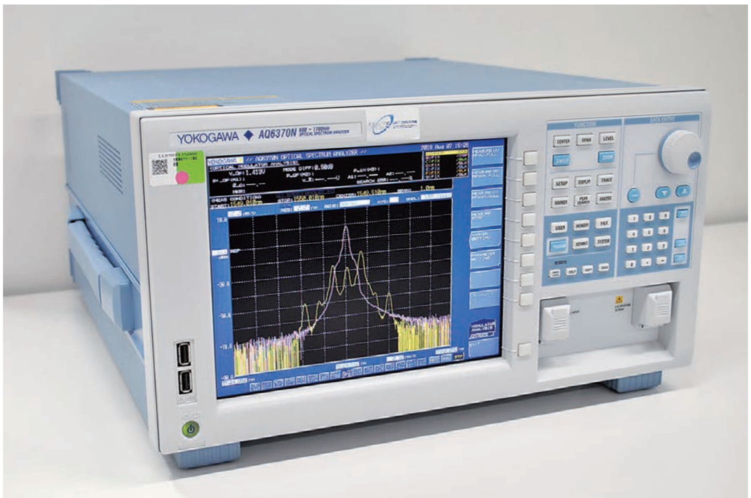


Figure 3 Instrument for measuring optical modulator characteristics

Standardization activity regarding radio over fiber at the ITU-T

To improve future wireless communication services, the International Telecommunications Union, Telecommunication Sector (ITU-T) has been conducting standardization activities regarding radio over fiber. When this activity started, access networks were thought to be a suitable application for fiber over radio, so they were targeted by a group handling optical systems for fiber access networks (hereinafter, Q2/15). In February 2013, the first contribution for radio over fiber, including analog technologies, was proposed. However, most discussions on optical access networks at the time assumed digital transport, so the idea of radio over fiber was not understood adequately, and agreement on the proposal could not be reached. So, to build understanding of radio over fiber, at the Q2/15 meeting in May 2013, we proposed that work begin on supporting documents related to radio over fiber, outlining radio over fiber technology and organizing technology categories and elements, with the goal of creating a common awareness. This proposal was agreed upon at the meeting, and officially accepted at the ITU-T SG15 plenary meeting in July 2013. Thereafter, the proposal and agreements were followed, and after approximately two years of work, the Supplement 55 to ITU-T G-Series Recommendations (hereinafter, G Suppl. 55) entitled "Radio-over-fibre (RoF) technologies and their applications" was formally accepted at the ITU-T SG15 plenary meeting in July 2015. At this same meeting, with the acceptance of G Suppl. 55, it was also agreed to begin work on new standards for radio-over-fiber systems, and discussion of radio-over-fiber standardization is being continued.

Activities within ITU are clearly divided into roles, with ITU-T handling wired communication, and the Radiocommunication sector (ITU-R) handling wireless communication. With the events above, ITU-T began standardization activities deeply related to wireless communication, signifying a new direction unifying the fields of wired and wireless communication.

Standardization activity regarding radio over fiber at the IEC and ASTAP

Prior to the activities at ITU-T, there were on-going standardization activities related to radio over fiber in the International Electrotechnical Commission (IEC) and the Asia-Pacific Telecommunity (APT) Standardization Program (ASTAP). The IEC is conducting standardization on measurement technologies necessary to evaluate devices used in systems with radio over fiber. For example, they are working on international standards for evaluating characteristics of optical modulators and photo-detectors for converting between electrical and optical signals. An international standard for technology to measure photodetectors using optical reference signals, which is based on NICT intellectual property, was issued in July 2016. We are transferring measurement technology based on these standards (See Figure 3) and working on both systems and technology to implement radio over fiber in society. ASTAP is conducting standardization on system architecture technology needed from a systems perspective. With IoT and M2M communication playing a major role in future access systems, high capacity communication will be needed in various locations and environments beyond urban areas and near major roadways. Even within Japan, judging from the service areas published by each of the telecommunications carriers, it is clear that existing networks are inadequate in terms of covering land area. Furthermore, a scheme working from the basic research stages will be more effective if it considers business in all of Asia in terms of the global market, and does not focus only on Japan's needs. NICT is promoting and conducting joint research on access network technologies under a research support scheme called the ICT Virtual Organization of ASEAN Institutes and NICT (ASEAN IVO). We are collaborating on standardization, discussing technical development with consideration of various natural and societal environments. We have made great contributions creating technical documents related to systems integrating wired and wireless technologies, and these documents have been reflected in establishing ITU-T Recommendation G Suppl. 55, as mentioned above.

Building on these activities, we believe that the importance of radio over fiber will continue to increase internationally as a technical element supporting future wireless communication networks.

Success in building networks with microtubule-protein motor interactions and modeling them mathematically

The research group composed of Distinguished Researcher Dr. Kazuhiro Oiwa and Researcher Dr. Takayuki Torisawa, from NICT's Advanced ICT Research Institute, as well as Associate Professor Shuji Ishihara and Researcher Daisuke Taniguchi, from Meiji University School of Science and Technology, has quantified the behavior of microtubules and kinesin motor proteins forming self-organizing networks and successfully modeled it mathematically. This result was reported in the July 26, 2016 issue of "Biophysical Journal" (digital edition published at noon, EST on Tuesday, July 26) and was featured on the cover.

Microtubules and kinesin are a major skeletal component of cells that are fundamental to important life functions such as cell shape formation, cell division, and intracellular transport. Building a system to observe operation of these networks and establishing theoretical models hold great promise for understanding the mechanisms by which the ordered structures appearing in living phenomena are formed, and for technology to manipulate such structures.

* This research was conducted under a strategic team research program (CREST) of the Japan Science and Technology Agency (JST) in the research area "Creation of Fundamental Technologies for Understanding and Control of Biosystem Dynamics," on the topic, "Understanding mechanisms of orderly formation of cell structure and adhesion, and developing technology to manipulate the epithelial barrier" (Research representative: Sachiko Tsukita).

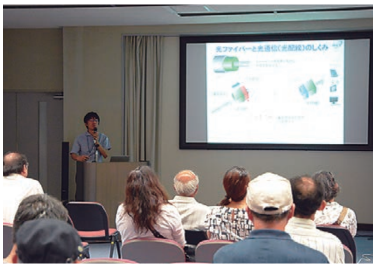
Cover photo from the July 26, 2016 issue of "Biophysical Journal"
Network structure created with microtubules and kinesin. Kinesin accumulates in the center of the aster.

Advanced ICT Research Institute Open House

Experience the future of information and communications!!

The Advanced ICT Research Institute (Kobe City) held an open house on July 23, with 524 visitors attending. Visitors participated in the quiz rally, which is popular every year. They enjoyed various exhibition booths and some were provided with experimental tours organized by researchers.

In addition, the ninth public lecture was presented, explaining some of the latest research using simplified examples. It was a great success with hardly an empty seat.



Lecture

Experiencing polarized light by making a sparkly kaleidoscope

Kashima Space Technology Center Open House

Connecting the earth and space with radio and satellites!

NICT held an open house at the Kashima Space Technology Center (Kashima City, Ibaraki Prefecture) on July 30, 2016, with 806 visitors attending.

The event introduced technologies in simple terms, such as satellite communications using radio and light, and VLBI research. In particular, there were hands-on exhibits that attracted the interest of visitors, including a workshop for making an FM-radio by hand, video telephony by satellite (WINDS), and using an optical telescope and broadcast satellite antenna.

Experiencing aiming an optical telescope (toward an optical communications satellite)

BS capture contest (aiming an antenna by hand, toward a broadcast satellite to receive the signal)

Awards

The ITU Association of Japan Special Achievement Award is given to persons with particularly outstanding achievement, contributing widely to society in fields of information and communications, broadcasting, and international cooperation around the world. A Japan Federation of Engineering Societies Fellowship is conferred upon individuals that have outstanding achievement in the fields of engineering and industry, and have broad experience and recognition in engineering. The "Advanced Technology" Award was set up in 1986 by Fuji Sankei Business i. The award was established to support young researchers in the advanced technology field with the aim of increasing their motivation for research and encouraging creativity.

The ITU Association of Japan

2016 ITU-AJ Award Special Achievement Award

The Japan Federation of Engineering Societies

JFES Fellow

Miwako DOI

Auditor

Comment from the recipient [ITU-AJ Special Achievement Award]

I am extremely honored to receive an award as prestigious as the ITU-AJ Special Achievement Award. The fact that the previous recipient was Ms. Cristel Takigawa prompted my family to take a bit more notice too (smile).

I also had the opportunity to develop many products that were industry firsts in the field of human interfaces, which studies making computers user-friendly, such as ekita.com, a pedestrian navigation service for mobile phones, and also to participate in ITU-T standardization for network robots. To receive this Special Award has been owing to the strong encouragement from the many who supported me. For this I offer my sincere thanks.

data

- Date: May 17, 2016
- Description: A leader without precedent among women technologists, who deserves special mention, having worked on many "firsts" and encouraged many of her juniors (excerpt).

Comment from the recipient [JFES Fellow]

I received this recommendation from the Information Processing Society for many years of research in the field of human interfaces, and for many notable accomplishments. I am very thankful for this recognition of my work as a leading woman technologist in the field of information processing, across industry, academia, and government, including as a member of the Science Council of Japan, the MIC Information and Communications Council, the MIC Evaluation Committee for Independent Administrative Institutions, the MEXT Council for University Chartering and School Corporations, University Chartering branch, the MEXT Council for Science and Technology and others.

data

- Date: June 3, 2016
- Description: The Fellow designation recognizes very remarkable achievements in the fields of engineering and manufacturing.

Fuji Sankei Business i

The Special Award at the 30th Ceremony for "The Advanced Technology Award" in the Business and Industry Category

Ben PUTTNAM*
Ruben SOARES LUIS*
Werner KLAUS*
Jun SAKAGUCHI*
Jose Manuel DELGADO MENDINUETA*
Yoshinari AWAJI**

Photonic Network System Laboratory, Network System Research Institute

* Senior Researcher ** Research Manager

Naoya WADA

Director General, Network System Research Institute

↑Group photo of recipients (Puttnam is on the right in the back) [Photo provided by Sankei Shimbun Group]

Reception (From the right: Puttnam, Her Imperial Highness Princess Takamodo, Delgado Mendinueta, Awaji) [Photo provided by Sankei Shimbun Group] ↓

Comment from the recipients

It is a great honor for our team to receive this award. This work is a result of team work among our international team members together with Japanese and international industrial collaborators. We are grateful for strong support received and we hope to further improve our ability to meet the challenges of increasing optical data transmission, supporting the development of society.

data

- Date: July 28, 2016
- Description: Ultra-large capacity optical transmission system based on multi-core fiber and optical frequency comb —Toward future optical networks—

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