R&D Spirits

Pursuing the Limits of Measurement Technology for the 40-Gbit/s Optical Network Era

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NTT Access Network Service Systems Laboratories is researching and developing optical-line measurement technology to achieve smooth and efficient operations and quality control in ultrahigh-speed optical fiber networks. We asked Senior Researcher and Group Leader Fumihiko Ito to tell us how optical communications in the 40-Gbit/s era can be supported and what technologies will be necessary to provide that support.

Development of signal measurement technology in response to faster optical networks

—Dr. Ito, please tell us about your current research theme.

Transmission rates as high as 10 Gbit/s are now being achieved, and we expect next-generation networks to operate at the 40-Gbit/s level. At that level, it will no longer be possible to detect the optical signals traveling through fiber cables by electrical means. Against this background, our research group is undertaking the development of high-performance and high-sensitivity tools for next-generation networks. Our present work is mainly devoted to the development of an oscilloscope that can handle 40-Gbit/s optical signals. We are also researching an optical time domain reflectometer (OTDR) for determining the location of an optical fiber's fracture plane, but we are not yet at a stage where we can formally present this product. I'd like to point out here that the research of our group is future oriented compared with other areas of the Access Network Service Systems Laboratories. We are free to pursue new ideas outside the present framework. The members of this group, by the way, are all young researchers, and my role as group leader is to put them on a path to full personal development with an eye to the future.

—Could you describe some technical features of your R&D?

I think the main technical feature is the use of linear sampling for our oscilloscope (**Fig. 1**). This method utilizes the optical interference phenomenon that occurs when a laser-generated sampling pulse is applied to an optical signal and measures signal amplitude using a semiconductor optical sensor in the detector. Another measurement system based on optical interference uses a nonlinear optical crystal in the detector, but that system, which has been known for some time, switches the light, causing interference with other light and resulting in insufficient sensitivity. Our method, in contrast, measures optical signals directly, resulting in an exceptionally sensitive system. We also use two channels to offset the time of sampling pulses so that the state of phase modulation can also be observed. These features are not possible in existing systems.

Another feature is the use of an optical 90° hybrid element in our prototype equipment (**Fig. 2**). Setting the relative optical path difference between channel 1 and 2 to be $\Delta\tau$ makes it possible to simultaneously measure the amplitude and phase of an interference pattern as opposed to simply generating interference in a plane. Optical 90° hybrid technology itself is well known and is not our original design, but we are the

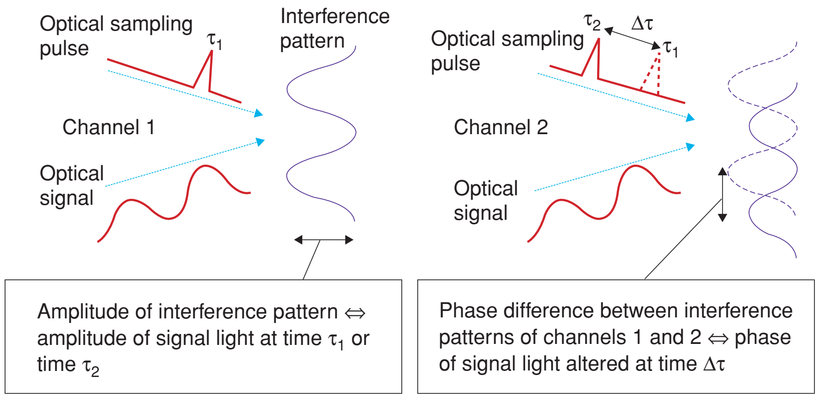

Fig. 1. Principle of linear optical sampling.

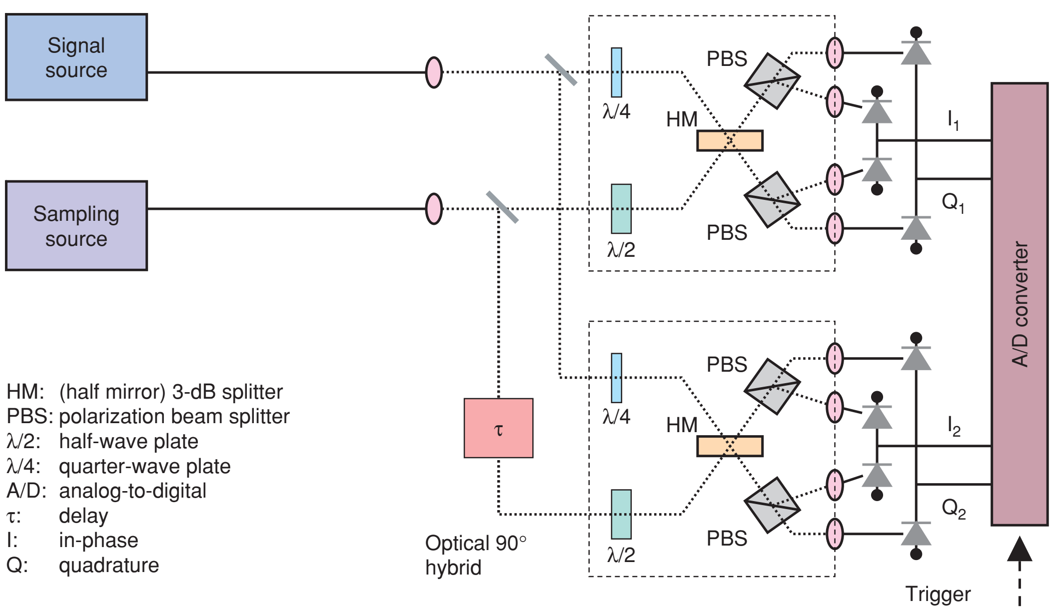

Fig. 2. Equipment configuration.

first to apply it to linear optical sampling.

—How do you think this research will contribute to NTT and society on the whole?

The most straightforward contribution will be the ability to quickly find the location of a fault that has occurred in the optical fiber network. This will obviously make network maintenance and management more efficient and reduce the cost of maintenance, but it will also help stabilize service quality. Optical-line measurement technology will also be indispensable for checking the performance of existing facilities and for assessing quality. Incidentally, phase modulation systems are slated to be the main kind of modulation for high-speed transmission at rates of 40 Gbit/s and higher, and for this reason, we believe that this technology in the form of a next-generation oscilloscope will be very influential.

—What is the current state of progress and what problems must be solved?

We have checked the validity of the basic principle

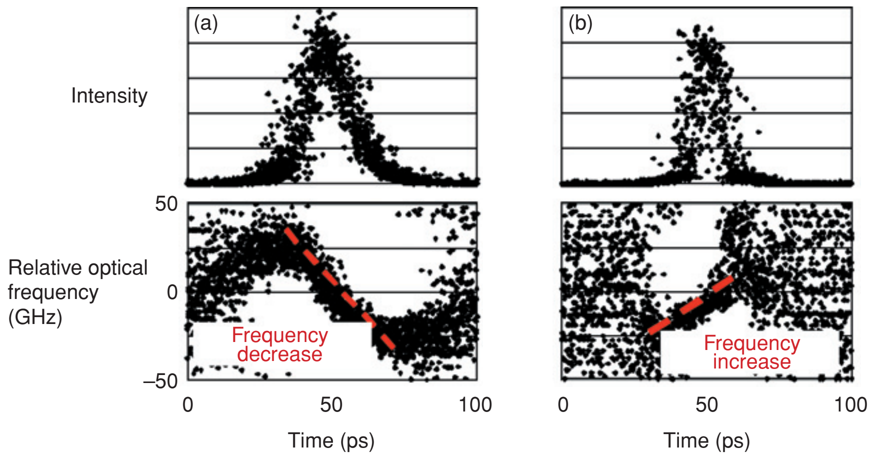

Fig. 3. Experimental results for linear optical sampling.

behind this technology and its general operation. We achieved a first by clearly determining how amplitude information and frequency change during the application of a pulse (**Fig. 3**). That was a big turning point for us.

At the same time, our R&D goal here is a practical, working system, but there are still a number of problems that must be solved before we get to that point. For example, there is the problem of transforming our experimental system into real equipment. Performing measurements with various components connected by fiber cords does not constitute the use of "equipment." Until these components are neatly installed in a cabinet and operating stably, we can't really call the system an "oscilloscope." I'm afraid that we are still two to three years away from that stage.

—How do you see this technology developing in the years to come?

Another factor in achieving a practical, working system is downsizing. Needless to say, the system must be as compact as possible if it is to be used as an effective tool. And still another factor is the development of applications. Various applications can be considered, but right now we are looking at the possibility of analyzing wavelength dispersion and polarization dispersion in detail by exploiting our measurement technology's key feature of allowing phase and amplitude to be observed simultaneously. Wavelength dispersion and polarization dispersion of an optical signal can only be understood by observing signal phase. And analyzing optical dispersion enables the user to not only assess the quality of signals traveling through an optical fiber cable, but also determine why a signal is bad and where the problem is located. This makes it easier to control quality and to pinpoint and correct a problem. I think that accumulating application examples like this one should lead to further development of our technology.

Taking on diverse themes through a foundation in optical communications technology

—Dr. Ito, what was your major as a university student and what motivated you to enter NTT Laboratories?

I was researching optical conducting devices using gallium arsenide (GaAs), and thinking that I wanted to research topics related to optics after entering the work force, I visited several corporate research laboratories including those of manufacturers and airlines. But the company that I thought had the most activity in this area was NTT. I also heard from a fellow student that NTT was a place where one could pursue long-term research without being pressured by corporate product strategies and other factors. In the end, I decided on NTT with no misgivings.

—What research themes have you been involved with at NTT up to now?

Immediately after entering NTT Laboratories, I was assigned to a group conducting research on transmission lines. As it turned out, this was a period in which the research on optical fiber cables was entering a mature stage, compelling NTT to look for the next research target. Consequently, as I was known to have been researching optical conducting devices, I was given the theme of researching optical switches that were to be incorporated into the network. Unfortunately, this research came to an end after three years.

I next took on technology related to optical computing, a big topic of discussion at that time, and researched, in particular, optical memory through the use of photoreactive crystals. A photoreactive crystal can act as a medium for storing the spatial information of light as a hologram by having two waves of light interfere with each other. My initial objective here was to apply this optical memory to image operations in optical computing. But eventually I came to feel that this was not something that could be easily achieved. Academically speaking, it was a topic that I found very interesting, and papers that I wrote on this subject were well received at academic societies. Nevertheless, I found that it was too difficult to achieve output in a useful form, and I decided to make a small change in my direction. Specifically, the idea came to me that I could use the same hologram to record the temporal waveform of light instead of a spatial image. If I could capture a signal having various frequencies that change over time and record in a photoreactive crystal the amplitude and phase corresponding to each frequency, I should be able to record not only two-dimensional image information but temporal changes as well. I was involved with this research from about 1990 to 1995, during which time I wrote many papers and even obtained a degree through them. It was also at this time that I first got the idea of applying the results of this research to sampling, which is what I am researching now.

After that, I left research for a four-year period starting in 1996 to work at the NTT main office on facility investment and a next-generation network vision. I returned to NTT Laboratories in 2000 and became involved in operations research with the aim of developing home network operations. Then, in 2004, NTT Laboratories announced a policy of focused research on optical measurement systems, and as I had experience in optical-interference research, I was appointed group leader in this area. And that brings me to the present.

—What has been your common goal in all of the research projects you've been involved with?

Whatever the theme, I always challenge myself to come up with something original on the basis of my own ideas. In today's research, there are very few examples of completely original work. Even though research work may take on various forms, there is usually one researcher who is out ahead of the others. The only way to outstrip those that have come before you is to establish originality. For this reason, I have always tried to incorporate my own ideas into my research endeavors.

Receiving high praise for original work in the world of optical communications technology research

—Dr. Ito, what are the R&D trends in interference-measurement technology in Japan and overseas?

Research and development in the field of optical interference measurement actually takes on various forms, but within this range, I think we can say that the optical sampling method is NTT-created technology. There are consequently no competitors at all in this regard, at least not at present. But in terms of applications, there are, I admit, competing research groups, which means that we cannot become overconfident in our achievements.

But if we look around with a broader perspective, one field that deserves attention is research into the characterization of laser pulses, which are the basis for the linear sampling method. Though this research is not in direct competition with our current research, both types of research deal with the universal phenomenon of optical interference. We are keeping a constant watch on this field. There is also much activity in detection technology, especially in the research on coherent detection. From the viewpoint of signal processing such as when making optical-dispersion guarantees, coherent detection enables phase to be observed just like the linear optical sampling method. This capability is prompting a reevaluation of this technology. There are research groups on coherent detection in Japanese universities, leading electrical-equipment makers, and elsewhere, and their knowledge has much in common with ours.

—What kind of reaction have you received at academic presentations and elsewhere?

I first presented a paper on measuring waveforms through the use of optical interference in the 1990s. After the presentation, a number of researchers came up to me saying things like "That was a wonderful presentation!" and generally praising my work. That was a happy occasion for me. Now, after about ten years of many twists and turns in my research, I have finally come to the point where I can make a contribution to society using the principle I introduced back then, and I feel even more emotion thinking back to that first presentation.

—How do you evaluate NTT based on your personal experiences?

Interference measurements and OTDR technology that I am now researching are part of the field of optical communications. NTT has a long history of optics-related research that has garnered much praise. For example, in terms of very fundamental technology, it was NTT Laboratories that proposed the manufacturing method for optical fiber. And in Japan, NTT Laboratories is unrivaled in transmission equipment that connects both ends of optical fiber. I don't think it would be an exaggeration to say that NTT built up Japan's optical-communications industry. In the future, I believe that our research will be part of the continuing growth in this industry.

—Are you involved in any collaborative research with other research institutions? How about international activities?

At present, we are not involved in any collaborative research either in Japan or overseas. But as for international activities, I am seeing to it that our group is actively involved in academic societies. I, personally, have not presented any papers over the last one or two years because I want as many young members in the group as possible to do this for me to get training as next-generation researchers. We are not involved in standardization activities at present.

Pursuing the limits of possibility as self-actualization while making a contribution to business and society

—Looking to the future, where do you think your R&D work is headed?

In terms of research on the whole, I would like to pursue the limits of possibility. In my current research using the linear optical sampling method, my ultimate objective is not to create a measuring instrument but to clarify the full potential of this system by determining how far measurements can be performed based on scientific principles. This holds true for OTDR as well. Of course, it is also important to produce results that are useful for NTT's business and for society, but if a system's potential can be understood, I believe that demands at the practical level can be efficiently met.

—What is your goal as a researcher?

First and foremost, I want to establish the technology related to my current area of research. Whether it be the linear sampling method or OTDR, I want to give concrete form to technology that will impact society to a degree that people will say that "the world with this technology is vastly different than the world without it."

Next, as another major objective, I want to actively develop next-generation researchers. Though this is just my personal opinion, there seem to have been fewer aggressive young researchers in recent years. One reason for this, I believe, is that since its privatization, NTT has been requiring even R&D to output immediate results in the face of a competitive market. At any rate, I sense a scaling back of true research. However, if NTT intends to continue its role as a leader of Japan's information-communications industry, young people that have a good understanding of communication and measurement systems and that can perform creative research will be indispensable.

—Then what would you say to young researchers?

When I was a young researcher, a more experienced member of the group that I belonged to would often recite interesting sayings. One was "when starting out on some research, everyone is a latecomer, and the only way to keep up or overtake the groups of researchers ahead of you is to have an original idea." He also said that "you should feel mortified if your superior, who is probably more inflexible than you, comes up with a good idea first" and "always endeavor to be original." These sayings reflect the free and broadminded culture of NTT Laboratories that motivates me to continue my research. I would ask all young researchers to keep these words in mind. Never be satisfied with the status quo and always keep moving forward!

—Dr. Ito, what is it like for you personally to work at NTT Laboratories?

It's an amazing place where you can do what has never been done before while also providing something very useful for society. Although a researcher should not be allowed to pursue research simply for self-satisfaction, NTT enables you to undertake relatively long-term research without being at the mercy of the company's business strategies. This may also be true at other research institutions, but I believe that this quality is particularly strong at NTT Laboratories. It's a unique environment where scientists and engineers can experience self-actualization.

Interviewee profile

■ Career highlights

Fumihiko Ito received the B.E. and Ph.D. degrees in electrical engineering from the University of Tokyo, Tokyo, in 1985 and 1999, respectively. Since joining NTT Ibaraki Electrical Communications Laboratories in 1985, he has been engaged in research on coherent optical signal processing for ultrafast communication. Since 2000, he has been in NTT Access Network Systems Laboratories and has worked in the field of ontology-based network operation. His current work is developing future optical measurement technology for fiber network management and evaluation.