R&D Spirits

Planar Lightwave Circuit Technology: The Key to Constructing Large-capacity Optical Networks

Yasufumi Yamada
Department Director
Design Department
Planar Lightwave Circuits Group
Photonics Business Group
NTT Electronics Corporation

As Fiber to the Home (FTTH) continues to expand, one promising approach to ensuring sufficient network transmission capacity is planar lightwave circuit (PLC) technology for fabricating optical integrated circuits. This technology is being developed by NTT Electronics Corporation (NEL), the major hardware manufacturer in the NTT Group. What features does NEL's PLC technology provide, and what strategy will NEL adopt to stay ahead of its competitors? We put these and other questions to Yasufumi Yamada, manager of the Planar Lightwave Circuits Group.

Keeping one step ahead of the competition through next-generation multifunction technologies

—Dr. Yamada, could you summarize your current R&D activities for us?

In the Planar Lightwave Circuits Group of NEL*, I manage the development and design of PLC products. "PLC" refers to optical circuits formed by depositing a film of silica glass on a silicon substrate and processing that layer to form optical waveguides. Today, as the move to FTTH progresses, it is becoming essential to ensure enough transmission capacity between offices to enable the processing of huge amounts of traffic. The key to achieving this is various types of wavelength-multiplexing products including optical power splitters, arrayed-waveguide-grating (AWG) optical multiplexers/demultiplexers, optical switches, variable optical attenuators, and optical couplers. In our group, we are working on PLCs from a total perspective, from establishing a technology platform for designing and manufacturing PLC products to devising cost-reduction measures and upgrade techniques.

—What is the current trend in PLC products and technology and what is NEL's approach?

To put it simply, there is a shift taking place from single-function products to multifunction products. At present, the current focus of the PLC business is on single-function products like optical splitters and AWGs. However, we are beginning to see the commercialization of multifunction products as next-generation products. I think that the PLC business will become centered on these multifunction products in about one or two years' time (**Figs. 1(a)** and **1(b)**). I also believe that this trend proves that the market for PLC products is growing. Up to now, NEL has shown considerable strength in achieving exceptional performance in individual products while also providing an extensive lineup of products. Our competitors, however, have recently begun to flex their muscles and competition is intensifying. We must find ways of differentiating NEL from its competitors, so we are focusing our energy on developing innovative multi-

* http://www.nel-world.com/

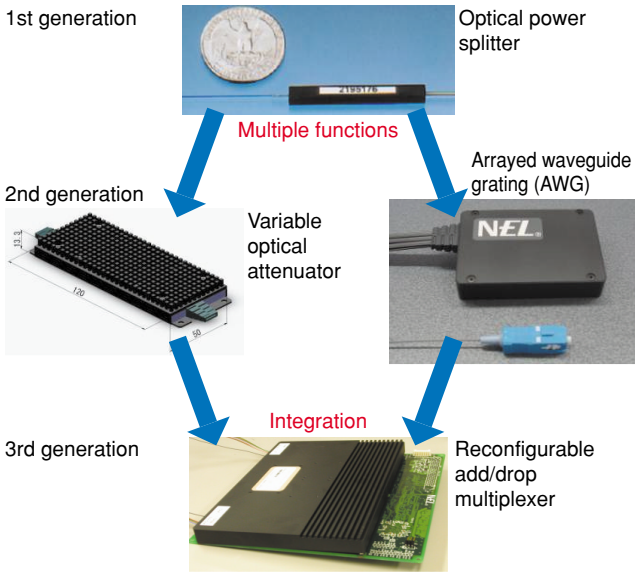
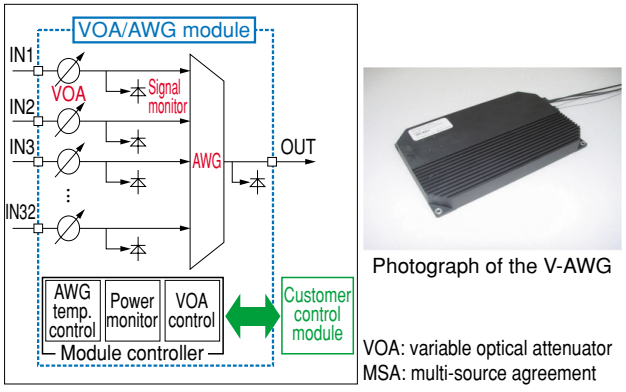


Fig. 1(a). PLC generations.



Photograph of the V-AWG

VOA: variable optical attenuator
MSA: multi-source agreement

Fig. 1(b). Example of 3rd-generation products. (MSA compatible V-AWG (VOA+AWG))

function products.

—What are some of the technical issues surrounding product development?

One thing that slows up the manufacturing of PLC products is the fiber connection process. In general, fibers can be connected by fusing, but connecting a cable having ten, twenty, or even more fibers can be extremely time-consuming since those fibers must be connected one at a time. Moreover, most of this work is done manually, so using a less costly labor force overseas is one obvious way for a company to differentiate itself in the PLC business. However, we feel that such an approach is unbecoming to NEL. We'd much rather find a technical solution to this problem.

One possibility here is optical wiring board technology that attempts to apply the same ideas behind an electrical wiring board to light. Another idea is to install a connector on the board to enable one-touch connection. Yet another is PLC direct-connection technology that I myself researched during my days at NTT Laboratories. This technology achieves fiberless connection using a PLC having a fairly complicated structure. In any case, taking the best technology from our research results at NEL and turning it into new products is a strong point of the NTT Group, which is known for its collective strength. Making use of this, I believe that we ourselves can create trends in technologies that we excel in.

—What lies ahead in your research?

Our main problems for the time being are how to create products with a stable level of quality using existing technology and how to create them at low cost. Then, once we have reached a certain level in this regard, our next task is to reduce the amount of manual labor that goes into PLC products, as I just mentioned. And while some areas of PLCs are still at the research stage, needs are growing, and we'd like to get our new products out the door in one to two years.

Maintaining top share through technical expertise and brand power

—What are other companies up to in regard to PLC technology and product development?

Despite the severe competition in the PLC business, I think it would be fair to say that NEL is strongest at this point in time. As I mentioned earlier, the main focus in terms of products is currently on AWGs and splitters. If we examine how the share for these two products breaks down among various manufacturers, we see that NEL has the top share in AWGs. As for splitters, we have yet to establish an overseas market

for these, but we are nevertheless shipping the most units at this time. Our competitors are quickly gaining on us, however, and we cannot rest on our laurels. In particular, a number of our rivals have reached a fairly high technical level in PLCs, and we are coming to compete with them head-on in terms of market share, technology, and price.

—How is NEL evaluated by users?

While it is true that NEL has brand power and that we were quick to market AWGs and to expand our share, I am proud of the fact that we have consistently been receiving high marks from users. But to maintain our reputation here, we must strive to develop new products and bring costs down. The front line of the PLC business is fast paced with endless worries and concerns, but all things considered I think I am enjoying this work more than when I was a researcher pursuing only technology. I now deal with issues more attuned to the real world like how to increase profit or how to lower product price. In pure research, it is difficult to appreciate how interesting this can be.

—Are you collaborating with any outside companies or research institutions?

Speaking just for myself, no, I am not collaborating with anyone at this time. But with regard to collaboration on PLC technology, another section in NEL is entering into multi-source agreements with a number of American and European companies. Their aim is to establish a *de facto* standard for multifunction products, but results have been slow in coming. The reason for desiring such a standard is that most large orders for PLC products have been for custom use. Some standard products are included in catalogs, but it has not been easy to get customers to use them. In the case of electronic circuit components, it has long been the practice in design work to use inexpensive standard products in large volumes whenever possible. But PLCs are not yet used in large volumes as packaged products, and this might be the reason for the lack of progress in establishing a *de facto* standard. On the other hand, some progress is being seen in the standardization of core-network products like splitters. For example, NEL began mass production of a 1×8 splitter ahead of its competitors, and the splitters of those companies are now modeled on our product in terms of dimensions, shape, and other attributes.

Pursuing optical integration technology from early days at NTT Laboratories

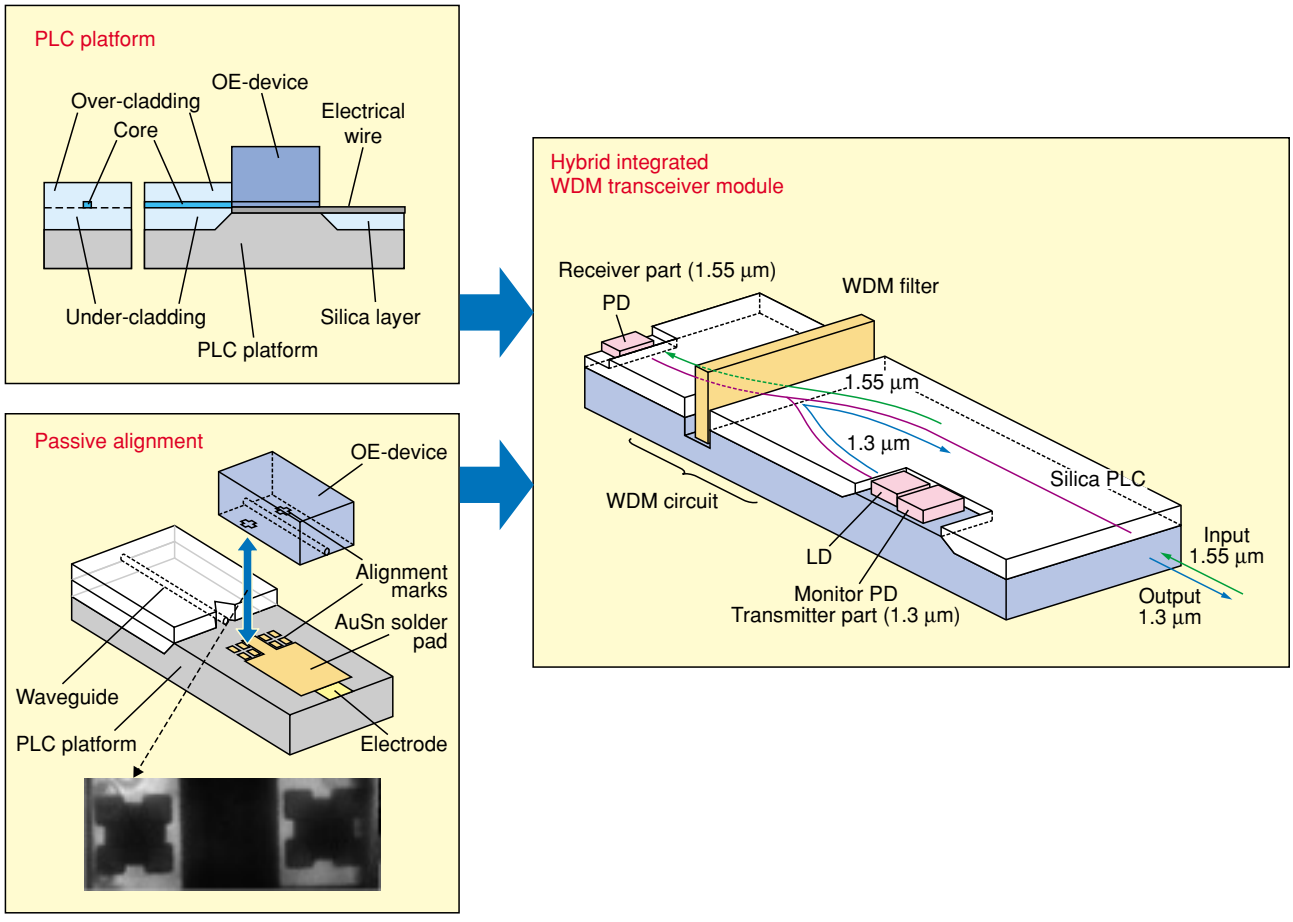
—Dr. Yamada, what was your major at university? Why did you enter NTT Laboratories?

At university, I majored in crystal physics in the department of applied physics and researched the structure and characteristics of various types of transparent crystals by optical means. I have therefore had some association with optical fiber since those early days. But what really got me interested in this field was a set of articles that appeared in a newspaper while I was on my master's course. It introduced to me trailblazing research on optical fiber and lasers in relation to optical communications. I found this subject immensely appealing and thought that I too would like to pursue this kind of research. I then read that this research was being conducted at none other than Nippon Telegraph and Telephone Corporation, the forerunner of NTT. Therefore, an absolute condition for me to pursue optics-related research was to enter NTT Laboratories.

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

I am happy to say that for a 22-year period beginning during my time at NTT Laboratories and running to the present, my only research theme has been optical integration technology. Although I researched non-PLC material in 1982, the year I entered NTT Laboratories, I got started in research on silica-based PLC in the following year. At first, I researched the fabrication of optical waveguides by the microprocessing of a layer of silica glass deposited on a silicon substrate. Although there had already been about two years of research in this area, nobody knew whether PLC technology would amount to anything. Our group consisted of only three people, but we were nevertheless able to fabricate prototype devices that could demonstrate the basic functions of optical splitting/coupling, wavelength adding/dropping, and switching, for example.

We then wondered where we could go from there, and in 1986, our group started to expand significantly with research divided into two main topics. One was waveguides and associated performance and the other was hybrid products. At that time, I became interested in ways of combining multiple functions, and I consequently started researching hybrid integrated platform technology. The idea here was to



OE: opto-electronic

Fig. 2. Hybrid PLC technique.

mount a semiconductor laser or other device directly on top of a silica-based PLC. Unfortunately, we were not able to form a base surface with a highly precise height on top of a PLC while making high-quality waveguides at the same time, and our research was suspended before a practical product was achieved.

Later, around 1993, when NTT decided to pursue true FTTH, the need was seen for components such as splitters and optical transceiver modules for laying optical fiber up to individual homes. This time, the decision was made to actively develop fabrication technology for hybrid PLCs and to develop business for them (**Fig. 2**). Once a practical optical transceiver module was achieved, it was transferred from NTT Laboratories to NEL. But even after five years of sales, the cost performance of this product was not as good as expected, and its manufacture was discontinued in 2002. As a result, nothing remains of my research results in any tangible form. Nevertheless, despite many twists and turns, I am now back to researching and developing the same theme that I have been involved with since entering NTT. Such a case is rare at NTT and I feel very fortunate to be given this chance.

—What, in particular, have you been searching for in your research?

For most people, the first thing that comes to mind on hearing the words “integrated circuit” is an electrical integrated circuit as opposed to the optical integrated circuit that I have been involved with. The main difference between the two is that the former is achieved by “monolithic integration” in which much can be done by simply writing a process onto silicon, while the latter is achieved by “hybrid integration” that combines various types of materials. In short, the research and development of optical integration attempts to demonstrate the “wonders of combination” with respect to various technologies. That is the

first thing that I have been searching for in my work.

Besides that, I have always been pursuing the problem of "how to connect light." In the case of electricity, a signal flows whenever electricity in any state comes in contact with a conductor. For light, however, no signal will be transmitted unless the position and orientation of the optical connection are perfectly aligned. Ensuring good optical connections between fibers is fundamental to optical technology. However, while this is simple in theory, it can be quite difficult to achieve. It is no exaggeration to say that the various issues surrounding optical integration all come back to this primary problem in the end. Looking back at my R&D activities over the years, I think they all come down to a quest for ways of "connecting light." This problem is one that concerns the business of optical communications as well, and researchers will no doubt continue to pursue solutions to it in the years to come.

—Dr. Yamada, what is your personal policy as an engineer and as a researcher and developer? And what do you find interesting about R&D?

In my second year in NTT, the supervisor that assigned me my research theme said something to me that I still keep in mind in relation to my work. He said that "Searching in the light under a lamppost for a key dropped elsewhere in the dark is unlikely to lead to you finding it—you must go to the place where you dropped it." In other words, to achieve your objective you must do whatever it takes, no matter how difficult it is. He often said that ignoring this advice would result in failure as a researcher. I agree with this completely. It is this that I find interesting about research and development. Once you decide to do what is really necessary in your work, you will eventually get results despite the difficulty. After considering various ideas and trying different approaches in a trial-and-error manner, you should eventually end up on the right path. I don't think there are that many endeavors that can provide such a feeling of satisfaction as the R&D process.

A win-win relationship with NTT Laboratories: an essential requirement for ongoing development

—Dr. Yamada, what lies ahead for PLC R&D?

My goal is to see that NEL optical products become distinguished in the end by absolute technical superiority. It has often been said that we have not made sufficient effort in the past to lower costs. This must be corrected, but we must also keep in mind that technical prowess has been the foundation of NEL from the start. Moving forward, I see us working to cut costs extensively over the next year and then, for next-generation multifunction products, to concentrate our expertise on achieving absolute technical superiority. That's how I see things from here.

—At this stage, can you envision the research theme of the future?

It's a bit vague, but I'd like to bring the ultimate concept of an opto-electronic assembly to the product level. This would merge hybrid integration technology for direct mounting of semiconductor optical devices, which I was researching at NTT Laboratories before that research was suspended, with the multifunction technology that we are working on now (**Fig. 3**). We have not yet worked out the details, but I think a specific target will gradually come into view during our present work on multifunction technology.

—What is your ultimate goal as an engineer?

My life's work has been to bring PLC technology to the level of an industry. I have been involved with PLC technology since its birth, and while I have experienced many ups and downs and have even seen a product that I myself developed come to naught, I

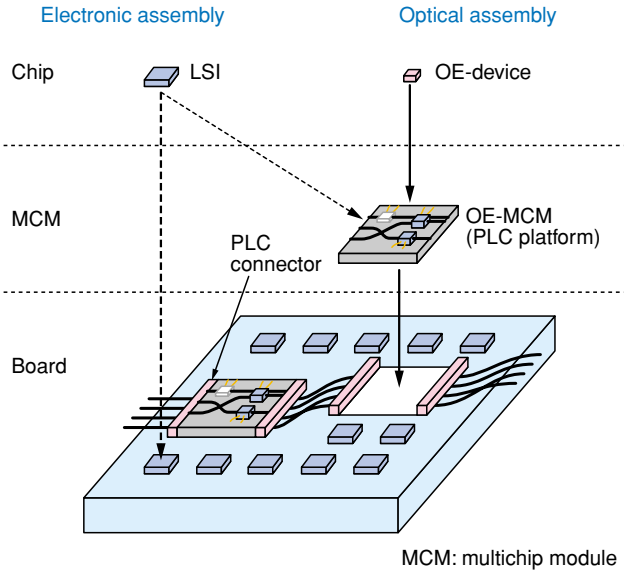


Fig. 3. Future concept of opto-electronic assembly.

think there are few examples of a researcher whose career has paralleled the birth and growth of a single technology. As this appears to have been my fate, I'd like to see this technology grow into an industrial field. In other words, I'd like to see it take root in the form of silicon devices for electrical integration and PLCs for optical integration. I hope to participate in this endeavor even if not in an R&D capacity. Since I have left NTT Laboratories, I'd be glad to participate in a business or production-management role. Whatever the form, my ultimate dream is to participate actively at the front line of PLC technology as a PLC pioneer.

—What is your opinion of and hopes for NTT Laboratories?

I'd like NTT Laboratories to research those areas that present particular difficulties for us. For this reason, we need to make it clear to NTT Laboratories what areas might be a problem for us, and to this end, we need to make more of an effort to communicate our needs. In this way, NTT Laboratories can research the technology that we need and we can take the results of that research and provide it in some form to the world at large. That is to say, I'd like to construct a win-win relationship with NTT Laboratories.

—Dr. Yamada, could you leave us with a message for young researchers and our other readers?

Certainly. I think the most important thing for a researcher and developer is to pursue what one believes in with a great sense of purpose. I take great pride in having done just that in my research work up to now. If you think only of whether certain research will lead to a journal paper, you will accomplish little. My advice might be difficult to take if you need sound results in a hurry, but I'd like to see a researcher carefully and steadily pursue what he or she believes to be truly important even if that means no journal paper for the time being.

In addition, I mentioned earlier that NEL is a world leader in the field of optics and a cutting-edge enterprise having state-of-the-art technologies. For those researchers that would also like to spread new optical technologies throughout society with us, please come and join us. And finally, to our customers, I'd like to say that we hope you look forward to the products that we provide, and for our part, we hope to provide products that always surpass your expectations.

Interviewee profile

■ Career highlights

Yasufumi Yamada received the B.S., M.S., and Ph.D. degrees from Waseda University, Tokyo, Japan, in 1980, 1982 and 1990, respectively.

In 1982, he joined Nippon Telegraph and Telephone Public Corporation (now NTT). Since 1983, he had been engaged in research and development on silica planar lightwave circuits (PLC) at Opto-electronic Laboratories. His main field had been packaging technique for PLCs, especially optical hybrid integration technique where LDs or PDs are assembled on the PLC chip surface in order to establish highly functional optical modules. In 1998, he moved to NTT Electronics Corporation where he has been engaged in PLC business development. He became a Department Director of Design Department, Planar Lightwave Circuit Group in April, 2004.

■ Major awards

Inose Award, and Best Paper Award, of IEICE (The Institute of Electronics, Information and Communication Engineers) (1998).