"Electronics, Information and Communication" field

Achievement : Pioneering research on semiconductor lasers for high-capacity, long-distance optical fiber communication

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Summary

Optical communication network using optical fiber is the pillar of present information society. Dr. Yasuharu Suematsu, Honorary Professor of Tokyo Institute of Technology, has been undertaking the study of optical communication since the early 1960s, the dawn of the optical electronics age. Dr. Suematsu was also a forerunner in taking a "problem-solving approach" in research. In this approach, levels of performance required by society are projected first, and theory and experiments are combined to achieve the goal. In the early 1980s, Dr. Suematsu gave shape to his idea of dynamic single-mode laser, which emits light in the wavelength range where the minimum loss is achieved and has a stable wavelength even with high-speed light modulation when transmitting information. His research on semiconductor lasers has greatly contributed to the realization of a high-capacity, long-distance optical fiber communication.

Semiconductor laser innovation: The driving force behind the achievement of the optical fiber network

The term "information society" was coined in the 1960s when the world was entering a new phase after World War II. The term refers to a society where information technology permeates and revolutionizes various facets of our lives such as economic activity, culture, education and daily lives. In order to realize this information society, scientists and engineers have taken on the challenge of innovation in communication technology. For example, owing to the development in wireless communication technology using microwaves and millimeter waves, Japan and the United States succeeded in launching satellite transmission in 1963. In 1979, a car phone service, which was the forerunner of mobile phones, started in the Tokyo Metropolitan area.

Another technology which contributed to the sophistication of the information society is optical communication using optical fiber. Optical fibers enabled transmission of a large amount of data by sending laser light modulated with high speed to carry information over light waves through optical fibers.

In the early 1960s, Dr. Yasuharu Suematsu, Honorary Professor of Tokyo Institute of Technology, undertook the development of a semiconductor laser which oscillates light used for optical transmission. In 1981, he succeeded in developing a semiconductor laser that uses a wavelength band that minimizes loss of the light signal in an optical fiber (essential to long-distance communication), while maintaining a stable wavelength during a high-speed modulation (essential to large-capacity transmission). This technology greatly contributed to realizing a high-capacity, long distance optical fiber network.

Surpassing millimeter waves in one leap, taking on the challenge of the new frontier of optical communication technology

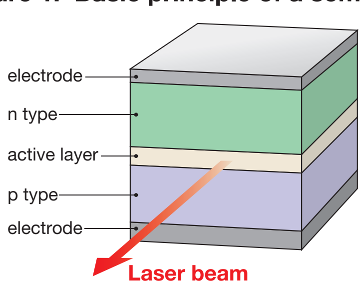
Dr. Suematsu was born in Gifu Prefecture, central Japan, in 1932. From childhood, he was one of the so-called "Radio Boys," creating vacuum-tube radios with his own hands. He went on to go to Tokyo Institute of Technology, heeding his uncle's advice, "If you want to study technology, TIT is the place to go."

At the university, he was deeply impressed by his mentor Professor Kiyoshi Morita's experiments with microwave communication, and was spurred on to carry out studies in communication himself. However, as he proceeded with his postgraduate research, he came to wonder if microwaves and millimeter waves can handle high-capacity communication. He thought: "According to Shannon's theorem, with electromagnetic waves, the limit in information volume is half the number of frequencies. However, using a shorter wavelength, it may be possible to transmit several thousand times the information millimeter waves can carry." When he became an assistant professor in 1961 after completing his postgraduate studies, he surpassed millimeter waves and chose optical communication as his research theme.

However, it was not an easy decision for him to make as prevailing opinions in the university at that time were that one should tackle the task at hand, rather than engaging in research on a technology that seemed to be far away from practical use. Yet what served as a tailwind was that element technologies that led to the realization of optical communication sprang up one after another. In 1964, Professor Junichi Nishizawa of Tohoku University proposed a "self-focusing optical fiber" which made possible a wide-area signal transfer. Then, in 1966, Charles Kao (1996 Japan Prize Laureate) theoretically forecasted that low-loss optical fiber is feasible. Thus, expectations mounted toward a digital communication network using optical fiber.

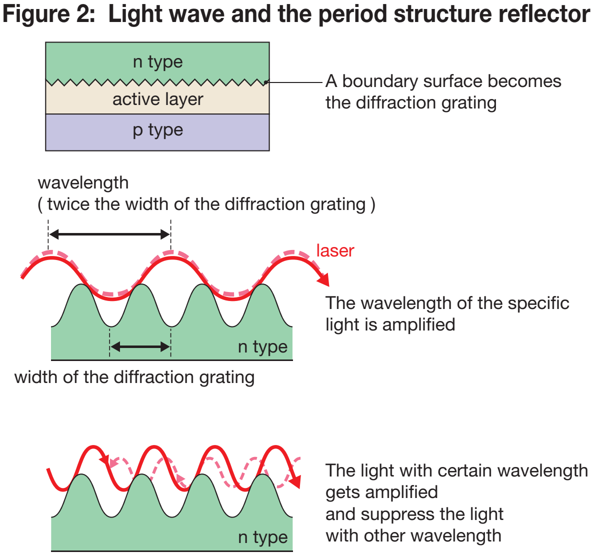
The main challenge was to develop an optimum laser for optical

Figure 1: Basic principle of a semiconductor laser



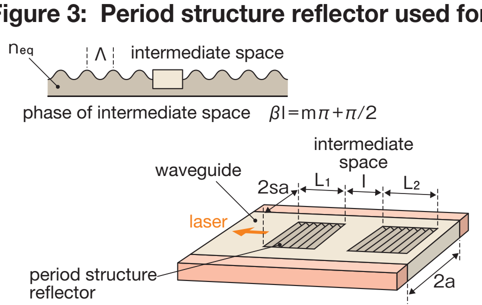
A semiconductor laser has structure in which matter called the active layer is sandwiched between two types of semiconductors, namely the n type and the p type. When voltage is applied to these two semiconductors, oscillation of light with wavelength according to the changes in energy takes place.

Figure 2: Light wave and the period structure reflector



When a "zigzag cut" diffraction grating is inserted onto the surface of the semiconductor at half the interval of the wavelength, light with a fixed wavelength is amplified, and the other wavelengths are cancelled. Thus, the wavelength of the light oscillated becomes uniform.

Figure 3: Period structure reflector used for the integrated laser



The period structure reflector used for the proposed single-mode laser by Dr. Suematsu. By creating an intermediate region between the two reflectors place in the waveguide, light with a more uniform wavelength was achieved.

fiber communication. In order for information to be passed without attenuation through such scales as several tens of kilometers or several hundreds of kilometers of fiber, a laser with adequate wavelength and direction was necessary. At the time, various types of lasers had been developed; however, with optical fiber digital communication where information is transmitted in combination of 0s and 1s, information could not be transmitted long distance with precision when various types of lights are mixed. A high-precision laser with stable oscillation of a fixed wavelength was required.

Dr. Suematsu's choice was semiconductor lasers, which were invented in 1962. A semiconductor laser has a structure in which matter called an "active layer" is sandwiched between two types of semiconductors, namely the n type and the p type. By applying voltage to the semiconductor, the electrons are transferred between both semiconductors, light with wavelength corresponding to changes in energy (photon) results. The resultant light continues to be amplified within the active layer in order to induce the transfer of the next electron, and when it exceeds a certain strength, it oscillates as a laser light (Figure 1).

However, the issue with semiconductor lasers is that the wavelength changes with high-speed modulation, and specialists use such expression as "oscillation mode hopping" or "multimode oscillation" to describe this phenomenon. In order to transmit digital data, an unchanging mode (single mode) even with high-speed modulation of light to carry high-capacity information was required.

Dynamic single-mode laser achieved - long-distance optical fiber communication becomes a reality

Dr. Suematsu's research style of tackling a challenge was unique for a university professor. His research stance was to achieve the performance demanded by the society and university researchers were to thoroughly pursue a basic theory to arrive at an "optimum solution."

For example, there exists a technology in which a period structure of a light reflector is used in order to align the light wavelength. When inserting a "zigzag cutting" into the surface or inside the semiconductor at half the interval of the wavelength, the target light of the wavelength strengthens one another and cancels the others (Figure 2). Dr. Suematsu not only pursued the theory of this technology, but also applied this technology by introducing a device which could actually be used for optical communication, thereby stabilizing the laser motion.

Afterwards, he undertook research of an integrated laser. In a semiconductor laser, there is an "active region" which strengthens the laser light, a "waveguide" which leads the light in a fixed direction, and a "reflective part" which reflects light. By using a period structure reflector on the reflective part, and integrating it with the other parts, Dr. Suematsu anticipated that this would become the foundation of next-generation technology such as the "optical integrated circuit." Thereafter, in 1974, 13 years after beginning his research at the university, he proposed a single-mode laser which oscillates light with uniform wavelength by placing two periodic structure reflectors within the integrated "waveguide," and creating an intermediate region between the respective reflectors so that half of the wavelength phase is deviated (Figure 3).

Furthermore, when it was discovered in the 1970s that light loss within the optical fiber is minimal when the wavelength band is 1.5 micrometers, Dr. Suematsu began an independent study of semiconductors and succeeded in the room-temperature continuous-wave operation of 1.5 micrometer wavelength using an InGaAsP laser. In the fall of 1980, by means of an integrated laser using with a unique period structure reflector, he succeeded in creating a prototype for a 1.5 micrometer wavelength band laser. It was verified that light oscillation was stable even under high-speed modulation in order to transmit data, and in the following year (1981), at the academic conference in Europe, this invention was presented as a "dynamic single-mode laser."

The dynamic single-mode laser proved to be an indispensable technology in the field of optical fiber communication in the years that followed. In the mid-1980s, technology using optical fiber for long distance communication was established and began to be used as inter-city and international communication infrastructure. It can be said that the Internet, which has become widespread to the general public from 1995 onwards, would not have been possible without this technology.

Dr. Suematsu has also contributed toward the sophistication of the integrated laser technology. In 1983, Dr. Suematsu et al. became the first in the world to achieve a variable wavelength semiconductor laser which can electrically control the oscillation wavelength. Coming into the 2000s, a new technology, namely, wavelength division multiplexing was introduced into the optical fiber field to achieve an even faster communication network, and the technology pioneered by Dr. Suematsu has greatly contributed to this development.

The integrated laser technology pioneered by Dr. Suematsu will continue to evolve our information society in the future.