SUEMATSU Yasuharu

"Pioneering Research on Single-Mode-Diode Laser for Wide-Band and Long-Distance Optical Fiber Communication"

1. BIOGRAPHY

(*SUEMATSU Yasuharu*)

1960; Doctor of Engineering (DE)- Graduate School of Tokyo Institute of Technology, 1961; Associate Professor- Tokyo Institute of Technology, 1987; Chairperson- Organizing Committee, IOOC, 1973; Professor-, 1989; President- Tokyo Institute of Technology, 1992;President-Institute of Electronics, Information and Communication Engineer, 1993;Foreign Associate- National Academy of Engineering, USA, 1994; Commissioner- Space Activities Commission for Prime Minister, 1995;Director General- National Institute for Advanced Interdisciplinary Research, MITI, 1997;President- Kochi University of Technology, 1997; Member- Science Council of Japan, 2000; Foreign Member- the National Academy of Engineering, Korea, 2000; External Director- JR East Japan, 2001; Director General- National Institute of Informatics, 2003; Chairperson- Science and Technology Council, Ministry of Education and Culture, 2010; Chairperson-Kenjiro Takayanagi Foundation, 2011; Honorary Professor- Tokyo Institute of Technology.{1994; University Doctor- Surry University, 1992; Honorable Doctor of Engineering- the University of Maryland, 1991; Honorable Chair- Tsinghua University}

MAIN HONORS

1982; IEEE Quantum Electronics Awards, 1983;Valdemar Poulsen Gold Medal, 1983; Prime Minister's Award, 1985; Electronics Letters Premium Award, shared, 1986;David Sarnoff Award, IEEE, 1993;John Tyndall Award, 1989; Tore Science and Engineering Award, 1994; C&C Prize, 1996; Medal with Purple Ribbon, 1997; Eduard Rhein Prize, 2003; IEEE James H. Mulligan, Jr. Education Medal, 2006; Okawa Prize, 2014; Japan Prize, 2015; The Order of Culture- from the Emperor of Japan, 2016; SSDM Award for presentation of 1979, shared.

2. SUMMARY

SUEMATSU Yasuharu engaged on basic research intended for the realization and its development of the wide-band and long-distance optical fiber communication after 1960 [1], by demonstration of the world first optical fiber communication experiment in 1963 [42], by developing the GaInAsP/InP semiconductors emitting at 1.5μm wavelength for the lowest loss wavelength bad of silica fiber, in 1979 [18]-[20], followed by the demonstration of the 1.5μm single-mode-diode laser (called as dynamic single mode laser) in 1981 [2][23]-[25], as well development of fundamentals of optoelectronics. In 1983, he achieved the 1.5μm phase-shift distributed feedback laser [30] [31], and in the same year he demonstrated the tangible wavelength tunable diode lasers [29], those have been utilized as standard laser for the wide-band and long-distance optical fiber communications [4] [5]. Furthermore, he promoted the photonic integrated circuits (PICs) by demonstration of integrated lasers [11][13][35].

He engaged for education and management as Professor and President of Tokyo Institute of Technology and mentored sixty graduate students, and further engaged to establish Kochi University of Technology as President emphasized for enrichment of the human power of students. He worked for government as Chairperson of Science and Technology Council, Ministry of Education and Culture.

3. RESERCHES

Light is an electromagnetic wave specified as the highest frequency under human control, and superior for higher performance communication compared with radio waves. SUEMATSU engaged on basic research intended for the realization and its development of wide-band and long-distance optical fiber communication after 1960 [1]. In the early day of this research, he pointed out that following three performances should be requested to diode lasers for high performance optical fiber communications, namely, 1) the operating wavelength should be at the lowest loss wavelength band at 1.5μm which was fixed during the early research period, 2) the stable single-mode-operation to reduce the dispersion effect of fiber, and 3) the wavelength tunability for multiwavelength use which is common in communication technology [3].

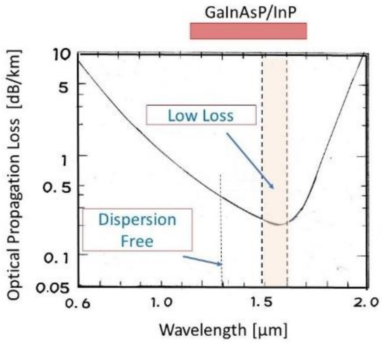

Fig. 1 GaInAsP/InP for Low Loss Wavelength Band of silica fiber *1979* [1]

3.1 Development of GaInAsP/InP Emitting at 1.5μm

As a possible lowest loss band of silica fiber, a wavelength range of 1.4-1.7μm had been prediction by D. Keck et al. of Corning, in 1973. In response to this prediction, GaInAsP/InP semiconductor emitting at 1.55μm wavelength was developed for laser material in 1979 as shown in Fig.1, [17]-[20], where that lowest loss wavelength was fixed as 1.55μm in the same year by the fiber development. Transverse mode control of laser diode by dielectric current channel proposed in 1972 [9] was in practice by use of the buried hetero-structure.

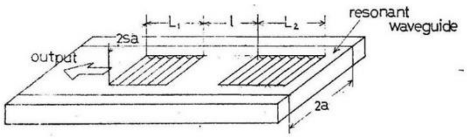

Fig. 2 Single-mode resonator consisted with two distributed reflectors *1974* [10]

3.2 Development of 1.5μm Single-Mode-Diode Laser

In 1974, He and his student found that stable single-mode-diode laser can be made when two distributed reflectors (DFB, DBR) were jointed together with designated separation as shown in Fig. 2 [10]. In 1980, 1.5μm wavelength single-mode laser consisted with one distributed Bragg reflector (DBR) and one flat mirror, for simplicity, was demonstrated in the first time, as shown in Fig. 3 [17]-[20]. This achievement triggered the development of the 1.5μm wavelength DFB lasers with a facet reflector at KDD, NTT, and BTL followed by long-distance fiber communication experiment with direct modulation of these lasers.

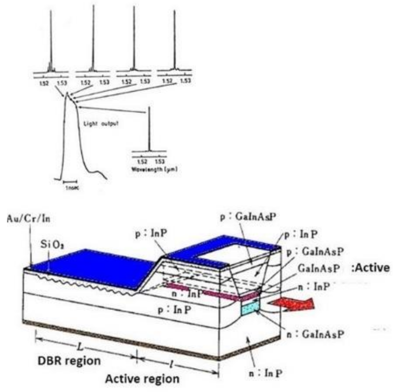

Fig. 3 First single-mode-diode laser at 1.5μm wavelength band ***1980*** [23]

In 1983, the 1.5μm band phase-shift distributed-feedback laser was achieved for demonstration with K. Furuya et al. as shown in Fig. 4 [31], which consisted of two active distributed reflectors connected face by face, where the corrugation period was, as a result, shifted by half pitch at the connection portion. The phase-shift DFB lasers were fabricated by butch process including the phase-shift section of grating by photo resist work with electron beam exposure [30], that the production yield is high to reproduce lasing performance. The lasing mode is stable against temperature variation that the lasing wavelength can be tuned by temperature smoothly, as thermo-tunable lasers. Thus, laser array, consisted of a dozen of phase-shift DFB lasers on a same chip with different central wavelengths, have been utilized to cover the commercial wavelength band at the lowest loss region [4]. Later the strained multi-quantum well structure was utilized for the active region. The phase-shift DFB lasers are used under cooled operation to keep the wavelength constant. Thus the phase-shift DFB lasers are utilized world widely as standard laser for the long-distance fiber communications [2][3].

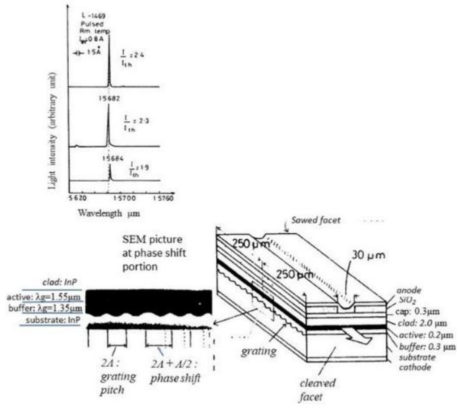

Fig. 4 First phase-shift distributed feedback laser at 1.5μm wavelength band *1983* [31]

In contrast, the wavelength tunable laser with electro-tuning was demonstrated in 1983 as shown in Fig. 5 [29], at 1.5μm band [33]. Then, wider tunable range was achieved by Y. Tohmori and L. Coldren, for dense WDM transmission systems [4].

Furthermore, the distributed reflector laser, abbreviated as DR laser, as shown in Fig. 6 [36][37], was proposed and demonstrated in 1988, to improve the power efficiency. The DR laser consists with active and passive distributed reflectors, thus the light is emitted from only one side facet. Due to its high operational efficiency and high direct modulation capability, DR laser is used at 1.3μm band (with AlGaInAs/InP) for short distance optical network with direct modulation under un-cooled condition.

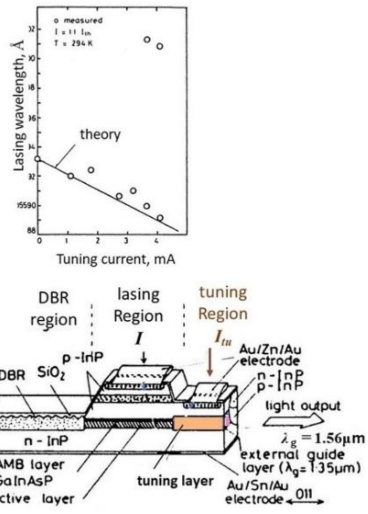

Fig. 5 Demonstration of electrically wavelength tunable lasers *1983* [29]

3.3 Laser Dynamics, PICs and Fiber

This research activity for optical fiber communication had been started just after the appearance of laser, in 1960, thus, many scientific and technical aspects should be understood rigorously. The upper limit of direct modulation frequency of diode laser was given [6], and the electronic relaxation model of diode laser was developed so as to find the gain suppression effect [8]. The spontaneous emission factor was formulated [14], and the dynamic line shift was found [26] in relation with the transmission bandwidth of optical fiber [34].

The active integrated circuit [13] demonstrated in 1977 was called as PICs (Photonic Integrated Circuits) in 1987 [35] which has been developing further. The random bend loss caused by cabling process of optical fiber was formulated theoretically and found that the allowable core diameter of single mode fiber was around 10μm [16]. In 1992, Hirayama and the author et al achieved the laser operation of quantum dot structure [39]. In 1986, Chaki and the author proposed the resonant tunneling electronic device [38], which has been extended to the tera-Herz oscillator.

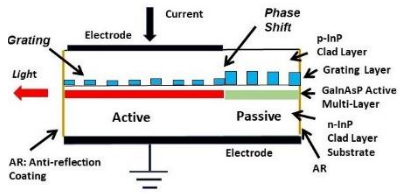

Fig 6 Distributed reflector (DR) laser *1988* [36]

3.4 Social Contribution of Research Achievement

The major optical fiber communications are operating at two typical wavelength band.

In the first place, the wavelength band at 1.5μm is applied for the wide-band and long-distance fiber communications, where the phase-shift DFB lasers [30][31] and the wavelength tunable lasers [29][33], both demonstrated in the first time based on the GaInAsP/InP semiconductor emitting at 1.5μm band, which we developed [18]-[20], have been utilized as standard laser, due to its purity, stability and controllability of lasing wavelength. Those systems had been developed together with the developments of optical fibers, the high-speed modulators, the detectors, the optical circuits and components, the electronics, and the modulation schemes [4].

On the other hand, the wavelength band at 1.3μm is utilized for the short distance communications, namely LAN and Data-station et al, where the DR lasers of single-mode operation [36][37], which was demonstrated at this work are used frequently for the light sources by direct modulation,

Presently, the optical fiber communications bear burden of the information infrastructure and those transmission performances index, given by the product of the bandwidth and the transmission distance, reached up to a couple of million times superior compared with that of coaxial cable, which resulted in the drastic reduction of transmission costs of information. After the middle of 1990, these advancements have been created the network industry such as Google and Rakuten. The developments of optical communications have been triggered the daily transmission of large capacity information and became the driving force for the ICT civilization. It is said that the present internet society may not be achieved without optical fiber communication headed by the 1.5μm single-mode-diode lasers.

4. SPECIAL REMARKS

This work was heavily supported at its early time of research by YAMAZAKI Teiji, President of TDK of those day, requested with KAWAKAMI Masamitsu, Dean of Engineering of the Tokyo Tech., and with installations of the Electron Beam Exposure System by the University Expenses and the Spectrometer of Perkin Elmer by the first year installation cost of establishment of the new Department of Physical Electronic, daily warm support of Senior Professors SUETAKE Kunihiro and KISHI Genya, and later by support of the Special Promotion Research of Ministry of Education with Professor SAITO Shigebumi of the University of Tokyo. The author had been encouraged by the extra-ordinary circumstance so as to make challenge toward high goal of research. In the last, Suematsu wish to express cordial gratitude to who supported this research, and also thanks to whom cooperated research together.

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