

***Japan Academy Prize to:***

Masataka NAKAZAWA  
 Professor, Research Institute of  
 Electrical Communication,  
 Director, International Advanced  
 Research and Education Organization,  
 Director, Research Organization of  
 Electrical Communication  
 and  
 Distinguished Professor, Tohoku University



for “The Realization of Erbium-doped Fiber  
 Amplifier and its Application to Sophistication  
 of Optical Communication Technology”

***Outline of the work:***

Optical communication with an optical fiber which transmits signals of a semiconductor laser diode (LD) was initially operated at an wavelength of 0.84 micrometer. The transmission loss was lowest at this wavelength that was 20 decibel/kilometer. Reduction in transmission loss of the optical fiber was achieved by improving the purity of silica and the fabrication processes. Then the minimum loss of less than 0.2 decibel/kilometer was found at a longer wavelength of 1.5-1.6 micrometer. It allowed the long-distance optical communication as long as 100 kilometer.

Repeaters are required for optical communication for a longer distance. Then the received optical signal at a repeater was detected and the signal was electrically amplified, which modulated the next LD to be transmitted to the next repeater. Thus the signal bandwidth was limited by the electrical amplifier that was a few gigahertz. The repeater for transmission with wavelength division multiplexing (WDM) required multiple electrical amplifiers or a wide-band optical amplifier. The optical amplifier at that time in the 1980's was pumped by an argon-ion laser or a color-center laser which was operated with liquid-nitrogen cooling. They were bulky, costly and unreliable so that they were unable to be used for optical repeaters.

Prof. Masataka Nakazawa had a conception of using an erbium-doped fiber amplifier (EDFA) which was pumped by a semiconductor laser diode in 1984. He built a compact and efficient erbium-doped fiber amplifier pumped by a 1.48 micrometer InGaAsP laser diode in 1989. It had a bandwidth of no less than 100 nanometer (ca. 13 terahertz) with low noise and high gain. Besides, he demonstrated a long-distance error-free soliton transmission with erbium-doped fiber amplifiers and repeaters.

Erbium-doped fiber amplifiers and repeaters have now been used world-wide in submarine optical cables across the pacific ocean and the atlantic ocean as well as in surface cables for ultrahigh-speed optical communication systems. In 2000 he demonstrated a world-record of 1.28 terabits/second optical transmission by using short-pulse high-repetition-rate erbium-doped laser. Prof. Nakazawa achieved optical frequency stabilization with an absorption line of acetylene and femtosecond pulse generation with the erbium-doped fiber amplifiers. Recently he demonstrated 1024 quadrature-amplitude-modulation (QAM) single carrier coherent optical transmission over 525 kilometer. It has achieved the highest efficiency in frequency-bandwidth of 14 bits/sec./hertz, compared with the former efficiency of ca. 0.1 bits/sec./hertz.

His contribution to optical information processing such as optical time-domain Fourier transformation, polarization-multiplexed phase-shift keying and quadrature-amplitude-modulation coherent optical transmission must also be mentioned. Development of ultrahigh-speed optical communication systems has allowed rapid increase in information capacity of 40 percent/year. Ubiquitous use of cell phones and computers has thus been realized in the present society.

Prof. Nakazawa has been highly recognized within the international and domestic community as a leading person for optical communication in the future. His contributions have been published in a number of international journals as well as invited papers in international conferences. Prof. Nakazawa has been awarded so many prizes and obtained so many patents that may not be mentioned.

### Selected publications

- 1) M. Nakazawa, Y. Kimura and K. Suzuki, "Efficient Er<sup>3+</sup>-doped optical fiber amplifier pumped by a 1.48 μm InGaAsP laser diode," *Appl. Phys. Lett.*, 54 (1989) 295-297.
- 2) M. Nakazawa, Y. Kimura and K. Suzuki, "Soliton amplification and transmission with Er<sup>3+</sup>-doped fibre repeater pumped by GaInAsP diode," *Electron. Lett.*, 25 (1989) 199-200.
- 3) M. Nakazawa, Y. Kimura, K. Suzuki and H. Kubota, "Wavelength multiple soliton amplification and transmission with an Er<sup>3+</sup>-doped optical fiber," *J. Appl. Phys.*, 66 (1989) 2803-2812.
- 4) Y. Kimura, K. Suzuki and M. Nakazawa, "46.5 dB gain in Er<sup>3+</sup>-doped optical fibre amplifier pumped by 1.48 μm GaInAsP laser diodes," *Electron. Lett.* 25 (1989) 1656-1657.
- 5) M. Nakazawa, K. Suzuki and Y. Kimura, "3.2-5 Gb/s, 100 km error-free soliton transmission with erbium amplifiers and repeaters," *IEEE Photon. Tech. Lett.*, 2 (1990) 216-219.
- 6) M. Nakazawa, E. Yamada, H. Kubota and K. Suzuki, "10 Gbit/s soliton data transmission over one million kilometres," *Electron. Lett.*, 27 (1991) 1270-1272.
- 7) M. Nakazawa, E. Yoshida and Y. Kimura, "Ultrastable harmonically and regeneratively modelocked polarization-maintaining erbium fibre ring laser," *Electron. Lett.*, 30 (1994) 1603-1604.
- 8) M. Nakazawa, T. Yamamoto and K. R. Tamura, "1.28 Tbits/s-70 km OTDM transmission using third- and fourth-order simultaneous dispersion compensation with a phase modulator," *Electron. Lett.*, 36 (2000) 2027-2029.
- 9) K. Kasai, M. Yoshida and M. Nakazawa, "Acetylene (<sup>13</sup>C<sub>2</sub>H<sub>2</sub>) stabilized single-polarization fiber laser," *IEICE Trans. Electron.* J88-C (2005) 708-715.
- 10) M. Nakazawa, M. Yoshida, K. Kasai and J. Hongou, "20 Msymbol/s, 64 and 128 QAM coherent optical transmission over 525 km using heterodyne detection with frequency stabilized laser," *Electron. Lett.*, 42 (2006) 710-712.
- 11) K. Kasai and M. Nakazawa, "FM-eliminated C<sub>2</sub>H<sub>2</sub> frequency-stabilized laser diode with an RIN of -135 dB/Hz and a linewidth of 4 kHz," *Opt. Lett.*, 34 (2009) 2225-2227.
- 12) P. Guan, T. Hirano, K. Harako, Y. Tomiyama, T. Hirooka and M. Nakazawa, "2.56 Tbit/s/ch polarization-multiplexed DQPSK transmission over 300 km using time-domain optical Fourier transformation," *Opt. Express*, 19 (2011) B567-B573.
- 13) Y. Koizumi, K. Toyoda, M. Yoshida and M. Nakazawa, "1024 QAM (60 Gbit/s) single-carrier coherent optical transmission over 150 km," *Opt. Express*, 20 (2012) 12508-12514.