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2023
Development of
a wider-temperature-range 100 Gbps Electro-absorption Modulator integrated Laser (EML) for data centers
(Mitsubishi Electric)

~ Discrete Semiconductor/Others ~

Internet traffic is exploding and entering the "zettabyte" era. More than 70% of this traffic is intra-data center traffic, and optical interconnect, which enables high-speed, large-capacity data transmission over short distances (<10 km), plays an important role. Optical links in data centers are generally in the form of "pluggable optical transceivers", which are inserted into the equipment and optical fiber cables are connected (Figure 1). The speed and capacities of pluggable optical transceivers continue to increase, and 400 Gbps optical transceivers are in practical use at present. 800 Gbps and 1.6 Tbps optical transceivers are being planned [(1)].

There are various standards for 400 Gbps optical transceivers. A method to achieve 400 Gbps data communication by Wavelength Division Multiplexing (WDM) of four Electro -absorption Modulator integrated Lasers (EMLs) operating at 100 Gbps was established in the Multi Source Agreement (MSA).

Power consumption in data centers has been also an important issue and technologies to reduce power consumption of optical transceivers have become important. Mitsubishi Electric has developed an Elector-absorption Modulator integrated Laser (EML) that operates stably over a wide chip temperature range from 5℃ to 85°C without the need for temperature adjustment [(2)]. The Thermo-Electric Cooler (TEC) for temperature control of the EML, which was conventionally required for optical transceivers, is no longer necessary, reducing power consumption and cost.

The EML consists of a Distributed Feed-Back (DFB) laser [(3)], which oscillates CW in a single mode, and an Electro-Absorption Modulator (EAM), which turns the signal light on and off. (Figure 2). Each semiconductor layer is grown on an n-type InP substrate by Metal Organic Vapor Phase Epitaxial Growth (MOVPE). Both the active layer of the laser and the absorption layer of the modulator consist of Multiple Quantum Well (MQW) structures.

Mitsubishi Electric adopted an embedded structure for the laser part as shown in Figure 3(a), which had excellent high-temperature characteristics. A current blocking layer structure is devised to ensure the desired optical output power even when the laser is operated at a high temperature of 85°C.

The modulator utilizes the phenomenon of Quantum Confined Stark Effect (QCSE). When an electric field is applied to the quantum well layer, the electron states in quantum well shift to lower energies, while the hole states shift to higher energies due to the shift of the wave functions of electrons and holes, resulting in a narrowing in the energy gap and a shift of the fundamental absorption wavelength edge of light to the longer wavelength side (Figure 4). When no electric field is applied, the laser oscillation wavelength is away from the absorption spectral edge and the laser light is transmitted without attenuation. But when an electric field is applied, the modulator is designed so that the laser wavelength enters into the absorption region and light transmission is prevented.

There is a trade-off relation between securing a wide operating frequency bandwidth for modulators and securing a high extinction (on/off) ratio. In order to achieve a 3 dB cutoff frequency of 35 GHz or higher while maintaining a sufficient extinction ratio at low temperatures, Mitsubishi Electric has adopted a high-mesa structure with a large ratio of light confined in the absorbing layer, as shown in Figure 3(b). In addition, a spot size converter is connected to the EAM to improve coupling efficiency of the light to a single-mode fiber.

Mitsubishi Electric has developed four types of EMLs oscillating in O-band (1260~1360nm wavelength) with a wavelength spacing of 20nm [(2)] (Figure 5). The lasers achieved a wavelength shift of approximately 7 nm or less (standard: 13 nm) in the chip temperature range from 5°C to 85°C. The EML chip temperature control TEC, which was conventionally installed in optical transceivers for data centers, was no longer necessary.

NTT Device Innovation Center and Furukawa Electric have developed Semiconductor Optical Amplifier (SOA) integrated EMLs, respectively [(4, 5)]. That has enabled 40 km transmission at 400 Gbps, useful for data center-to-data center and metro access systems. Mitsubishi Electric has also successfully developed a 200Gbps EML chip that can support to realize 800Gbps and 1.6Tbps optical transceivers [(6)].

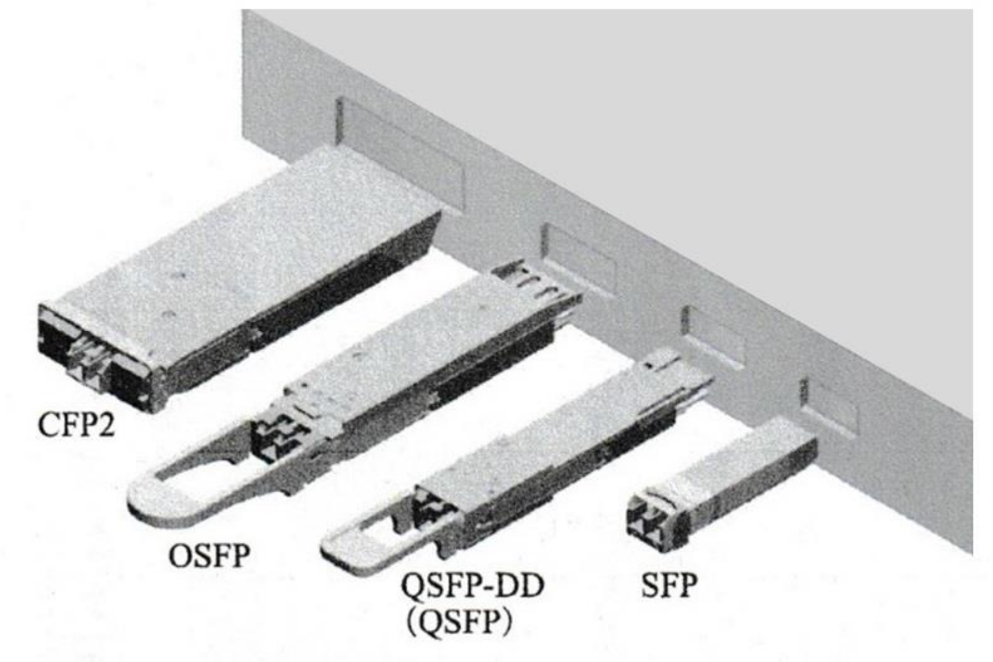

Figure 1 Example of pluggable optical transceivers (1)
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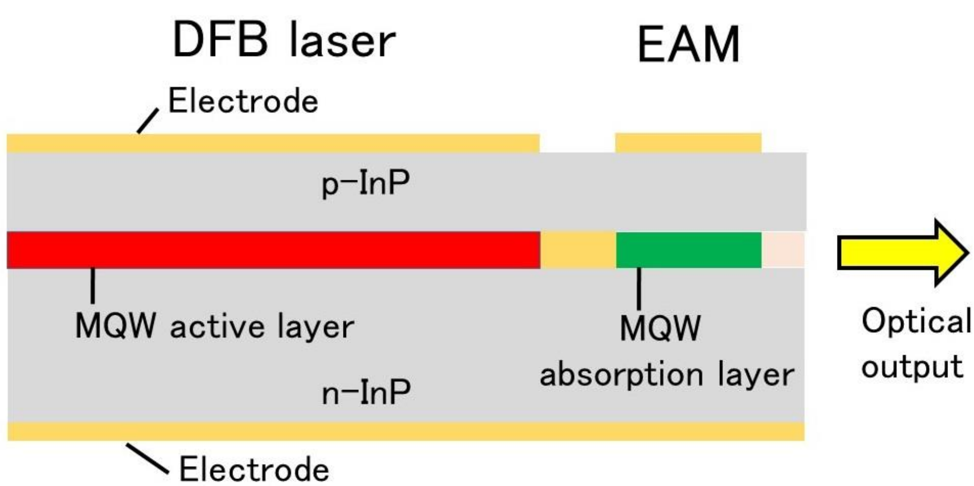

Figure 2 Schematic of the structure of the Electro-absorption Modulator integrated Laser (EML)

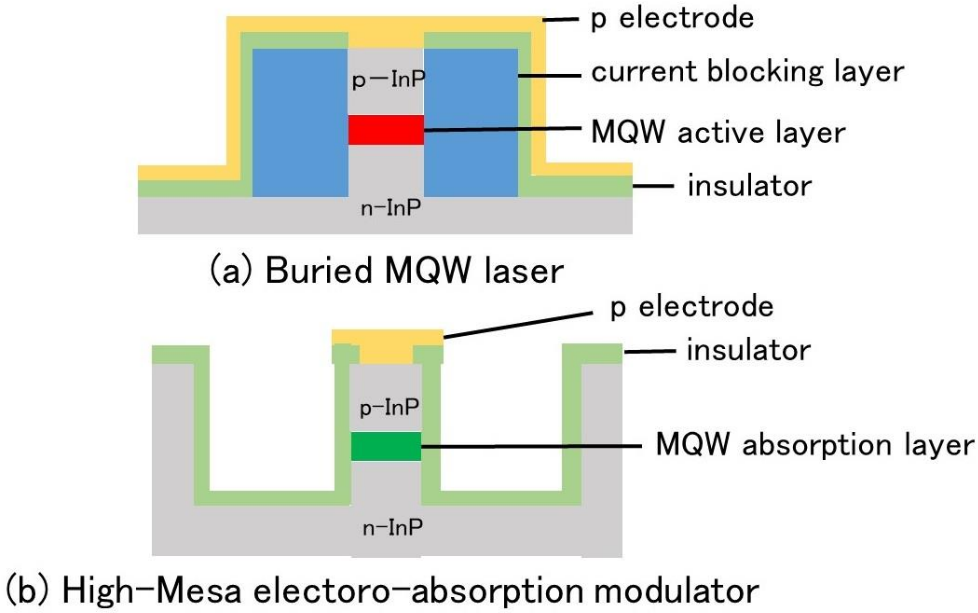

Figure 3　Cross-sectional structure of EML element
(Drawing by SHMJ based on Reference (2))

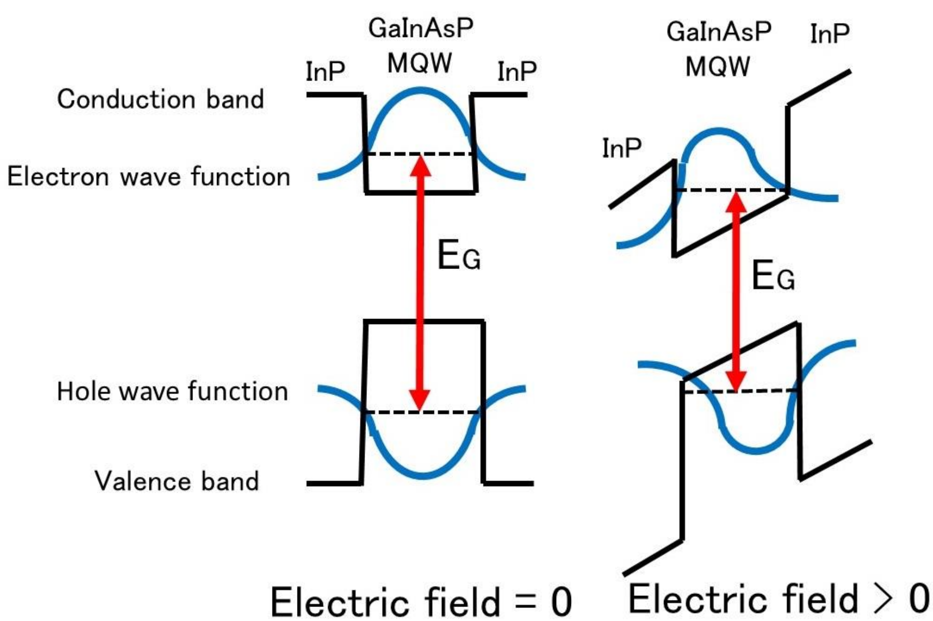

Figure 4　Conceptual diagram of Quantum Confined Stark Effect (QCSE)

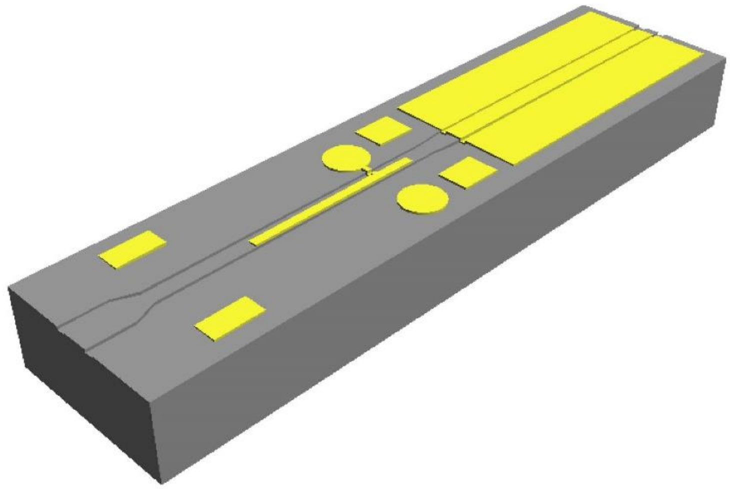

Figure 5　Electro-absorption Modulator integrated Laser (EML)
(Courtesy of Mitsubishi Electric Corporation)

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(5) Furukawa Electric News Release, "Development of an electro-absorption modulated laser with integrated semiconductor optical amplifier", (March 1, 2023) https://www.furukawa.co.jp/en/release/2023/comm_20230301.html
(6) Asami Uchiyama, Shinya Okuda, Yohei Hokama, Mizuki Shirao, Kenichi Abe, Takeshi Yamatoya, and Yasuhiro Yamauchi, "225 Gb/s PAM4 2 km and 10 km transmission of electro-absorption modulator integrated laser with hybrid waveguides structure for 800 Gb/s and 1.6 Tb/s transceivers" Journal of Lightwave Technology, Vol. 42, Issue 4, pp. 1225 -1230, (15 February 2024)