Optical Devices for Optical Access Network Systems

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Our newly-developed OLT optical transmitter module offers high optical output power over a wide range of operating temperatures by using a DFB laser that operates over a wide temperature range and by applying highly efficient optical system using an aspherical lens. The OLT receiver module achieves high sensitivity thanks to a high-responsivity APD and a low-noise pre-amplifier IC.

In addition, the cost of our newly-developed ONU optical transmitter device has been reduced by using a lens-equipped cap.

1. Optical Devices for Optical Access

1.1 DFB Laser

For optical transmitter devices in OLTs (Optical Line Terminals), narrow-spectral-width and high-output-power light sources lasing in the 1.49-µm band are required. We therefore apply a DFB (Distributed-Feedback) laser which is capable of selective single-mode lasing with the help of a grating close to the active regions. The device employs an FSBH (Facet Selective-growth Buried Hetero) structure with MQW (Multiple Quantum Well) active regions. Since the lasers with this structure exhibit high efficiency over a wide temperature range, this device structure is particularly useful for PON (Passive Optical Network) systems. Figure 1 shows the I-L curve of the DFB laser. As device characteristics, the laser features a low threshold current, a wide operating temperature range, a high side-mode suppression ratio (of 40 dB typical), and high-speed response (0.12 ns rise and fall time (20% – 80%)). A reliability of 100,000 hours or more is secured under actual usage conditions.

1.2 FP Laser

In the case of optical transmitter devices for ONUs (Optical Network Units), lens-capped FP (Fabry-Perot) lasers are used to reduce the cost of optical modules. For PON systems, since the ONU transmitter also needs high optical output power, we increased the output power of the FP laser. To increase the optical output power launched from the front facet of the laser, we optimized the FP laser design and achieved an efficiency of 0.45 W/A and an optical output power of 20 mW at 25°C. Figure 2 shows the I-L curve of our FP laser. Furthermore, we reduced the capacitance of the device to permit high-speed modulation at 1.25 Gbps.

We also improved the lens to increase the coupled optical power. In the case of bi-directional modules that are used in subscribers, optical couplings are often made by means of lenses that are attached to lasers. By using a high-refractive-index lens, high optical coupling efficiency of 20% can be achieved, and this has been further increased to 28% by introducing a low-aberration lens. Owing to these improvements, a high-coupling-efficiency LD (laser diode) module using an inexpensive lens has become possible.

![Fig. 1 I-L curve of DFB-LD used in OLT equipment](image1)

![Fig. 2 I-L curve of FP-LD used in ONU equipment](image2)

1.3 APD

High-responsivity APDs (Avalanche Photo Diodes) are used in optical receiver devices for OLTS because the intensity of light incident on them has come down due to optical branching loss. When the APD is biased...
near its breakdown voltage, photocurrent amplification action takes place, making it possible to obtain a large photocurrent. We adopted InGaAs which has sufficient responsivity in the wavelength range from 1.0 µm to 1.6 µm for the absorption region and employed an InGaAs-InP planar structure which applies InP for the avalanche region. For reference, the active diameter of the APD is 35 µm. The APD’s responsivity is 0.9 A/W at a wavelength of 1.31 µm and frequency bandwidth is 2.5 GHz, thus the APD is suitable for GE (Gigabit Ethernet)-PON systems. Figure 3 shows the I-V curve of the APD. The breakdown voltage is 60 V, and a multiplication factor of 10 or greater at an incident optical power of 0.3 µW is obtained.

![I-V curve of APD](image)

**Fig. 3 I-V curve and multiplication factor of APD**

### 2. Optical Modules for Optical Access

This section introduces our high-output-power optical transmitter module (or LD module) and high-responsivity optical receiver module (or pre-amplifier IC-embedded APD module), both to be installed into OLT transceiver equipment. Figure 4 shows a photograph of both modules.

![Photographs of optical modules](image)

**Fig. 4 Photographs of optical modules**

#### 2.1 LD Module

Figure 5 shows the internal structure of the LD module. We adopted a coaxial structure which is easy to mass-produce and reliable, yet low in cost. The 1.49-µm high-efficiency DFB laser discussed in the preceding section is used. With the help of an aspherical lens that has an excellent optical coupling property, a high optical coupling efficiency of about 65% is achieved. A monitor PD (photo diode) is mounted at the back of the DFB laser in order to detect optical output power from the DFB laser and to control the DFB laser so as to keep optical output power constant in case of the laser temperature change. On the other hand, an optical isolator is employed to suppress the generation of noise from the DFB laser due to optical feedback. The size and cost of the optical isolator have been reduced by mounting it on the optical input end of the optical fiber where the diameter of the beam launched from the DFB laser becomes minimum.

**Fig. 5 Schematic structures of optical modules**

#### 2.2 Pre-amplifier IC-embedded APD Module

Figure 5 shows the internal structure of the pre-amplifier IC-embedded APD module. We adopted a coaxial structure as in the case of the LD module. This module includes the high-responsivity APD discussed in the preceding section and our newly-developed low-noise burst pre-amplifier IC [1, 2] which is responsive to weak signals received by the APD and outputting the amplified signals. Because the APD has large active diameter, an optical coupling efficiency of almost 100% is achieved and the optical alignment is simplified. Since the pre-amplifier IC is required to instantaneously respond to various signal levels being sent from each subscriber, it uses a continuous AGC (Auto Gain Control) scheme which is designed to continuously vary conversion gain according to the signal levels. Owing to the high-responsivity APD and low-noise pre-amplifier IC employing the continuous AGC scheme, a high sensitivity of –30.1 dBm is achieved even under the worst conditions where a signal of a large level of –6 dBm is followed by a burst signal of a small level. [2]
References
