A Laser Module for 100Gbps Digital Coherent Optical Transmission System

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We recently developed a 100 Gbps digital coherent transmission laser module. As the key to realizing miniaturization, low power consumption and high output, we established a wavelength tunable LD (laser diode) device that has an array of 16 LDs, and also wavelength monitoring technology using the light emitted from the back of the LD, and successfully obtained the characteristics required for transmission.

1. Introduction

The 100 Gbps digital coherent system uses a wavelength tunable laser device that enables the wavelength of the emitted light to be varied, as the light source for the transmitter and also as the local oscillator light source for the receiver. The interface is standardized as an ITLA (integrable tunable laser assembly) by the OIF (Optical Internetworking Forum). In this paper, we report on the development of a laser module that complies with the standard for the Micro-ITLA,(1) which is one size smaller than the ITLA. This standard was ratified aiming at second-generation optical transceivers.

2. Structure of the Laser Module

Figure 1 is a photograph of the 100 Gbps digital coherent transmission laser module that we developed. The external size of the module excluding the fiber is 45×20×7.5 (mm), which complies with the Micro-ITLA standard. Figure 2 shows the internal structure of the package. The package consists of a wavelength tunable LD, a TEC (thermo-electric cooler) which regulates the wavelength tunable LD temperature, an optical power monitor that detects the power of the emitted light, and a wavelength monitor that detects the wavelength of the emitted light. The wavelength tuning method is a temperature regulating type that uses a highly stable DFB (distributed feedback) LD. The light emitted from the front side (output side of the laser module) of the wavelength tunable LD passes through a lens where it is coupled to the optical fiber. The light emitted at the rear side (opposite side) enters the rear-side wavelength monitor. Based on the information detected by the monitor, the injection current and the temperature of the wavelength tunable LD are controlled by a control circuit, thus stabilizing the optical output and wavelength.

Generally, in order to realize the various characteristics required for 100 Gbps digital coherent transmission, namely an optical output of at least 14.0 dBm, power consumption of no more than 5.0 W, linewidth of the output of no more than 500 kHz, and optical frequency stability of ±2.5 GHz, it is necessary to resolve two major issues. The first one is the question of how to simultaneously reduce the power consumption and realize high optical output. In order to cover the entire wavelength bands (C, L bands) used for optical communication, it is necessary to vary the temperature of the DFB LD section over a wide range, and also integrate multiple DFB LDs that emit light of different wavelengths. However, widening of the temperature adjustment range causes the TEC power consumption to rise, while an increase in the number of DFB LDs results in a greater loss in the coupler section where the light emitted from each LD is combined. The second issue is the realization of a highly accurate rear-side wavelength monitor. A wavelength monitor consists of an etalon,
which is an optical filter, and a PD (photodiode), which receives light that has passed through the etalon. As the transmittance of an etalon depends upon the wavelength, any fluctuation in the wavelength of the emitted light can be detected as a fluctuation of the optical power received by the PD. In this development, in order to save the power consumption, we developed a wavelength monitor structure that uses the light emitted from the rear side of the wavelength tunable LD, which is not normally used. However, in the case of a wavelength tunable LD comprising integrated multiple DFB LDs, the characteristics of the wavelength monitor for each DFB LD vary from one monitor to the other, making it difficult to realize a highly accurate wavelength monitor. The technology used in this model to resolve both of these issues is described below.

3. Technology Used in a Laser Module

3.1. Wavelength tunable LD

Figure 3 is a schematic diagram showing the construction of the newly developed wavelength tunable LD.\(^{(2)}\) This LD consists of an array of 16 DFB LDs integrated on an InP (indium phosphide) substrate, S-bent passive waveguides, an MMI (multimode interference) optical coupler, an SOA (semiconductor optical amplifier), and unequally spaced passive waveguides for the rear-side wavelength monitor. The chip size is 4.8\(\times\)0.5\(\times\)0.1 (mm). The light emitted from the DFB LDs passes through the S-bent passive waveguides and the 16\(\times\)1 MMI optical coupler, and is then amplified by the SOA. The pitch of the grating of each DFB LD is designed so that all 88 channels in the L band (1565-1625 nm, 50 GHz spacing ITU-T grid) can be covered when the temperature adjustment range of the wavelength tunable LD is 30°C or less. Also, in order to simultaneously realize a linewidth of no more than 500 kHz and high optical output, we used a long DFB LD cavity that has a length of 1.2 mm, and also optimally designed the shape of the waveguide of the SOA. Figure 4 shows the dependency of the output power of the optical fiber to which the light emitted from the front side is connected on the SOA current. Measurement was carried out when the temperature of the wavelength tunable LD was 25°C and 55°C, and in addition the current injected into all 16 DFB LDs was a constant 180 mA. At both temperatures, optical fiber output of at least 14 dBm was obtained.

3.2 Rear-side wavelength monitor

Figure 5 shows the construction of the conventional front-side wavelength monitor and the newly developed rear-side wavelength monitor. The newly developed structure minimizes the branch loss of the light emitted from the front side of the wavelength tunable LD. However, the wavelength monitor characteristics vary randomly for each driving DFB LD. This is caused by variations in the angle of incidence of the light to the etalon, which in turn is due to the different locations of rear-side emission points for each DFB LD. We utilized the fact that the transmittance of the etalon has a periodic spectrum, and carried out the design to modify the location of each rear-side emission point of DFB LD as unequal so that the transmittances coincide on equal frequency grids for all of driving DFB LDs.\(^{(3)}\) Figure 6 shows the wavelength monitor characteristics of the prototype laser module. Due to the etalon angle of incidence that differs from one beam

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**Fig. 3** Schematic structure of the developed wavelength tunable LD

**Fig. 4** Measured fiber output power of 16-DFB LD by changing the SOA current

**Fig. 5** Construction of a wavelength monitor

**Fig. 6** Measured etalon spectral transmittances of the lights from the unequally spaced 16 emitting-point array
to another, the spectra of the light emitted from the DFB LD do not match each other; however, the wavelength monitor coefficients in the ITU-T grid, match each other. At that time, the random variations in the wavelength monitor characteristics were within ±1.2 GHz, which is within the target value of ±2.5 GHz.

4. Characteristics of Laser Module

We evaluated the characteristics of the newly developed 100 Gbps digital coherent transmission laser module. Figure 7 shows the optical output for each wavelength channel, Fig. 8 shows the power consumption, Fig. 9 shows the linewidth of the emitted light, and Fig. 10 shows the stability of the light frequencies. The tunable range of the wavelength is the entire L band, which consists of a total of 88 channels.

The measured characteristics of the optical module are indicated below. All of these results satisfy the target values.

- The optical output for all channels is 14.3 dBm or higher.
- The power consumption is 3.6 W or less when the case temperature is 75°C, which is the worst condition.
- The linewidth of the emitted light beam is 320 kHz or less. This measurement is limited to the worst condition for each LD.
- The discrepancy of the emitted light frequency from the ITU-T grid is 0.6 GHz or less.

5. Summary

We have developed a 100 Gbps digital coherent transmission. This laser module is expected to serve as a key device for the miniaturization of 100 Gbps digital coherent transmission systems while also reducing power consumption, thus paving the way for various applications in the future.

References
(2) Horiguchi, Y., et al., The 24th ISLC, TC2 (2014)
(3) Mochizuki, K., et al., The 24th ISLC, TC3 (2014)