1.55μm Tunable DFB-LD for 400G Digital Coherent Optical Transmission System

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1. Introduction

In metro and long-haul networks, data center interconnects, and so on, the demand is rising for high speed, large capacity digital coherent communication.

In this article, we describe the development of a wideband, tunable Distributed Feedback Laser Diode (DFB-LD) chip targeting 400 Gbps digital coherent communication with integrated 16-array DFB-LD and Semiconductor Optical Amplifier (SOA).

2. Background

Because the speed and capacity of optical communication devices are increasing as communication traffic increases, multi-value modulation and light polarization are used, and the demand is rising(1) for digital coherent communication using digital signal processing in modulation and demodulation, so wideband variable wavelength lasers are required as local light sources for that signal beam and the optical receiver. In recent years in particular, the demand has been rising for a speed increase from the conventional 100 Gbps to 400 Gbps in metro and long-haul networks and data center interconnects.

400G digital coherent communication employs 16QAM (Quadrature Amplitude Modulation) or 64QAM, which are the combination of intensity modulation of the optical spectrum and QPSK (Quadrature Phase-Shift Keying) which modulates optical signals by changing the light's phase shift. Such modulation methods require a light source with low phase noise, narrow spectral linewidth, and sufficient intensity. The industry standards group, the Optical Internetworking Forum (OIF), proposes the specification for the light sources such as Micro-Integrable Tunable Laser Assembly (ITLA), etc. applied to those modulation methods. The specification also includes other requirements such as wavelength grid, wavelength stability, etc.

The wavelength-tunable laser methods include the external resonator type, the Distributed Bragg Reflector (DBR) type, and the Distributed Feedback (DFB) array type as shown in Table 1. In the development we are describing here, we used a DFB array type which can realize stable optical output with a simple control to develop the ML9CP61 tunable DFB-LD chip with integrated SOA to supplement the light intensity.

Table 1 Tunable laser type

Type	Output power	Optical spectral linewidth	Tunable range of wavelength	Controllability
External resonator	△	○	△	△
DBR	○	△	○	×
DFB array	△	△	○	○

3. Tunable DFB-LD Chip Design

Figure 1 shows the structure of the tunable DFB-LD chip we developed. Integrated into the InP substrate are 16 DFB-LDs with differing oscillating wavelengths, 16 x 1 Multi Mode Interferer (MMI) optical couplers combining the DFB-LD's optical output in the output port, and SOA to compensate for the losses occurring in the optical couplers and to amplify the optical output. For the purpose of a reduction in the reflected return light, the SOA waveguide is inclined and, at the same time, the chip end surface has a window structure with anti-reflective coating. The chip size is 3.8 mm x 0.75 mm x 0.1 mm.

Changes in the oscillating wavelengths are carried out through the selection of the DFB-LD and the chip temperature adjustment using the Thermoelectric Cooler (TEC). Because the temperature dependency of DFB-LD oscillating wavelength is small at approximately 0.1 nm/°C, in the case that DFB-LD array number is small, it is necessary to significantly change the chip temperature, so the TEC's power consumption is

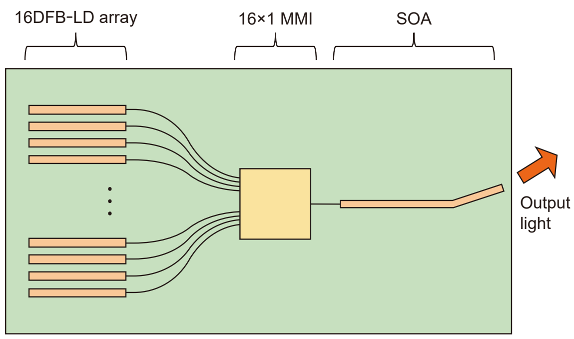

Fig. 1 Schematic structure of tunable DFB-LD chip

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increased. When there are many arrays, although the losses in the optical coupler parts increase, it is possible to narrow the temperature adjustment range and this is advantageous for reducing the power consumption. Here, the number of arrays is 16 and the temperature range is 25 - 55°C, and the diffraction grating pitch of each DFB-LD is designed to satisfy the wavelength standard of the 1.55 μm band of OIF-IC-TROSA-01.0[3] and OIF-400ZR-01.0[4]. To realize the light spectral linewidth of 500 kHz or less required for digital coherent communication, the diffraction grating length was lengthened to 1.4 mm.

4. Element Characteristics

Figure 2 shows the optical output power of the fabricated tunable DFB-LD chip. The Laser Diode (LD) current was set to 220 mA (chip temperature of 25°C) or 250 mA (chip temperature of 55°C), and the SOA current was set to 400 mA. It was confirmed that an optical output of 17 dBm or more was obtained with a variation of 1 dB or less across the full range of the 1.55 μm band. Figure 3 shows the output light spectrum when one of the DFB-LD arrays is operated. The tunable wavelength width corresponding to one DFB-LD at a chip temperature from 25°C to 55°C is 2.9 nm. The Side Mode Suppression Ratio (SMSR) maintains 45 dB or more in an operating temperature range of 25°C to 55°C.

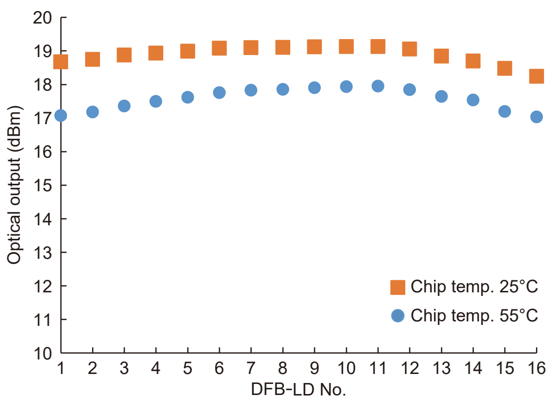

Fig. 2 Output light power of tunable DFB-LD chip

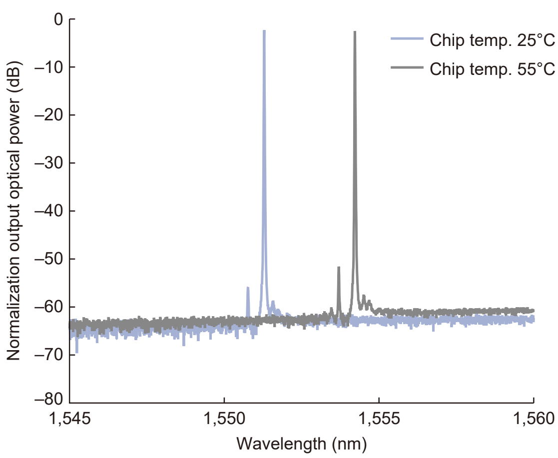

Fig. 3 Optical spectrum of a DFB-LD output light

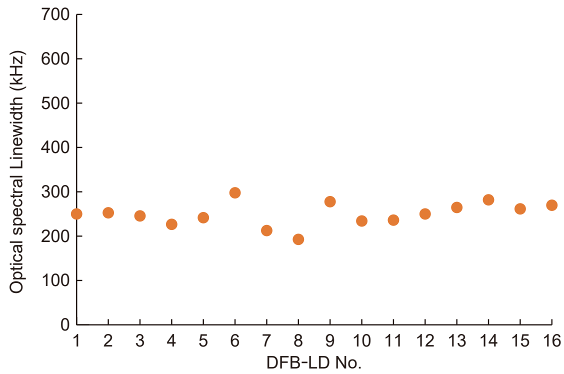

Fig. 4 Optical spectral linewidth of tunable DFB-LD chip

Figure 4 shows the light spectral linewidths at 55°C, an LD current of 250 mA, and an SOA current of 400 mA. The light spectral linewidths are 300 kHz or less, so realization of the performance target of 500 kHz or less was confirmed.

5. LD Modularization

The LD module in Fig. 5 was prototyped using the fabricated DFB-LD chip. Figure 6 shows the block diagram. The output light of the DFB-LD chip parallelized with a collimating lens is separated by prisms 1 and 2, then input respectively into a light intensity monitor PhotoDiode (PD) and a PD for use with a wavelength

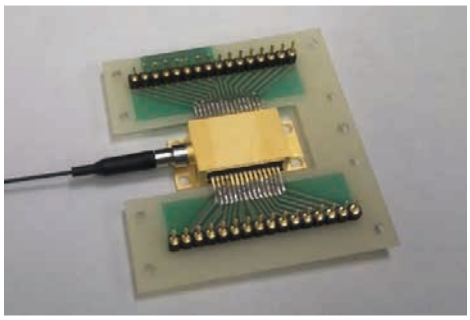

Fig. 5 LD module

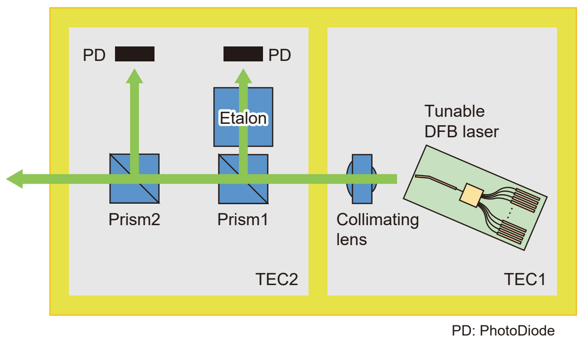

Fig. 6 Schematic block diagram of LD module

monitor via an etalon. To control the temperature independently of the DFB-LD chip, the DFB-LD chip and the collimating lens are installed above TEC1, and the other parts are installed above TEC2.

Figure 7 shows the LD module's tunable wavelength range. The drive current was supplied to the 16 DFB-LDs in order, the chip temperature was kept between 25°C and 55°C, and the oscillating wavelength was measured. It was confirmed that the tunable wavelength range was from 1526.49 nm to 1567.94 nm and that the OIF-IC-TROSA-01.0 (1527.99 nm - 1566.72 nm) and the OIF-400ZR-01.0 (1528.77 nm - 1567.13 nm) were satisfied.

Figure 8 shows the power consumption simulation results and the evaluation results. The total values of the power consumption of the LD chip and the TEC are shown in the case that the LD module temperature was changed to between –5°C and 75°C while keeping the temperature of the LD chip on TEC1 to 25°C or 55°C. In the simulation, the maximum was 4.0 W with an LD chip temperature of 25°C and an LD module temperature of 75°C. The measurement result was 4.3 W under the same conditions so a value close to the designed one was obtained, and meeting the power consumption specifications of the OIF MicroITLA was estimated to be possible.

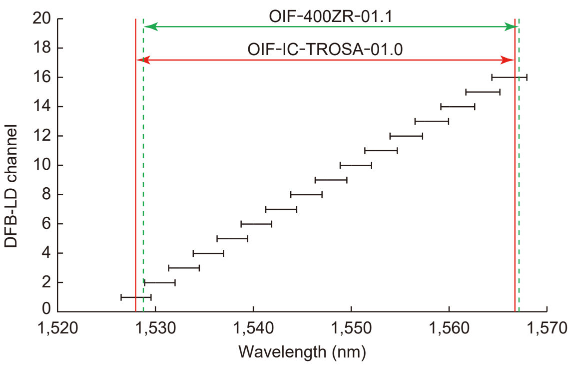

Fig. 7 Tunable range of oscillation wavelength of LD module with DFB-LD chip temperature controlled in the range of 25°C to 55°C

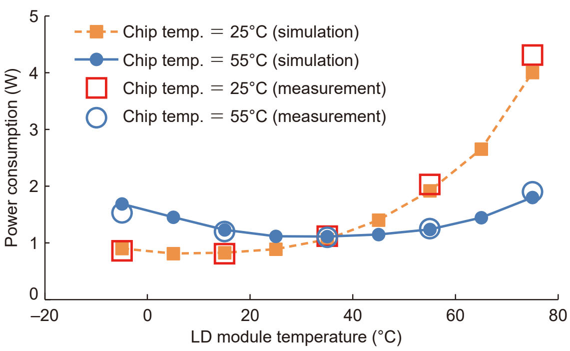

Fig. 8 Power consumption of LD module

6. Conclusion

We developed a tunable DFB-LD chip for use with 400 Gbps digital coherent communication integrated with 16 DFB-LDs with differing oscillating wavelengths and SOA. We realized characteristics suitable for 400 Gbps digital coherent communication with optical output ≧ 17 dBm, SMSR ≧ 45 dB, linewidth ≦ 300kHz, and a wavelength range of 1526.49 nm to 1567.94 nm.

We expect that the technology developed here will contribute to increasing the capacity of digital coherent communication and contribute to an optimal package design for the customers' optical transceiver.

References

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(3) OIF-IC-TROSA-01.0
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(4) OIF-400ZR-01.0
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