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16 channel tunable and 28 Gbd PAM-4 modulated DBR-EAM with high thermal efficiency

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Abstract *We propose an optical waveguide structure which can effectively confine the heat produced by the thin-film heater and fabricate the DBR laser diode integrated with the intensity modulator. Under the 28 Gbd PAM-4 modulation, the fabricate device shows 16 channel operation with clear eye patterns.*

Introduction

With the advent of cloud service and high-definition media streaming, a rapid increase in transmission bandwidth is required in the optical communication. Transmission capacity was achieved through the increase in the number of channels and modulation bandwidth extension. Wavelength division multiplexing (WDM) was used to respond to the increasing data demand, and an increase in the number of channels is continuously required [1,2]. Apart from the use of the WDM technology and the increase of modulation bandwidth, multi-level modulation like the pulse amplitude modulation 4-level (PAM-4) has been recently utilized for increasing the transmission capacity. 400GE, IEEE 802.3bs is being studied using 28 GBaud PAM-4 8 wavelength-lane. Distributed-feedback laser monolithically integrated with electro-absorption modulator (DFB-EAM) has been considered as one of the most promising candidates because it can supply the power extinction ratio with a high linearity suitable for the PAM-4 operation [3,4]. These types of laser diodes have been reported by several advanced research groups. [5,6] Given the price and operation aspects in the WDM-based access and 5G fronthaul networks, the device is required to have the tuning range satisfying the channel grid as well as the same price and power consumption as the conventional DFB-EAM. In case of using the tunable lasers in these networks, the auxiliary management and control channel (AMCC) function for initial installation and maintenance can be effectively used for all channels. As the number of channels are extended, price competitiveness and miniaturization can become crucial issue in this system, and consequently, a distributed Bragg reflector (DBR)-EAM laser diode (LD) with the tunable range of more than 10 nm and modulation rates of over 25 Gbps per channel, will be play an increasingly important role in these networks.

In this study, the heater-tuned DBR-EAM LD including the waveguide structure with a unique form and a high thermal efficiency was proposed and fabricated. The static and dynamic properties of fabricated LD were evaluated under 16 channel operation at a spacing of 150 GHz near 1290 nm for the application of 5G/5G+ fronthaul.

Device structure

Figure 1 show a schematic diagram of the EAM-DBR LD. The device is composed of five sections: gain, phase control section (PCS), DBR, EAM, and spot size converter (SSC). The overall structure and its operational principle of the LD are similar to those of previously reported one [7]. In this work, we proposed the reverse mesa structure in order to effectively isolate the heat generated by the micro-heater from the substrate

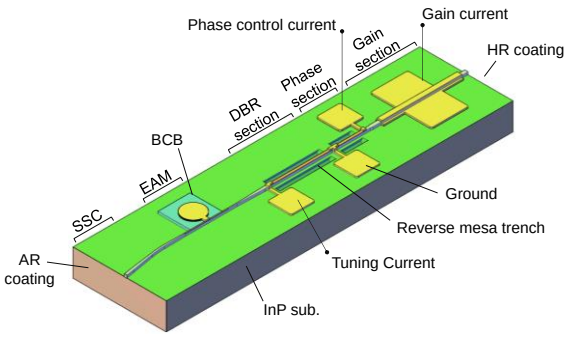

Fig. 1: Schematic diagram of designed laser diodes.

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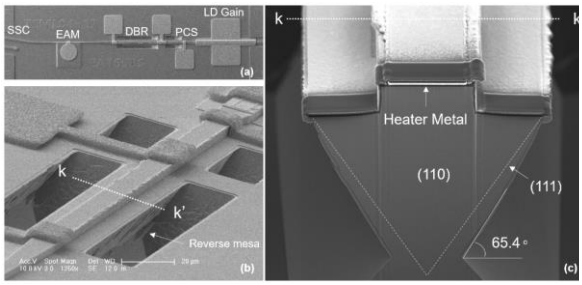

Fig. 2: SEM image of (a) fabricated DBR-EAM LD (top view) (b) DBR section with a micro-heater (c) reverse mesa structure of the DBR section (cross sectional view).

without using any scarification layer.

Figure 2(a), 2(b), and 2(c) show SEM images of the fabricated device (top view), the DBR section with a micro-heater, and the reverse mesa structure of the DBR section (cross-sectional view), respectively. The reverse mesa was formed by using selective (InP) wet-etching technique [8,9].

Experimental results

The static and dynamic characteristics were tested in a form of chip-on-carrier (CoC) with the control and signal lines and a 50 ohm thin-film resistor for impedance matching under the thermo-electric cooler (TEC) temperature of 40℃.

Figure 3(a) and (b) show the wavelength tuning and side mode suppression ratio (SMSR) characteristics with respect to the injection current of the heater for the conventional and the proposed structures, respectively. Under the same current, the proposed structure is shown to be 3.2 times higher in the tuning range. The SMSR appears to be more than 40 dB on a whole tuning range. Figure 4 show the super-imposed tuning spectra with a channel grid of 150 GHz under 28 Gbd PAM-4 operation. A guard band of 300 GHz, which was placed between channels 8 and 9. PCS, was adjusted by controlling the current of the PCS. In all channels, the maximum deviation of peak power was found to be less than 2.2 dB even under the same gain current. The (dynamic) SMSR tended to be slightly reduced with the increase of the tuning range. We think this may be due to the local change of Bragg condition due to the non-uniform thermal distribution across the DBR section.

In this 28 Gbd PAM-4 experiment, the pseud-

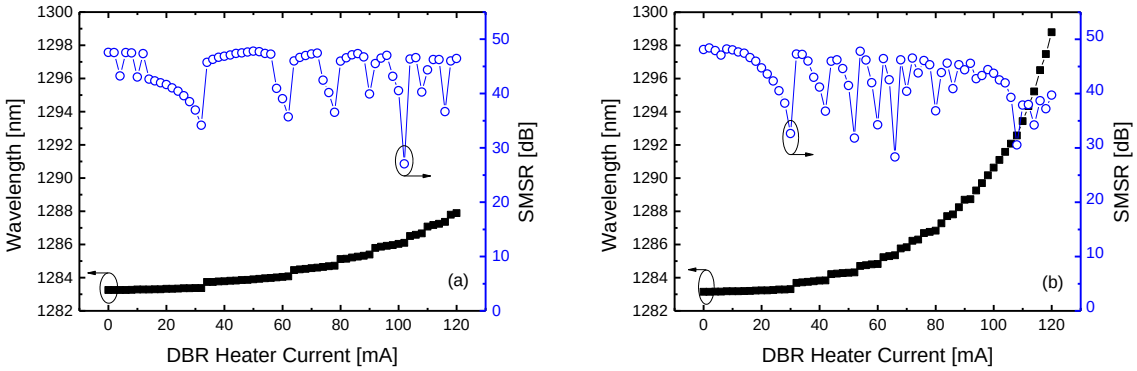

Fig. 3: Lasing wavelength (black) and SMSR (blue) of the DBR-EAM with (a) conventional and (b) the proposed structures (i.e., reverse mesa) with respect to the DBR heater current.

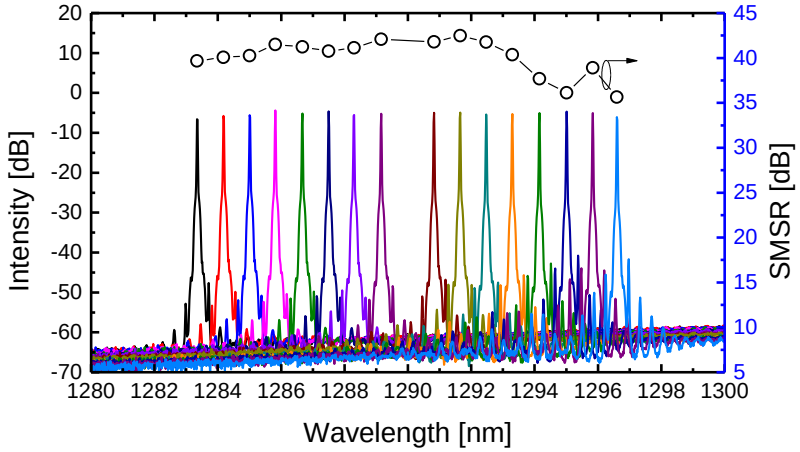

Fig. 4: Superimposed spectra and SMSR of 16 channels under the 28 Gbd PAM-4 operation.

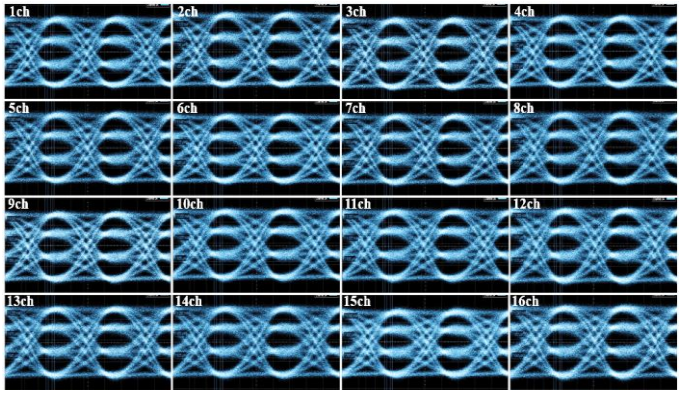

Fig. 5: Measured 28 Gbd PAM-4 eye patterns for 16 channels.

orandom binary sequence (PRBS) 2^{15}-1 pattern was used. The gain current and the peak-to-peak voltage (V_{pp}) were 80 mA, and 2.0 V, respectively. Figure 5 shows the measured PAM-4 eye diagram for 16 channels. The outer extinction ratio (ER) decreases gradually 6.0 to 4.5 dB with the increase of the channel number. For this result, we think this decrease may be closely related to the absorption saturation with the increase of detuning between the lasing wavelength and the EAM absorption peak wavelength.

Conclusion

The DBR tunable laser diodes with reverse mesa structure for high thermal isolation efficiency was designed and fabricated. The wavelength tuning range under the same heater power consumption was increased 3.2 times from 5 nm to 16 nm by the proposed structure. Stable dynamic single mode spectra of 16 channels with the grid of 150 GHz were achieved successfully. All channels showed eye openings under about 28 GBaud PAM4 operation.

Acknowledgements

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