400G cost-effective EML for B5G/6G Fronthaul Network

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Abstract: We demonstrate a cost-effective 400G EML operating within O-band CWDM. This device, designed with an identical active layer, maintains a TDECQ value below 2 dB under 100G PAM4 modulation at 50 ℃.

1. Introduction

For the development of beyond fifth-generation and sixth-generation (B5G/6G) networks, there is a rising demand to fulfill diverse requirements including high-speed modulation, low latency, cost-effectiveness, and more [1]. Therefore, extensive research is underway to develop various technologies essential for constructing B5G/6G fronthaul networks. Specifically, one critical component in fronthaul networks is the high-speed light source for optical transmitters. Electro-absorption modulated lasers (EMLs) include electro-absorption modulators (EAMs), which have a high extinction ratio and high-speed modulation characteristics with minimal chirp. Moreover, when utilizing InAlGaAs multi-quantum well structures as the active layer material, it is possible to achieve superior both of high-temperature operation and high-speed modulation characteristics due to its higher conduction band offset and lower valence band offset compared to InGaAsP [2]. However, the reliability of devices is critically affected by Al oxidation during multiple butt-joint regrowth processes in InAlGaAs materials. Therefore, by fabricating EMLs with an identical active layer, stable device production using InAlGaAs materials becomes feasible while improving process reliability and cost-effectiveness as well [3]. In this study, we present a demonstration of a 400G four channels identical active EML (IA-EML) operating within the entire O-band coarse wavelength division multiplexing (CWDM) range. We successfully validate the 100 Gb/s pulse amplitude modulation 4-level (PAM4) eye diagrams per channel with low transmitter and dispersion eye closure quaternary (TDECQ) values below 2 dB and EO response with bandwidth over 40 GHz at 50 ℃. Our research provides simplified EML with consistently superior performance across the entire O-band range. We expect to contribute to the rapid deployment of B5G/6G networks in the future.

2. Device structure

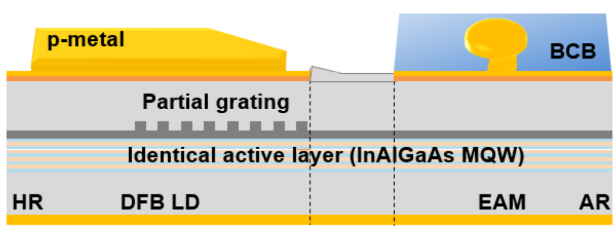

Fig. 1. Schematic structure of IA-EML device.

The IA-EML consists of distributed feedback laser diode (DFB LD) and EAM regions, and due to the identical InAlGaAs active layer across the entire device, it eliminates the need for any additional active layer regrowth (Fig. 1). The MQW consists of eight compressively strained InAlGaAs wells and nine tensile strained InAlGaAs barriers, grown using metal-organic chemical vapor deposition (MOCVD). In order to achieve single-mode lasing of DFB LD, an InGaAsP partial grating structure was fabricated using holographic photolithography. Additionally, the rear and front facets were coated with high-reflection (HR) and anti-reflection (AR) coatings, respectively. To reduce the parasitic capacitance of device for high-speed modulation, p-metal pad of EAM region exist on the benzocyclobutene (BCB).

3. Experimental Results

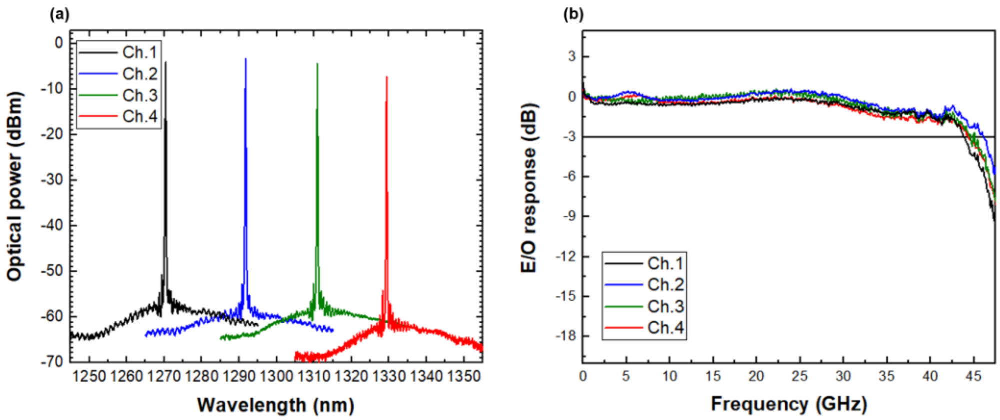

Fig. 2. (a) Optical spectra and (b) EO response of each IA-EML at 50 ℃

Fig. 2(a) shows the optical spectra of four channels within O-band CWDM at 50 ℃. We utilized CWDM wavelength to validate the characteristics of device across the entire O-band range, which includes both negative and positive dispersion properties. Single-mode lasing can be confirmed with a side mode suppression ratio (SMSR) of over 45dB across all channels, which can be attributed to the effective adjustment of detuning between PL and DFB LD lasing wavelengths, as well as the impact of the partial grating and AR/HR coating configuration. We conducted EO response measurements to ascertain the 3dB bandwidth of the device. For the measurement, the IA-EML chip was integrated on a submount with 50 Ω load matching resistor for RF signal injection. Fig. 2(b) indicates that all devices have a 3dB bandwidth exceeding 40 GHz at 50 ℃.

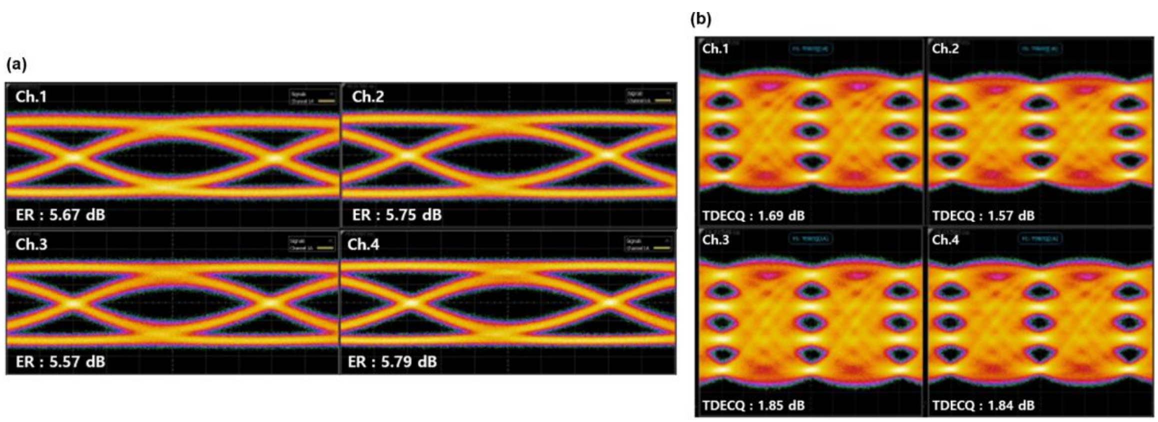

Fig. 3. Eye diagrams of back-to-back (a) 50 Gb/s NRZ and (b) 53.125 GBaud PAM4 modulation at 50 ℃.

To clarify the further dynamic characteristics, we constructed a transmitter optical sub-assembly (TOSA) with a built-in thermoelectric cooler (TEC). We performed 50 Gb/s NRZ and 53.125 GBaud (100 Gb/s) PAM4 eye diagram measurements at 50 ℃. The non-return-to-zero (NRZ) and PAM4 signals were generated by pulsed pattern generator (Anritsu MU196020A) and measured by Keysight N1030A. Fig. 3(a) indicates the 50 Gb/s NRZ eye diagrams of each IA-EML. We observed a clear eye-opening with the dynamic extinction ratio (ER) of more than 5 dB. The 100 Gb/s PAM4 eye diagrams obtained using a fourth-order-Bessel-Thomson (26.6 GHz) filter and a 5-Tap T-spaced feed-forward equalizer (FFE) based on IEEE 802.3cd [4]. Fig. 3(b) shows uniform operation across all wavelengths with low TDECQ values of less than 2 dB.

4. Conclusion

We demonstrate a 400G IA-EML for the optical transmitter advantageous to both high-speed modulation and cost-effectiveness. Each IA-EML device is optimized for entire CWDM spectrum in the O-band, which show consistent single mode lasing for all of four channels with a SMSR of exceeding 45 dB. Notably, every channel has a TDECQ value of less than 2 dB under 100 Gb/s PAM4 modulation at 50 ℃. We anticipate that our research will contribute the efficient implementation of B5G/6G fronthaul networks.

5. Acknowledgment

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6. References

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[4] IEEE 802.3cd 50 Gb/s, 100 Gb/s, and 200 Gb/s ethernet task force," (2018), http://www.ieee802.org/3/cd/.