200G per Lane Uncooled CWDM Hybrid CMBH-Ridge Electroabsorption Modulated Lasers for 2-km Transmission

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Abstract: We report uncooled (20-70C) hybrid CMBH-Ridge O-band CWDM EMLs with 60 GHz bandwidth (BW). At 112.5GBd PAM4 and 1.1Vpp, 4 dB extinction ratio (ER) and greater than 7 dBm output power is demonstrated over temperature. © 2022 The Author(s)

1. Introduction

Electroabsorption modulated lasers (EML) consist of a DFB laser integrated with an electro-absorption modulator. EMLs with their compact size and low voltage swing requirement have been a popular solution for short-reach data center applications. State of the art uncooled EMLs in production have a 3 dB electro-optic bandwidth (EO-BW) greater than 40 GHz and transmit at 100G per lane. For 800G and beyond, 200G per lane cuts down the number of lasers by half and provides cost advantages to scale to 1.6T Ethernet [1]. 200G per lane with 2-km fiber transmission has been recently demonstrated using conventional EMLs [2] and with flip chip bonding approach [3] at 1310 nm.

In this paper, we report a hybrid capped mesa buried heterostructure (CMBH)-Ridge uncooled Indium Phosphide (InP) system based EML over four O-band CWDM channels. For the first time, 20-70C EML 3 dB EO-BW exceeded 60 GHz using lumped electrodes and conventional wire bonding, suitable for 200G per lane applications. Back to back (BTB) PAM4 data at 112.5 GBd is presented over temperature with a RF ER of 4 dB and output power greater than 7 dBm. 2-km fiber transmission is demonstrated at 100 GBd for 1270 and 1330 channel with less than 3.25 dB transmission dispersion eye closure quaternary (TDECQ).

2. Device description

The DFB Laser in the hybrid EML had a InP based multi-quantum well (MQW) structure with a CMBH waveguide (WG) (Figure 1b) in order to support uncooled high power applications, while the modulator had a ridge WG to minimize capacitance for high-speed operation. Suitable passive waveguide tapers electrically isolated the laser and modulator and were also used near the facet to minimize coupling loss. The hybrid approach enabled the use of optimized current blocking layers in the laser for minimum leakage without imposing a penalty on the modulator's capacitance. A 3D Schematic of the EML is shown in Figure 1a. The laser and modulator facets were coated with high-reflection (HR) and anti-reflection (AR) coatings respectively for increasing the output power. Low-κ dielectric was used underneath the metal pad in the modulator to minimize parasitic capacitance. The MQW designs were individually optimized in the laser and modulator for sufficient output power and ER. EMLs from all the four CWDM channels (1270, 1290, 1310 and 1330 nm) were individually bonded to an Aluminum Nitride carrier (COC) for PAM4 measurements. The modulator electrodes were designed to be driven as a lumped element and the RF signal was terminated using a 50Ω resistor on the carrier.

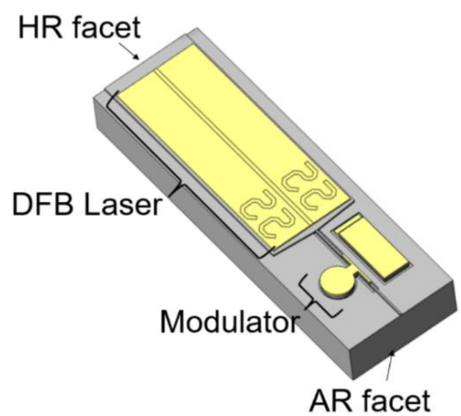

Figure 1a: 3D Schematic of Hybrid EML

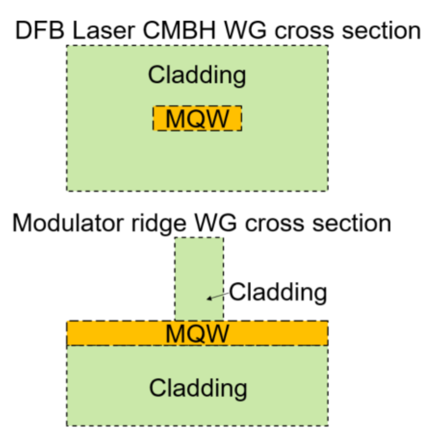

Figure 1b: Cross section schematic of laser and modulator WG

3. Results

The COCs were tested at 20 and 70C on a fixture whose temperature was controlled by a thermo-electric cooler. L-I data using a broad area detector at a modulator bias of 0V for all four channels is shown in Figure 2a. Solid lines represent the 20C data while the dotted lines represent the 70C data. Output power from all four channels were greater than 10 dBm from 20-70C at a laser bias of 100 mA. Because of the separately optimized current blocking layers for the lasers, the devices show minimum L-I roll over up to 120 mA even at 70C. Figure 2b shows the optical spectra for all four channels at 20C, 100 mA and 70C, 120 mA. Laser spectra show a side mode suppression ratio (SMSR) greater than 45 dB for all channels from 20 to 70C. Peak lasing wavelengths were 1270.56 nm, 1289.7 nm, 1310.54 nm and 1330.44 nm @ 20C. Peak and average relative intensity noise (RIN) was less than -150 dB/Hz and -155 dB/Hz respectively for all channels from 20-70C. DC ER for all channels were greater than 10 dB @ 20C and 20 dB @ 70C.

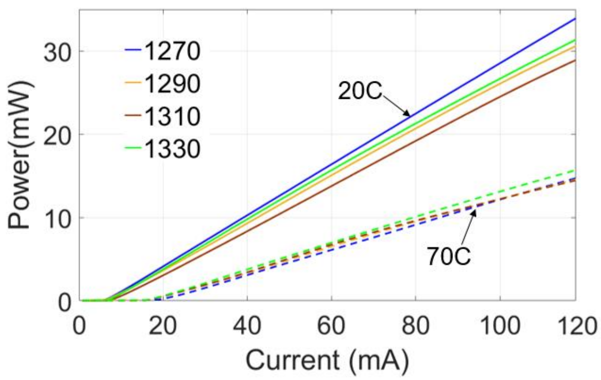

Figure 2a: L-I data over temperature

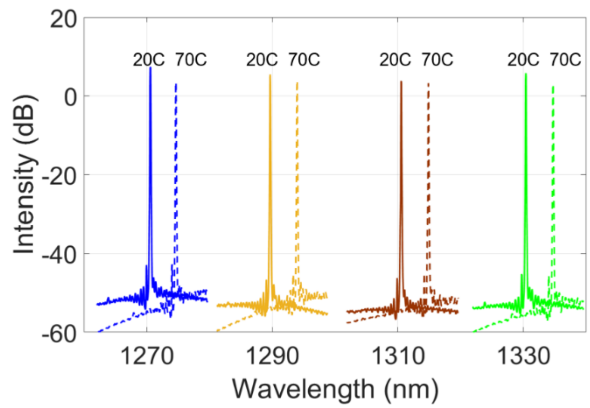

Figure 2b: Laser spectra for CWDM channels

In addition to minimizing the modulator capacitance, inductance must be controlled for maximizing EML BW. For the COCs, two wire bonds were used to reduce the inductance between signal trace on the carrier and the modulator metal pad on the chip. A single wire bond is used from the modulator pad to the 50Ω termination resistor. EO S21 and S11 measurements were carried out using a 67 GHz VNA and high-speed photodetector. The modulator was biased close to its inflection voltage to have maximum electro-optic efficiency, with the laser bias set at 100 mA for 20 and 55C and 120 mA for 70C. The EO-BW for the 1310 channel at three different temperatures are shown in Figure 3. Solid lines represent the S21 and dotted lines represent the S11 data. Because of the hybrid design and the low capacitance ridge waveguide, 3 dB EO-BW is greater than 60 GHz for all the temperatures with S11 < 4.8 dB. S21 data shows slight peaking in the low frequency region, which could be adjusted by controlling the termination wire bond length. This demonstration of high EO BW makes these EMLs attractive for greater than 100 GBd PAM4 applications.

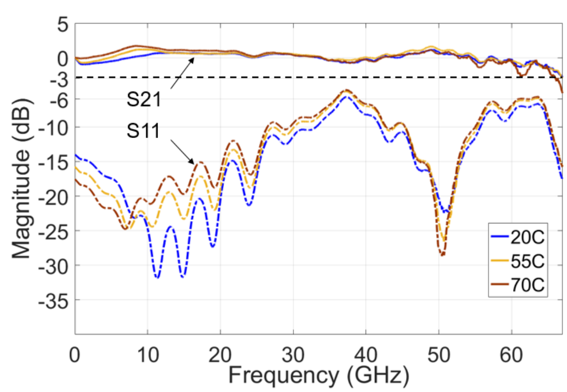

Figure 3: EO S21 and S11 over temperature, 1310 channel

4. PAM4 measurements

PAM4 measurements were carried out by generating a 112.5 GBd (225 Gb/s) PAM4 electrical signal with SSPRQ pattern using an arbitrary waveform generator (AWG) with 0.6Vpp output swing. A voltage swing of 1.1Vpp was achieved after amplifying the inbuilt signal using an external amplifier. Modulator DC bias was applied through the built in bias tee in the amplifier. The fiber coupled output signal was measured using a 65 GHz Digital Communication Analyzer (DCA) which had the fourth order Bessel Thomson filter set to half-baud rate, 56.25GHz. For TDECQ measurements, 5 taps and 7.6 E-3 symbol error rate was used. Laser bias for BTB measurements was set at 100 mA and 120 mA for 20 and 70C respectively. The modulator was biased closer to inflection, -2.25V±0.25 V @ 20C and -1.35V±0.25 V @70C for low chirp and adjusted to achieve 4 dB ER. Unequalized BTB measurements for all four CWDM channels are shown in Figure 4a. All four channels demonstrated open eyes before equalization at both 20 and 70C with a TDECQ under 2 dB. Output power (Pout) from the chip when the modulator is biased for 4 dB ER is greater than 7 dBm for all channels even at 70C. To have a better input electrical signal, the fiber transmission experiment was carried out at 100 GBd (200 Gb/s). 2-km fiber transmission data for 1270 and 1330 channels @ 50C with 4 dB ER and 100 mA laser bias is shown in Figure 4b. TDECQ penalties of 1.18 and 2.26 dB were seen between BTB and fiber measurements for 1270 and 1330 channels respectively.

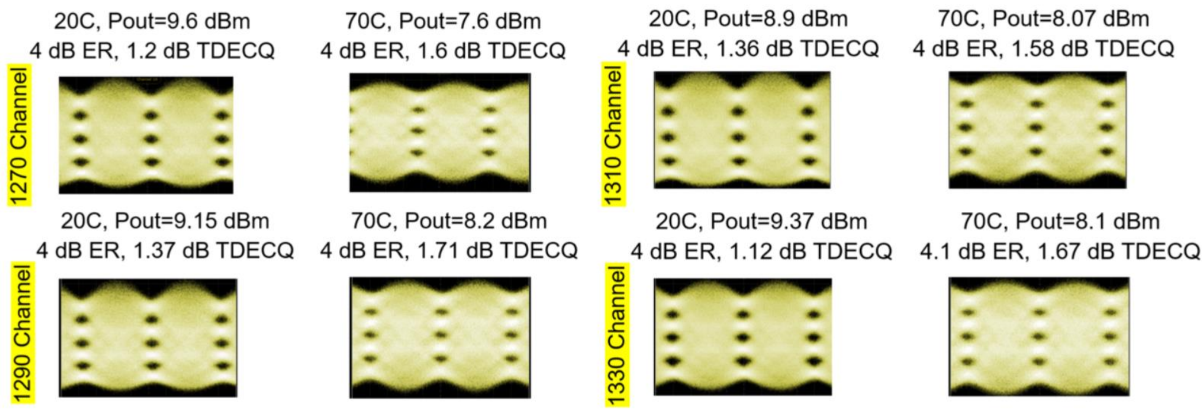

Figure 4a: BTB 112.5 GBd (225 Gb/s) PAM4 with Vpp=1.1V for four CWDM channels @ 20 and 70C

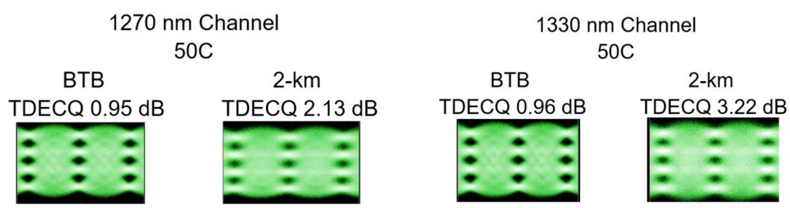

Figure 4b: 100 GBd PAM4 (200 Gb/s) BTB and 2-km fiber transmission data after equalization for 1270 and 1330 channel @ 50C

5. Summary

A hybrid CMBH-Ridge EML was designed and used to demonstrate 112.5 GBd (225 Gb/s) PAM4 BTB transmission over four O-band CWDM channels with a 3 dB EO BW of 60 GHz. All four channels had 4 dB ER and a high output power greater than 7 dBm over 20-70C. 2-km fiber transmission using 1270 and 1330 channel EMLs @ 50C showed a TDECQ of less than 3.25 dB. This combination of high power over temperature, high ER and BW makes these EMLs suitable for short reach 200G per lane datacenter applications.

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