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A Low Chirp Electroabsorption Modulated Laser suitable for 200Gb/s PAM4 CWDM Transmission over 2km

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Abstract: *200Gb/s PAM4 operation was demonstrated using a packaged electroabsorption modulated laser at 1271nm and 1331nm wavelengths. 4.5dB extinction ratio at 1.0Vpp in back-to-back and clear PAM4 eye diagrams after 2km transmission were observed. ©2022 The Author(s)*

Introduction

Due to the increasing traffic on cloud-based services, the data traffic through the data centres continues to grow exponentially [1]. To meet the fast growing demands, Ethernet standards have evolved to 400GbE and discussions are ongoing for 800GbE and 1.6TbE standardization [2]. For the short reach interconnects within datacentres, intensity-modulation direct-detection (IM/DD) systems are highly attractive due to their simpler architecture and lower power consumption [1]. Generally operation at O-band has been chosen as the fibre dispersion is better. Electro-absorption modulated laser (EML) consisting of distributed feedback laser (DFB) and electro-absorption modulator (EAM) is well suited for short-reach optical interconnect applications at 2km range, thanks to its smaller footprint, high bandwidth, high extinction ratio (ER) and low driving voltage which may allow oDSP directly driven. 224Gb/s PAM4 2km transmission at 1310nm and 384Gb/s PAM8 operation using EML CoC at 50ºC with 1.0Vpp Swing over 2km transmission at 1310nm have been reported [3,4]. To boost the 3dB bandwidth, a stepped AlN submount was used to shorten the incoming wire bonding to enhance the 3B bandwidth [5].

In this study, a packaged low chirp EML suitable for 800GbE was developed, it has demonstrated back-to-back (BTB) and 2km transmission of 200Gb/s (100Gbaud) PAM4 signals and clear PAM4 eye opening at semi-cool temperature of 52°C at 1271nm and 1331nm for the first time.

Device Structure and DC characterisation

A standard lumped electrode EML has been chosen due to its simplicity and better suitable for mass production. The EAM was butt-couple grown to DFB on an n-InP substrate. InGaAlAs based multiple quantum wells (MQWs) were employed for both DFB and EAM sections for higher efficiency and better performance. The EAM is electrically isolated from DFB via a passive section. Ridge waveguide was used for both DFB and EAM. For low reflection and high optical output power, an anti-reflection (AR) coating (with a reflectivity of lower than 0.1%) and a high reflection (HR) coating were coated on the front and back facets, respectively.

To reduce its parasitic capacitance, the n and p-doping profiles were carefully controlled, and the EAM bond-pad capacitance was reduced. To reduce junction capacitance of the EAM, the waveguide width and length were optimised to achieve good ER and bandwidth. The lowered EAM capacitance leads to a high bandwidth of greater than 60GHz.

EMLs with conventional DFB with HR and AR facets are sensitive to the facet phase change, the front and back facet output power ratio (FBR) distribution is generally between 3-30, as shown in Fig.1(a). To improve the EML distribution and yield, the DFB laser's doping profile, grating, grating coupling coefficient and length were optimised to have more uniform distribution without compromising the laser performance. As a result, the front and back facet output ratio distribution is very uniformly distributed around 8, c.f. Fig.1(b). Two lasing wavelength at 1271nm and 1331nm were evaluated, representing the two outermost channels in a CWDM4 application. Side mode suppression ratio (SMSR) greater than 40dB was achieved at 0°C, 52°C and 80°C as shown in Fig.1(c).

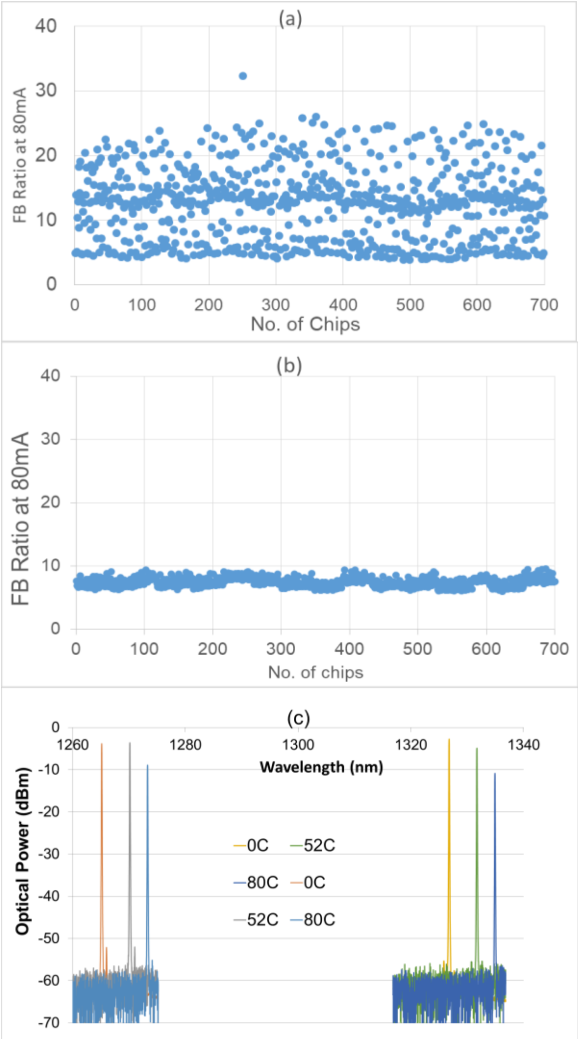


Fig. 1: EML DC characteristics (a) the FB Ratio of a conventional EML (b) the FB Ratio of the improved EML (c) the EML spectra at 1271nm and 131nm at 0, 52 and 80C of the improved EML

The low FBR means the EML can maintain good Relative Intensity Noise (RIN) performance even with -20dB back-reflection, as shown in Fig.2. The EML was designed and processed suitable for non-hermetic environment operation, i.e. can pass 85C and 85% humidity test.

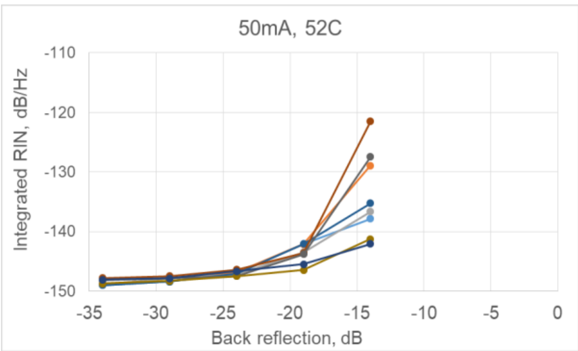


Fig. 2: 8 EML RIN measurements under external reflection

A conventional AlN submount was used to bond the EML chips, The CoC was attached to a thermo-electrical cooler (TEC) to control the temperature. The thickness of heat sink was properly controlled so that the GSG terminations of the CoC and G3PO packaging have similar height to reduce the wire-boding length. A single lens was used to couple light to the optical fibre. The packaged EML chip's S21 is shown in Fig.3, and 3dB bandwidth of 58GHz was achieved at 52°C.

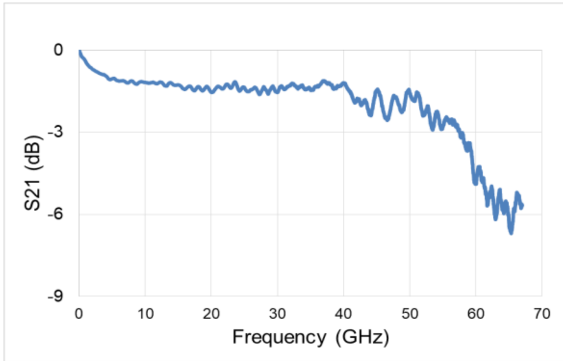


Fig. 3: A typical E/O S21 response of a packaged EML chip at 52C

The detuning wavelength between the DFB and EAM was optimised to ensure good output power and high enough ER. ER_DC > 15dB were achieved for both 1271nm and 1331nm.

Chromatic dispersion increases by the square of the baud rate, so for 100GBaud CWDM applications, reducing the EML chirp is key to extend the transmission distance. By optimizing the EAM MQW design, at the V_bias point the EML chirp value was between 0-0.5 for both 1271nm and 1331nm, as shown in Fig.4.

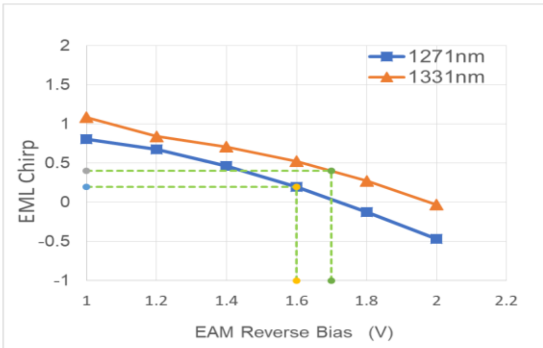


Fig. 4: Measured EML chirp at 1271nm and 1331nm

System Results

A schematic experimental setup for evaluating 200Gb/s PAM4 operation of the EML is shown in Fig.6. An arbitrary waveform generator (AWG) with sampling rate of 256Gsa/s and 67GHz bandwidth was used to generate a 200Gb/s drive signal with a SSPRQ of 65535. The electrical signal from the AWG was amplified by a linear driver with bandwidth of 67GHz and gain of 11dB to obtain high enough driving voltage. DC bias voltage was then applied to the EAM through a bias tee with bandwidth of 67GHz. The drive voltage of the EAM was set to 1.0Vpp at 52°C. Drive voltage and electrical eye diagrams were measured by connecting a coaxial cable to a digital communication analyser (DCA) with a five-taps Transmitter and Dispersion Eye Closure Quaternary (TDECQ) equalizer. The electrical eye diagram after equalization at different outputs are also shown in Fig.5. In the experiment, the packaged EML was connected with electric signal by G3PO cable and its temperature was controlled by TEC. The DFB laser currents was set to about 80 mA.

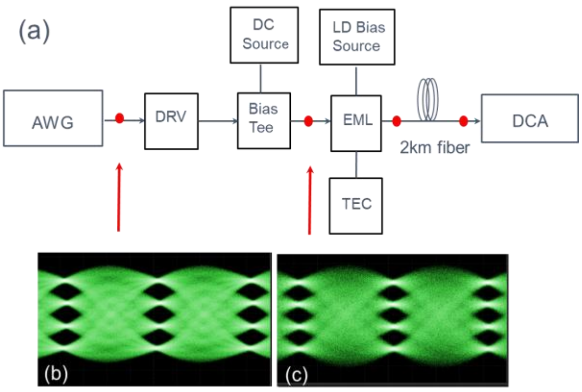
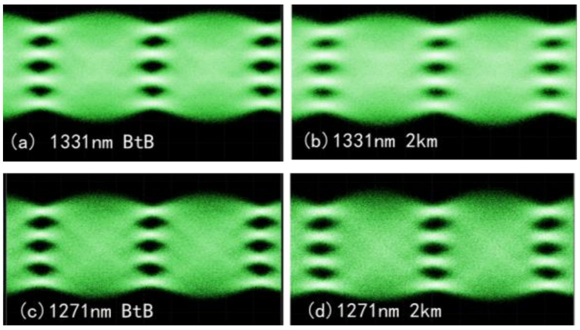


Fig. 5: Experimental Setup (a); Electrical waveforms at the AWG output (b); Bias Tee output (c).

Optical output of the EMLs was coupled to a lensed single-mode fibre (SMF) with dispersion of about -6.4ps/nm at 1271nm wavelength and about 4.1ps/nm at 1331nm, and it was detected by the DCA. The bandwidth of fourth-order Bessel Thomson filter and target symbol error rate was set to 50GHz and 4e-3 (corresponding to BER 2e-3), respectively.

Fig.6 shows the 200Gb/s optical eye waveforms after equalization at 1271nm and 1331nm. The waveforms on the left and right sides represent BTB and 2km transmission, respectively. V_bias voltage was set to around 1.5V to get better the level separation mismatch ratio (RLM), which is above 0.97. Thanks to the high bandwidth, as shown in Fig.3, clear eye openings at 52°C with extinction ratio over 4.5 dB at 1.0Vpp and 1.3dB TDECQ at BtB are confirmed. Clear eye openings after 2km SMF transmission were also observed at 52°C. TDECQ was confirmed to be less than 2.5 dB at 52°C. The maximum penalty of 2km transmission is less than 1dB. These low TDECQ values and penalty suggest that the newly developed EML could be applicable to 224Gb/s transmission.



Temperature	Wavelength	TDECQ (5tap, 4e-3, SSPRQ)		ER
		EML output	After 2km fiber	
52C	1331nm	1.3 dB	2.28 dB	4.8dB
	1271nm	1.3 dB	1.30dB	4.6dB

Fig. 6: Optical waveforms after equalization in BtB (a) (c) and 2km transmission (b) (d) of 200Gb/s PAM4 at 1271nm and 1331nm of 52°C . The results of TDECQ and ER are listed in the table

Conclusion

A low chirp EML was developed and it demonstrated 2km SMF transmission of 200GB/s PAM4 signals at 1271nm and 1331nm with TDECQ less than 2.5 dB at 52°C. A clear eye opening (with ER of more than 4.5dB) was shown. These results show that the newly developed EMLs are a promising optical light source to realize the upcoming 800GbE and 1.6TbE applications in data centres.

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