Wide Temperature Range (0 to 85ºC), 40-km SMF Transmission of a 1.55-μm, 10-Gbit/s InGaAlAs Electroabsorption Modulator Integrated DFB Laser

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Abstract: A new uncooled 1.55-μm InGaAlAs electroabsorption-modulator integrated DFB-laser suitable for low-power-consumption 10-Gbit/s small-form-factor modules is demonstrated. For the first time, 10-Gbit/s 40-km normal SMF transmission with 1-dB power penalty is achieved from 0 to 85ºC.

OCIS codes: (140.5960) Semiconductor lasers; (230.3120) Integrated optics devices

1. Introduction

Modulator integrated semiconductor lasers are key components in 10-Gbit/s Intermediate-Reach (IR: 40 km) and Long-Reach (LR: 80 km) categories for MAN/WAN applications. For the lightsources used in these applications, cooled or quasi-cooled-electroabsorption modulator integrated distributed feedback lasers (EA/DFB) are commonly adopted. Most of these devices are packaged in small-form-factor (SFF) modules such as 300-pin, XENPAK or XFP. For such applications, peltier-free uncooled operation of EA/DFBs has been strongly desired as a way of improving the power consumption to achieve the compact IR/LR modules that are compatible to Short Reach (SR: < 25 km)-SFF modules.

However, achieving uncooled EA/DFBs has been highly challenging, because the devices are very sensitive to the change in temperature. This is because the temperature sensitivity of the EA absorption peak wavelength (λ_{EA}) is about six times larger than that of the DFB lasing wavelength (λ_{DFB}). This makes the large temperature variation in the wavelength detuning (the difference between λ_{DFB} and λ_{EA}); a key parameter that determines the modulator performance. To overcome this problem, the voltage-offset method was proposed to demonstrate a 1.3-μm uncooled EA/DFB for SR application [1]. Some attempts have also been made to achieve uncooled EA(/DFB)s for 1.3/1.55-μm 10-Gbit/s [2-4], and 1.55-μm 40-Gbit/s [5] applications. Until now, no study has been reported on an uncooled 1.55-μm EA/DFB for 40-km SMF transmission.

In this paper, we describe for the first time an uncooled 1.55-μm IR EA/DFB based on newly developed InGaAlAs EA modulator technologies. Successful 10-Gbit/s 40-km normal SMF transmission is demonstrated from 0ºC to 85ºC.

2. Device structure and fabrication

Figure 1 is a schematic cross section of our uncooled EA/DFB laser. The device consists of a 200-μm-long InGaAlAs EA modulator, a 400-μm-long DFB laser, and a 100-μm-long bridge waveguide in between. All components are monolithically integrated on an InP substrate. By adopting a temperature-tolerant InGaAlAs material in the modulator region, substantial improvement is expected in the trade-off relationship between extinction ratio (ER), chirp and power handling capability [6]. The improvement is based on the ideal band structure of InGaAlAs material; a larger conduction band offset combined with a smaller valence band offset compared to the conventional

InGaAsP materials.

The EA/DFB integrated structure was fabricated using a newly-developed multistep butt-joint etching/regrowth technique [7,8]. A DFB corrugation was then formed by conventional holographic exposure and wet-chemical etching. An InP cladding layer was then grown on the entire structure, and the wafer was processed into a standard ridge waveguide structure with a small-area bonding pad at the EA modulator for lower parasitic capacitance. Furthermore, by etching the p^+ contact layer of the waveguide region, we can obtain the electrical isolation between the EA modulator and the DFB laser. Highly reflective coating films and an anti-reflective film were deposited on the facet at the end of the DFB laser and on the front of the EA modulator, respectively. The chip was die-bonded junction-up on a temperature controlled carrier with a 50-Ω terminal resistor.

3. Device performance

The typical lasing spectra of uncooled EA/DFB at 0ºC, 25ºC and 85ºC operations are shown in Fig. 2. A side-mode suppression ratio (SMSR) larger than 40 dB was obtained for all operating temperatures. Figure 3 plots the static extinction ratio (SER) characteristics at various operating temperatures from 5°C to 85ºC. By carefully optimizing the InGaAlAs quantum well design, wavelength detuning and modulator length, we were able to obtain a moderately gentle extinction curve with SER of over -20 dB with a maximum EA bias of 4.3 V. Note that these ER value can never be achieved with conventional InGaAsP-based EA modulators. The measured 3-dB frequency bandwidths were typically 14 GHz, which were less temperature sensitive.

Figure 4 shows non-filtered eye diagrams obtained under 10-Gbit/s modulation. We used a 2^{31}-1 pseudo-random bit stream (PRBS) at all operating temperatures. Modulation bias amplitude was 2.3 V and maximum offset bias at 0ºC was 1.6 V. Reflecting the ideal band structure of InGaAlAs MQW, the measured dynamic extinction ratios (DER) were 10.6 dB and 12.8 dB at the respective operating temperatures of 0ºC and 85ºC. Figure 5 plots the bit error rate performance before and after 40-km transmission through the normal SMF at 0ºC and 85ºC operations. The power penalty after 40-km transmission was about 1 dB at both temperatures. The temperature dependence of back-to-back DER and power penalty after 40-km transmission is in Fig. 6. As shown in this figure, we obtained high DERs of more than 10 dB with power penalties of almost 1 dB at all operating temperatures. These results are sufficient for practical use as the light source for 10-Gbit/s-IR. To our best knowledge, it is the first demonstration of 10-Gbit/s 40-km transmission over a wide temperature range by 1.55-µm EA/DFB.

4. Conclusion

An uncooled 1.55-µm InGaAlAs-MQW EA/DFB laser has been developed for use as a light source in 10-Gbit/s WAN/MAN links. For an EA bias amplitude of 2.3 V with a maximum offset bias up to 1.6 V, 10-Gbit/s 40-km SMF transmission was achieved with an extinction ratio over 10 dB with a 1-dB power penalty at operating temperatures from 0ºC to 85ºC. This device would therefore be promising for next-generation high-speed data links.

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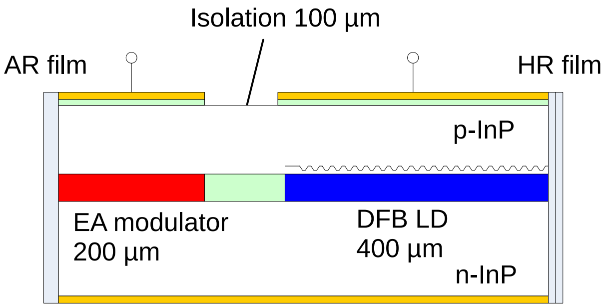


Figure 1 Schematic structure of uncooled EA/DFB.

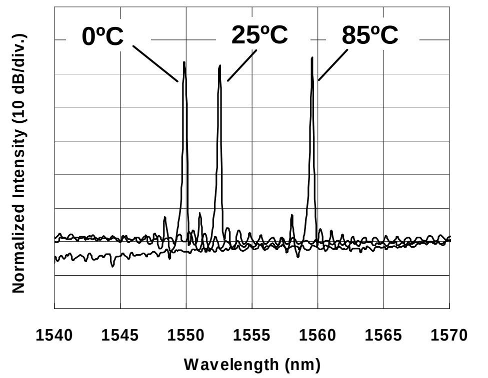


Figure 2 Lasing spectra at various operating temperatures.

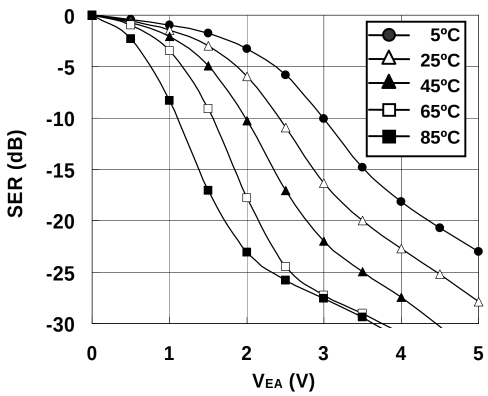


Figure 3 Static ER characteristics over wide temperature range.

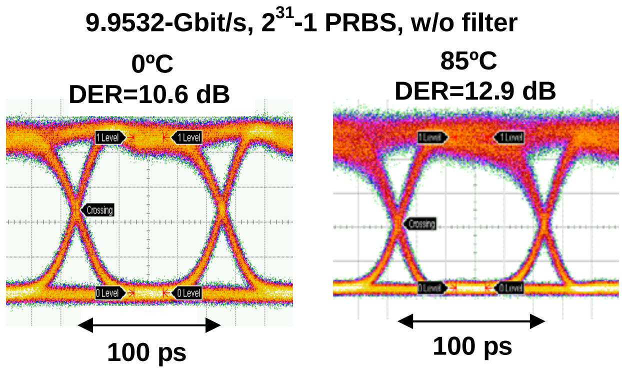
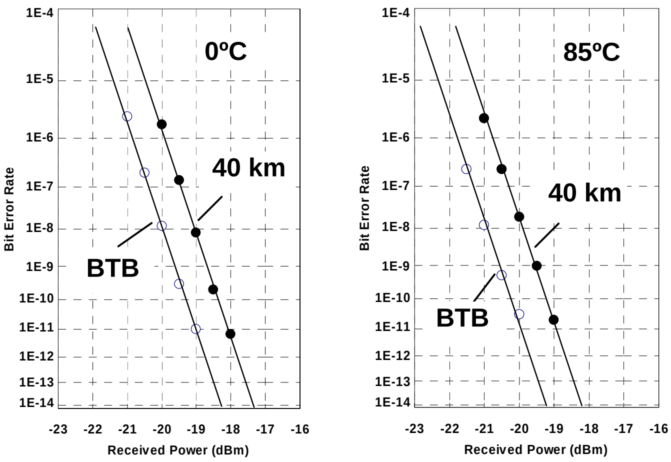


Figure 4 Eye patterns for 10-Gbit/s modulation at 0ºC and 85ºC.



(a) 0ºC (b) 85ºC

Figure 5 Bit error rate curves back-to-back and after 40-km normal SMF transmission at 0ºC and 85ºC.

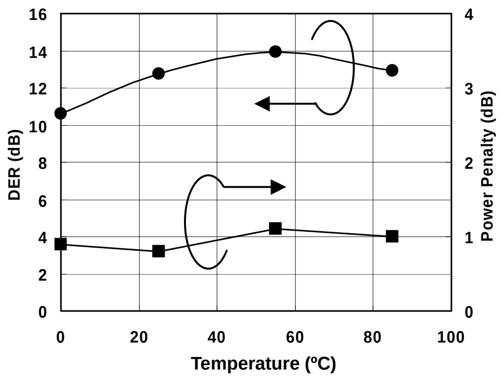


Figure 6 Temperature dependence of back-to-back dynamic ER and power penalty after 40-km normal SMF transmission under 10-Gbit/s modulation.