High Speed AlGaInAs Electroabsorption Modulated Laser and its Optically Equalized Operation at 86 Gb/s

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Abstract

We demonstrate a novel compact AlGaInAs electroabsorption modulated laser at 86 Gb/s including bit-error rate measurements using an optical equalizer.

Introduction

Due to new services generating an increase in data traffic, transponder serial interface speeds up to **112 Gb/s** are of high interest. Ultrahigh speed serial links using simple on/off keying (OOK) are driven by short-reach applications where footprint, power consumption and cost are of utmost importance. Most of the current experiments using binary 80-112-Gb/s modulation employ bulky $LiNbO_3$ Mach-Zehnder modulators (MZM) [1] and stand-alone InP MZM or electro-absorption modulators (EAM) [2,3]. Integrated rlectroabsorption modulated lasers (EML) appear also as good candidates as they have already an important place in 10- and 43-Gb/s transmission applications due to their small size and low drive voltage requirements, the latter being particularly important for efficient modulation at higher speeds. Because EAMs are very short and since the EML monolithically integrates the laser, EMLs allow for extremely compact transmitters.

Recently we demonstrated a simplified integration technology based on a low-capacitance semi-insulating buried heterostructure (SIBH) for both laser and modulator sections. Realized components with 50-µm EAM sections demonstrated an extinction ratio of 18 dB and up to 60 GHz of bandwidth [4].

In this work, we took advantage of the very small modulator length and developed a new high-frequency carrier allowing to feed the EML as a lumped insert in a transmission line. This component has been successfully used in an **85.5-Gb/s** OOK experiment using a passive optical equalizer (OEQ). The OEQ has previously been demonstrated on 40-Gb/s and 100-Gb/s modulation formats generated with $LiNbO_3$ [1] and InP MZMs, but never with an EAM or EML. Error-free operation has been obtained for the first time for such a simple device with low-cost potential.

EML design, realization and characteristics

The EML was designed with 10 InAlGaAs compressive strain quantum wells (QWs) as the active structure. Laser and modulator section lengths are 450 µm and 50 µm respectively. The chip size is 700 × 250 µm^2. The laser wavelength has a 50-nm positive detuning from the modulator absorption edge [5]. A buried heterostructure has been chosen for integration as it presents superior thermal conductance and stable modal behavior [3]. In order to obtain a low capacitance, iron-doped InP was used to bury the 5-µm height active stripe. A cross section of the final structure is shown in Fig.1.

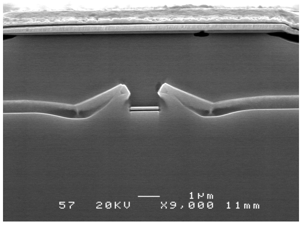

Figure 1: SEM photograph of an EML cross section

Typically, the fibre coupled optical output reached 2.5 mW at 20°C for grounded EAMs. Static Extinction Ratio was in the range of 16-18 dB. More measurements and data are given in [4-6]. Due to the very small size of the EAM the device acts as a lumped element even at 86 Gb/s. Therefore, chips were assembled on a carrier as a lumped insertion [6] between two micro-strip transmission lines with a 35-Ω resistor termination placed after the EML. The on-carrier EML frequency response is shown in Fig 2. The bandwidth is above 60 GHz for a laser drive below 50 mA.

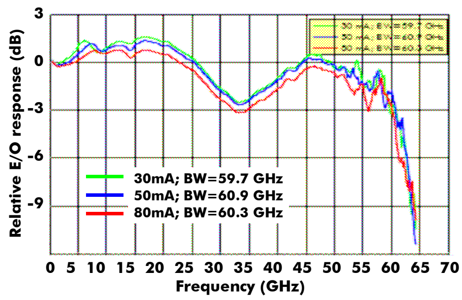

Figure 2: 60-GHz response of the EML [3]

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86-Gb/s bit error measurements

Using the EML described above, we performed bit error ratio (BER) measurements at a line rate of 85.5 Gb/s using the setup shown in Fig 3. We multiplexed a pseudo-random bit sequence (PRBS) of length 2^{15}-1 at 42.73 Gb/s with a delayed and inverted copy of the same bit stream using a 2:1 electronic SiGe multiplexer. The 85.5-Gb/s eye diagram at the multiplexer output had a peak-to-peak voltage swing of ~ 400 mV (Fig 3). A high-speed driver amplified the drive signal up to a peak-to-peak swing of ~ 4 V, with a bandwidth limitation apparent from the eye diagrams shown in Fig. 3.

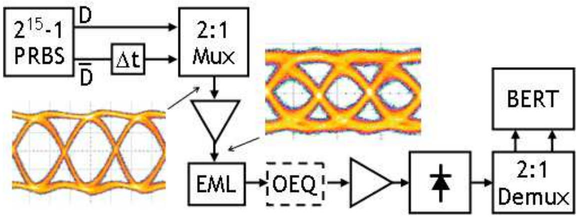

Figure 3: Setup to measure BER at 85.5 Gb/s, with electrical eyes before and after the driver amplifier

The drive signal was applied to the EML chip together with a reverse bias of ~ 2.5 V through a bias-T and a ground-signal-ground probe. The resulting optical eye diagram, recorded with a high-speed photodiode (90-GHz 3-dB bandwidth) and a 70-GHz optical sampling oscilloscope, is shown in Fig. 4(a). The open eye confirms the EML's high bit rate capability. An OEQ was optionally used to improve the signal quality, resulting in the eye diagram shown in Fig. 4(b). The OEQ is a 2-tap feed-forward structure with a tap delay of 10 ps manufactured in SiO_2:Si planar lightwave technology [7].

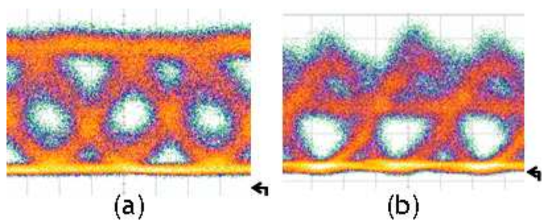

Figure 4: 85.5-Gb/s optical signals without (a) and with (b) OEQ.

At the receiver side, a variable optical attenuator in combination with a multi-stage optical amplifier was used to set the optical signal-to-noise ratio (OSNR) and to maintain a constant signal power at the photodetector. The photodiode was directly coupled to a fully integrated electronic 2:1 demultiplexer [8], and the two 42.7-Gb/s tributaries were sent to a BER test set (BERT) for error measurement.

Figure 5 shows the measured BER for both 42.7-Gb/s tributaries for the optically equalized signal as a function of the OSNR, defined with a noise bandwidth of 0.1 nm and including both polarizations of amplified spontaneous emission. No indication of an error floor was observed with the OEQ (for the unequalized system we observed an error floor at ~$5 \cdot 10^{-3}$). At the BER = 10^{-3} correction threshold of enhanced forward error correction (EFEC), we measure a required OSNR of 25 dB. Scaled to the same bit rate, this makes our EML results fall short by ~2 dB of a non-return-to-zero (NRZ) system using an optically equalized $LiNbO_3$ MZM [8]

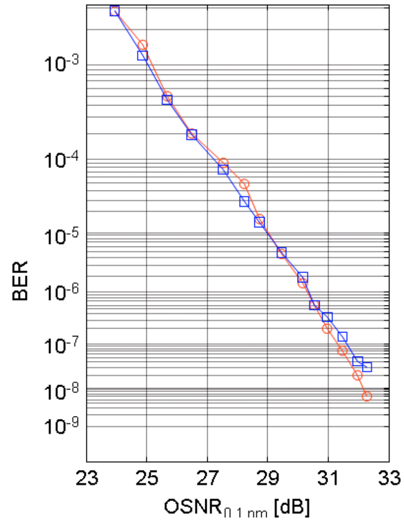

Figure 5: BER versus OSNR at 85.5 Gb/s for both 43.7-Gb/s tributaries, with OEQ.

Conclusions

We reported 86-Gb/s operation from an integrated high speed EML chip mounted on an optimized carrier. Using an OEQ with the EML allowed an OSNR of 25dB at a BER = 10^{-3} EFEC threshold, reflecting a moderate penalty with respect to comparable $LiNbO_3$ MZM experiments.

Due to their low-cost, low-drive, and low-footprint features, such EMLs are expected to be useful for short-reach 100 GbE applications.

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