40 Gb/s Directly Modulated InGaAsP Passive Feedback DFB Laser

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Abstract *Error free operation at 40 Gb/s with high extinction ratio of 6 dB is demonstrated for 1.55 µm InGaAsP DFB lasers for the first time. The enhanced modulation bandwidth is enabled by an integrated feedback section.*

Introduction

High bit rate 40 Gb/s transmission systems are one way to handle the continuous increase of internet and intranet traffic. For very-short-reach (VSR) optical links and metro application the direct modulation of lasers provides low cost and compact transmitters. Only for a few types of lasers large signal modulation and transition experiments at 40 Gb/s have been demonstrated so far [1-3]. High modulation bandwidths have been achieved by Al-containing quaternary active material, very short active cavities in DFB or DBR structures and/or high bias currents.

In this paper we demonstrate for the first time, to our knowledge, the 40 Gb/s direct current modulation of an InGaAsP passive feedback DFB laser (PFL) with emission wavelength of 1.55 µm. The high speed operation capability is based on a feedback enhanced modulation bandwidth. In Travelling Wave Model simulations the improved high speed modulation properties of a passive feedback laser have been predicted [4]. The present work verifies experimentally the excellent performance of the PFL transmitter under 40 Gb/s large signal modulation and evaluates the transmission characteristic over a short optical standard single mode fibre (SSMF) link.

Device structure and small signal analysis

We have realized PFL-structures consisting of a DFB laser and an integrated passive feedback (IFB) section (Fig. 1).

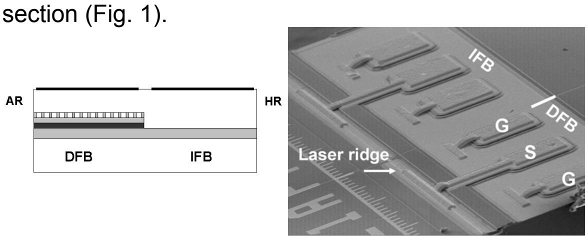

Fig. 1: Scheme of the high speed laser structure (left) and realized device with electrical contacts on top (right).

The compact two section laser device with a total length not exceeding 600 µm is based on a ridge waveguide design. Antireflection (AR) and high reflection (HR, > 90%) coatings have been applied to the DFB and the IFB facets respectively. The active region consists of $In_{1-x}Ga_xAs_{1-y}P_y$ strained layer multi-quantum wells (MQWs) embedded between asymmetric quaternary waveguides. The coupling coefficient of the DFB grating was in the range of 130 cm^{-1} to 170 cm^{-1}.

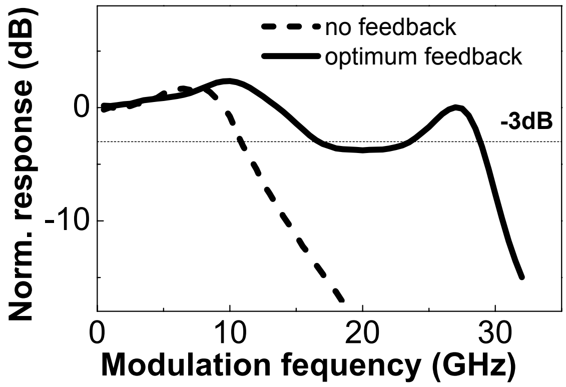

Fig. 2: Influence of feedback conditions on small signal modulation bandwidth of PFL structure (DFB: 40 mA)

The device characterization has been performed on chip level. A Ground Signal Ground (GSG) microwave probe head was used for biasing and modulation of the DFB laser section, an additional dc bias was applied to the IFB section. For the small signal amplitude modulation analysis the DFB facet output was coupled to a lensed fibre from where it was passed to a 40 GHz photodetector combined with an electrical spectrum analyzer.

The investigated PFL devices exhibit a stable single mode emission with a side mode suppression ratio of more than 30 dB. When recording the optical modulation response under different IFB biasing a strong change of the modulation bandwidth is observed. Fig. 2 illustrates the feedback effect in more detail. Without any support from the feedback section (absorbing IFB section, dashed line) the situation is found similar to that of a single section DFB laser: The modulation bandwidth is limited by the carrier photon (CP) resonance frequencies which are typically in the range of 8 to 12 GHz.

A high modulation bandwidth of about 30 GHz which exceeds the CP frequency limit by a factor of 3 is measured for optimum feedback conditions. In this case the modulation properties are improved by inducing a photon-photon (PP) resonance close to a desired frequency of 30 to 40 GHz [4]. It has to be noted that the high bandwidth can be accomplished already at moderate DFB current levels (40 mA).

In the following paragraph the high bandwidth operation regime of PFL lasers is tested under large signal modulation.

Large signal analysis

Eye patterns as well as Bit Error Rate (BER) measurements are carried out with 2^7-1 pseudo random bit sequence (PRBS) data streams for Non-Return-to Zero (NRZ) 40 Gb/s signals.

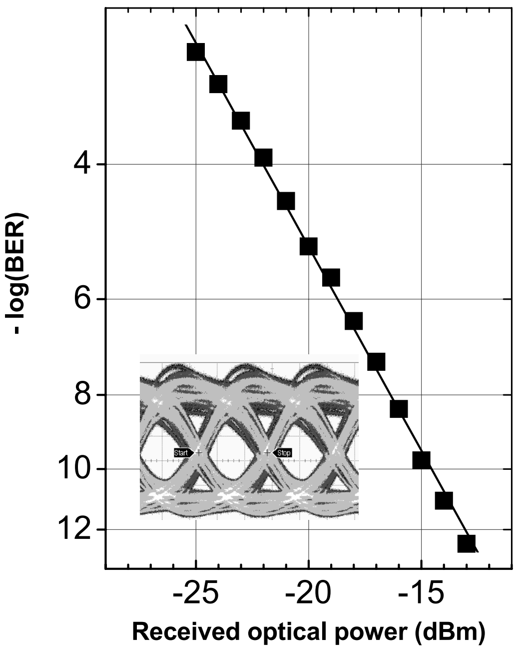

Fig. 3: Results of back to back BER measurements

At DFB currents of 60 to 80 mA clearly opened eyes have been recorded with extinction ratios (ER) of 4 to 6.6 dB, depending on the modulation power. The respective eye signal–to-noise ratios (SNRs) range from 5 (ER of 4 dB) to 4 (ER of 6.6 dB).

Results of BER measurements are shown in Fig. 3. The BER curve follows a straight line where an error free operation is observed down to 1E-12 with no indication of an error floor. In our measurements the quality of eye diagrams suffers from signal degradation by traces. In our chip level measurements the traces result from electrical mismatch between of the 50 Ω high frequency setup and the low impedance laser load. An accurate impedance matching in a packaged device overcomes this problem and will improve the SNR significantly, but even for our chip level characterization we could verify a long time operation over more than one hour without eye pattern degradation or additional error events in the centre of the eyes.

Fig. 4 shows eye diagrams recorded after transmission over different lengths of SSMF links with a typical dispersion of 17 ps/nm/km (no dispersion compensation) at the wavelengths of our lasers. Starting from a back to back ER of 6 dB and eye SNR 4.3 the eye pattern shows no detectable decrease of quality after 500 m, a slightly degraded but clearly opened eye after 1 km (power penalty of 4 dB) and stronger degraded but still opened eyes after 2 km.

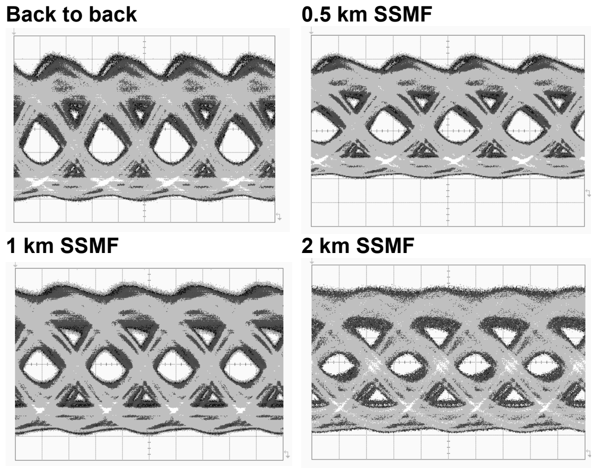

Fig. 4: 40 Gb/s NZR eye patterns after transmission over SSMF links of different length.

Summary

Large signal 40 Gb/s direct current modulation with 6 dB extinction ratio is demonstrated for a 1.55 µm InGaAsP based DFB laser. The underlying effect of enhanced optical modulation bandwidth is caused by an integrated feedback section. It allows stable error free eye patterns which are still opened after transmission over up 2 km SSMF links. The investigated PFL structure will provide a promising moderate sized laser for modulator free and low cost transmitter solutions in 40 Gb/s VSR optical links.

Acknowledgment

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