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RECENT PROGRESS OF 40 Gbit/s DIRECTLY MODULATED LASERS

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Abstract

High Extinction ratio of 6 dB is demonstrated in 40 Gbit/s directly modulated lasers based on InGaAsP/InP. The increase of modulation bandwidth up to 32 GHz is enabled by integrated optical feedback.

Introduction

For very-short-reach (VSR) optical links and metro application the direct modulation of lasers provides low cost and compact transmitters. Different approaches for high speed lasers have been investigated in the past. With single section lasers (1.55 µm) having 4 dB extinction ratio a four channel 40 Gbit/s transmission over 40 km standard single mode fibre (SSMF) including dispersion compensation was reported [1]. In [2] an optimized composition of the heterostructure and an increased number of QWs were used to improve the modulation dynamic. The resulting overall bandwidth of 19 GHz was limited by parasitic role off. The highest extinction ratio of 5 dB reported for single section edge emitters so far was achieved with Al-containing quaternary active material (1.3 µm) and a very short active cavity [3].

Other approaches for high speed lasers are based on injection locking (e.g. in VCSELs [4]) and multi-section laser concepts [5, 6].

Recently, we could demonstrate the 40 Gbit/s direct current modulation of an InGaAsP passive feedback DFB laser (PFL) with emission wavelength of 1.55 µm [7]. The high speed operation capability is based on a feedback enhanced modulation bandwidth [8]. The present work verifies experimentally the excellent performance of the PFL transmitter under 40 Gbit/s large signal modulation and evaluates the transmission characteristic over a short optical 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).

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. Both, index and complex coupled DFB gratings have been used.

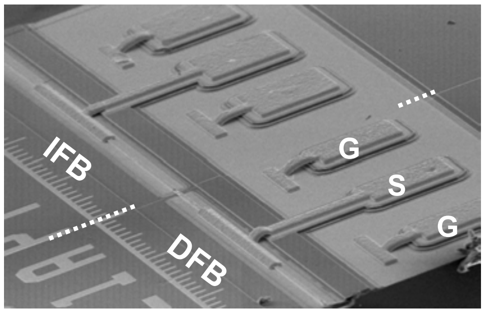

Fig. 1: SEM picture of the high speed laser structure

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.

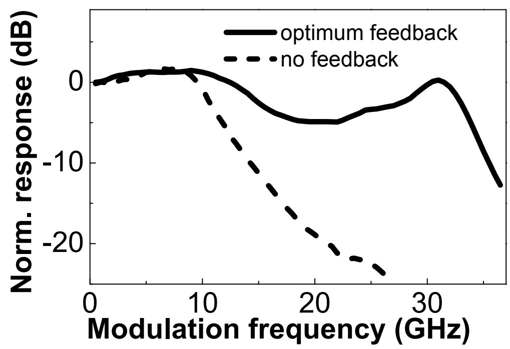

Fig. 2: 32 GHz small signal intensity modulation bandwidth of PFL structure (DFB: 50 mA).

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 impact by 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 32 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 [5]. It has to be noted that the high bandwidth can be accomplished already at moderate DFB current levels.

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 Gbit/s signals (Fig. 3).

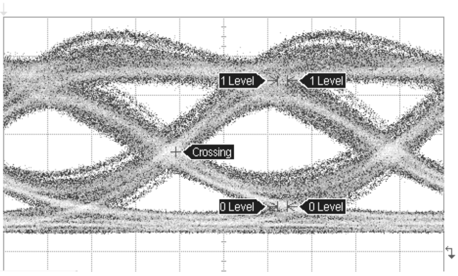

Fig. 3: 40 Gbit/s NRZ eye pattern of directly modulated laser (DFB: 60 mA).

In the 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 signal–to-noise ratio (SNR) significantly.

At DFB currents of 60 mA clear open eyes have been recorded with extinction ratios (ER) of 4 to 6.6 dB, depending on the modulation power. The respective eye SNRs range from 5 (ER of 4 dB) to 4 (ER of 6.6 dB).

Results of BER measurements are shown in Fig. 4. The BER for back-to-back configuration 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. The BER increases 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 0.5 km, a slightly degraded but clearly opened eye after 1 km (penalty of 4 – 5 dB) and stronger degraded but still opened eyes after 2 km.

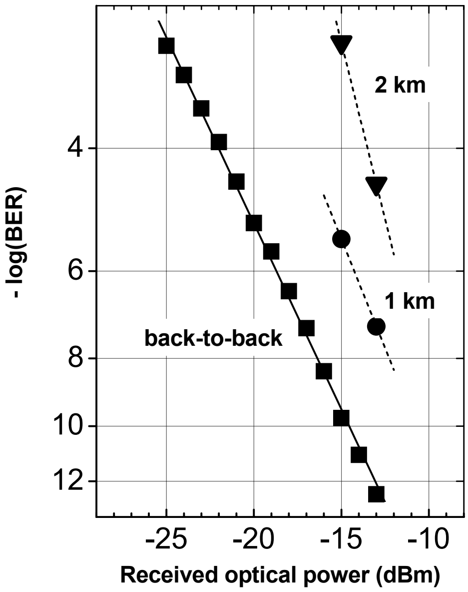

Fig. 4: Results of BER measurements for back-to back configuration and for transmission over short SSMF links.

Summary

Large signal 40 Gbit/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 without dispersion compensation. The investigated PFL structure will provide a promising moderate sized laser for modulator free and low cost transmitter solutions in 40 Gbit/s VSR optical links.

Acknowledgment

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