100°C, 10 Gb/s Directly Modulated InGaAsP DFB Lasers for Uncooled Ethernet Applications

White Paper

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Abstract

Combining an optimized active region based on InGaAsP strained MQW (Multi Quantum Well) and a low parasitic lateral confinement region, we fabricated 10 Gb directly modulated uncooled DFB lasers which represent, we believe, the state of art. Our DFB lasers work up to 100°C (substrate base temperature), with eye diagram perfectly open (showing an extinction ratio > 5 dB), and with Bit Error Rate over 10 km without error floor. Up to 90°C our DFBs show threshold current as low as 29 mA, optical power as high as 13 mW and meet perfectly the 10 Gb scaled Ethernet mask with extinction ratio > 6 dB.

Introduction

Optical communication systems operating at 10 Gb/s, such as 10 Gigabit Ethernet, are becoming more and more important even in Local Area Networks (LAN) and Metropolitan Area Networks (MAN). An uncooled DFB laser directly modulated at 10 Gb/s is a key element for these network applications and can be used in optical transceivers in order to reduce cost, size and power consumption. It has been frequently indicated that the use of InGaAsP/InP active layers has been the cause of poor temperature characteristics of lasers emitting at 1300 nm. So in recent years, significant effort has been reported in the literature to find alternative active MQW layers with improved temperature performance. AlGaInAs was considered to be the best candidate, and 10 and 12.5 Gb/s operation up to 85° C has been demonstrated[1,2].

In this paper, we demonstrate that high temperature performance can also be obtained by using Phosphorus-based MQW active structure and we report what, we believe, is the current state of art for uncooled DFBs emitting at 1300 nm (including in the comparison Al-based MQW[1,2] and P-based MQW[3]). The DFBs have been obtained by combining an optimized active region based on well assessed InGaAsP strained MQW and a low parasitic lateral confinement region. The DFBs work up to 100°C (substrate base temperature, about 110° C active stripe temperature), with perfectly open eye diagrams (showing an extinction ratio of 5 dB), and with a Bit Error Rate over 10 km of fiber without error floor. Up to 90°C our DFBs show threshold current as low as 29 mA, optical power as high as 13 mW and meet perfectly the 10 Gb scaled Ethernet mask with extinction ratio > 6 dB.

Device design and fabrication

The laser is a multi-junction buried structure, with an active stripe typically 1.3 µm wide. The active MQW stack consists of 11 InGaAsP compressive strained (+0.8%) wells, 6 nm thick and 10 InGaAsP tensile strained (-0.2%) barriers, 7.5 nm thick, grown by MOCVD (Metal Organic Chemical Vapor Deposition), similar to the structure optimized for the 2.5 Gb/s applications[3]. The MQW stack is surrounded by two symmetric, undoped SCH (Separate Confinement Heterostructure) InGaAsP layers, 65 nm thick each. The InP cladding and InGaAs contact layers were optimized to give low series resistance (4.5Ω for 250 µm long devices) and capacitance less than 3 pF. The grating was etched in a separate InGaAsP layer, in order to obtain a kL product (coupling coefficient multiplied by device length) of about 1 – 1.5. To improve the temperature performances, the grating wavelength was slightly positively detuned (4 – 10 nm) with respect to the material peak gain at room temperature. The devices, 250 and 300 µm long, have been coated by HR/AR (High Reflection/Anti Reflection) coatings on the two facets and mounted on AlN carriers.

Experimental results

250 µm and 300 µm long devices have shown similar results and confirming the “robustness” of the design. Typical static performances are reported in Figure 1, showing threshold current as low as 6 mA at 20° C, as well as high efficiency (more than 40 mW at 100 mA) and good linearity. The plots also demonstrate the good temperature behavior of the lasers (37 mA of threshold, 10 mW of maximum power at 100° C). The negligible lateral leakage at high temperature is also confirmed by the flatness of the series resistance plots (also reported in Figure 1). Figure 2 shows the +4 nm detuning at room temperature used in the wafer, as well as the high Side Mode Suppression Ratio (SMSR) values obtained (> 35 dB in the 20 – 100° C range).

The small signal modulation bandwidths are shown in Figure 3 (measured directly on chip by RF probes) at 20° C and 90° C substrate base temperatures (about a 100° C active stripe). About 20 GHz at 20° C, and 10 GHz at 90° C have been demonstrated. It is also worth underlining the extremely low device parasitics: the equivalent RC constant, obtained from the S_{21} plots by a three-pole fitting, is 15 ps, which can be related to an equivalent capacitance of about 3 pF.

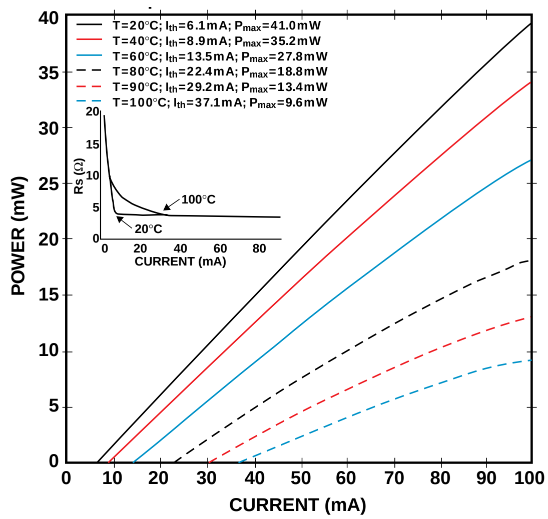

Figure 1: Power versus current at 20, 40, 60, 80, 90 and 100°C; the measured threshold currents and maximum powers are also reported. The inset shows the differential series resistance plots.

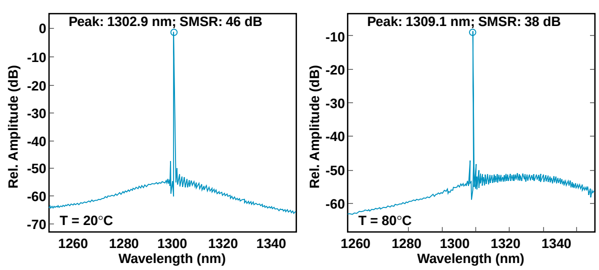

Figure 2. Optical spectrum at 20°C (*left*) and 80°C (*right*), showing the +4 nm of detuning at room temperature, and the good SMSR.

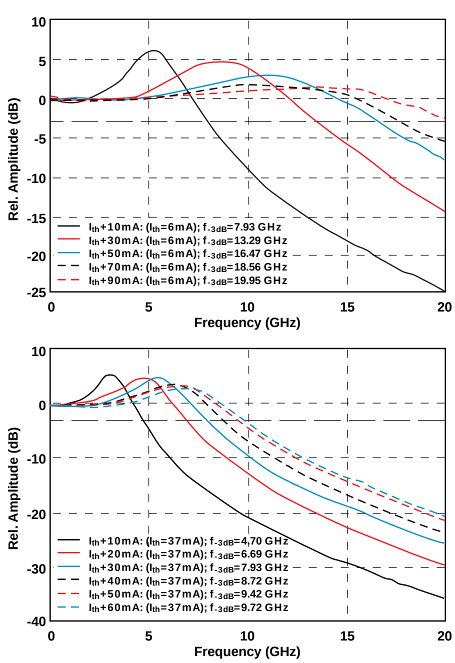

Figure 3. Modulation bandwidth at 20°C (*upper*) and 90°C (*lower*) substrate base temperature, showing the extremely low parasitics, as well as the wide bandwidth (10 GHz) still present at 90°C.

The devices have been tested with a digital signal input, by using a PRBS (2^{31}-1) 10.3 Gb/s binary sequence, and probing the chip with 50Ω matched probes. The optical eyes were detected by an HP83485B 10 Gb/s optical plug-in, and tested by using the “scaled-Gigabit Ethernet mask”. The results are reported in Figure 4, showing the excellent eye quality obtained, with the lasers passing the device mask test between 20°C and 90°C (substrate base temperature). Open eyes have been obtained at up to 100°C substrate base temperature, and therefore we have measured at 100°C the BER performance of the device. The results are reported in Figure 5, (BER plots, back to back and after 10 km of standard fiber), together with the eye diagram recorded at the same working condition. The measurements show no error floor up to 10^{-12}, and a negative penalty for the 10 km long haul of about 0.5 dB, due to the pulse re-shaping by the fiber in the anomalous region.

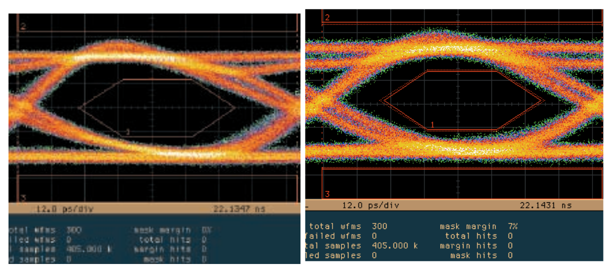

Figure 4. Eye diagrams at 20°C (*left*) and 90°C substrate base temperature (*right*), showing the excellent quality of the eyes with extinction ratios from 8 to 6 dB, and the positive results of the mask test (no hits on the complete mask).

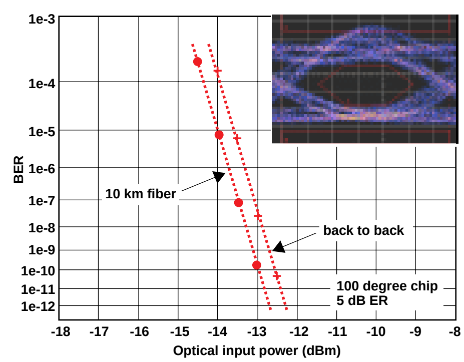

Figure 5. BER plots at 100°C substrate base temperature, back-to-back and 10 km of standard fiber, and eye diagram of the laser (5 dB extinction ratio).

Conclusions

100°C, 10 Gb/s InGaAsP MQW DFB lasers have been realized, demonstrating a transmission experiment over 10 km of standard fiber without error floor.

References

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