1.55-μm VCSEL Transmission Performance up to 20 Gb/s for Access Networks

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Abstract

We experimentally demonstrate for the first time 1.55μm vertical-cavity surface-emitting laser (VCSEL) transmission over 6.5 km single mode fiber (SMF) at 20 Gb/s for optical access networks. Characterization of the device is also investigated.

Introduction

Long wavelength vertical cavity surface emitting lasers (VCSELs) are attracting increasing interest for metro optical access networks because they can be highly cost-effective light sources. With the increasing bandwidth demand for both downstream and upstream data transmission, it is desirable to reduce the cost per bandwidth in order to make higher speed broadband access affordable [1]. VCSELs modulated at bit-rates of up to 25 Gb/s were demonstrated at 850nm for short reach data communications [2]. Direct modulation at 12.5 Gb/s for 1.3μm VCSEL [3] and 10 Gb/s for 1.55μm VCSEL [4] have been demonstrated recently. However, 1.55 μm wavelength is preferred over 1.3 μm because the lower fiber transmission loss helps meet the strict power budget in passive optical access networks [5]. The wavelength of VCSELs may be tuned to the DWDM grid, and together with their other advantages (excellent spatial mode for coupling to fibers, low threshold current for high speed transmission, potential for low cost manufacturing and packaging). Long wavelength VCSELs are of increasing interest for high speed WDM PON applications.
In this paper, we reported a successful demonstration of direct modulation at 20 Gb/s of a 1.55-μm VCSEL and test the transmission performance over 6.5-km SMF.

Device structure

The schematic layout of the laser chip is shown in Fig. 1. BCB is used as low-dielectric constant passivation to enable high-speed operation. The epitaxial output mirror consists of 32 pairs of InGaAlAs and InAlAs with no fundamental absorption. To achieve high-speed operation and sufficient gain at elevated temperatures, the active region consists of 7 heavily strained InAlGaAs

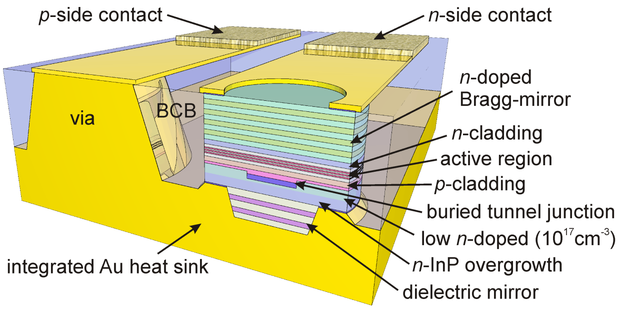

Fig.1 Schematic figure of the VCSEL

quantum wells of 6 nm thickness each. The strain was tailored to be 2.5% of compressive strain (pseudomorphic) going near borderline of critical layer thickness. This should both enhance gain and differential gain and therefore enable low threshold currents and high relaxation oscillation frequencies. The mode-gain offset is optimized for high-temperature behavior. So, negative T_0 values can be obtained. This effect is caused by the different red-shift of gain and cavity-mode over temperature. Due to the BTJ, which allows the elimination of nearly all *p*-conducting material with higher electrical resistances and optical losses, a differential series resistance of 40-50 Ω has been achieved, well suited for direct modulation.

Experiment and Results

The VCSEL used in this paper was developed improved high-speed long wavelength BJT one with superior bandwidth [6]. It had a room temperature threshold current of 1.4 mA, a differential resistance of 43.9 Ω, lasing output wavelength of 1537nm and maximum output power of 2.46 mW at 20°C. The light from the 5-μm diameter output aperture of the VCSEL was coupled in a SMF. The maximum fiber coupled power was 700μW at 10mA current bias. In the experiment, the VCSEL was biased at 5.5mA, 8mA respectively. The 20 Gb/s Non-Return-to-Zero driving data (2^{31}-1 PRBS) had a peak to peak voltage of 500 mV. The chip was mounted on a TEC set to a temperature of 20°C for 10 Gb/s and 14 Gb/s measurement while 15°C for 20 Gb/s measurement. The 20 Gb/s optical spectrum after modulation is shown in Fig.2. The 3dB bandwidth was 0.03 nm measured with a 0.01-nm resolution optical spectrum analyzer. It was much narrower compared with previous result in 10 Gb/s modulation [1]. The modulated optical signal was detected by a 20GHz photo detector and 20GHz oscilloscope.

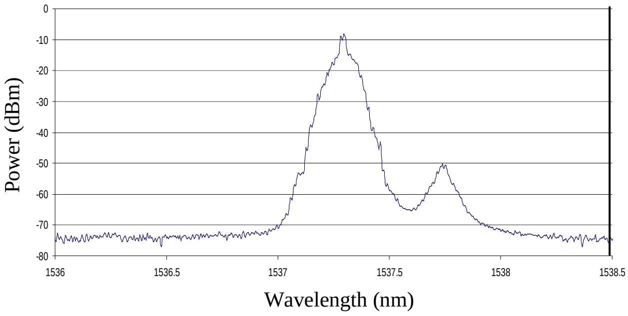

Fig.2 Optical spectrum after 20Gb/s modulation

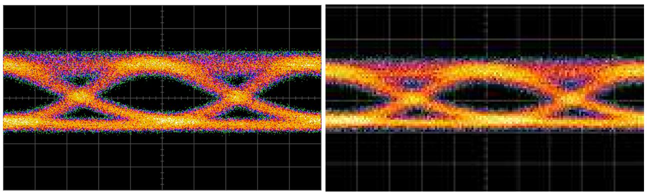

Fig.3 10Gb/s back-to-back and after 6.5km SMF eye diagrams at 5.5mA, 20°C

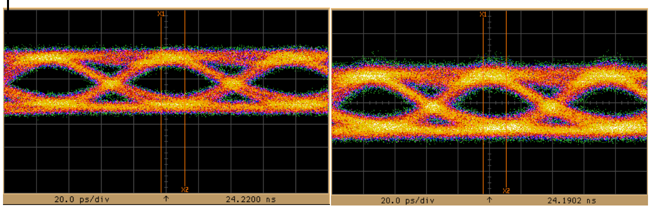

Fig.4 14Gb/s back-to-back and after 6.5km SMF eye diagrams at 5.5mA, 20°C

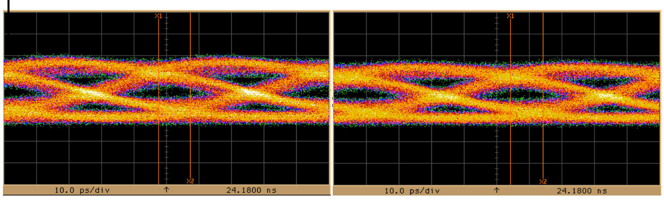

Fig.5 20Gb/s back-to-back and after 6.5km SMF eye diagrams at 5.5mA, 15°C

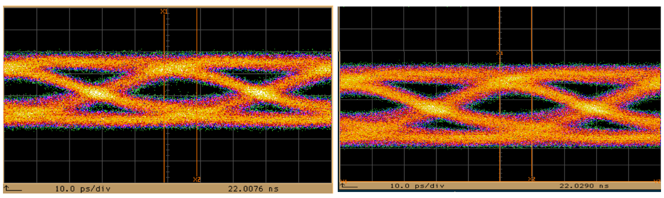

Fig.6 20Gb/s back-to-back and after 6.5km SMF eye diagrams at 8mA, 15°C

Figs. 3-6 show eye diagrams back-to-back (BTB) and over a 6.5-km link of standard single-mode fiber (SMF) for data-rates of 10, 14 and 20 Gb/s. The PRBS was 2^{31}-1 for all configurations.

Fig.3 shows 10 Gb/s eye diagrams with measured Q-factor of 6.3 for BTB and 6.02 for fiber transmission case at 20°C. Fig.4 shows the same experiment at 14 Gb/s yielding eye diagrams with measured Q-factor of 5.16 for BTB and 4.57 for fiber link at 20°C. In Fig. 5 presents eyes recorded at the record-high data-rate of 20 Gb/s. The bias point was set to 5.5 mA. The achieved Q-factors were 3.03 and 2.97, respectively. The TEC was set to 15°C. Fig. 6 shows the same experiment at a bias point of 8 mA. 20 Gb/s eye diagrams with measured Q-factor of 3.62 BTB and 3.38 for fiber transmission case can be stated at 15°C heat-sink temperature.

This are the first preliminary experimental results so far. Consequently, the performance is expected to be further improved by optimizing bias current and stabilizing the coupling efficiency.

Conclusions

We have presented transmission performance of a 1.55-µm VCSEL over a fiber link with a record data rate of 20 Gb/s. To the best of our knowledge, this is the highest value achieved so far for 1.55-µm wavelength. These VCSELs are potential candidates for next generation broadband optical access networks

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