12.5 Gbit/s data rate fiber transmission using single-mode selectively oxidized GaAs VCSELs at $\lambda = 850$ nm

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We demonstrate for the first time 12.5 Gbit/s data rate fiber transmission using high performance single-mode GaAs VCSELs with 12.3 GHz modulation bandwidth. The bit-error rates remain better than 10^{-11} *for transmission of PRBS signals over 100 m multimode fiber and 1 km single-mode fiber, respectively.*

1. Introduction:

Over the past years vertical-cavity surface-emitting lasers (VCSELs) have become devices with excellent electrical and optical properties. Selective oxidation has led to VCSELs with threshold currents in the sub-100 μA range [1,2], low threshold voltages and high wallplug efficiencies [3], and modulation bandwidths of up to 21.5 GHz [4]. High bit rate data transmission of 10 Gbit/s over 500 m multimode fiber (MMF) using proton implanted InGaAs VCSELs [5] and 10 Gbit/s over 100 m MMF using oxidized InGaAs VCSELs [6] have been reported. These experiments show that VCSELs are very attractive light sources for fiber based local area networks like the Gigabit Ethernet standardized for data rates of 1 Gbit/s, 850 nm wavelength and 50 μm core diameter MMF of lengths up to 550 m [7]. The continuously increasing need to provide higher network capacities mainly initiated by the Internet boom will require even faster networks than the Gigabit Ethernet.
In this work, we report 12.5 Gbit/s data transmission over 100 m MMF and 1 km single-mode fiber (SMF) using single-mode selectively oxidized GaAs VCSELs emitting at 850 nm. In both cases the bit-error rate (BER) remains better than 10^{-11} for pseudo-random bit sequence (PRBS) transmission.

2. Device structure:

The one-wavelength thick inner cavity of the VCSEL contains three active GaAs-$Al_{0.2}Ga_{0.8}As$ quantum wells designed for 850 nm gain peak wavelength. Lateral current confinement is achieved by selective wet oxidation of a single 30 nm thick AlAs layer. This layer is shifted towards a node of the standing wave pattern in order to reduce the built-in effective index guiding and optical losses for increased single-mode output power. Polyimide passivation serves to reduce the parasitic capacitance of the electrical contacts.

3. Device characteristics:

Current is supplied using a microwave probe and light is launched in a butt-coupled 50 μm core diameter MMF or 5 μm core diameter SMF. Fig. 1 summarizes the CW output characteristics of the laser diode with 3 μm active diameter. Threshold current and voltage are 1.3 mA and 2 V, respectively. Laser emission at 3 mA driving current and about 275 μW output power is centered at 846 nm as displayed in the inset in Fig. 1. The side-mode suppression ratio is 30 dB even under modulation.

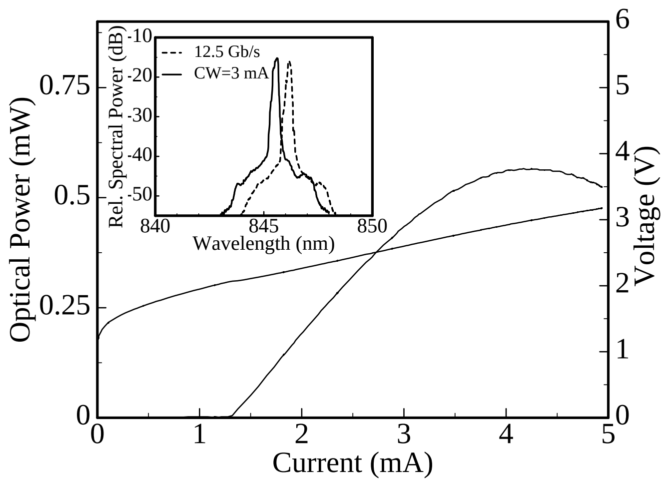

Fig. 1. Output characteristics and spectra at CW and modulated operation with $V_{pp} = 1$ V at 3 mA bias of the 3 μm active diameter, laterally oxidized GaAs VCSEL.

To measure the modulation characteristics free from external parasitics the laser diode is contacted with a microwave probe. The modulated light is detected with a 15 GHz bandwidth InGaAs pin photodiode and recorded with an RF spectrum analyzer. Fig. 2 depicts typical small-signal amplitude characteristics. The modulation bandwidth increases with increasing driving current. The maximum electrical and optical bandwidth obtained at a current of 3 mA is 12.3 GHz and 13.3 GHz, respectively.

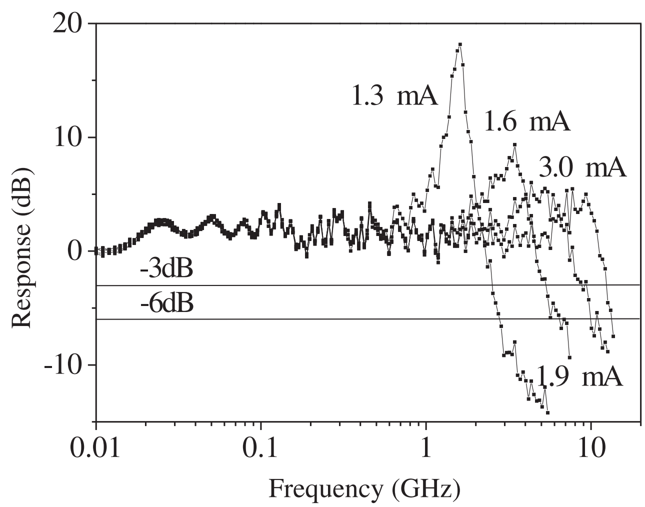

Fig. 2. Small-signal frequency response of 3 μm active diameter VCSEL for various bias currents.

4. Fiber data transmission:

Fig. 3 summarizes the transmission experiments performed at 3 mA bias current and 12.5 Gbit/s PRBS transmission over 100 m of MMF with a wordlength of $2^7 - 1$ and $V_{pp} = 1$ V modulation voltage. Circles denote back-to-back (BTB) testing, triangles represent 1 km 5 μm core diameter SMF transmission, and squares depict 100 m 50 μm core diameter MMF transmission. In all cases the BERs remain better than 10^{-11}. The received optical power for a BER of 10^{-11} is -12.5 dBm and the power penalties for 1 km SMF and 100 m MMF transmission are 1.2 and 7 dB, respectively. The relatively high optical powers necessary for BERs of 10^{-11} are primarily due to the low sensitivity of the InGaAs photodetector used. The eye diagram in the inset of Fig. 3 is recorded at a BER of 10^{-11}. The eye opening is about 400 mV

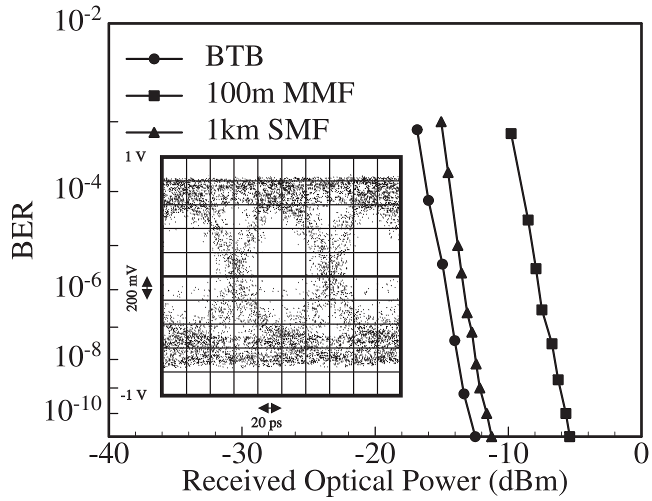

Fig. 3. BER characteristics for $2^7 - 1$ word length PRBS data fiber transmission over 100 m MMF and 1 km SMF. For comparison, results for back-to-back (BTB) testing are also given. The inset shows the eye diagram recorded for BER = 10^{-11} after 100 m transmission.

with a slightly asymmetric shape but without any significant relaxation oscillations. The relatively broad rising traces of about 40 ps width are due to the pattern dependent turn-on jitter.

5. Conclusion:

In summary, we have for the first time demonstrated 12.5 Gbit/s data fiber transmission using selectively oxidized GaAs VCSELs. The BER remains better than 10^{-11} for 100 m MMF as well as for 1 km SMF transmission. 12.5 Gbit/s is the limit of the bit-error test set used. Due to dispersion the transmission distance for MMF is limited to about 100 m which is in accordance with the graded-index fiber bandwidth-length product of 1.25 Gbit/s·km at $\lambda = 850$ nm. Transmission experiments with 5 μm core SMF were restricted by the available fiber length. The obtained results clearly indicate that GaAs VCSELs are attractive transmitters for high speed fiber optic interconnects.

6. Acknowledgement:

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