2.5 Gbit/s Data Transmission with Single-Mode GaAs VCSELs Over a -20°C to 100°C Temperature Range

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Single-mode GaAs based vertical-cavity surface-emitting lasers (VCSELs) are being investigated for high bit-rate data transmission in an industrially relevant temperature range between -20°C and 100°C. The bit-error rate (BER) for 2.5 Gbit/s transmission over 250 m of graded index multimode fibre (MMF) is better than 10^{-11} *for all temperatures under fixed bias and modulation conditions. The temperature dependent power penalty for 250 m MMF transmission is as low as 0.009 dB/K.*

1. Introduction

Vertical-cavity surface-emitting lasers have become promising candidates for low-cost applications in optical interconnects like Gigabit-Ethernet or mobile infotainment links like the D2B in-car bus. GaAs or AlGaAs based VCSELs with threshold currents in the sub-100 μA range [1] and threshold voltages close to the bandgap voltage in combination with extremely high wallplug efficiencies over a large operation range [2] help to reduce power consumption and dissipated heat in system applications. Reported single-mode emission of 4.8 mW [3] and modulation bandwidths of 21.5 GHz [4] show the capability for ultra fast optical fiber links up to 12.5 Gbit/s data rates [5]. Earlier studies on temperature dependent data transmission at 1 Gbit/s showed power penalties in the range of 0.05 dB/K [6]. Here we report on 2.5 Gbit/s data transmission over 250 m MMF in an industrially relevant temperature range of $-20°$C to $100°$C using high-performance selectively oxidised single-mode GaAs VCSELs.

2. Experiment

The temperature behaviour of VCSELs can be optimized by adjusting the length of the Fabry-Perot resonator (FPR) and the refractive index profiles of the Bragg-reflector layers relative to the gain peak of the quantum wells. With increasing temperature, refractive indices of Bragg reflector and active layers increase resulting in a cavity mode shift of 70 pm/K whereas the peak gain shifts at a higher rate of about 0.3 nm/K. If, for a given temperature, the cavity mode is on the long wavelength side of the gain peak VCSEL performance will increase with increasing temperature. The device employed in the experiments is a selectively oxidised GaAs VCSEL with optimised mode offset. The active diameter is about 3 μm. The VCSEL is mounted on a Peltier element for temperature control and wire-bonded to an SMA socket to keep the feeding lines as short as possible. The bias current of 2.5 mA and a 2.5 Gbit/s non-return-to-zero (NRZ) pseudo-random bit sequence signal (PRBS) with $V_{pp} = 0.6$ V are combined in a bias-tee.

The light is launched butt-coupled into a 250 m long 50 μm core diameter MMF and at the far end the light is passed through a variable attenuator and fed to a Germanium avalanche photodiode (APD). The electrical signal is preamplified and analysed with a BER detector or a fast sampling oscilloscope.

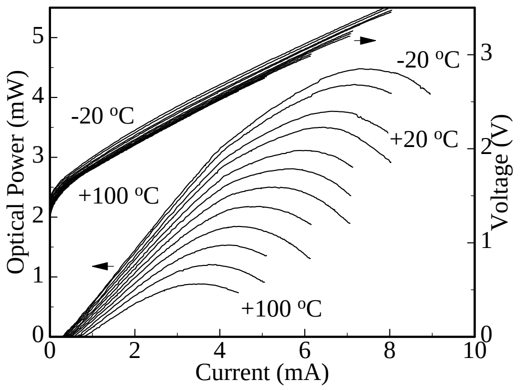

Fig. 1. Temperature-dependent output characteristics of selectively oxidised GaAs VCSEL with 3 μm active diameter.

Fig. 1 illustrates the output characteristics of the VCSEL for various heat sink temperatures between $-20°$C and $100°$C. Threshold current and threshold voltage vary between 0.3 mA at 1.69 V for $-20°$C and 0.78 mA at 1.74 V for $100°$C. The maximum output power varies between 4.51 mW at $-20°$C and 0.94 mW at $100°$C for driving currents of 7.35 mA and 3.5 mA, respectively.

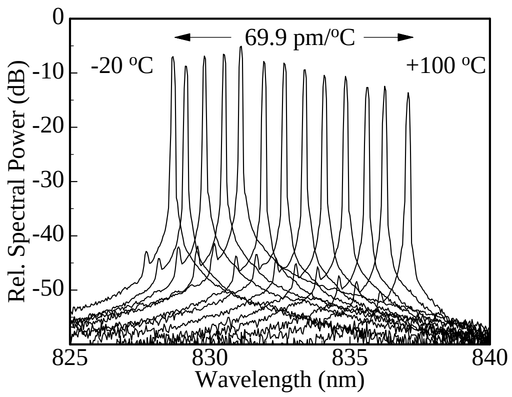

Fig. 2. Temperature dependent CW-spectra of 3 μm GaAs VCSEL at a fixed driving current of 3 mA.

The continuous wave spectra for 3 mA driving current displayed in Fig. 2 all show single-mode emission with peak wavelengths increasing from 828.7 nm at $-20°$C to 837.1 nm at $100°$C which is on the short wavelength side of the gain peak. The emission remains single-mode up to 4 mA driving current for all temperatures. The observed thermally induced temperature shift of 69.9 pm/K is in good accordance with the value of 60 pm/K given in [7].

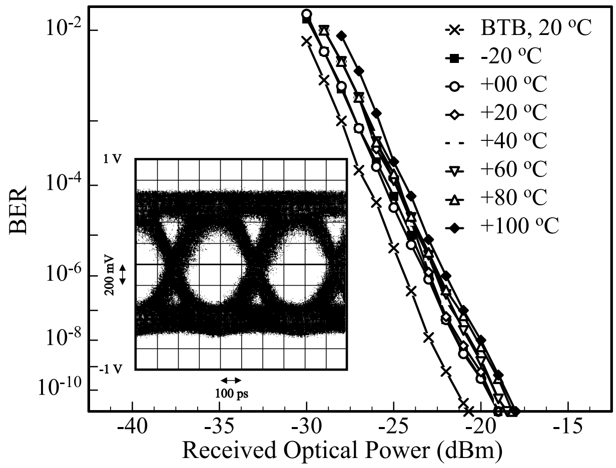

Fig. 3. Eye diagram at 100°C for a BER of 10^{-11} and temperature dependent bit-error rate characteristics at 2.5 Gbit/s and $2^{31}-1$ word length for 250 m MMF transmission.

The inset of Fig. 3 displays the eye pattern recorded for 2.5 Gbit/s PRBS with $2^{31}-1$ wordlength at $100°$C. For all temperatures, the eye pattern is wide-open, symmetric, and shows no remarkable relaxation oscillations. The results of the transmission experiments for back-to-back testing (BTB) and 250 m MMF transmission are summarized in Fig. 3 where different symbols denote the various temperatures: filled squares $-20°$C, circles $0°$C, diamonds $20°$C, open squares $40°$C, down-triangles $60°$C, up-triangles $80°$C,and filled diamonds $100°$C. At all temperatures the BER for 2.5 Gbit/s data transmission over 250 m MMF remains better than 10^{-11}. At 20°C a received optical power of -19.0 dBm for 250 m MMF data transmission and -20.5 dBm for BTB is necessary to achieve a BER of 10^{-11}. The maximum power penalty, compared to BTB, observed for transmission at $100°$C is 3 dB. The $100°$C-transmission shows the highest on-off ratio of 6.3 dB while the lowest on-off ratio of 5.6 dB is observed for -20°C transmission.

3. Conclusion

We have successfully demonstrated 2.5 Gbit/s PRBS data transmission over 250 m of MMF for temperatures from $-20°$C to $100°$C using a high-performance single-mode VCSEL source operated at fixed 2.5 mA bias current and fixed modulation voltage. Data transmission characteristics are nearly independent of temperature. BER remains better than 10^{-11} for all temperatures. The experiments clearly demonstrate that VCSELs can easily fulfill extended temperature requirements of advanced high-speed optical interconnect systems.

References

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