10 Gbit/s transmitter based on directly modulated InGaAlAs laser operating up to 126°C

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High-performance operation of a 10 Gbit/s optical transmitter based on a directly modulated InGaAlAs Fabry–Perot laser, in the laser temperature range of −1 to 126°C, is demonstrated. Clear open eye diagrams are obtained over this entire range, with margins greater than 5%, and with minimal variations in output power and extinction ratio.

Introduction: Optical communication systems operating at 10 Gbit/s are becoming increasingly important even for short reach applications such as metro, access and data-link networks. In fact, approximately 40% of all commercial 10 Gbit/s interfaces to be deployed between 2003 and 2006 are expected to be short reach (<2 km) [1]. A key enabling technology for the development of such systems is a reliable, high-speed optical transmitter that can be produced at low cost. In this respect, directly modulated semiconductor Fabry–Perot lasers offer several advantages over DFB lasers, including higher yield and no need for optical isolators. Uncooled operation is required to further reduce the transmitter cost, size, and power consumption, which requires laser devices capable of maintaining a high level of performance over a wide temperature range.

For high-temperature operation, use of an InGaAlAs multi-quantum-well (MQW) active material is advantageous [2], primarily because of its larger conduction-band offset relative to the more traditional InGaAsP MQW system. This property results in a stronger electron confinement in the quantum wells, which in turn reduces the degradation in threshold current and relaxation frequency with increasing temperature. Introducing compressive strain in the quantum wells is also favourable for both high-temperature and high-speed performance. In the past few years, several InGaAlAs strained MQW lasers have been reported in the literature [2–5], showing superior static and dynamic properties at high temperatures. In particular, characteristic temperatures T_0 in excess of 100K [3] have been demonstrated, as well as operation at 10 Gbit/s up to laser temperatures of over 100°C [4, 5].

However, most of the work reported so far in this area has focused on the performance of the individual diode lasers, while less attention has been paid to the high-temperature characteristics of the complete transmitter modules. In this Letter, we report on the operation of a 10 Gbit/s transmitter based on a directly modulated 1.3 μm InGaAlAs Fabry–Perot laser with the transmitter case temperature ranging from −10 to 109°C. Clear open eye diagrams were obtained with 7.5 dB extinction ratio, and meeting the ITU G.693 mask test over this entire temperature range. The upper limit of 109°C case temperature corresponds to a laser temperature of 126°C (as measured with a temperature sensor close to the laser in the package), which is the highest reported to date for successful large-signal modulation at 10 Gbit/s.

Laser characteristics: The active material of the lasers, grown by low-pressure organometallic vapour-phase epitaxy (OMVPE) on *n*-InP substrates, consists of a stack of compressively strained InGaAlAs quantum wells and tensile strained InGaAlAs barriers. The cavity length is 250 μm. The devices are mounted *p*-side down on a high-speed silicon optical submount together with an InGaAs PIN photodiode back-facet power monitor and a collimating ball lens at the laser front facet [6]. Submount-level measurements gave median values of about 107 K for the threshold-current characteristic temperature T_0, and of about 0.8 dB for the slope efficiency degradation in the laser temperature range of 25 to 85°C. The laser output is single-transverse and multi-longitudinal mode, with centre wavelength around 1320 nm at room temperature. Small-signal modulation measurements were also performed, giving modulation-efficiency slopes of over 1.6 GHz/mA$^{1/2}$ at room temperature and 1.3 GHz/mA$^{1/2}$ at 85°C.

Transmitter results: The transmitter used in this work consists of a laser package combined with its tuning circuitry for automatic output power and extinction ratio control. After assembly, the transmitter is tuned for an extinction ratio of about 7.5 dB and an average output power of about −2.5 dBm, using empirical parameters appropriate for operation in the laser temperature range of 25 to 75°C. An embedded digital control system corrects the laser bias and modulation currents throughout the temperature range.

Fig. 1 shows the transmitter eye diagrams for a $2^{31}-1$ pseudorandom bit stream, measured after a standard OC-192 filter, at various case temperatures from −10 to 109°C (corresponding to the laser temperature range of −1 to 126°C). No obvious degradation is observed even at the highest temperature, suggesting the laser could be run even hotter. However, at higher temperatures the control circuitry becomes unstable as the temperature sensor use is only rated to 125°C. The eye mask margin, relative to a G.693 mask, are plotted against temperature in Fig. 2: as can be seen, values in excess of 5%, and as large as 13%, are measured at all temperatures.

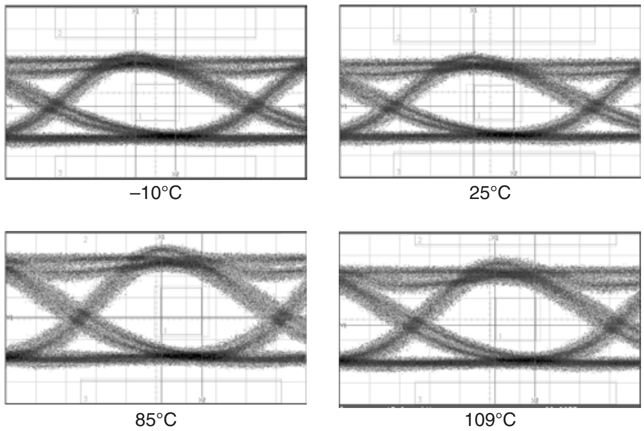

Fig. 1 *Eye diagrams of transmitter with extinction ratio of about 7.5 dBm at four different case temperatures, showing positive results of mask test. Measured margins are 5, 10, 8, 6% at −10, 25, 85, 109°C, respectively*

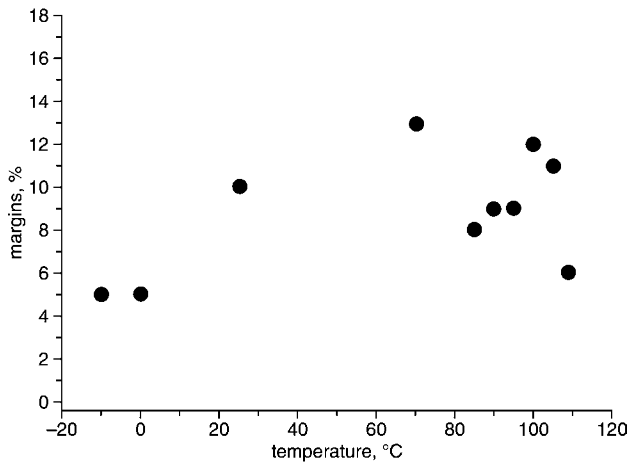

Fig. 2 *Eye diagram margins relative to ITU G.693 unshifted mask against case temperature*

Fig. 3 shows the extinction ratio and average optical output power against the transmitter case temperature, and small variations of about 0.5 and 1.2 dB, respectively, are observed. This feature is an important requirement for real field use of the transmitter over the entire measured temperature range, and in turn it poses rather stringent requirements on the laser characteristics, particularly in terms of extremely low temperature sensitivity of its threshold current, slope efficiency, and relaxation frequency.

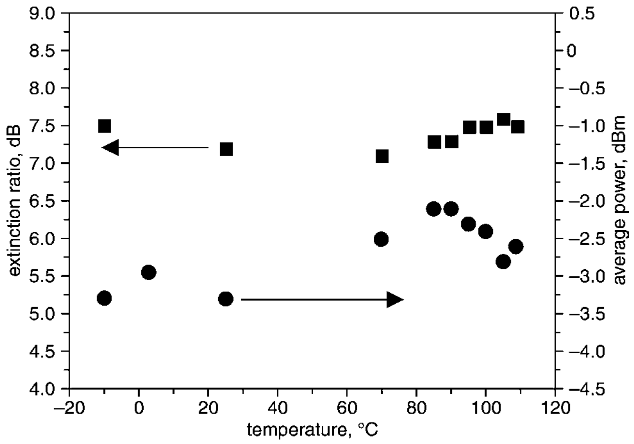

Fig. 3 *Extinction ratio and average output power of transmitter against case temperature, showing small variations over entire temperature range*

Conclusion: 10 Gbit/s operation of an optical transmitter has been demonstrated up to a case temperature of 109°C, corresponding to a record laser temperature of 126°C. The key enabling feature is the superior high-temperature high-speed laser performance allowed by the InGaAlAs strained MQW active material. These results indicate the potential of this module to be used in uncontrolled telecom environments and to allow significant cost reductions.

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