Small Optical Sources with Improved Speed/Power Dissipation

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For optical interconnects it is desirable to maximize the date rate for a given power dissipation. In our recent work we have managed to obtain a record data-rate/power dissipation value of 3.5 Gps/mW in a novel VCSEL that was transmitting 35 Gps data at an optical power level of 2.5 mW . At somewhat lower powers a bandwidth/√‾current of 17 GHz/mA$^{1/2}$ was also found. These results were obtained by engineering the VCSEL cavity to have low optical loss, low parasitics, and a small volume. This involved the use of optimized tapered oxide apertures, additional deep oxidation layers, and carefully engineered compositions and dopings in the mirrors. This talk will discuss the design principles involved.

In the past several years, vertical-cavity surface-emitting lasers (VCSELs) have received renewed interest for their potential applications in optical interconnects. Compared with edge emitters, VCSELs are preferable due to their small footprint, ease of fabrication in arrays, on-wafer testing, high-speed operation at lower power dissipation, and cost effectiveness.

Figure 1 illustrates some of our results for a device with a 3μm aperture. Details of the device structure and fabrication can be found in refs. [1, 2]. The design of the structure involves many trade-offs, including electrical resistance vs.optical absorption loss and mode confinement vs. optical scattering loss. A new blunter taper was used compared to our prior work[3]. The voltage, output power, and temperature rise against current (L-I-V-T) curves show a very low threshold current of 0.144 mA and a high slope efficiency of 0.67 W/A. This low threshold as well as high efficiency indicates that our short tapered oxide aperture does not introduce excess optical loss even down to 3 μm diameter range. However, it does result in a modal volume reduction factor of 1.73, corresponding to a 31% increase in intrinsic bandwidth. The bit-error-rate curve at 35 Gb/s was taken with a non-retrun-to-zero signal having a 2^7-1 word length. The bias current was 4.4 mA and the RF voltage swing was ~0.84 $V_{p\text{-}p}$. The inset shows the optical eye diagram and the eye is clearly open with an extinction ratio of 5.4 dB, despite a relatively low 25 GHz bandwidth reciever that limited the measurement. The VCSEL power dissipation, excluding the RF circuitry, is only 10 mW. This corresponds to the highest data-rate/power-dissipation ratio of 3.5 Gbps/mW.

[1] Y.-C. Chang, C.S. Wang and L.A. Coldren: "High-efficiency, high-speed VCSELs with 35 Gbit/s error-free operation," *Electron. Lett.*, **43** (9) pp. 1022–1023, 2007.

[2] Y.-C. Chang, C.S. Wang, L.A. Coldren: "Small-dimension power-efficient high-speed vertical-cavity surface-emitting lasers," *Electron. Lett.*, **43** (7) pp. 396–397, 2007.

[3] E.R. Hegblom, D.I. Babic, B.J. Hibeault, and L.A.Coldren: "Scattering losses from dielectric apertures in vertical-cavity lasers," *IEEE J. Sel. Topics Quantum Electron.*, **3**, pp. 379–389, 1997.

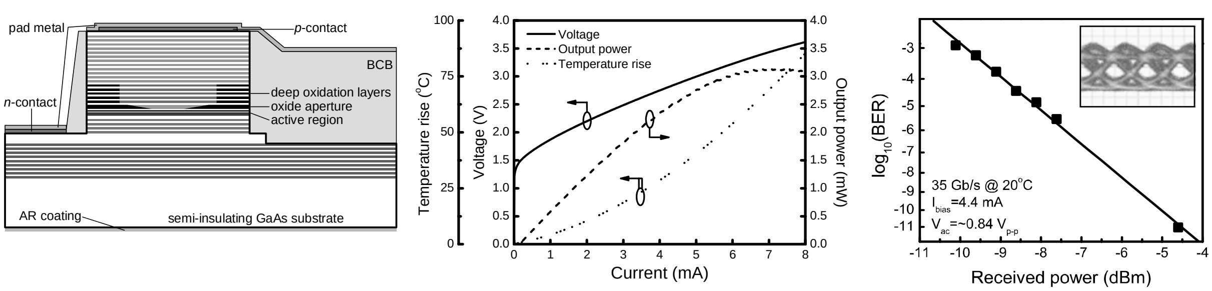

Figure 1: Tapered-oxide-aperture VCSEL and results.