Optimum Damping Level for High-Speed Large Signal VCSEL modulation

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Introduction

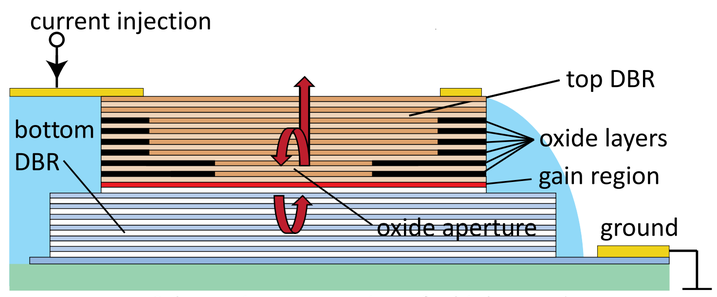
Facebook's data center in Luleå.

The optical interconnects used in datacenters and high performance computers have recently been pushed to lane rates of 25-28 Gbps. Near future standards will require even higher lane rates and further work to increase the speed is therefore necessary. Typically the 850 nm vertical-cavity surface-emitting laser (VCSEL) is employed as light source in such optical interconnects, due to its excellent high-speed properties at low drive currents, low power consumption, and low manufacturing cost.

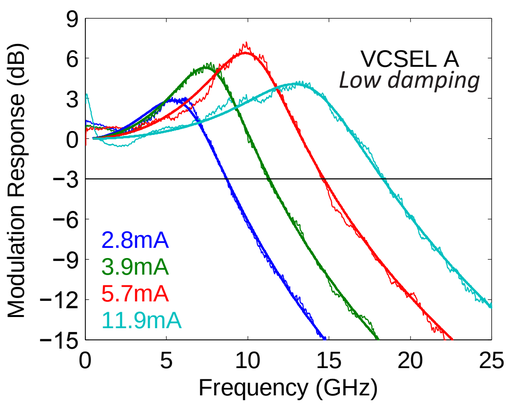
High-speed VCSELs

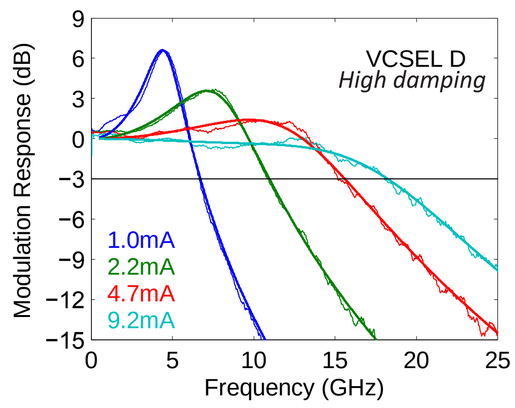
High-speed VCSELs require:

- Low electrical parasitics
- High differential gain and optical confinement
- Low thermal impedance
- Optimized damping of the small signal modulation response.



Schematic cross-section of a high-speed oxide-confined VCSEL.





The small signal modulation bandwidth (BW) can be increased by reducing the damping and there is an optimum damping for maximum BW [1].

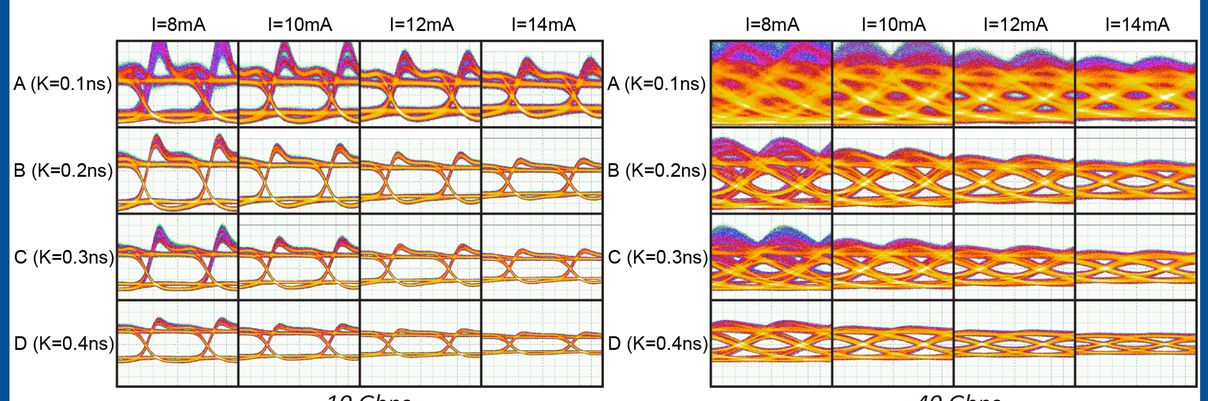
→ Record-high BW of 28 GHz [2] and error-free [bit error rate (BER) $<10^{-12}$] transmission up to 57 Gbps [3].

Large signal modulation

The optimum damping for maximum BW does not necessarily correspond to the damping that produces the highest quality eye and best receiver sensitivity under large signal modulation.

- Low damping provides fast rise time, but causes excessive overshoot and ringing, which translates to excessive timing jitter.
- High damping results in slower rise time, but suppresses overshoot and ringing, thereby reducing the timing jitter.

Below are eye diagrams for VCSELs with different damping (quantified by the *K*-factor) operated at 10 and 40 Gbps [4].



10 Gbps *40 Gbps*

The optimum damping under large signal modulation depends on the data rate.

Low data rates: low BW sufficient

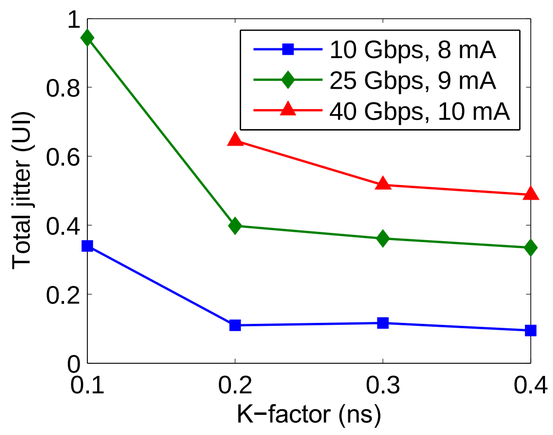
→ low bias and large damping can be afforded, which results in a low timing jitter.

High data rates: requires sufficiently fast rise time and large BW

→ increased bias and reduced damping necessary [4].

Timing jitter

Low damping induces more timing jitter, which can be seen in the measured timing jitter vs. *K*-factor at 10, 25 and 40 Gbps below [4].

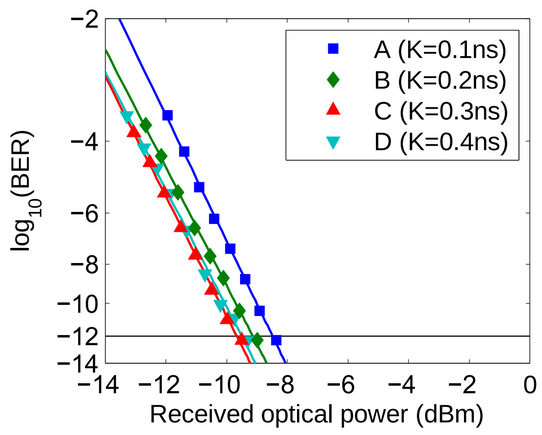


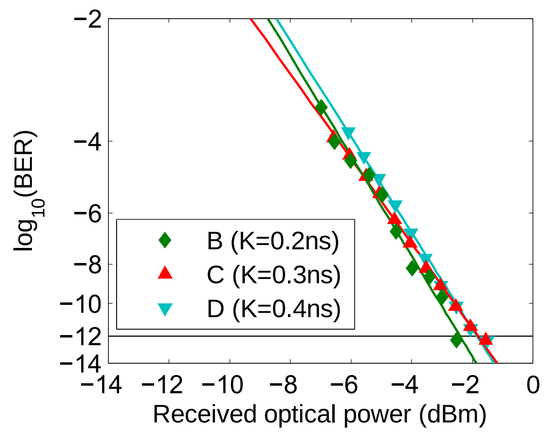
BER measurements

BER measurements show the dependence of optimum damping on data rate:

- 10 Gbps: the most damped VCSELs achieved the best receiver sensitivity.
- 40 Gbps: a less damped VCSEL achieved the best receiver sensitivity.

Too low damping results in excessive timing jitter and prevents error-free transmission [4].





Conclusion

Large signal VCSEL dynamics is strongly dependent on damping. The optimum damping for large signal modulation is dependent on the data rate. The damping should be tuned to yield sufficiently fast rise time, high BW, and low timing jitter to produce a clear eye opening. A large damping can be afforded at low data rates, whereas less damping is required at higher data rates.

References

[1] P. Westbergh, et al., "Speed enhancement of VCSELs by photon lifetime reduction," *Electron. Lett.*, vol. 46, no. 13, p. 938, 2010.

[2] P. Westbergh, et al., "High-speed 850 nm VCSELs with 28 GHz modulation bandwidth operating error-free up to 44 Gbit/s", *Electron. Lett.*, vol. 48, no. 18, pp. 1145-1147, Aug. 2012.

[3] P. Westbergh, et al., "High-speed 850 nm VCSELs operating error free up to 57 Gbit/s", *Electron Lett.*, vol. 49, no. 16, pp. 1021-1023, Aug. 2013.

[4] E. P. Haglund, et al., "Impact of damping on high-speed large signal VCSEL dynamics," *J. Lightw. Technol.*, preprint, 22 Oct. 2014 .

Acknowledgement

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