Millions of optical links in a single supercomputer: What next?

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As long as Moore's law continues to hold, the computational power of computers will increase rapidly, by about three orders of magnitude per decade (presently 10-20 Petaflops [1]). To match the demand, the interconnect bandwidth must keep pace, with the serial bit data rate per channel increasing four-fold every 5 years. Copper wiring gives up at speeds about and above 10 Gigabits per second (Gb/s). Already in the 10 Petaflop-scale IBM machine the number of 10 Gb/s optical links has reached 5 million [2]. The first two 20 Petaflop systems are arriving in 2012 (IBM [3] and Cray), while the same year four types of copper interfaces at 25 to 28 Gb/s are to be standardized: CEI-25G-LR, CEI-28G-SR, CEI-28G-VSR, and FC32G [4]. The roadmap for 50 Gb/s is already set (CEI-50G-SR, 2015). As a consequence, it is expected that in the near future billions of optical links will be deployed in a single exascale computing system and up to 80% of the cost, power consumption and performance will be determined by optical interconnects [5].

Presently 850 nm vertical-cavity surface-emitting lasers (VCSELs), top-illuminated PIN GaAs photodetectors, and the related multimode optical fiber (MMF) are the basis for high-speed energy-efficient [6] optical links in local- and storage-area networks (LAN, SAN) and in high-performance computing. How long can this combination withstand the pressure of the exploding data rates?

I will address new opportunities for further dramatic improvement in speed, temperature performance, modal composition of VCSELs and novel "VCSEL-inspired" devices.

1. http://www.top500.org/static/lists/2011/11/TOP500_201111_Poster.pdf
2. B. J. Offrein, *IBM Silicon Photonics Workshop*, Munich (May 2011).
3. http://www.hpcwire.com/hpcwire/2012-01-12/first_racks_of_20petaflop_sequoia_supercomputer_arrive_at_llnl.html
4. http://www.lsi.com/AIS2011/Documents/LSI_Deploying100GtoPreparing400G.pdf
5. A. F. Benner, "Optical interconnects for HPC", *Short-Distance High-Density Optical Interconnects OIDA Roadmapping Workshop*, Stanford, CA (April, 2011).
6. P. Moser, J. A. Lott, P. Wolf, *et al.*, "99 fJ/(bkm) energy to data-distance ratio at 17 Gb/s across 1 km of multimode optical fiber with 850-nm single-mode VCSELs", *IEEE Photonics Technol. Lett.* **24**, 19 (2012).