Ultrafast nanophotonic devices for optical interconnects

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The ever-growing high serial transmission speed of electrical interfaces (a 4-fold increase in speed each 5 years that is roughly a Moore's Law for data communications) is primarily driven by an increase in microprocessor bandwidth and silicon scaling. The same scaling enables faster and more power efficient CMOS ICs for transceivers operating at these ever-increasing speeds.

Electrical interfaces for serial transmission at speeds beyond 10 Gb/s are being standardized for a variety of applications including, for example: Fibre Channel FC16G (expected data rate of 17 Gb/s, expected implementation in 2009); Infiniband (20 Gb/s, 2011); FC32G (34 Gb/s, 2012); CEI-25 (25 and 28 Gb/s), USB 4.0 (expected to be 20-60 Gb/s), and many others.

Within this range, the maximum copper link length is limited to meters or even a few centimeters, depending on the particular transmission speed and the form factor of the cables used. Consequently, one must apply fiber optics to extend the link length to the required distances of 0.1–100 meters.

High-speed optical components traditionally based on vertical-cavity surface-emitting lasers (VCSELs) are thus of extreme importance for the future development of local and storage area networks, intrasystem links, as well as for applications in optical fiber cables for industrial and consumer applications.

The optical transceiver should be capable of operating at the same or higher transmission speed as the electrical interface. Going to parallel optical links starting from a higher serial speed electrical interface using time division demultiplexing would require twice the number of CMOS drivers and amplifiers, and, most importantly, integrated circuits for demultiplexing and multiplexing at both the transmitting and the receiving ends of the link. The latter is prohibitively power-consuming and complex. But developing optical components that are suitable for high-speed transmission and that operate at moderate current densities up to high temperatures, thereby avoiding degradation problems, has always been quite a challenge.

The most recent tests on multimode fiber transmission links equipped with VIS devices at both ends, have resulted in error-free transmission at up to 40 Gb/s and are limited only by the overall BERT measurement system. The time needed for a rectangular signal to rise from the 20% to the 80% level after passing through all the components of the optical link test system, including the VCSEL, is 15 to 16 ps. We have determined that the deconvoluted VCSEL rise time is a mere 9 ps or less. Moreover it is particularly important to underline that there is essentially no temperature dependence in the VCSEL's rise time up to a fixed substrate temperature of 100 ^{o}C.

The next strategic goal for VIS technology is to achieve 60–100 GHz -3dB optical bandwidth via vertical integration of the VCSEL and modulator sections. The reflectance of the top Bragg mirror is electro-optically modulated, the Bragg mirror thus acting as a chopper for the continuous emission from the VCSEL section. Further remarkable reduction in power consumption and cost of the high-speed transmitter using either a VCSEL or a resonant-cavity LED will become possible. Optical modulation with a -3dB bandwidth beyond 30 GHz and up to 100 ^{o}C has already been demonstrated. Transfer of the approach to long haul applications is possible.