Terabit-per-second Data Signal Integrity in Silicon Photonic Nanowire Waveguides for Optical Networks On-Chip

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Abstract–*We report experiments validating the use of silicon nanowire waveguides as ultrahigh-bandwidth chip-scale links. Multi-wavelength-encoded 1.28-Tb/s data signals are successfully propagated through a 5-cm link, while crosstalk and power penalty measurements are performed on 240-Gb/s signals.*

Motivation

The trend toward multi-core architectures in high-performance microprocessors has been driven by the increasing emphasis on performance per Watt. As a result, the performance of chip multi-processors (CMPs) is tightly linked to the performance of the interconnects or the interconnection networks that unite the cores. Already, the interconnects, in order to meet considerable bandwidth and latency requirements in today's CMPs, are dissipating a large fraction of the overall processor power budget.

Photonics provide a promising path toward realizing low-power high-throughput chip-scale interconnects. Advances in silicon photonic micro-fabrication have led to the development of an optical toolbox consisting of the vital networking elements (e.g. modulators, switches, receivers). Of fundamental importance is an easily integrated medium that can efficiently link the communicating nodes, while also providing a high-speed path to off-chip destinations. These links must be low-loss to facilitate minimal power dissipation, compact in order to occupy negligible footprints, and ultra-wide-band to provide virtually unlimited scaling of throughput bandwidth. Highly-confined silicon photonic waveguides provide a broadband medium to meet these requirements. Termed nanowires because of the nano-scale cross section (Fig. 1), these links can implement micron-scale bending radii without added scattering losses. Moreover, typical propagation losses (3 dB/cm [1]) are nearly negligible for chip-scale distances.

Terabit-Scale Data Integrity Experiments

By encoding wavelength-parallel data, the full bandwidth potential of the broadband links may be utilized. We confirm the feasibility of ultrahigh-bandwidth data transfer in these links by generating a 1.28-Tb/s data stream (32 40-Gb/s wavelength channels) and propagating it through a 5-cm-long link (Fig. 2) [2], representing the highest reported bandwidth in a silicon waveguide to date [3].

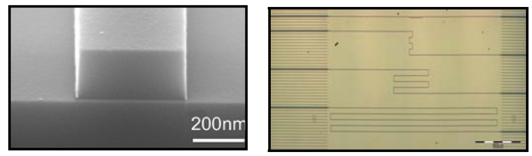

Fig. 1. Left: SEM image of a silicon nanowire cross section (200-nm scale). Right: microscope image of four nanowires of various length (1-mm scale).

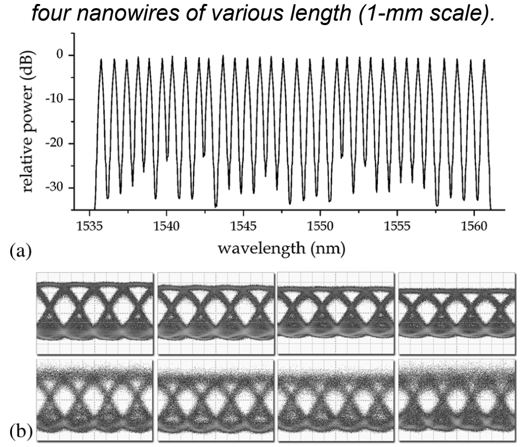

Fig. 2. (a) 1.28-Tb/s spectrum and (b) eye diagrams before and after propagation through the 5-cm link for channels C23, C28, C46, and C51.

Also, we measure the bit-error-rate (BER) crosstalk between wavelength channels in the link using 24 10-Gb/s channels [2]. The overall 24-channel power penalty is 3.3 dB. Given the length of the silicon photonic wire and the number of channels in the input signal, the measured penalty is quite tolerable.

Self-phase modulation (SPM) has been observed in sub-centimeter-length silicon waveguides using picosecond pulses with injection powers of a few tens of milliwatts [4]. Consequently, it is important to consider the penalty induced when relatively high-power signals are launched into much longer links. By injecting a single 10-Gb/s channel at a peak power of 7 dBm, we obtain an input power dynamic range for the 5-cm link of more than 13 dB [2].

References

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