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Demonstration of a wavelength division multiplexed chip-to-chip optical interconnect

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Abstract: We demonstrate operation of a 10-channel wavelength division multiplexed chip-to-chip optical interconnect using a single broadband source. Individual circuits and optoelectronic devices have been shown to work at data rates approaching 1 Gb/s.

Wavelength division multiplexing simplifies optical interconnect packaging in that many channels can be combined and transported over a single fiber. The use of a single broadband optical source potentially decreases cost in a short-distance interconnect, while the use of femtosecond pulses provides additional advantages, including the removal of interconnect skew and jitter [1]. We combine these advantages by using a mode-locked Ti:Sapphire laser as the optical source in a proof-of-concept chip-to-chip optical interconnect. The 150-fs pulses from the laser have a spectral bandwidth of approximately 5 nm, at a center wavelength of 860 nm. While previous work [2] has demonstrated the principle of using short pulses for wavelength division multiplexing, we demonstrate operation of a full system including GaAs devices hybridly integrated to functional silicon logic.

The chips were fabricated in 0.5 µm silicon CMOS and include 1x10 linear arrays of transmitter and receiver pairs. The optoelectronic devices consist of p-i-n GaAs multiple-quantum well diodes flip-chip bonded to the CMOS. Because the contrast ratio of these modulators is relatively low at CMOS voltage levels, they are used in differential pairs. With an applied reverse bias, the diodes also serve as detectors for the sense-amplifier receivers.

A schematic of the system operation is shown in figure 1. For full ten-channel operation, the modulators are run with data from an on-chip pseudo-random bit sequence generator. Incoming optical pulses are dispersed by a grating into a spectral stripe across the modulator array. Reflection off these diodes defines the approximately 0.5 nm (200 GHz) wavelength channels, an example of which is shown in figure 2. This light is then recombined into a single beam by a second reflection off the grating and sent to the receiver side, where the signals are similarly demultiplexed onto the receiver array. To allow monitoring of the link performance, the received data is then retransmitted on a neighboring modulator, which can be read out using a beam from a continuous-wave diode laser.

To avoid issues of electrical and optical crosstalk, which are the subject of future work, we here demonstrate operation of a single channel. In this case, a portion of the spectral stripe was modulated by a pair of modulators on the transmitter chip. This channel was driven with an external 32-bit pseudo-random data sequence, frequency-locked to the 80 MHz laser repetition rate. The data received at the corresponding channel on the receiver chip was read out through a high-speed electrical connection. Figure 3 shows both the input to the transmitter channel and the received data at the other end, indicating successful operation of the link at 80 Mb/s.

We have demonstrated operation of a wavelength-division multiplexed optical interconnect using a broadband source. The system data rate of 80 Mb/s is limited by the repetition rate of the laser, but the individual circuits and optoelectronic devices have been shown to work at data rates approaching 1 Gb/s. Such a system has many potential advantages for future short-distance optical interconnects.

[1] G. A. Keeler, B. E. Nelson, D. Agarwal, and D. A. B. Miller, "Skew and Jitter Removal Using Short Optical Pulses for Optical Interconnection," *IEEE Photon. Technol. Lett.*, **12** , 714-716 (2000).

[2] E. A. De Souza, M.C. Nuss, W. H. Knox, and D. A. B. Miller, "Wavelength-division Multiplexing with Femtosecond Pulses," *Optics Letters*, **20**, 1166 (1995).

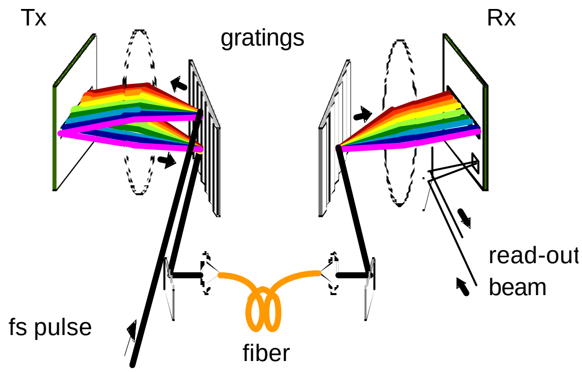

Figure 1. A schematic of the optical setup showing signal path from the transmitter to receiver chip.

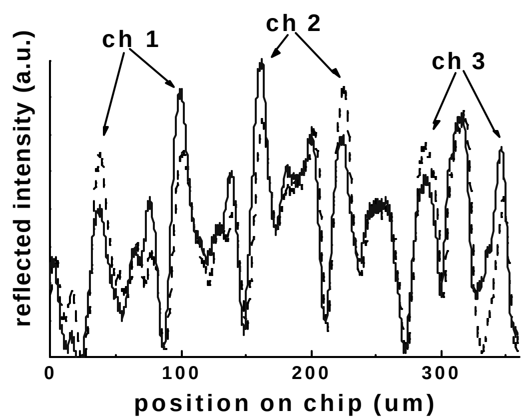

Figure 2. Spectral slicing plot of reflection from six modulators for two different states in the pseudo-random sequence (dashed and solid lines). All three channels have changed state, as indicated by the change in reflected intensity.

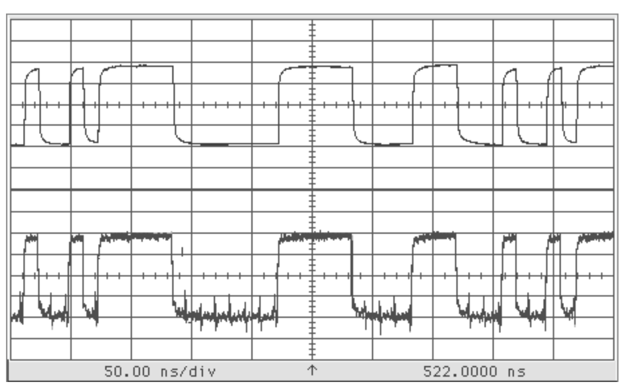

Figure 3. Oscilloscope plot showing electrical input to modulators (top) and electrical output of receivers (bottom). Glitches in bottom scan are due only to electrical feed-through in the circuits and do not indicate errors.