

# Performance Enhancement of an Optical Interconnect Using Short Pulses from a Modelocked Diode Laser

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**Abstract** We demonstrate significant performance improvements in a chip-to-chip optical interconnect by employing a modelocked diode laser. BER measurements show a receiver sensitivity enhancement of 3.3 dB when compared to operation with a continuous-wave laser.  
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Ultrafast techniques have found applications in almost all fields of science and engineering. In this work we investigate the advantages that short pulses can provide in short-distance optical communications. We demonstrate the first high-repetition-rate, chip-to-chip optical interconnect using a practical short-pulse source and describe several benefits of the system.

A significant advantage of short-pulse-based optical interconnects is receiver sensitivity enhancement. This phenomenon occurs both with receivers based on transimpedance amplifiers [1], and on the sense-amplifier integrating designs used here. System measurements described herein quantify this enhancement. Other benefits of the link to be discussed include: reduced link latency [2], simplified clock recovery, removal of transmitter skew and jitter [3], and the potential for optical clocking.

Our short-pulse optical source is an actively-modelocked external cavity diode laser with a variable repetition rate, a pulse width of less than 80 ps (measurement was limited by detector bandwidth), and low jitter. The center wavelength is tunable and the linewidth is approximately 0.7 nm. The laser can be modelocked at harmonics of the 200 MHz fundamental frequency, and we electrically clock the silicon circuits at the same frequency (400 MHz in this experiment). The chips used in this work were fabricated in 0.5  $\mu\text{m}$  silicon CMOS, and have optoelectronic I/O devices attached via flip-chip bonding to improve performance and increase channel density. The devices are MBE-grown GaAs multiple-quantum-well p-i-n diodes that serve as modulators and photodiodes.

The optical link is a simple free-space imaging setup, with optics mounted on stainless steel baseplates for stability. A simplified schematic of the interconnect is shown in Figure 1. A single laser beam (either continuous-wave or short-pulse) is split with a diffractive optical element, generating an array of beams for the multi-channel link. Data is generated on-chip using a  $2^2-1$  pseudo-random bit sequence (PRBS) generator. Each beam is modulated with this data from the transmitter chip, then imaged onto a detector of the receiver chip. The output of a selected receiver can then be compared to the expected data, which is generated by a complementary PRBS circuit on the receiver chip. This on-chip bit error rate (BER) tester allows us to make quantitative measurements of the system performance as interconnect parameters are varied.

In this experiment, we compare link performance between conventional non-return-to-zero (NRZ) signaling (i.e., employing the continuous-wave laser) and short-pulse operation, both at 400 Mb/s. Figure 2 shows BER data for the link as a function of transmitted signal power. An improvement of 3.3 dB is obtained through the use of short pulses. This improvement can be attributed to the sensitivity enhancement of the integrating receiver, as well as transmitter RC speed limitations that are avoided in the short-pulse case.

In conclusion, we have demonstrated a short-pulse optical interconnect that uses a practical, high-repetition-rate modelocked source. BER measurements show that operation with short pulses improves system performance by providing a receiver sensitivity enhancement of 3.3 dB. The link has additional benefits related to timing issues and latency reduction that will be explored further during the talk.

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- [2] D. Agarwal and D. A. B. Miller, "Latency in short pulse based optical interconnects," *IEEE LEOS 2001 Annual Meeting*, November 11-15, 2001, paper ThR3.
- [3] 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).

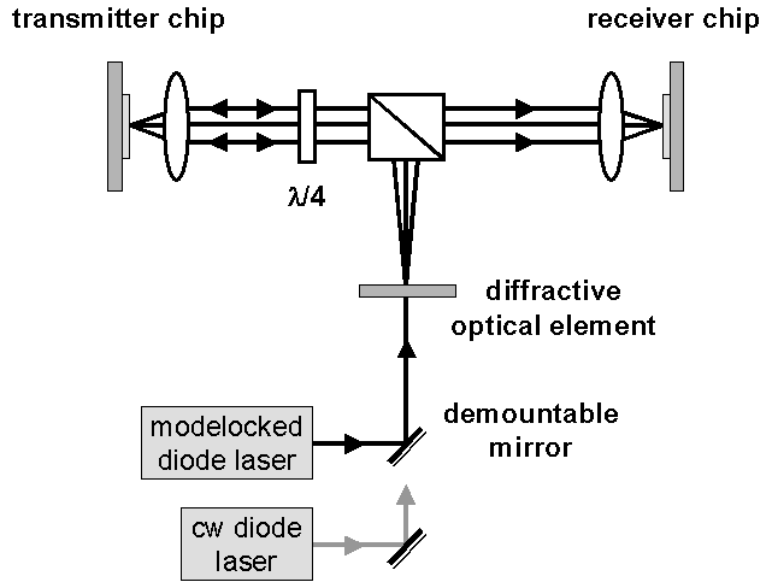


Figure 1. Simplified schematic of the short-pulse interconnect optical setup.

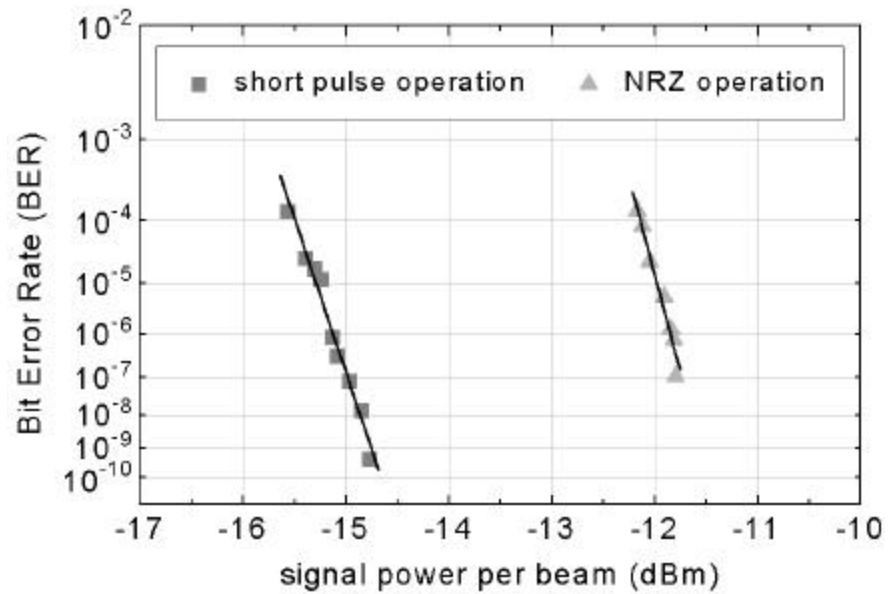


Figure 2. Measured bit error rate of the link at 400 Mb/s, comparing short-pulse operation to NRZ operation. A power savings of 3.3 dB is obtained by the use of short pulses.