A 55Gb/s Directly Modulated 850nm VCSEL-Based Optical Link

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Abstract: We report a directly modulated 850nm VCSEL-based Optical link operating at 55Gb/s. This is the highest modulation rate for VCSEL-based link of any wavelength.

OCIS codes:*s; (060.2340) Fiber optics components (060.2360) Fiber optics links and subsystems; (060.2380) Fiber optics sources and detectors; (200.4650) Optical interconnects.*

1. Introduction

High Performance Computing, Data Centers and the Internet in general, are driving the demand for high bandwidth interconnects. Already, serial data rates of 25.78Gb/s (Ethernet, Infiniband) and 28.05Gb/s (Fibre Channel) have been standardized with directly modulated 850nm VCSELs as part of the solution. It is anticipated that there will be proposals for the next generation of these standards with serial data rates above 50Gb/s. For VCSELs, the highest serial data rates demonstrated, error free, thus far are 44Gb/s for 850nm [1][2], 49Gb/s for 980nm [3], 40Gb/s for 1100nm [4], and 35Gb/s for 1550nm [5]. In this paper, we demonstrate that advanced VCSELs combined with equalization can operate above 50Gb/s and should continue to be part of the solution for future high speed serial links. To the best of our knowledge, this reported data rate of 55Gb/s is the highest data rate for any VCSEL link, regardless of wavelength.

2. Experiment

The full link is comprised of a SiGe 8HP (standard IBM 130nm BiCMOS) driver chip with two tap feed forward equalization (FFE) wirebonded to an 850nm VCSEL and a GaAs PIN photodiode wirebonded to a SiGe 8HP receiver IC, also with two tap FFE. Figure 1 shows a block diagram of the link. The driver IC is similar to a previously published design [6], but with a 100 Ohm output impedance providing higher modulation efficiency. The receiver is identical to the one in [6]. The ICs and corresponding OEs are separately packaged on a printed circuit board with short (~0.5") 50 Ohm transmission lines to vertical SMP coaxial connectors. All components on the circuit boards are either wirebonded or soldered. The circuit board contains a chip thermistor for temperature monitoring.

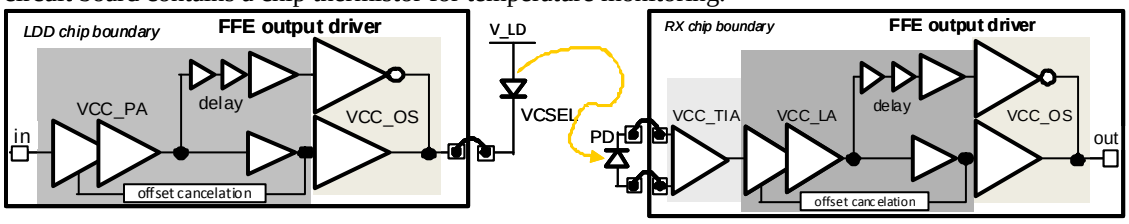

Figure 1 Block Diagram of full optical link showing internal elements of the driver and receiver ICs

The VCSEL used in this work was grown on an N-Type substrate by low pressure MOCVD and consists of a lower N-type DBR, a four quantum well active region, and a P-type upper DBR. The VCSEL was fabricated with a single anode contact on the top and a cathode contact through the substrate. Parasitic capacitance was minimized by thick dielectric coating under the anode bond pad connection. The approximately 7 μm current and optical emission aperture is formed by steam oxidation. The VCSEL has a threshold current of approximately 600μA, slope efficiency of 0.3W/A, and series resistance of 100 Ohms. The measured 3dB optical bandwidth is approximately 24GHz. The photodiode has a 25μm active diameter and is described in [7]. The photodiode 3dB electrical bandwidth is 22GHz at -3V.

3. Results

The full link is characterized from 40 to 56 Gb/s using PRBS7. The link is comprised of 5m of 50/125 OM2 grade fiber with 3 connectors. Error-free operation (defined as BER <1E-12) is obtained up to 55Gb/s. At 56Gb/s, the BER was 1E-6, however, future Fibre Channel standards will incorporate FEC, effectively allowing an uncorrected BER of 1E-6 to run error-free when corrected and provide margin towards product requirements. Figure 2 shows the eye diagrams and bathtub curves for 3 data rates: 40, 50 and 55Gb/s using the settings which gave the best results at 55Gb/s. The VCSEL bias was 8.1mA and the

photodiode bias was -5V. The transmitter temperature is 25°C. The received photocurrent is 622μA which corresponds to 1.1mW average power. At 40Gb/s, the eye opening is 0.38UI which is lower than the 0.58UI obtained in [6] using conditions optimized for 40G. At 55Gb/s, there is 0.4ps (0.02UI) of eye opening at BER=1E-12. The eye opening from the test equipment back-to-back is 0.68UI at 55Gb/s. The total link power dissipation is 1.25W = 738mW Tx + 512mW Rx, corresponding to energy consumption of 25pJ/bit for the system at 55Gb/s, and a low 250fJ/bit for the VCSEL by itself.

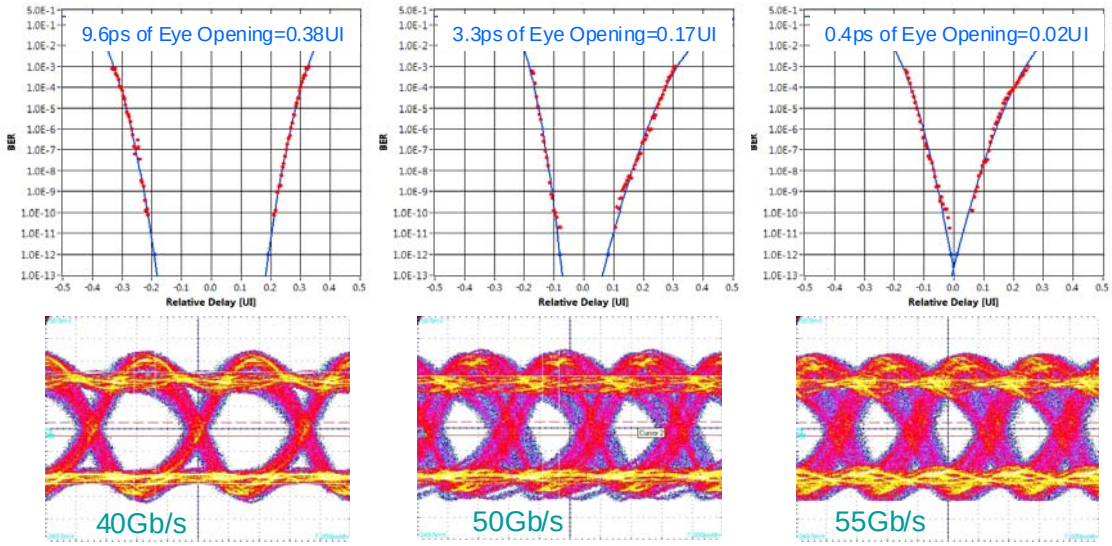

Figure 2. Link Eye Diagrams and Bathtub curves for three data rates: 40, 50, and 55Gb/s (left to right). For the eye diagrams, vertical scale is 50mV/div and the horizontal scale is 7.2ps/div.

3. Conclusion

We have demonstrated a full optical link, IC to IC, at the highest serial bit rate yet published for any NRZ directly-modulated VCSEL. The use of 850nm, the industry standard, is compatible with the high bandwidth OM3 and OM4 fiber. This performance, which exceeds the capabilities of the individual OE devices on their own, is made possible by a higher bandwidth VCSEL and by the use of transmitter equalization. Equalized links using direct NRZ modulation are a convenient and viable path forward to satisfy the needs for future higher serial data rates without having to resort to complicated coding or modulation schemes.

Acknowledgements: Partial support by DARPA under contract MDA972-03-3-0004 is gratefully acknowledged. The views, opinions, and/or findings contained in this article are those of the authors and should not be interpreted as representing the official views or policies, either expressed or implied, of DARPA or the Department of Defense. Approved for Public Release, Distribution Unlimited.

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