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## 120Gb/s VCSEL Based Parallel Optical Transmitter and Custom 120Gb/s Testing Station

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**Abstract:** A 120Gb/s parallel optical transmitter using 850nm VCSELs for 12-fiber ribbon (12 channels x 10Gb/s/ch) is described and experimentally verified. All channels run simultaneously, driven a custom-built low cost 120Gb/s test station. Open eyes are obtained at 300m and error free operation with margin is confirmed. A 2.3dB penalty is observed for simultaneous transmission compared to single channel operation. The transmitter consumes 1.3W and occupies the same volume as existing 40Gbps modules.

**OCIS Codes:** 250.7260 Vertical cavity surface emitting lasers, 060.2330 Fiber optics communications, 120.4800 Optical standards and testing

## Introduction

As data rates and clock speeds in servers, routers, switches and computers increase toward 10Gb/s, optical communication between racks and boards becomes a practical necessity. A parallel optical interconnect (POI) platform has already been established for advanced systems[1]. At a nominal 2.5Gb/s per channel data rate, the platform includes 12-fiber ribbons of multi-mode fiber (MMF) on 250μm pitch, MT-based connectors, 850nm VCSEL and PIN photodiode arrays, and Si based driver and receiver arrays. At the same time, an 850nm VCSEL/MMF-based platform for serial links has been established for a data rate of 10Gb/s, with specifications defined in 10-Gigabit Ethernet[2], 10Gigabit Fibre-Channel, and in the Optical Internetworking Forum. Therefore the eventual combining of both platforms to create a 12-channel POI platform at channel rates of 10Gb/s/ch seems inevitable. This paper explores extending the existing POI packing platform to the 10Gb/s/ch level. A collaboration between Picolight and IBM has produced a 120Gb/s optical transmitter and a custom low cost 120Gb/s test station to break into this next generation POI.

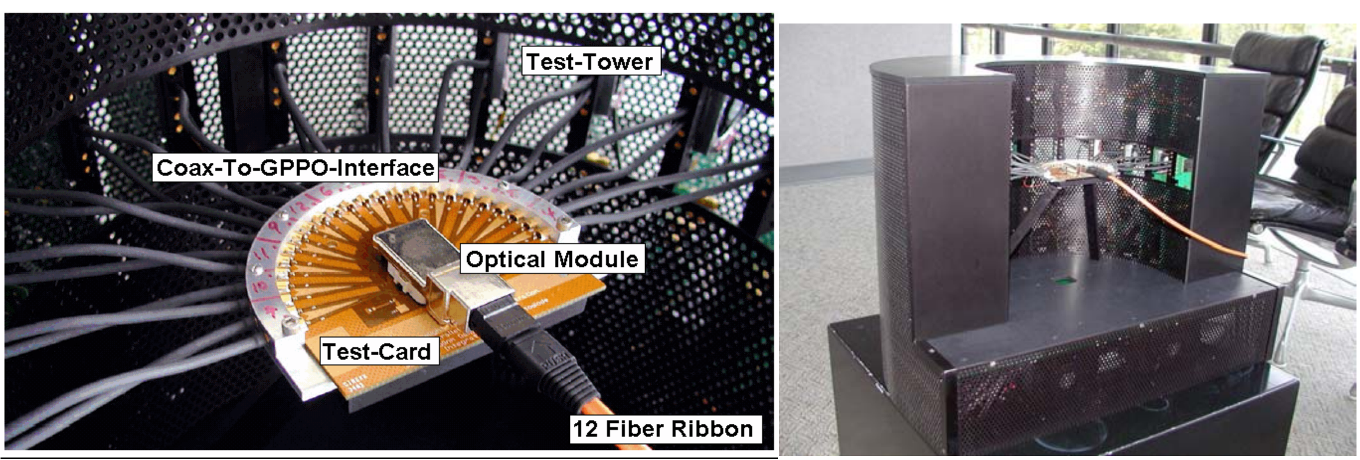


**Figure 1.** (Right) Custom 120Gb/s test station with parallel optical module in the center and 12 test boards on the outside. (Left) Overhead view of the parallel optical module mounted on evaluation board.

## Optical Transmitter Module

The optical module form factor conforms to the SNAP12 multisource agreement [3]. SNAP12 modules provide a 12-channel optical connector and a pluggable 100 pin electrical connectors called MegArray®[4]. The transmitter module used a monolithic laser diode driver (LDD) array fabricated from an advanced IBM SiGe Bipolar technology and a monolithic array of 10Gb/s Picolight VCSELs. The driver input is 100Ω fully differential and operates from a single 3.3V supply. Power dissipated was 100mW per channel. Minimum acceptable input voltage swing is 150mVp-p and is LVDS compatible. The inputs to each of the channels can be either DC or AC coupled. The input signal is conditioned to reduce common mode artifacts, then amplified and limited to make the output drive signal insensitive to input amplitude. The output modulation current is adjustable up to 10mA p-p and the DC bias is adjustable up to 7mA. This LDD sets a common bias and modulation level for all 12 channels. To avoid the use of analog control voltages external to the module, the control voltages were generated within the module using digitally controlled potentiometers and op-amp buffers. The outputs of the LDD are on a 250um pitch to facilitate direct wire bonding to a common cathode VCSEL array.

The VCSEL and driver arrays were mounted onto a redesigned circuit substrate using the same base technology as used in 3Gb/s modules. The VCSELs in the array are similar to 3Gb/s production VCSELs, but optimized for reliable 10Gb/s performance over temperature.

## Test Station

The test station in shown in the right side of Figure 1. It is a semi-circular tower with the POI module placed on an elevated test card in the center. 12 test boards are arranged radially in the tower, each holding a 10Gb/s Ethernet PHY chip. This geometry allows equal lengths between the module and each of the twelve test boards. It also allows the cable length to be very short (4 inches), to minimizing signal degradation. The short cables also result in small interchannel skew, <6ps. The 10GbE PHY chips are used as pattern generators for transmitter testing and as error detectors for receiver testing. They can generate a number of test patterns including the standard PRBS31 and a CLK/22 square wave. Rise and fall times for each channel are <30ps (20-80%). Voltage output amplitude is adjustable from 500mV to 2.0V, and signaling is 100Ω differential. Individual enabling/disabling of channels allows for crosstalk and single channel measurements. All test boards have a PC interface for remote control and data collection. The testing tower consumes only 140W with all 12 boards enabled.

## Optical Transmitter Test Results

Figure 2 shows 12 eye diagrams, each at 10.3125Gbps, obtained from a transmitter module. The NRZ pattern is PRBS31. The mean coupled power for all 12 channels is 2.4dBm with a variation of +/-0.8dB across the array. The mean extinction ratio is 3.9dB with a variation of +/-0.2dB. This small variation in extinction ratio is attributed to the uniformity of the VCSEL properties and the LDD driving conditions and validates the use of common bias and modulation levels. The measured optical rise and fall times (20-80%) are 39.4 and 39.8ps respectively and are <35ps when deconvolved from the measuring equipment. The VCSELs are 850nm multi-transverse mode with typically 3 modes lasing. Across the array the spectrum varies by 1.4nm. The mean RMS jitter is 6.3 ps and increased to 6.6 ps for 12 channel operation. At room temperature with forced air cooling, the temperature of the VCSELs is 18 degrees above ambient with a single channel operating. With all 12 channels operating this temperature increases to 23. The temperature across the array varies by <3 degrees C.

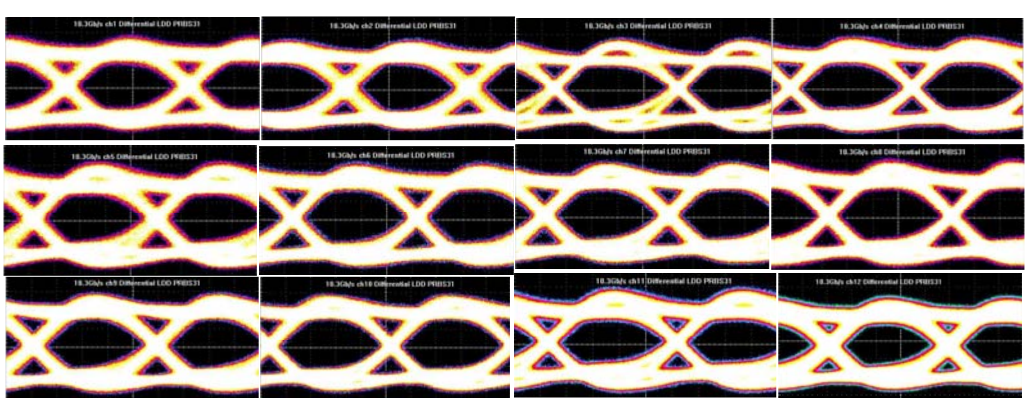

**Figure 2.** 12 eye patterns, each at 10.3125Gbps, obtained from the array transmitter.

The transmitter meets the TIA/EIA encircled flux specification [5] for all 12 channels. Open eyes can be obtained at 300m fiber length using a 12 fiber ribbon of Next Generation Multimode 50/125 fiber. Using the testing station, all 12 channels were operated simultaneously at 10.3Gb/s. Using a reference receiver, error free operation can be observed on all 12 channels. Comparing single channel performance with 12 channel performance, a maximum penalty of 2.3dB due to crosstalk is observed. Figure 3 shows the BER vs optical modulation amplitude (OMA) for channel 5, the channel with the largest crosstalk penalty. The left curve is measured with only channel 5 operating. The right curve is measured when all other 11 channels are running at 10.3Gb/s with PRBS31. The penalty varies from channel to channel with the lowest at 0.9dB. The right side of figure 3 shows the penalty measured on channel 5 versus a single aggressor channel. It can be seen that the nearest neighbor penalties are not equal. Although package crosstalk was measured to be –29dB for nearest neighbors, it was often found that a next nearest neighbor could generate a comparable or larger penalty. This effect was attributed to the layout of the differential signal traces as they exited the MegArray pin field. The crosstalk has an inverted derivative response indicating that it occurs from either capacitive or inductive coupling between channels.

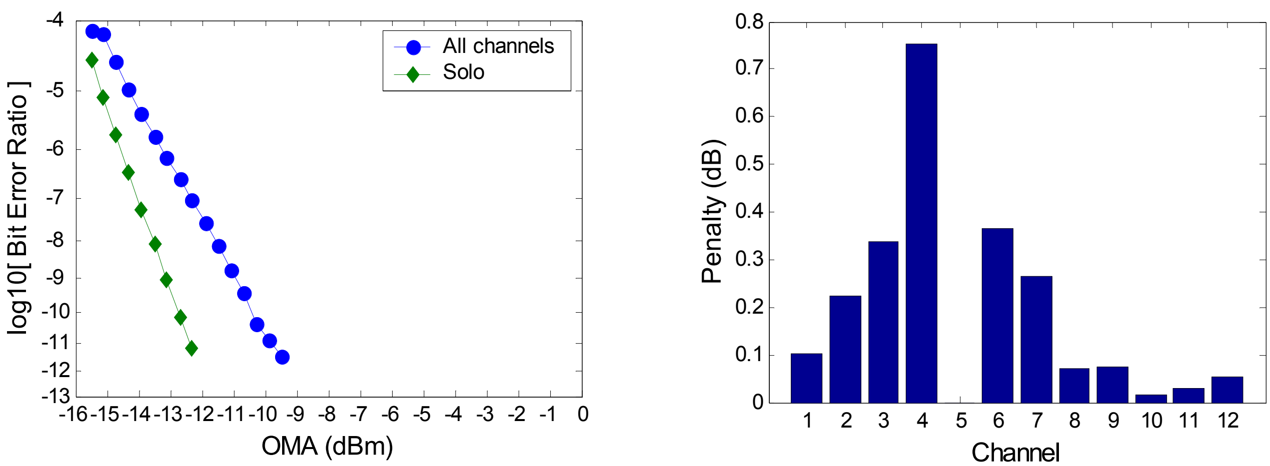


Figure 3. BER Curves for single and 12 channel operation.

Conclusions

A parallel optical transmitter capable of 120Gb/s is demonstrated and verified using a custom-built 120Gb/s test station. Simultaneous operation of all 12 channels resulted in a penalty of 2.3dB above single channel operation. This transmitter occupies approximately one square inch of board space and sets a new benchmark for bandwidth density as measured in Gb/s per square inch and Gb/s per watt.

References:


[1] MAGNUS™ Parallel Optical Interconnect, Data Sheet, Picolight (Boulder, Colorado, 2002).

[2] IEEE Standard 802.3ae™,, IEEE (Piscataway, New Jersey, June 2002).

[3] http://www.snapoptics.org

[4] MEG-Array ® Connector System, Datasheet and Application Notes, FCI USA (Etters, Pennsylvania, 2002).

[5] TIA/EIA Fiber Optic Test Procedure (FOTP) 203, "Collection and Reduction of Two-dimensional Nearfield Data."