Wavelength Division Multiplexed Optical Interconnects Using Femtosecond Optical Pulses

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I. INTRODUCTION

The application of well-known concepts from the telecommunications industry to optical interconnects is common; however, significant modifications of the typical approaches may be required to keep costs low. We suggest such an approach by demonstrating the operation of a multiple channel chip-to-chip wavelength division multiplexed (WDM) interconnect through a single fiber using GaAs diodes flip-chip bonded onto silicon.

Multiplexing information onto a single fiber can minimize the high costs of fiber pigtailing, while avoiding time-division multiplexing circuits with their associated power consumption, latency, and very high-speed electronics. Additionally, traditional WDM systems use a separate laser for each channel. This increases both cost and complexity by requiring multiple sources and wavelength stabilization. We eliminate these concerns by using a mode-locked Ti:sapphire femtosecond laser as a broadband WDM source and employing the technique of “spectral slicing” to define our WDM channels.

II. EXPERIMENT

The experimental set-up is shown in Figure 1. Previous work has demonstrated the principle of WDM interconnects [1], but here we explicitly show WDM transmission through a fiber and detection with an integrated silicon IC photoreceiver. A 1200 line/mm reflective grating is used to spectrally disperse a 100 fs (3 THz) pulse across a 1x20 modulator array. The degree of spectral spread ($d\lambda/dx$) can be chosen by the incident angle with the grating. We use a spread such that the channel spacing is approximately 0.6 nm (250 GHz) per channel. A 50 mm achromatic lens is used to focus the spectrum onto the modulator array in a 10 μm thick stripe. The wavelength channels are thus spectrally sliced from the incoming beam, with light between the modulators absorbed by the silicon. A linear array of ten differential channels is run by clocking a $2^{28}-1$ pseudo-random data generator circuit on the chip that feeds all ten channels with different data. The retro-reflected modulated spectrum is then recombined at the grating into a single beam and sent through a fiber to the receiver end, where another grating demultiplexes the signal to the appropriate receiver diode pairs. After recovering the data to full logic levels, the receiver drives another modulator. This allows us to optically interrogate the output state of the receivers, avoiding the problem of limited pad numbers on the chip.

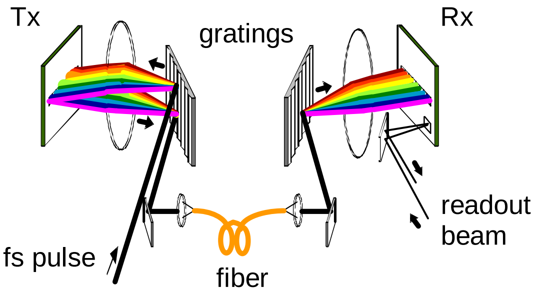

Figure 1. Schematic of experimental set-up showing signal path from transmitter chip to receiver chip, and test readout beam.

The modulators are GaAs multiple quantum well diodes, flip-chip bonded onto 0.5 μm silicon CMOS. A voltage swing of 3.3 V across a modulator produces a contrast ratio of roughly 2:1. The same diode structures are used as detectors. Our broadband optical source is a Spectra-Physics Tsunami mode-locked Ti:sapphire laser that generates 100 fs optical pulses at 850 nm. The chip is driven by a clock signal frequency locked to the repetition rate of the laser (approximately 82 MHz). A separate cw laser is used to optically read out modulators driven by the receiver channels. This signal is analyzed using a Tektronix P6701 detector with a signal bandwidth of 700 MHz, and is monitored and recorded using a high-speed digital oscilloscope. This demonstration system will allow us to investigate high-density interconnect issues such as crosstalk and skew between channels, and the effect of substrate and supply noise on receiver performance.

III. RESULTS

Figure 2 shows a pair of reflected spectra from the transmitter chip. The state of channels 1 and 4 changes between scans, as evidenced by the difference in contrast between diodes of a differential pair.

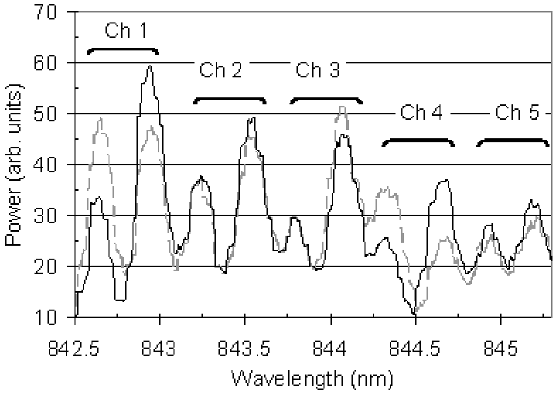

Figure 2. Two different reflected signal states from the transmitter chip. Channels 1 and 4 have changed state, while the others have remained the same.

Figure 3 shows an eye diagram from a single receiver channel output. Since the receiver is asynchronous, the output can be seen to relax to the off state with a characteristic time constant, making it look much like a typical RZ signal. Hence we have shown connection from logic levels on one silicon chip, through a WDM interconnect over a fiber, to logic signal levels on another silicon chip. Additionally, through the use of an optical readout beam, we have shown the simultaneous operation of optical inputs and outputs on a single chip.

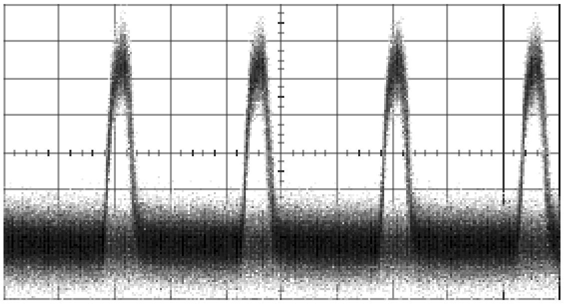

Figure 3. Eye diagram from a receiver circuit operating at 82 Mb/s, measured by optically reading out a modulator driven by the receiver circuit output.

IV. CONCLUSIONS

We demonstrate the implementation of a wavelength division multiplexed optical interconnect using a single optical fiber, with a femtosecond laser as our optical source. The maximum speed of this interconnect is currently limited by the repetition rate of the laser, but separate tests of the modulator and receiver circuits demonstrate the possibility of system operation at much higher speeds. These results support our assertion that WDM optical interconnects should be considered as a potential low-cost alternative to fiber links.

This work was supported by the Air Force Office of Scientific Research, Air Force Materiel Command, USAF, under Grant Number F49620-97-1-0517 (DARPA Ultra-Photonics), and by grant number MDA972-98-1-0002 from DARPA and a subaward from the University of New Mexico.

REFERENCE

[1] E. A. De Souza, M. C. Nuss, W. H. Knox, and D. A. B. Miller, *Optics Letters*, **20**, 1166 (1995).