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All-Optical Regenerative OTDM Add/Drop Multiplexing at 40 Gbit/s using Monolithic InP Mach-Zehnder Interferometer

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co-propagating SMZ switch is relatively flat up to very small offsets when the finite pulse widths become a factor. The TOAD geometry is effectively half co-propagating, half counter-propagating so its performance lies in the middle. The minimum detectable switching window sizes shown in Fig. 3(a) for the experimental configurations of the SMZ, TOAD, and CPMZ switches are 2.5, 3.5, and 8.3 ps, respectively. These minimum switching window widths agree closely with the values predicted by the theoretical model shown in Fig. 3(b).

Of the three geometries, the SMZ switch exhibits the best performance in terms of the minimum switching window width and output peak-to-peak amplitude. The TOAD has nearly comparable performance to the SMZ but is an inherently balanced interferometer unlike the two fiber-based Mach-Zehnder geometries. The control pulse energy requirements of all three devices are at least an order of magnitude less than the energy required by passive structures.

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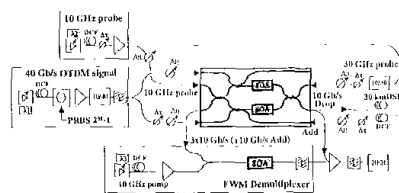
CWD3 (Invited) 8:30 am

All-optical regenerative OTDM add/drop multiplexing at 40 Gbit/s using monolithic InP Mach-Zehnder interferometer

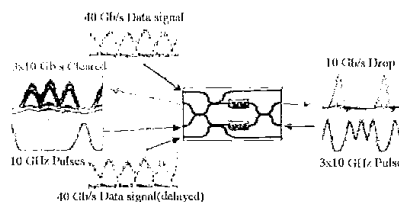
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Add-drop time multiplexing is a necessary function required in an optical time-division multiplexed (OTDM) network node.¹ Perfect clearing of the time slot which corresponds to the drop channel should be performed in order to avoid interferometric crosstalk. Simultaneous add-drop multiplexing using a Semiconductor Optical Amplifier (SOA) based Mach-Zehnder Interferometer (MZI) has been previously performed.² However the performance was limited by pattern effects after clearing and the compromise between either perfect clearing or dropping. We present a novel method which allows for simultaneous perfect dropping and clearing for 40 Gb/s OTDM signals using a monolithically integrated SOA-MZI. Further the proposed technique introduces regenerative capabilities at each add-drop node avoiding the cascading limitation of OTDM add-drop nodes.³

The principle of operation and experimental set-up is shown in Fig. 1. The SOA-MZI is



CWD3 Fig. 1. Principle of operation and experimental set-up.



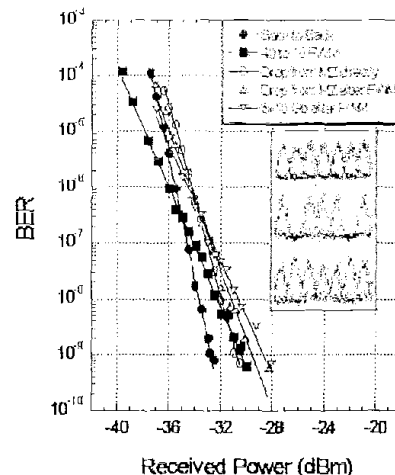
CWD3 Fig. 2. Drop and clear performance. Measured eye diagrams and probe pulses.

used as an ultra-fast modulator by injecting the 40 Gb/s RZ signal differentially into the two control arms of the interferometer which induces the necessary phase shift in the SOAs and gives high switching speed beyond the carrier dynamic limits of the SOAs.^{4,5} A 10-GHz probe stream which co-propagates with the data signals will see the modulation only from one of the OTDM channels and will constitute the drop channel. A 3×10 GHz probe stream launched counter-propagating with the data signal will perceive the modulation from the other three OTDM channels, and due to the high extinction ratio of the probe pulses no light will be present in the cleared time slot. Due to the sinusoidal transfer function of the SOA-MZI 2R regeneration is obtained both in the drop and cleared signal.

Gain switched (GS) DFB lasers are used as the 5 ps FWHM short pulse sources for both signal and control. The 40 Gb/s OTDM signal is generated by external modulation (PRBS = $2^{31} - 1$) and passive multiplexing from 10 to 40 Gb/s. The SOA-MZI is monolithically integrated fully packaged into a module.⁶

The excellent clearing of the drop time slot in the 3×10 Gb/s cleared signal can be observed in the histogram of the eye diagram, shown in Fig. 2. BER could be measured directly for the drop channel while for the 3×10 Gb/s and the 3×10 Gb/s + 10 Gb/s add channel a time demultiplexer based on four wave mixing in a SOA⁷ was utilized, see Fig. 1.

The BER performance can be observed in Fig. 3. A low penalty of 2 dB at BER of 10^{-9} was obtained for the drop channel. The FWM demultiplexer induced an extra 2 dB penalty and the different noise behavior of this demultiplexer can be observed in the slope of the BER measurements. The penalty observed in the 3×10 Gb/s cleared signal is also 2 dB. Further the drop channel was transmitted through 30 Km of dispersion shifted fiber and re-added into the empty time slot using a passive path through the device, see Fig. 1. No extra penalty for any channel after adding demonstrates the perfect clearing and dropping capability, also observed from the eye diagrams in the insert of Fig. 3.



CWD3 Fig. 3. BER measurements. Directly measured back-to-back and drop channel. After FWM in a SOA, BER performance of the 3×10 Gb/s remaining signal. BER curves for the 40 to 10 back-to-back demultiplexing and directly drop channel after FWM demultiplexing are included for comparison. Insert shows the eye diagrams of the original 40 Gb/s, cleared signal and 40 Gb/s signal after re-adding operation.

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CWD4 9:00 am

Smart optical cross-connect switch array with build-in monitoring functions

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Recently reconfigurable optical networks based on optical cross-connect (OXC) have gained considerable attention.¹⁻³ So far, only limited network control and management (NC&M) functions have been integrated into the switches.^{4,5} In this paper we present the design of a novel low-crosstalk optical switch matrix with build-in NC&M functions, via planar lightwave circuits (PLCs) technology using thermo-optic (TO) switches.

The design of our optical cross-connect is a strictly non-blocking matrix switch using dilated double-layer architecture which ensures that there is no first-order crosstalk.⁷ The gen-