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Turkiewicz, J.P.; Tangdiongga, E.; Rohde, H.; Schairer, W.; Lehmann, G.; Khoe, G.D.; de Waardt, H.

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MTs, while using the proposed protocol the data transmission as a whole would be kept uninterrupted regardless of the channel state of any single MT.

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Jindong Hou and D.C. O'Brien (Department of Engineering Science, University of Oxford, Oxford, OX1 3PJ, United Kingdom)
E-mail: jindong.hou@balliol.ox.ac.uk

Simultaneous high speed OTDM add-drop multiplexing using GT-UN1 switch


The authors describe the excellent capability of an all-optical gain-transparent ultrastable nonlinear interferometer (GT-UN1) in dropping, passing through, and adding optical time domain multiplexed (OTDM) channels. Error free operation without significant penalties of a complete OTDM add-drop node at 80 Gbit/s was achieved.

Introduction: The key functionality required in OTDM network nodes is add-drop multiplexing [1]. In an add-drop node a low bit rate single data channel will be separated (drop function) from an incoming high bit rate data stream. Simultaneously the remaining data channels should be left undisturbed (through function), and in the remaining vacant time slot a new channel can be added (add function). Recently, all-optical add-drop multiplexers operating at 40 Gbit/s based on cross phase modulation [2], a monolithic Mach-Zehnder interferometer [3], and an electroabsorption modulator [4] have been demonstrated. This Letter presents OTDM add-drop multiplexing in a GT-UN1 switch operating at 80 Gbit/s, to the best of our knowledge the highest bit rate in OTDM networking so far. Several OTDM demultiplexing experiments with the GT-UN1 switch have been reported e.g. [5], however complete add-drop multiplexing was not investigated. In our experiments we achieved error free operation without significant penalties of all add-drop node functionalities: drop, through, and add.

Experimental setup: Fig. 1 presents the experimental setup. A 8×10 Gbit/s OTDM data signal at 1.55 μm, enters the GT-UN1 switch by an optical circulator (circ1). The polarisation state at the input of a highly birefringent polarisation maintaining fibre (PMF), is set by a polarisation controller (PC1) such that the data pulses have equal components in the main axes of the PMF and after leaving the PMF they are separated in time by a delay τwf = 5 ps. Next, two sub-pulses are coupled via circ2 into a fold-back loop containing a 1.3 μm semiconductor optical amplifier (SOA). After passing the SOA, the sub-pulses are amplified by an erbium-doped fibre amplifier (EDFA) and are re-launched into the same highly birefringent PMF by circ2. Here, the polarisation states of the data sub-pulses are adjusted by the PC2 in such a way that the delay between two sub-pulses is reversed and a single pulse appears at the PMF end. There are two output ports, which are formed by a power splitter, polarisation controllers (PC3 and PC4), and polarisation filters (PF1 and PF2). In the absence of 1.31 μm control pulse both data sub-pulses experience the same condition in the loop. As a result, the recombined pulse leaves the GT-UN1 switch via the through port (PF1). For switching, a high intensity control pulse of 4 ps pulse width is inserted between the two data sub-pulses using a 1.5/1.3 μm multiplexer. A variable delay line controls the insertion timing. When a single control pulse is launched between data sub-pulses, the leading sub-pulse will preserve its original phase but the trailing sub-pulse will experience a nonlinear...
phase shift. The polarisation state of the switched recombined data pulse will therefore be rotated with respect to the polarisation state of the un-switched pulse. By this way, the data pulse will leave the drop port (PF2). In the case of the phase shift less than π rad, a fraction of drop pulses will appear in the through port, causing optical crosstalk for a channel eventually added in this time slot. A 10 Gbit/s add channel, controlled by another delay line, is inserted into the through port by a passive fibre combiner. The 10 Gbit/s drop channels can be directly evaluated using a bit error rate (BER) tester. The 7 x 10 Gbit/s remaining through channels and the inserted 10 Gbit/s Gbit/s add channel are first demultiplexed to 10 Gbit/s by a cascade of two electro-absorption modulators (10 ps gating time) and then evaluated by the 10 Gbit/s receiver and the BER tester.

**Results and discussion:** Fig. 2 presents eye diagrams of the outputs of the GT-UN1 switch. Fig. 2a shows the 80 Gbit/s data input stream, Fig. 2b a 10 Gbit/s drop channel, Fig. 2c seven remaining 10 Gbit/s channels in the through port. The perfect emptying of the drop time slot is visible. After dropping one channel we inserted a 10 Gbit/s data channel at the same wavelength in the empty time slot to form again the 80 Gbit/s data stream, Fig. 2d. All eye diagrams in Fig. 2 indicate clear open eyes and excellent operation of the GT-UN1 switch. For the BER measurements we used a pseudorandom bit sequence of length $2^7 - 1$. As a reference we measured an optimised 10 Gbit/s signal in a back-to-back configuration. Fig. 3a shows the BER measurements for eight drop channels and for seven remaining 10 Gbit/s through channels. The average sensitivity penalties at BER = $10^{-9}$ for the drop channels are 3.7 dB and for the through channels 2.7 dB. The difference between the worst and best channel in both cases is about 1.4 dB, proving proper operation of the GT-UN1 switch. The sensitivity penalty at BER = $10^{-9}$ for the drop channel is 4.0 dB and for the inserted add channel 3.6 dB. The sensitivity penalties are a combination of the reduction of optical-signal-to-noise ratio, polarisation misalignment, and in the case of the inserted add channel the interferometric crosstalk with the residual optical signal of the dropped channel. However these interferometric effects are so small, that they are barely observed in Fig. 2c and d and in the BER measurements.

**Conclusions:** We have demonstrated the excellent performance of an all-optical 80 Gbit/s OTDM add-drop node based on a GT-UN1 switch. We achieved error free operation for all add-drop functionalities. Insignificant penalties for all operations were observed. These remarkable results indicate the great potential of GT-UN1 switches for OTDM networking.

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**References**


**Transmission over 5.6 km large effective area and low-loss (1.7 dB/km) photonic crystal fibre**

B. Zsigri, C. Puechertet, M.D. Nielsen and P. Jeppesen

A 10 Gbit/s non-return-to-zero signal at 1550 nm over 5.6 km photonic crystal fibre (PCF) with 1.7 dB/km loss has been successfully transmitted, demonstrating the potential of PCF as transmission fibre.

**Introduction:** Photonic crystal fibres (PCF) are strong candidates to serve as basic building components for future optical communication systems. Their optical properties such as chromatic dispersion,