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A BIT-RATE FLEXIBLE AND POWER EFFICIENT ALL-OPTICAL DEMULTIPLEXER REALISED BY MONOLITHICALLY INTEGRATED MICHELSON INTERFEROMETER

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Abstract: A novel bit-rate flexible and very power efficient all-optical demultiplexer using differential optical control of a monolithically integrated Michelson interferometer with MQW SOA's is demonstrated at 40 to 10 Gbit/s. Gain switched DFB lasers provide ultra stable data and control signals.

Introduction: In future high capacity all-optical networks based on optical time division multiplexed (OTDM) and WDM systems, ultra high speed, compact and stable switching devices for, e.g., demultiplexing and add/drop multiplexing are required [1-2]. In the OTDM core network, strong candidates for practical switching devices are monolithically integrated interferometric structures using semiconductor optical amplifiers (SOA's) as optically controlled phase shifting elements. All-optical demultiplexing at 20 to 5 Gbit/s in a SOA Michelson interferometer (MI) [3] and 40 to 10 Gbit/s in a SOA Mach-Zehnder interferometer (MZI) [4], both realised in InGaAsP bulk material, have previously been demonstrated. The short, but fixed, switching window of the MZI demux is realised by displacing two SOA phase-shifters in the interferometer arms by a small off-set.

In this paper, we present for the first time a power efficient 1.55 μm MQW SOA-MI demultiplexer with variable switching window using differential optical control. It is capable of operating at different aggregate bit-rates and demultiplexing from 40 to 10 Gbit/s is demonstrated experimentally with data- and control signal powers of only -6 dBm and 1.5 dBm, respectively. Besides being inherently more power efficient than the MZI counterpart, the relatively simple SOA-MI structure is better suited for polarisation and wavelength independent operation, which is a key issue for practical use. Moreover, a simple and ultra stable 40 Gbit/s RZ OTDM signal source based on gain switched DFB lasers is demonstrated.

Principle of operation: The operation principle of the differential control scheme of the SOA-MI demultiplexer is shown in Fig.1. The incoming OTDM data channels are coupled to the output port

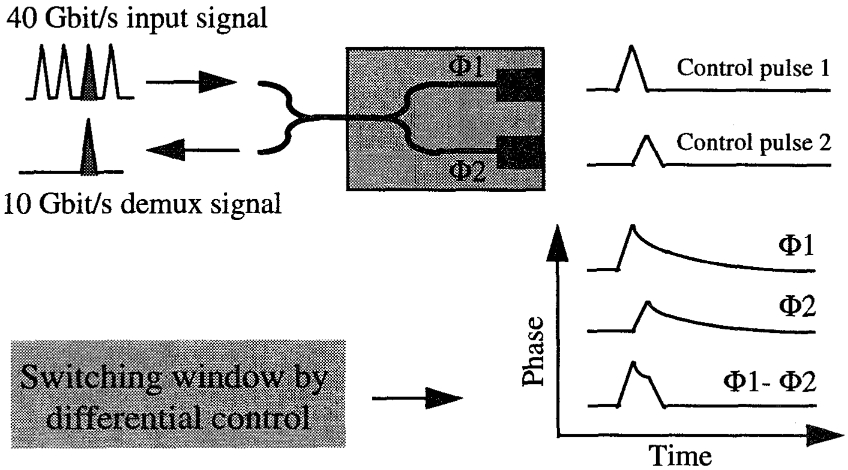

Fig. 1 *Operation principle of differentially controlled SOA-MI. Two control signals are used to eliminate the slow tails of the phase shift due to SOA gain recovery.*

depending on the phase condition of the interferometer. The phase condition is determined by the refractive index difference between the two SOA's which is controlled by gain saturation due to the injected optical control pulses. For a structure with only one amplifier, the switching speed would be limited by the SOA gain recovery mechanism as indicated by the slow tails shown in Fig. 1. For the present structure with two SOA's the demultiplexer switching window is, however, determined by the phase difference between the two amplifiers. The slow fall time can then be eliminated by injecting a control pulse to the second amplifier with proper time delay and amplitude. Using this differential control scheme, the width of the switching window is determined by the time delay between the control pulses and is only limited by the control pulse width. Hence, bit-rate flexible operation is obtained.

The direct fibre coupling access to the SOA's makes the SOA-MI inherently very power efficient. Furthermore, any power splitting asymmetry of the SOA-MI input coupler is not critical since the OTDM signal traverses the coupler twice. This feature also enables relatively easy implementation of polarisation and wavelength independent operation.

Experiments and results: The experimental set-up for 40 to 10 Gbit/s demultiplexing using differential control is shown in Fig. 2. The integrated SOA-MI, with a length of only 1.3 mm, is realised as an all-active tensile strained 1.55 μm MQW structure, and designed for high bit-rate operation with relatively high optical confinement factor and differential gain [5]. Control signals for the SOA-MI demultiplexer are derived from a 10 GHz gain switched MQW DFB LD followed by linear pulse compression in a dispersion compensating fibre (FWHM 12 ps) as shown in the figure. A variable attenuator and an optical delay line is used to control the SOA-MI switching window. For a coupled average control power to the two SOA's of only -0.5 and -2 dBm, respectively, a switching window with FWHM of 12.5 ps is generated. Note, that the switching window could be controlled

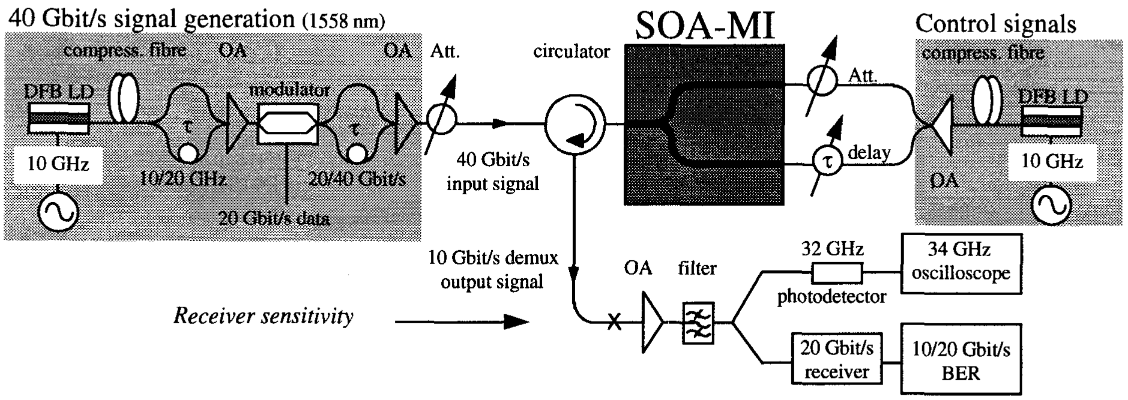

Fig. 2 *Experimental set-up for 40 to 10 Gbit/s demultiplexing using differential controlled integrated SOA-Michelson Interferometer.* OA: *Fibre amplifier.* LD: *Laser diode.* BER: *Bit error rate test-set*

electrically if two separate control sources are used. The 40 Gbit/s RZ signal is generated by gain switching of a second MQW DFB laser [6] at 10 GHz. The compressed pulses, with a FWHM pulse width of 8 ps and extinction ratio >20 dB, are passively multiplexed to 20 GHz, modulated at 20 Gbit/s, and finally passively multiplexed to 40 Gbit/s. An eye diagram of the high quality 40 Gbit/s signal is shown as an inset in Fig. 4.

By launching the 40 Gbit/s signal into the SOA-MI input port, the OTDM channels are effectively demultiplexed as shown in Fig. 3. The coupled signal input power is only -6 dBm (and not critical) and the extinction ratio of the demultiplexed signals is >20 dB. Selecting an arbitrary channel, error free all-optical 40-10 Gbit/s demultiplexing by the SOA-MI is achieved as shown with closed circles in Fig. 4. The receiver sensitivity of all four demultiplexed channels is within 1 dB. The BER performance is assessed with an optically preamplified 20 Gbit/s receiver for comparison with

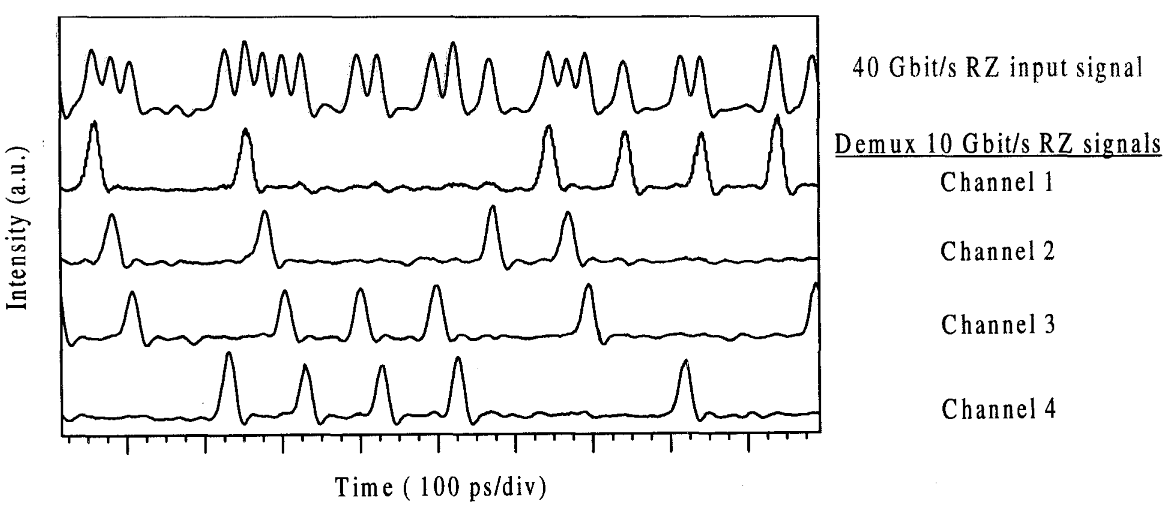

Fig. 3 *Bit patterns for demultiplexed 10 Gbit/s RZ channels 1-4. The 40 Gbit/s data stream is also shown.*

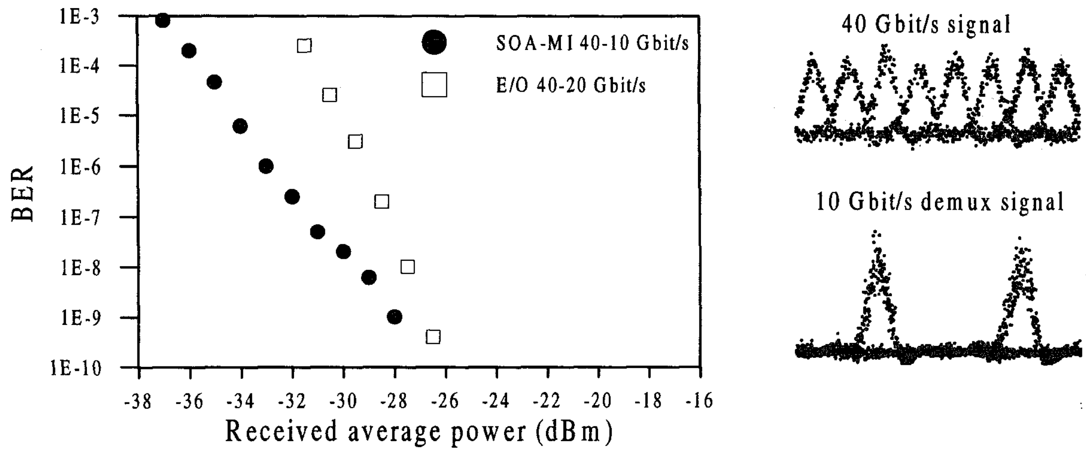

Fig. 4 *BER measurements of 40-10 Gbit/s SOA-MI demultiplexer with differential control. 40-20 Gbit/s demux by an electro-optic modulator is also shown.*

40-20 Gbit/s demultiplexing using an electro-optic modulator (open squares). By accounting for the 3 dB lower peak power of the 20 Gbit/s E/O demux signal compared to the same averaged power for the 10 Gbit/s signal, a penalty of approximately 1.5 dB is recorded for the SOA-MI demultiplexer. The small penalty and the different BER slope is attributed to the added noise from the SOA's. Finally, it is stressed that the simple SOA-MI has the potential for operating at bit-rates in excess of 100 Gbit/s and can be operated as an add/drop multiplexer as well.

Conclusion: An all-optical, bit-rate flexible and power efficient demultiplexer realised by a monolithically integrated MQW SOA Michelson interferometer with differential optical control is demonstrated for the first time. Error free 40 to 10 Gbit/s demultiplexing is achieved by a switching window of 12 ps limited only by the optical control pulse width. We believe that the flexible SOA-MI is a strong candidate for a practical high speed demux and add/drop element. In addition, we demonstrate a simple, high quality and ultra stable 40 Gbit/s RZ signal source employing a gain switched DFB laser.

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