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Up to 20 Gbit/s Bit-rate Transparent Integrated Interferometric Wavelength Converter

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Abstract: We present a compact and optimised multiquantum-well based, integrated all-active Michelson interferometer for 20 Gbit/s optical wavelength conversion. Bit-rate transparent operation is demonstrated with a conversion penalty well below 0.5 dB at bit-rates ranging from 622 Mbit/s to 20 Gbit/s.

Introduction: Among several techniques to accomplish wavelength conversion between wavelength channels within the EDFA window, monolithic integrated all-optical interferometric wavelength converters have recently demonstrated impressive performance [1]-[5]. Desirable and unique features such as efficient and wavelength independent operation, low and controllable chirp of the converted signal as well as regeneration capabilities have exposed interferometric converters as some of the most promising candidates for future network implementation. The integrated interferometric converters reported until now have been limited to bit-rates up to 10 Gbit/s [3]-[5] due to a relatively low optical confinement factor, low differential gain as well as low optical power levels inside the structures caused by increased losses from the integration. From the simpler but less effective cross-gain saturation scheme SOA wavelength converter 40 Gbit/s wavelength conversion has been demonstrated [6] by optimising these parameters indicating that also the interferometric converters should potentially be able to operate at high bit-rates.

Here, we demonstrate 20 Gbit/s wavelength conversion by an optimised 1.3 mm long integrated MQW all-active Michelson interferometer designed for high bit-rate operation. The new converter has been realised with a relatively high confinement factor and differential gain and operates at a moderate optical input power level of 6 dBm. Bit-rate transparency is confirmed by BER measurements with conversion penalties well below 0.5 dB from 622 Mbit/s to 20 Gbit/s. Furthermore, a high signal-to-ASE ratio of 25 dB (in 1 nm bandwidth) for the converted signal indicates the potentially fine cascadability properties of the device.

Device Technology: The monolithic integrated Michelson interferometer chip is realised using all-active multiquantum-well (MQW) based layer structures that allow for a very simplified and compact device realisation. Importantly, the optimised MQW stack layer results in a high differential gain and a high confinement factor that are both necessary for high-speed operation [3]. The same technology has very recently been used for realisation of 3-port Mach-Zehnder type interferometric wavelength converters with excellent performance [4]. The all-active device structure is completely grown by LP MOVPE techniques with the vertical layer stack containing a 10 well tensile strained InGaAs/InGaAsP waveguide core. The 3-section device has a length of only 1.3 mm (see Fig. 1). It consists of an active 3 dB coupler with anti-reflection coated input port and two linear amplifier sections (length: 600 µm). For lateral confinement a buried ridge stripe structure has been applied.

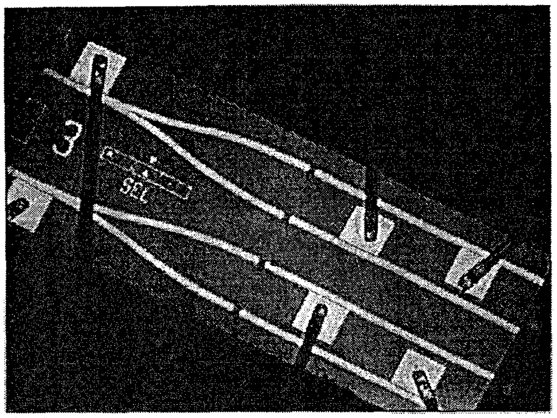

Fig. 1: Perspective view of the realised bit-rate transparent MQW based Michelson interferometers. Two converters are here mounted and bonded on one submount.

Experiments: The set-up for assessing the BER performance of the MI converter at 20 Gbit/s uses electrical multiplexing and demultiplexing between 10 and 20 Gbit/s at the transmitter and receiver, respectively (see Fig. 2). The signal to be converted is generated by externally modulating a laser (emitting at 1565 nm) at 20 Gbit/s by a $LiNbO_3$ modulator. The signal is coupled directly to the highly reflective input port (left facet in Fig. 2) of one of the interferometer arms thereby introducing a phase difference between the two interferometer branches according to the digital information of the input signal.

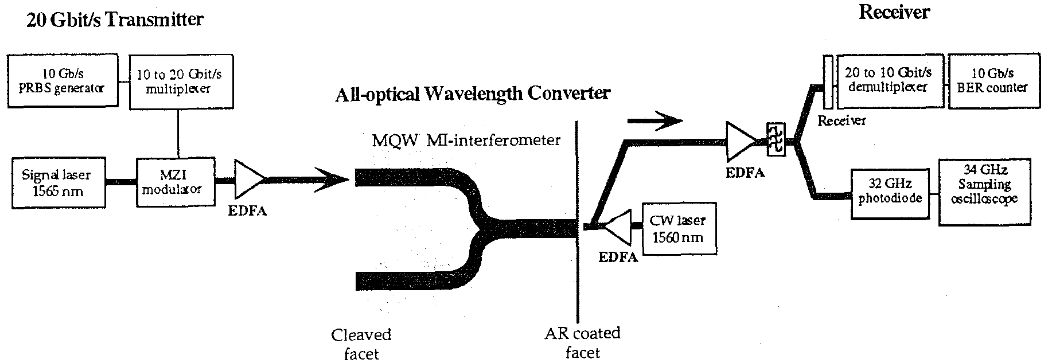

Fig. 2: Experimental set-up for assessing the BER performance at 20 Gbit/s for the integrated MQW Michelson interferometer wavelength converter.

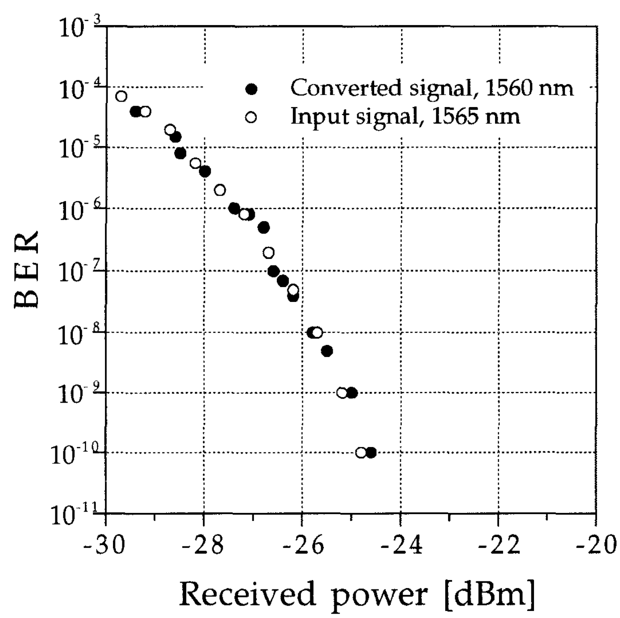

Fig. 3: Bit-error rate (BER) performance at 20 Gbit/s for the input and converted signal using the new integrated Michelson interferometer wavelength converter. Input wavelength/power: 1565 nm/6 dBm, converted signal wavelength: 1560 nm. CW input power: 9 dBm.

Wavelength conversion is obtained as CW-light at the desired output wavelength of 1560 nm is coupled to the AR coated input port of the active coupler section (right facet in Fig. 2) and experiences the modulation of the MI transfer function. At the output the wavelength converted signal is selected by a 1.3 nm filter before error-counting and monitoring.

Figure 3 gives the recorded bit-error rate, BER, performance at 20 Gbit/s for the wavelength converter. Negligible wavelength conversion penalty is obtained using a moderate input power of 6 dBm (in the fiber) demonstrating remarkably effective wavelength conversion at this high bit-rate.

Additionally, the converted signal exhibits a high extinction ratio of ~13 dB as well as a high optical signal-to-ASE ratio of 25 dB (in 1 nm bandwidth) implying that several of these converters can be cascaded. Clearly, this is essential in future optical networks or large switching fabrics.

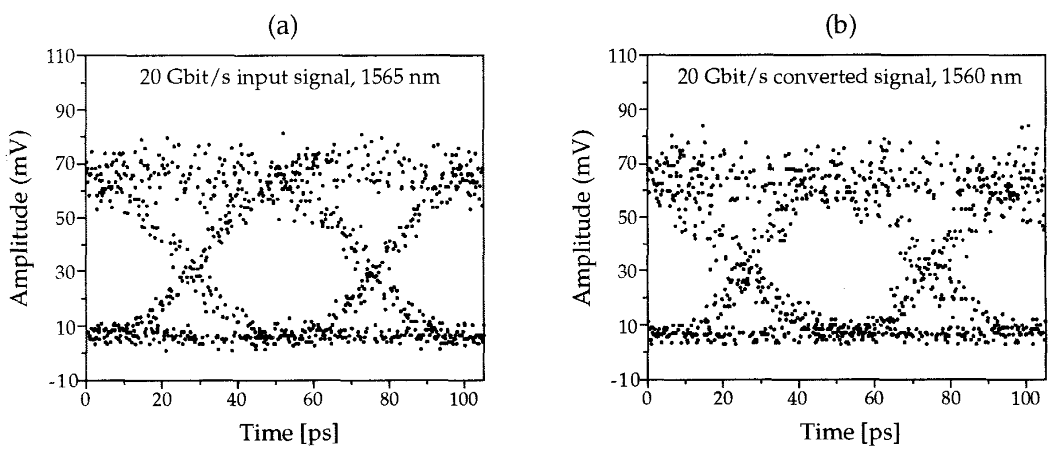

Fig. 4: Eye-diagrams for input (a) and converted (b) signal at 20 Gbit/s

The excellent high speed dynamics are also clear from the converter input and output eye diagrams shown in Fig. 4: The rising and falling edges of the 20 Gbit/s converted signal 4.b easily follows those of the input signal 4.a.

With the introduction of wavelength converters into optical networks the converter is expected to handle existing as well as future services. This implies that signals carrying variable bit-rate information must be accommodated by the same converter. In Fig. 5 the conversion penalty for the new converter is shown versus the signal bit-rate clearly demonstrating that bit-rate transparent operation from 20 Gbit/s down to 622 Mbit/s is feasible .

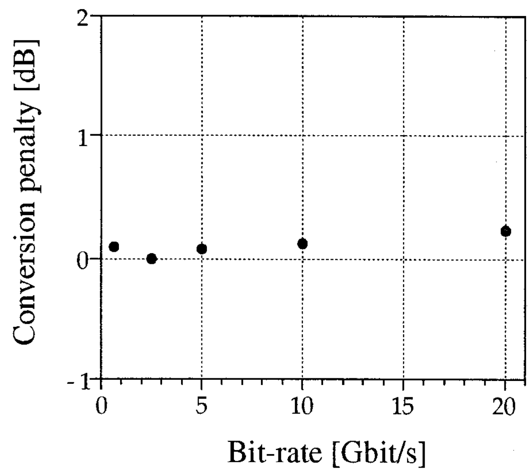

Fig. 5: Penalty for wavelength conversion versus signal bit-rate.

Summary: Wavelength conversion with negligible conversion penalty has been demonstrated by an optimised, compact all-active MQW interferometer at a record bit-rate of 20 Gbit/s. The newly developed converter show bit-rate transparent operation from 622 Mbit/s to 20 Gbit/s with conversion penalties well below 0.5 dB. It should be emphasised that the required signal power is moderate (6 dBm in the fiber) and that the converted signal is of high quality with ~13 dB extinction ratio and 25 dB signal-to-ASE ratio (in 1 nm).

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