In conclusion, in this Letter a new learning algorithm for pattern classification has been developed. The authors have shown that the performances of the proposed approach are better than those obtained using well known pattern classification techniques. It is worth noting that the choice of the neural model has been motivated by the fact that, differently from other neural architectures, CNNs make feasible the implementation of VLSI devices for real-time vision [6]. Therefore, this Letter introduces the possibility of implementing neural devices for efficient pattern classification.

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Compact 40 Gbit/s demultiplexing receiver based on integrated tandem electroabsorption modulators

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A compact 40Gbit/s demultiplexing receiver based on integrated tandem electroabsorption modulators is described. Error-free operation and a receiver sensitivity of –27dBm are achieved, while the feasibility of this device as an 80Gbit/s demultiplexing receiver is reported.

Introduction: High-speed demultiplexing is one of the key features in high bit rate time-division-multiplexed transmission systems. Demultiplexing based on high-speed integrated circuit technology has been demonstrated at 60Gbit/s [1]; however, it has been limited to 40Gbit/s in fibre transmission experiments [2, 3]. Conversely, optical demultiplexing using a sinusoidally-driven electroabsorption (EA) modulator has emerged as an alternative approach to electrical demultiplexing [4], with demonstrations at 80Gbit/s [5] and 160Gbit/s [6]. The major drawback with this technique is the high insertion (coupling) losses in EA modulators, which requires the demultiplexed optical channel to be externally amplified before detection using a receiver. There are two consequences to this: (i) each channel to be demultiplexed requires an optical amplifier and a receiver, which increases the cost and the complexity of the receiver node, and (ii) environmentally induced timing asynchronisation between the demultiplexer and the clock-recovery unit can lead to possible signal-to-noise ratio (SNR) deterioration. Therefore, it is desirable to integrate the demultiplexer and the photodetector, which not only allows for a compact receiver, but also provides efficient coupling without the need for additional optical components.

In this Letter, we demonstrate a compact 40Gbit/s demultiplexing receiver based on integrated tandem EA modulators. The feasibility of this device for 80 to 20Gbit/s demultiplexing and photodetection is also presented.

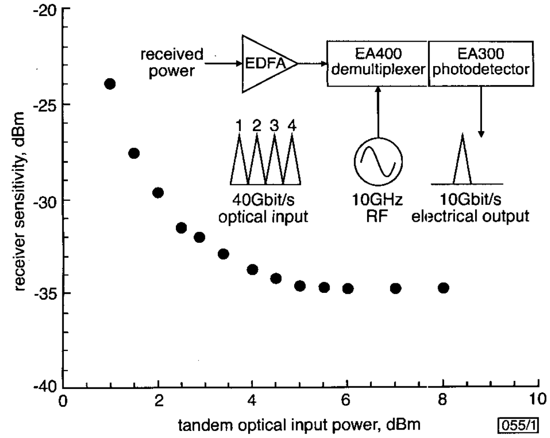

Fig. 1 *Single-channel 10Gbit/s performance of demultiplexing receiver for BER of 10^{-9} as function of optical input power*

Inset: Schematic diagram of device operation (EA – electroabsorption modulator)

Device characteristics: The tandem EA modulators (300 and 400μm long) are based on a travelling-wave electrode structure with ten periods of strain-compensated InGaAsP quantum wells fabricated by metal-organic chemical vapour deposition (MOCVD) on semi-insulating InP substrate [7]. The 400μm-long device (the optical demultiplexer) achieved a maximum extinction of 38dB at –6V while the 300μm-long device was used as a reverse biased photodetector with a responsivity of 0.5A/W. The two modulators were separated by a 20μm-long optical waveguide defined by H^+ ion implantation, which also extended 50μm into each modulator to reduce capacitance and microwave crosstalk. The measured impedance and the microwave crosstalk were 50kΩ and < –30dB, respectively, while the optical insertion loss of the ion-implanted region was estimated to be 2.3dB. Both modulators were terminated in thin-film resistors and dielectric capacitors, which reduced heating effects and allowed for long-term operation of the tandem without any external temperature cooling. The 400μm-long device had a modulation bandwidth of 16GHz while the 300μm device had a photodetection bandwidth of 18GHz, which is suitable for 20Gbit/s detection applications.

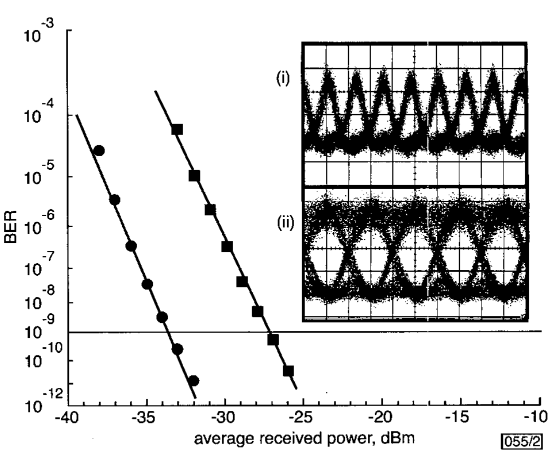

Fig. 2 *BER curves*

9.2dBm optical input power to tandem device
● 10Gbit/s single channel
□ 40Gbit/s data stream
Inset: (i) 40Gbit/s optical input (20ps/div)
(ii) 10Gbit/s demultiplexed and received channel (50ps/div)

Results: The operation of the tandem EA modulators as a demultiplexing receiver is shown as an inset to Fig. 1. The 40Gbit/s optical time-division multiplexed (OTDM) data stream was realised by passively multiplexing with 1m-long fibre delay lines of 10Gbit/s data-encoded ($2^7 - 1$ pattern length) 8ps pulses, which were generated by a harmonically driven EA modulator at 1555nm. The 40Gbit/s data stream was then optically preamplified before it was coupled into the tandem receiver. The 400μm EA modulator was reverse biased at –4.8V and driven by a $6V_{pp}$ 10GHz RF signal to generate a 14ps switching window, which was synchronised to the desired optical channel by an electrical delay line. The demultiplexed optical channel was then detected by the 300μm device biased at –8V.

Single-channel 10Gbit/s bit error rate (BER) measurements were performed in order to determine the photodetection performance of the tandem device. Fig. 1 shows the average received power (at the input of the optical preamplifier) required for a BER of 10^{-9} as a function of the optical input power into the tandem. Degradation in receiver sensitivity is observed for low input powers owing to the low SNR at the photodetector while no power penalty is acquired at high input powers. It is important to mention that a 2dB optical power penalty was observed for a pattern length of $2^{31} - 1$, which was determined to be due to electrical reflections from the RF termination of the 300μm photodetector device. Fig. 2 shows the BER measurements at 10 and 40Gbit/s. Error-free operation was achieved for 40Gbit/s operation with a receiver sensitivity of –27dBm. The insets to Fig. 2 show the 40Gbit/s optical input data stream and the received 10Gbit/s channel.

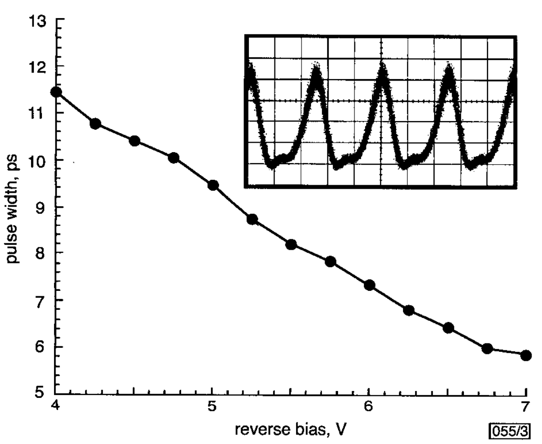

Fig. 3 *Pulse width as function of reverse bias at 20GHz modulation for 400μm EA modulator*

Inset: Oscilloscope trace of pulses measured using 40GHz photodetector (20ps/div)

To investigate the possibility for 80Gbit/s operation, the 400μm demultiplexing modulator was driven with a $6.4V_{pp}$ 20GHz RF signal and a CW input at 1555nm. The output pulses were then measured on a second harmonic generation autocorrelator and deconvolved assuming a Gaussian pulse shape as inferred from the optical spectrum measurements. Fig. 3 shows the pulse widths (FWHM) obtained as a function of reverse bias while the dynamic extinction ratio was estimated to be > 20dB. Pulse widths as short as 6ps were achieved, which indicates that penalty-free demultiplexing of 80Gbit/s data stream is possible [5, 8].

Summary: We have successfully demonstrated error-free 40Gbit/s operation of a compact demultiplexing receiver based on integrated tandem EA modulators. Our results indicate that these devices can be used as efficient receivers at bit rates up to 80Gbit/s.

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Demonstration of high robustness to SNR impairment in 20Gbit/s long-haul transmission using 1.5μm saturable absorber

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Improved robustness to signal-to-noise ratio impairment is shown for the first time at 20Gbit/s in an RZ transmission loop using a 1.5μm heavy-ion-irradiated quantum well saturable absorber. Error-free transmission is achieved over 7800km.

Introduction: Passive optical regeneration using saturable absorbers can contribute to increased bit-rate or error free distance in signal-to-noise ratio (SNR)-limited transmission systems [1, 2]. We recently showed the efficiency of a multi-quantum well (MQW) saturable absorber (SA) in a 10Gbit/s RZ long-haul transmission [3]. In this Letter we report the ability of such an ultra-fast passive device to reduce amplified spontaneous emission (ASE) accumulation at 20Gbit/s in a 1.55μm loop experiment, yielding both increased transmission distances and improved system robustness.

Saturable absorber characteristics: The vertical cavity structure of the MQW semiconductor saturable absorber is that detailed in [3]. The device is used in reflection mode and is polarisation-insensitive thanks to the normal incidence of the input light-wave. Under low repetition rate of short pulses, it was shown to exhibit an on/off contrast ratio of 10:0 and a reflectivity of 40% with a saturation energy < 2pJ. Irradiated by 11MeV Ni^+ ions, with an irradiation dose of $1 \times 10^{11} cm^{-2}$, it yields a response time of 10ps [4 – 6].

The discrimination properties of the SA have been analysed at higher frequency using purposely degraded 20GHz RZ signals