that the PSBT spectrum is already narrow enough that linear crosstalk is negligible for this channel spacing. With adjacent channels in parallel instead of perpendicular polarisation, the BER results are degraded by two decades, whether the interleaver is placed at the transmitting or receiving end. This degradation is mainly due to increased nonlinear effects; since the original BER values are recovered when the two adjacent channels are removed, we attribute it to cross-phase modulation.

Further improvements can be considered, taking advantage of the characteristics of the PSBT: for example, the narrow spectrum should allow implementation of 7% FEC with low crosstalk penalty. Also, a longer distance can be spanned if a large OSNR can be maintained. Finally, the performance could be improved by using enhanced-PSBT, which exhibits better resistance to noise [6].

Conclusion: We have demonstrated 50 GHz-spaced 80 × 40 Gbit/s WDM transmission over a 3 × 100 km amplified link of TeraLight™ fibre. The PSBT format is used at its full advantage of large tolerance against chromatic dispersion and narrow bandwidth. Thus, a capacity of 3.2 Tbit/s is achieved over the C-band only, with a spectral efficiency of 0.8 bit/s/Hz. To date, this is, to our knowledge, the largest capacity transmitted over the C-band without polarisation demultiplexing.

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40 GHz optical pulse generation using sinusoidally-driven travelling-wave electroabsorption modulator

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Optical pulse generation at a 40 GHz repetition rate using a sinusoidally-driven high-modulation-efficiency travelling-wave electroabsorption modulator is reported. Travelling-wave behaviour is demonstrated by comparing the pulse generation in the co- and counter-propagation configurations and confirmed by a theoretical model.

Introduction: As the bit rate per channel increases in modern optical communication systems, simple and stable optical pulse sources are needed because the RZ format is preferred at high bit rates [1]. Electroabsorption modulators (EAM) have been used to generate optical pulses with a simple sinusoidal drive [2–6] and have the advantages of low-chirp, low-jitter and high-speed when compared with gain-switched or modelocked lasers. Other network functions like simultaneous OTDM demultiplexing and detection [7] were also demonstrated with EAMs, indicating the versatility of this device. As the development of high-speed electronics advances, future 160 Gbit/s or higher optical time division multiplexing (OTDM) systems are expected to be constructed on a 40 GHz base rate. Therefore, EAMs operated at 40 GHz for both pulse generation and optical demultiplexing are needed for these systems. Previously we have reported 40 GHz operation using either dual-drive [5] or tandem [6] configurations. In this Letter, a simpler scheme is employed by using a single travelling-wave EAM (TWEAM) with one sinusoidal drive to generate optical pulses as short as 4 ps at 40 GHz. A theoretical model is also used to support the travelling-wave operation.

Device fabrication: InGaAsP material grown by MOCVD is used to fabricate 330 μm long ridge-waveguide TWEAM devices. The active region consists of 10 tensile-strain wells and 11 compressive-strain barriers, modified from [8]. Cladding layers of *p*-InP (top) and *n*-InP (bottom) are grown and sandwich the active region. After reactive-ion-etching (RIE), PMGI is utilised for passivating the etching surface of the ridge waveguide. The schematic diagram of the device is shown in the inset of Fig. 1. Two CPW lines forming the travelling-wave circuit are used as the microwave feed and load lines. The optical input and output ports are on the other two cleaved and AR coated facets. Fig. 1 shows the CW TE and TM mode fibre to fibre transmission loss measurement at 1555 nm. A high modulation efficiency of ~20 dB/V for the TM mode in the 0 V to 2 V reverse bias region and a total modulation depth of 47 dB were achieved.

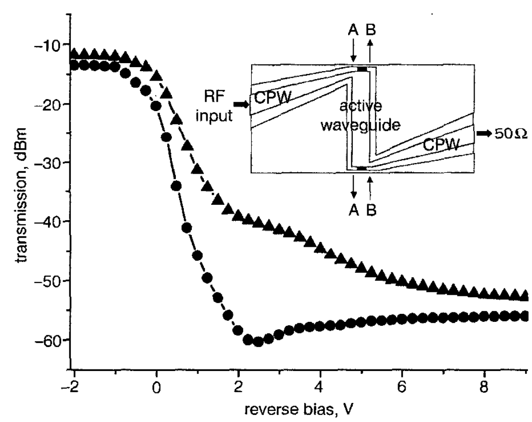

Fig. 1 *Fibre-to-fibre transmission against reverse bias*
Inset: Schematic diagram of TWEAM
● TM mode
▲ TE mode
A: co-direction configuration
B: counter-direction configuration

Experiment and modelling: For travelling-wave optical pulse generation, the TWEAM is terminated with a 50 Ω load and driven by a sinusoidal 5.6 Vpp microwave signal. A 2 dBm 1555 nm CW optical signal is sent into the optical input port. As shown by the inset of Fig. 1, there are two configurations: (A) the optical wave propagates in the same direction as the microwave, which is termed as co-direction configuration, (B) the optical wave propagates in the direction opposite to the microwave, which is termed as counter-direction configuration. The results for TM mode are shown in Fig. 2*a*. The output power is measured after the TWEAM without amplification. It is obvious that the results for these two configurations are different, as expected for travelling-wave modulators and not expected for lump-type modulators. The co-direction configuration gives about 4 dB higher output power than the counter-direction configuration. It also generates the shortest pulse, which is about 4 ps for the current setup. The difference in power can be explained by the fact that in the co-direction configuration the peak of the optical wave propagates with the peak of the microwave, which reduces the absorption in the QW by reducing the reverse bias locally. The velocity mismatch between optical and microwaves is not profound for the current device length.

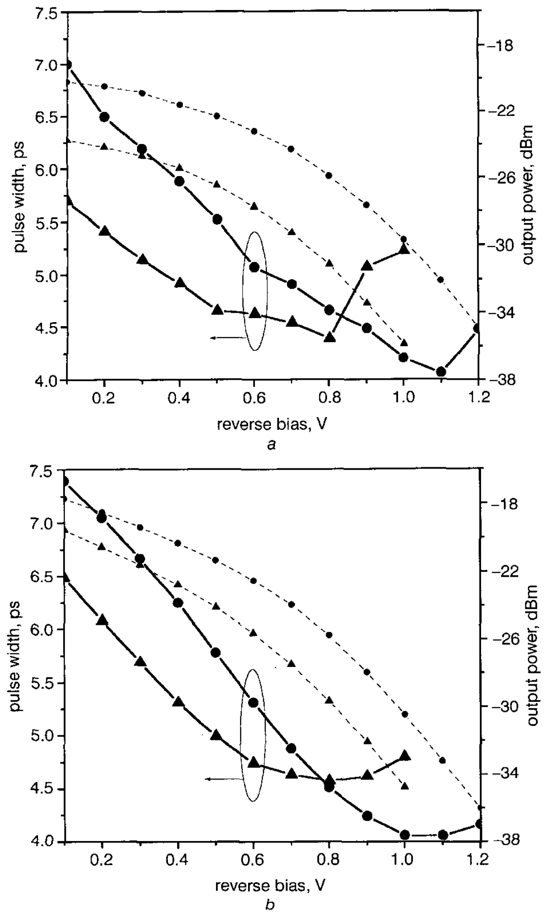

Fig. 2 *Pulse width and output power of pulse against reverse bias*
a experimental
b theoretical
● co-direction
▲ counter-direction

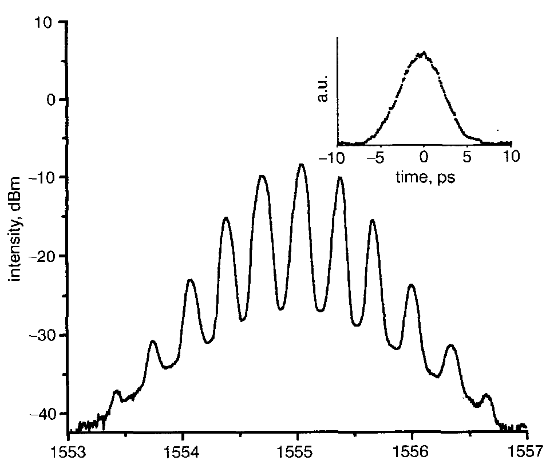

Fig. 3 *Spectrum of generated 40 GHz pulse train at 1 V reverse bias*
Inset: Autocorrelation trace of generated pulse

To further investigate the travelling-wave behaviour a theoretical model [9] based on transmission line theory has been developed, taking into account the temporal and spatial microwave and optical wave interaction via the transmission curve in Fig. 1. The only adjustable parameter in this model is the microwave coupling loss. The theoretical results are shown in Fig. 2*b* The close agreement between the theoretical and experimental results supports the travelling-wave operation of the device.

The spectrum and the autocorrelation trace for the co-direction configuration at 1 V reverse bias are shown in Fig. 3. The extinction ratio of these pulses cannot be fully determined from the autocorrelation trace because of the limited intensity resolution of the autocorrelator. However, from the theoretical model, the extinction ratios of the pulses are larger than 30 dB for the co-direction configuration and 3–4 dB smaller for the counter-direction configuration. The chirping property is estimated by measuring the time-bandwidth product. The value varies from 0.49 to 0.44 depending on the bias voltage, which indicates the low-chirp feature of the EAM-generated pulse.

Conclusion: A single sinusoidally-driven travelling-wave electro-absorption modulator is used to generate optical pulses at a 40 GHz repetition rate. 4 ps almost transform-limited optical pulses are generated with extinction ratios estimated to be larger than 30 dB. The experimental co-direction and counter-direction results presented in this work support the theoretical travelling-wave model of operation. Shorter pulses with higher extinction ratios can be expected if the microwave coupling loss can be reduced. This device is also a viable technology for optically demultiplexing OTDM data streams up to 160 Gbit/s.

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