optical SNR obtained was 14.8dB/0.1nm. Fig. 3 shows the Q-factors of 100WDM signals. The obtained average Q-factor was 14.3dB without FEC. This value is almost sufficient for practical undersea cable applications [6]. The flat performance was achieved for almost all the channels owing to the dispersion-flattened fibre spans. The Q-factor degrades for a few channels at both edges of the signal bandwidth. We found that this is because of poor optical SNR due to insufficient optimisation of the additional gain equaliser in this demonstration, and therefore is not an essential problem in practical applications. Therefore, the worst Q-factor can be much improved with some more refinement of the experimental setup.

The effectiveness of these key technologies has been confirmed through this demonstration. Fig. 4 shows the average Q-factor of five typical channels as a function of transmission distance. The obtained average Q-factor was 12.8dB without FEC after 10,050km transmission. The Q-factor was linearly reduced with distance. We did not observe any excess performance degradation except for SNR degradation due to distance expansion. From these results, we concluded that the transmission line used in this experiment is robust enough against fibre nonlinearity and suitable for transpacific undersea cable system applications.

Conclusion: We have conducted 1Tbit/s (100 × 10.7Gbit/s) DWDM transmission experiment over 7,750km using 30nm-wide single-stage 980nm-pumped C-band optical repeaters. The obtained average Q factor was 14.3dB without using FEC. No significant degradation due to nonlinear effects was observed when the distance was increased up to 10,050km. We have thus confirmed the feasibility of our transpacific terabit transmission system.

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All-optical modulation and time-division-multiplexing of 100Gbit/s signal using quasi-phasematched mixing in $LiNbO_3$ waveguides

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All-optical modulation and time-division multiplexing is experimentally demonstrated using quasi-phasematched mixing in an $LiNbO_3$ waveguide. A 100GHz, 1.543μm clock is modulated by two channels of 10Gbit/s signals to generate 1.559μm subchannels in a 100Gbit/s signal.

Introduction: Ultrahigh-speed modulation of optical pulses is one of the important technologies for optical time-division-multiplexed (OTDM) transmission over 100Gbit/s [1]. We have proposed all-optical modulation using four-wave mixing (FWM) in a semiconductor optical amplifier (SOA) and confirmed error-free operation at 100Gbit/s [2]. In this experiment, the signal-to-noise ratio (SNR) of the output FWM pulse was limited by the low conversion efficiency of the FWM process in an SOA and the accumulation of the amplified spontaneous emission (ASE) noise. Quasi-phasematched mixing in periodically poled $LiNbO_3$ (PPLN) waveguides are attracting interest because they have high conversion efficiency [3] with negligible additive noise. This Letter presents successful experimental results for all-optical modulation using a PPLN device. A 100GHz optical clock was all-optically modulated by two 10Gbit/s signals to produce a TDM signal with a 10ps time interval as a wavelength-converted component.

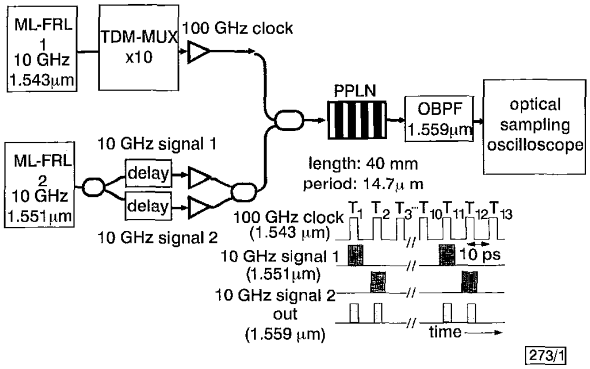

Fig. 1 *Schematic configuration of all-optical modulation and time domain multiplexing using quasi-phasematched mixing in PPLN waveguide device*

Experimental: Fig. 1 shows the experimental setup. A 4.2ps, 100GHz (1.543μm wavelength) optical pulse train was generated by a modelocked fibre ring laser (ML-FRL) followed by a planar-lightwave circuit (PLC)-TDM multiplexer. The two 10GHz signal pulses (all-mark) were generated by a 3.3ps, 1.551μm wavelength ML-FRL and an optical coupler. Time delay was added to each signal and the two signals were recombined by another optical coupler. The 100GHz clock and the two signals were then coupled and introduced into the PPLN device. The schematic structure of the PPLN device is also shown in Fig. 1. The PPLN device used in this experiment was a 40mm long waveguide with domain inversion period of 14.7μm. In this device, a cascaded nonlinear process generated the 1.559μm modulated component. First, the second harmonic of the 1.551μm pulse was generated, then the generated 0.750μm pulse and the 1.543μm, 100GHz pulse produced the 1.559μm frequency difference component between the 10GHz signal and 100GHz clock, through difference frequency generation. In the experiment, the temperature of the device was set to 98° C to avoid photorefractive effects. Fig. 2 shows the input and output optical spectra of the PPLN device. The average output power of the 100GHz clock, the 10GHz input signal and the modulated output signal were 5.1, 6.7 and –16.1dBm, respectively. The fibre-to-fibre insertion loss of this pigtailed device was low (3.2dB), thus high conversion efficiency is expected. The conversion efficiency from the 1.543μm component (100GHz clock) to the 1.559μm component for one channel was –12.1dB, where we considered that one of the ten pulses of the 100GHz clock overlapped the 10GHz signal. Fig. 3 shows the measured optical waveforms with a < 1ps resolution optical sampling oscilloscope (Anritsu-SA014B): (*a*) input 10GHz signal, (*b*) input 100GHz clock, and (*c*) output signal. In Fig. 3*c*, waveforms of the two 10GHz sub channels with relative time delays of 10, 20 and 40ps are shown. As seen in the Figure, no pulse distortion was observed in the optical parametric process and all-optical modulation and time domain multiplexing was realised with high SNR.

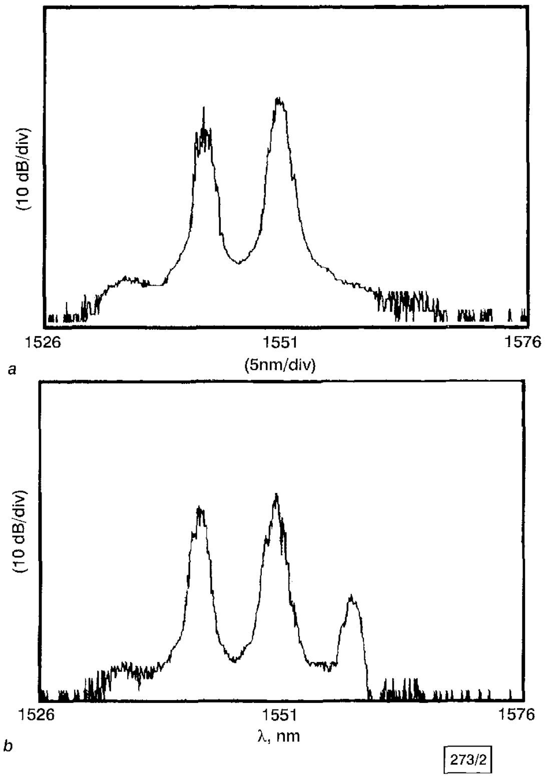

Fig. 2 *Optical spectra of PPLN device*

a Input
b Output
$\lambda 1 = 1.543100 \mu m$, $l1 = -27.50$
$\lambda 2 = 1.551600 \mu m$, $l2 = -40.39$
$L1 = 1.50 dBm$, $L2 = -7.30$
Resolution: 0.1nm

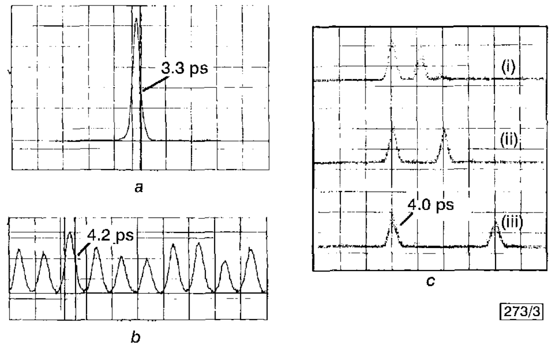

Fig. 3 *Measured waveforms*

a 10GHz signal (pulsewidth: 3.3ps)
b 100GHz clock (pulsewidth: 4.2ps)
c Output (pulsewidth: 4.0ps)
(i) $\Delta\tau = 10 ps$
(ii) $\Delta\tau = 20 ps$
(iii) $\Delta\tau = 40 ps$

Discussion: In the experiment, we used one PPLN device to confirm its basic operation. In all-optical time-domain multiplexing for all subchannels, it is necessary to cascade this process with several devices to avoid signal interference at the input of the device; this device has advantages in cascading because of its low insertion loss (3dB) and excess-noise-free nature. The wide wavelength tuning range of the device (~60nm) is another advantage because we can tune the output wavelength. The conversion efficiency, which depends quadratically on the input signal power, would approach 0dB with an increase of 6dB in the input power. A further increase is possible with improved waveguide designs. This configuration has the potential to realise a compact all-optical time-division multiplexer over 100Gbit/s.

Conclusion: An all-optical signal modulator and a time-division multiplexer have been constructed using quasi-phasematching in a PPLN device. A 100GHz clock was modulated and multiplexed in the time domain by two channels of a 10GHz signal to form subchannels of a 100Gbit/s signal.

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Broadband optical fibre amplification over 17.7THz range

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A lumped optical fibre amplifier exploiting the full spectrum of optical fibres and delivering a record bandwidth of 17.7THz (between λ = 1297nm and λ = 1605nm) has been achieved using a combination of erbium-doped, thulium-doped and Raman fibres.

Link fibre transmission spectrum: A requirement exists for total capacities exceeding 10Tbit/s per fibre for wavelength-division-multiplexed (WDM) point-to-point links of optical networks. It would be possible to cope with such large capacities by burying additional fibres into the ground, but this would be very expensive. To be cost-effective, it is necessary to take advantage of the usable transmission spectrum of existing fibre installations. The limits of the transmitted spectrum are bound by the guiding properties of the optical fibre. For most current embedded link fibres, signals having a wavelength up to λ = 1620nm (to avoid possible bending loss in the cables after deployment on the field) and ensuring a singlemode propagation (λ > 1250nm) can be transmitted, except in the part of the spectrum (1360–1420nm) lost due to