observed at all. The experiments also confirm that very high quality periodic gratings can be achieved for small grating periods.

Future work will investigate the possibility of extending the good results down to periods appropriate for doubling the 946nm Nd:YAG line, and to see whether the high quality can be maintained when working with thicker samples, and hence higher voltages.

Acknowledgements: J. Weibom received support from the Swedish Institute and V. Pruneri from Politecnico di Milano. We would like to thank C. Bollig for the use of his singlemode Q-switched Nd:YAG laser, and D. Murphy and his colleagues at the Microelectronics department for their help in making high-quality photolithographic masks.

References

Generation of transform-limited optical pulses at 10GHz using an electroabsorption modulator and a chirped fibre Bragg grating

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Indexing terms: High-speed optical techniques, Electroabsorption modulators, Gratings in fibres

Transform-limited pulses of 5.8ps have been generated at 10GHz using an electroabsorption modulator in conjunction with a dispersive transmission filter based on a chirped fibre Bragg grating. This method is compact, controllable and incorporates minimal fibre losses.

Electroabsorption (EA) modulators have been shown to be capable of generating short optical pulses at frequencies of 10-30GHz [1]. Recently the generation of 6.3ps pulses at 10GHz has been demonstrated using an electroabsorption modulator followed by dispersion compensating fibre [2]. A duty ratio as low as 6.3% was achieved by this technique allowing the realisation of optical time division multiplexing (OTDM) at data rates of up to 40GHz. A 400m length of dispersion compensating fibre (having a high negative (normal) dispersion coefficient at 1550nm) was incorporated in that scheme in order to correct for the residual chirp imparted to the pulses by the modulator and so compress the pulses to the bandwidth limit. The use of such a long length of fibre in a pulse source may, however, introduce a degree of unwanted phase and polarization drift in the output pulse train if the temperature and birefringence of the fibre are not actively stabilised. Alternatively, chirped fibre Bragg gratings have been proposed [3] and demonstrated [4] as dispersive filters capable of correcting for the chirp present on non-bandwidth-limited pulses. In this Letter we report the generation of high quality pulses as short as 5.8ps at a repetition rate of 10GHz from an electroabsorption modulator used in conjunction with a compact, low insertion loss dispersion compensator incorporating a tunable dispersion chirped fibre grating.

The experimental setup used is shown in Fig. 1. Approximately 1mW from a DFB laser diode at 1.5625µm was coupled into an InGaAsP/InGaAsP MQW electroabsorption modulator similar to that described in [2]. This was driven electrically with a DC reverse bias of up to 9V and a sinusoidal RF modulation at 10GHz with an estimated maximum peak-to-peak voltage of 8V into 50Ω. The optical signal generated was then amplified in an erbium fibre preamplifier and transmitted through the dispersive transmission filter. The output pulse train was amplified in another high power diode-pumped erbium fibre amplifier to a level at which autocorrelation measurements could be carried out. The all-fibre dispersive transmission filter was used to transform the reflection characteristics of the grating into a transmission characteristic with low insertion loss [5]. It consists of a polarization division multiplexing coupler, fibre Bragg grating and two polarization controllers, and its operation is described in [5].

The grating used was 8mm long, initially unchirped with a bandwidth of 0.33nm and had a nominal peak reflectivity at 1.561µm of 17dB. The chirp was induced on the grating using the temperature gradient method [6] which was produced by simultaneously heating one end of the grating and cooling the other end, enabling the reflection bandwidth of the grating to be controllably increased to greater than 1.575nm (giving a dispersion of –4.5ps/nm). The grating was also strain-tuned so that its reflection wavelength coincided with the operating wavelength of the DFB. The dispersion of the grating introduced by this method is inversely proportional to the grating bandwidth, so by controlling the grating bandwidth, the effective dispersion of the grating could be adjusted to ensure optimum chirp correction in the pulse source. It was found that in general the shortest pulses were obtained from the broader grating bandwidths.

Fig. 2 compares the pulses generated directly from the electroabsorption modulator (outline circles) with those generated from the combined modulator-grating system (solid circles). In this case the grating bandwidth was broadened to ~1.55nm and the RF drive supplied to the modulator was estimated to be ~8V peak-to-peak. The minimum pulse durations are dependent on the chirp parameter introduced by the modulator, which is a decreasing function of the bias voltage. In addition, the uncompensated pulse duration also decreases with increasing bias voltage on the modulator, hence the minimum compensated pulse duration will be a function of the bias voltage. We found that the minimum compensated pulse duration occurs at a DC bias of 7.2V for this grating bandwidth. Fig. 3a shows a typical autocorrelation trace and Fig. 3c the spectrum of the pulses generated. The periodic structure in the

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spectrum correspond to the 10GHz repetition rate. The measured time-bandwidth product of these pulses was 0.32. Fig. 3b shows the reflection spectrum of the chirped grating measured with the broadband ASE from the preamplifier. The dip in reflectivity, which occurs in this case at 1.5622μm, was found to always be present when the grating was chirped regardless of the degree of bandwidth broadening. This dip in reflectivity is advantageous as it can help to suppress any residual CW carrier radiation transmitted by the modulator resulting in significant suppression of the background. It is believed to be due to an asymmetric temperature gradient along the grating causing a slight nonlinear chirp.

Pulse duration achieved from system at varying DC reverse bias for fixed RF drive amplitude with and without dispersion compensation.

It should be noted that although pulses of almost comparable durations could be obtained directly from the modulator at very high DC bias values the quality of these pulses was relatively poor and they were not transform-limited. The shortest pulses generated with optimised chirp compensation were 5.2ps long and we believe this to be the shortest pulse duration obtained from an electroabsorption modulator without resort to nonlinear pulse compression techniques. We have also compressed these pulses to 180fs duration and generated pulses of tunable duration within the range 0.2-5ps using an external nonlinear compression technique. This will be reported in more detail elsewhere.

In conclusion, we have reported the use of an electroabsorption modulator in conjunction with a fibre Bragg grating as a narrowbandpass filter providing preamplifier noise reduction and pedestal suppression through spectral shaping. Although we produced a tunably chirped grating using a temperature gradient method to evaluate and optimise the performance of the system, the application of stable, permanent chirped gratings [7] would be preferable for practical applications.

Acknowledgments: This work was supported by the EPSRC. We would like to thank IRE POLUS GROUP for providing the diode-pumped erbium amplifiers used in the experiment.

References

Tunable photodetectors and light-emitting diodes for wavelength division multiplexing

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Indexing terms: Light emitting diodes, Photodetectors, Wavelength division multiplexing, Micromachining

The authors propose and analyse a hybrid device structure which extends the dynamic tuning range of vertical-cavity photodetodes and emitters. The device consists of a conventional, epitaxial cleaved quantum-well diode grown on a quartz-wafer mirror stack. The upper mirror is attached to the underside of a micromachined membrane fabricated on top of the epiwafer. This configuration allows the upper mirror to be electrostatically deflected towards the epilayer, reducing the overall vertical cavity length which tunes the resonance wavelength over the entire free spectral range of the cavity. Simulations of the device indicate that eight-channel operation between 900 and 1000nm can be achieved with low crosstalk. It is expected that this device will find use in wavelength-division-multiplexing applications.