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A 10 Gbit/s, 160 Gchip/s superstructured fibre Bragg gratings for OCDMA coding:decoding system

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Optical Code Division Multiple Access (OCDMA) is capable of providing future local area networks with higher connectivity, asynchronous multiple access and flexible bandwidth management. Much of the increased activity in this area has resulted from improvements in Fibre Bragg grating (FBG) fabrication technology driven mainly by the stringent requirements of DWDM. It is now possible to design and reliably fabricate superstructured fibre Bragg gratings (SSFBGs) with truly complex amplitude and phase responses [1], opening the possibility of using SSFBG components to perform fundamental OCDMA functions such as the coding and decoding of chip patterns described herein. In earlier work we demonstrated the generation of seven-chip, direct sequence, unipolar (amplitude) code OCDMA bits at 125 MHz using a SSFBG, and demonstrated optical pattern recognition using a matched SSFBG filter as a decoder [2].

In this paper we present results on upgrading the SSFBG approach to both far higher data rates (10Gbit/s) and far shorter chip-lengths (6.4ps) with far higher grating reflectivity (up to 50%) than previously demonstrated by fabricating bipolar (phase) coding and decoding SSFBGs using our continuous scanning technique. We present the results of BER measurements at 10 GBit/s on a decoded pulse sequence both before and after transmission through 25km of standard fibre which show there to be no noise-penalty associated with the either the coding:decoding process, or due to transmission of the coded pulse itself.

Our experimental set-up is shown in Fig.1a and comprises a 10 Gbit/s, ~2ps pulse transmitter (based on a regeneratively mode-locked, soliton fibre ring laser operating at 10 GHz), bipolar coding and decoding gratings, and an (optional) 25km standard fibre transmission span which had its dispersion compensated with a chirped FBG.

We fabricated seven-chip M-sequence, bipolar coding and decoding gratings. The total grating length in each instance was 4.64mm (corresponding to a temporal code length of 44.8ps) and the individual chip width was 0.66mm (corresponding to a chip length of 6.4ps). The bipolar grating design is shown inset in Fig.1a, and is a pure phase-encoded structure with discrete π phase shifts at the (NRZ) chip transition boundaries. The experimental and theoretical plots are shown in Fig.1b. The agreement between the theoretical and experimental spectral responses of the bipolar SSFBG is seen to be excellent, highlighting the precision of our grating writing process. The decoder grating is essentially identical to the encoder grating other than it has a spatially-reversed refractive index superstructure. Note that all of gratings used in these experiments (including the dispersion compensating FBG) were written by appropriate UV exposure through the same, uniform period phase mask.

Since the SSFBGs are relatively weak and within the Fourier theory grating design limit, the impulse response of the grating in the time domain is given by the superstructure modulation profile used to write the grating. We examined the intensity autocorrelation functions of the incident 2ps pulses on reflection from the individual coding:decoding gratings, and found the profiles to be in excellent agreement with our theoretical predictions as shown in Fig.2a. This includes the decoder response to the code after it has propagated over the 25km dispersion-compensated transmission line, there is evidence of some correlation signal degradation, however the effects are slight, and in fact negligible in terms of overall system performance. The spectral response of the decoded signal is also compared to the theoretical plot as shown inset in Fig 2a.

BER measurements were taken on the code:decode process, both with and without the 25km transmission. The results are summarised in Fig.2b where it is seen that no power penalty associated with code-decode process is observed in either instance. Eye diagrams for both the simple code:decode and transmitted code:decode case are shown inset within Fig.2b. No evidence of temporal features away from the main, chip-length long, correlation peak is observed as expected.

In conclusion we have demonstrated high-quality, 10 Gbit/s bipolar OCDMA coding and decoding using superstructured FBGs with a code chip rate of 160 Gbit/s. Error-free operation with no power penalty was obtained for the coding:decoding process after propagation of the code through 25km of fibre. These results highlight the precision and flexibility of our particular grating writing process and point to further applications of SSFBGs in future high-speed optical networks. For example our results demonstrate the possibility of using SSFBGs for header recognition in 160 Gbit/s OTDM based networks.

References

[1] M. Ibsen et al: IEEE Phot. Tech. Lett. Vol. 10, pp842-845 (1998).

[2] H.Geiger et al.: Proc. ECOC'98, Vol.1, pp337-338 (1998).

1 (a)

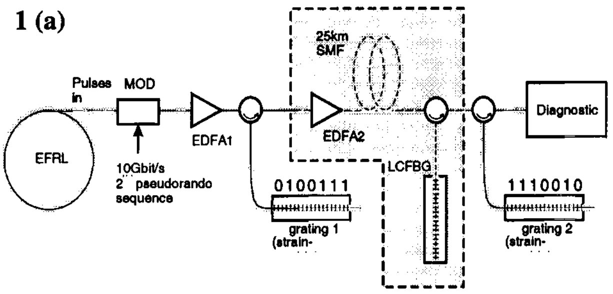

Fig 1 (a) Experimental set up. The pseudorandom sequence is 2^{31}-1 bits long. LCFBG – Linearly Chirped Fibre Bragg Grating.

1 (b)

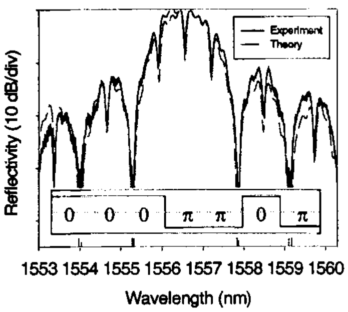

Fig.1 (b) Bipolar grating reflectivity spectrum (theoretical and experimental). The refractive index phase superstructure is shown inset. The peak reflectivity of this grating was ~50%.

2 (a)

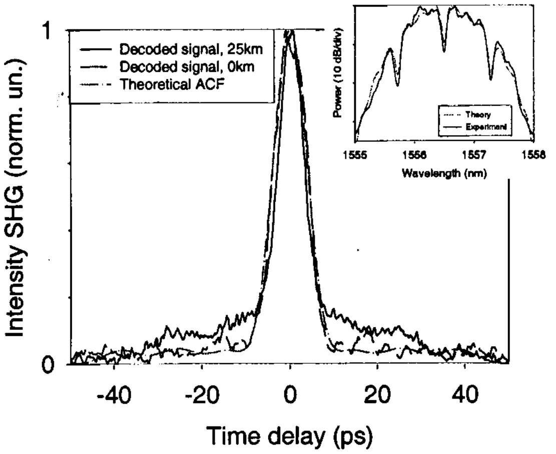

Fig. 2 (a) Theoretical and experimental pulse intensity autocorrelation functions for the code:decode process both before and after transmission through 25km of (dispersion compensated) standard fibre. The theoretical and experimental frequency responses of the decoded signal are shown inset.

2 (b)

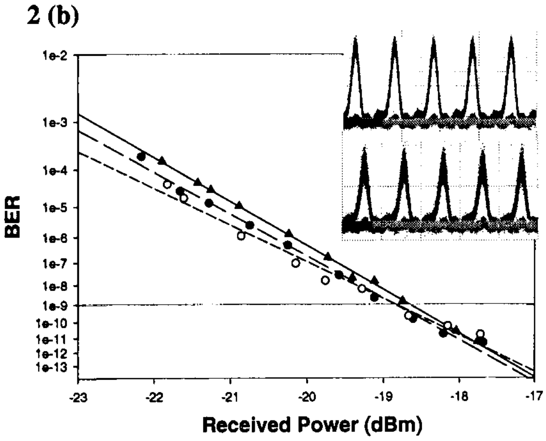

Fig. 2 (b) BER curves for back-to-back (open circles), and decoded signal before (closed circles) and after (triangles) transmission; the corresponding eye diagrams (without and with transmission) are shown inset.