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The generation, recognition and re-coding of 64-bit, 160 Gbit/s optical code sequences using superstructured fiber Bragg gratings

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We report the sequential generation, recognition and recoding of 160Gbits, 64-bit bipolar optical codes using superstructured fiber Bragg gratings. The results represent an eight-fold increase in code length relative to previous demonstrations of pulse processing using such technology.

Superstructured fiber Bragg grating (SSFBG) technology has developed considerably over recent years to the point that SSFBG structures can be written with truly complex phase and amplitude reflectivity profiles [1]. These developments have opened up the possibility of using SSFBGs for a wide variety of temporal pulse shaping and processing applications including optical code generation and correlation (pattern recognition). Such functions are required for example in Optical Code Division Multiple Access (OCDMA) and high speed packet switched networks. To date there have been relatively few pulse processing experiments employing SSFBGs and all have used short code sequences (<=8bits) [2,3,4]. Whilst this has been adequate to prove the underlying concepts it has left open the question as to whether this technological approach has the precision required to allow it to be extended to encompass the longer code sequences required for any significant practical application. In this work we show that it can be, by demonstrating the generation, recognition and recoding of 160 Gbit/s, 64-bit phase-encoded sequences.

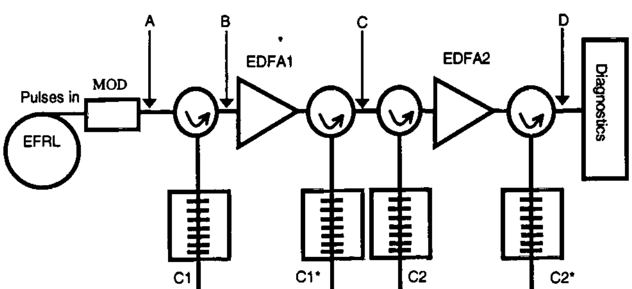

Fig. 1: Experimental set up

Our experimental set up is shown in Fig.1 and comprises a bit-rate tunable (500MHz-10 GHz), 2ps source based on an erbium doped soliton ring laser, and a cascade of two coding:decoding SSFBG pairs. Grating C1 is used to generate a temporally distributed 64-bit phase-shift keyed code from an incoming 2ps pulse. Grating C1* is used to decode the resulting code thereby generating a short distinct pulse with a duration of order the bit length. This pulse is then used to generate a second coded sequence on reflection from grating C2. Grating C2* then decodes this second code resulting again in the formation of a short distinct correlation peak. Thus in one experiment we demonstrate the key functions of code generation, recognition and recoding all with 64-bit codes. Recoding is a function required for ready switching of data between different optical networks. Our demonstration represents a truly stringent test of our gratings, and ultimately of our continuous grating writing process [5].

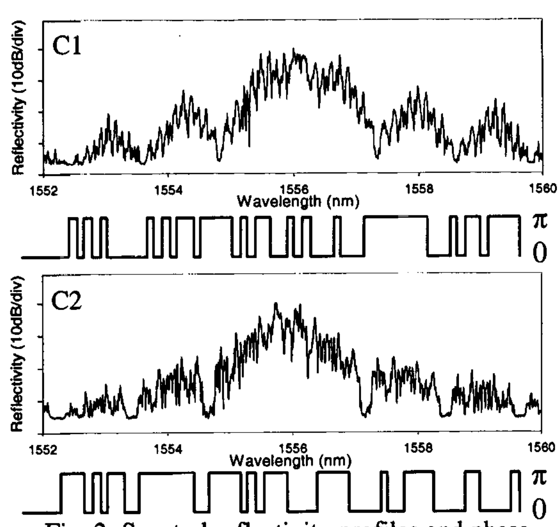

Fig. 2: Spectral reflectivity profiles and phase encoded 64-bit Gold sequence codes of gratings C1 and C2.

The intensity reflectivity profiles of gratings C1 and C2 used within our experiments are shown in Fig.2. The impulse response of a weak SSFBG (reflectivity <20%) follows the form of the spatial superstructured refractive index profile imposed upon the grating. The profile of the phase superstructure of the two gratings is shown also within Fig.2 and consists of discrete phase jumps at the interface of the localised regions within the grating that define the individual bits of the code. The phase jumps are distributed within the superstructures C1 and C2 in order to define two bipolar, 64-bit Gold-sequence codes. Gold-sequence codes were chosen since they constitute the subset of possible 64-bit codes that minimize the intercode cross-correlation functions, whilst at the same time possessing the distinct high-contrast autocorrelation properties required for self-pattern recognition [6]. There are 65 different Gold codes obtainable from a 64-bit Gold sequence. Gratings C1* and C2* are matched filters to gratings C1 and C2 respectively and are identical to the associated encoder gratings other than that their superstructure refractive index profiles are spatially reversed. The total length of each grating was 4.22mm and the length of grating representing an individual bit was 0.66mm, corresponding to code and bit durations of 409.6ps and 6.4ps respectively.

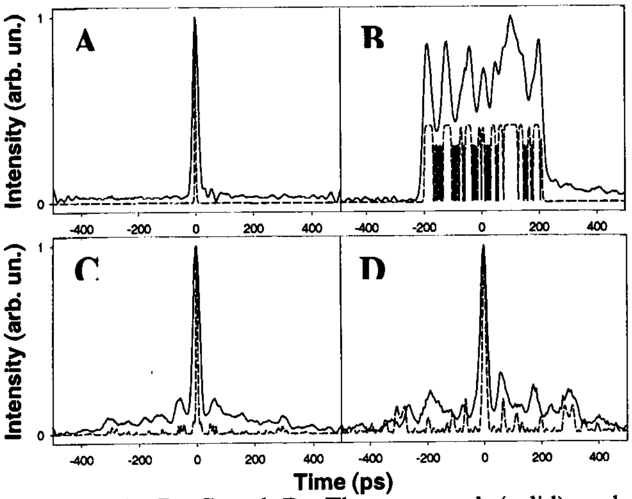

Fig. 3 A, B, C and D: The measured (solid) and theoretical (dashed) pulse shapes at points A (input pulse shape), B (C1 code), C (C1:C1* correlation) and D (C1:C1*:C2:C2* correlation) within the system (see Fig. 1). The temporal resolution of the experimental electronic measurement system is 20ps. The theoretical curves are not corrected for the electronic measurement system resolution i.e. are the true optical signals.

The main results of our experiments are summarised in Figs.3A-D where we plot the measured temporal pulse forms at corresponding points (A-D) within the system, along with the theoretically predicted forms. The pulse measurements were made with a fast diode and scope with ~20ps resolution, far less than required to resolve the individual bits, but sufficient to gain a good appreciation of the system's operation. SHG autocorrelation measurements with <100fs resolution were also performed to determine the actual width of both the input pulses and signal correlation pulses. The high quality of the code generation and pattern recognition obtained is evident from examination of Figs. 3B and 3C respectively. The actual width of the peak for the process C1:C1* (Fig. 3C) was confirmed to be ~6.8ps in good agreement with our theoretical expectations. The quality of the pattern recognition of the recoded pulse form (C1:C1*:C2:C2*) is slightly degraded relative to the single stage (C1:C1*) case, but is still reasonable given the fact that the pulses input to the second-stage coding process are longer, and already exhibit additional structure in the wings due to the initial correlation stage. The contrast could readily be improved by adding a nonlinear element to the system as in Ref[7].

In conclusion, we have demonstrated high quality pulse processing of far longer bit sequence codes than previously demonstrated using SSFBGs. We consider SSFBG technology to represent a highly practical, flexible and cost effective technology for the production of components for the temporal processing of optical pulses. The results highlight the quality and flexibility of our grating writing process, note that all the gratings used within this experiment were written using a single uniform pitch phase mask, and took less than 1 minute to write.

References

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