Reconfigurable Time Domain Spectral Phase Encoding/Decoding Scheme Using Fibre Bragg Gratings for Two-dimensional Coherent OCDMA

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Abstract

We demonstrate the reconfigurable time domain spectral phase encoding/decoding (SPED) schemes using fibre Bragg gratings (FBG) for the first time. Chirped FBG is used for coherent spectral phase encoded OCDMA. FBG array with two-dimensional optical code patterns is used for two-dimensional coherent OCDMA.

Introduction

In coherent optical code division multiple access (OCDMA) schemes, the ultra-short optical pulses are encoded and decoded based on the phase and amplitude of the optical field in either time or spectral domain [1-8]. In time domain OCDMA, the ultra-short pulses are directly time-spread using planar lightwave circuit (PLC) [1], superstructured fibre Bragg grating (SSFBG) [2], and arrayed waveguide grating (AWG) [3]. While in spectral domain OCDMA, the spectral phase of the ultra-short optical pulse are encoded using spatial lightwave phase modulator (SLPM) [4], high resolution phase encoder/decoder [5] or micro-ring-resonator [6]. The spectral phase encoding (SPE) scheme can be generally used in pulse shaping as well for applications such as high-repetition-rate pulse burst generation [7, 8], RZ-to-NRZ converting [9], etc. Recently, reconfigurable time domain spectral phase encoding/decoding (SPED) scheme has been proposed by time domain stretching and high speed phase modulation [10, 11].

Figure 1 shows the schematic diagram of the time domain SPED. The short optical pulses are stretched by the first dispersive component with dispersion value of -D, different spectral components of the signal spread at different positions in one bit duration. The phase modulator (PM) is driven by optical code (OC) patterns to modulate the phases of different spectral components. The second dispersive component with dispersion value of +D (opposite to the first one) is to compress the encoded signal and generate SPE signal.

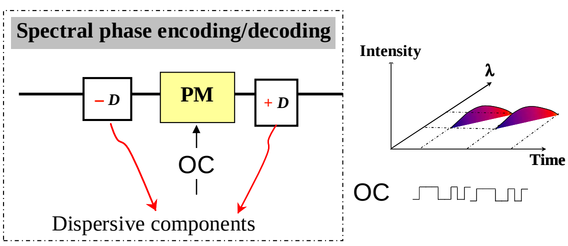

Figure 1: Schematic diagram of time domain SPED.

In previous experiments, optical fibres (reverse dispersion fibre (RDF) and single mode fibre (SMF)) are used as the dispersive components to demonstrate the proposed schemes [10, 11]. However, using optical fibres are not very efficient for this purpose in terms of size, insertion loss and flexibility. In addition, the residual part of the stretched SPE signal that exceeds one bit duration will degrade the performance [10]. An additional optical filter is needed in order to overcome this issue.

In this paper, we demonstrate the reconfigurable time domain SPED scheme using chirped fibre Bragg gratings (CFBG). We further propose the novel reconfigurable two-dimensional (2-D) SPED scheme and demonstrate for the first time using FBG array with 2-D OC patterns. This can be applied for 2-D coherent OCDMA.

Experiment with CFBG

Figure 2 shows the experimental setup of the proof-of-principle experiment with CFBGs. A 1.5 ps optical pulse train with central wavelength of about 1550 nm was generated @ 1.25 GHz repetition rate using a mode-locked laser diode (MLLD) and an intensity modulator (IM). This pulse was stretched by CFBG and modulated with a 20 GHz phase modulator (PM) driven by 8-chip, 50 ps/chip binary phase shift keying (BPSK) code patterns with repetition rate of 1.25 GHz. The compressor is another CFBG with opposite dispersion. The spectral responses of the CFBGs are shown in Fig.3. The dispersion slope is ~ 65ps/nm.

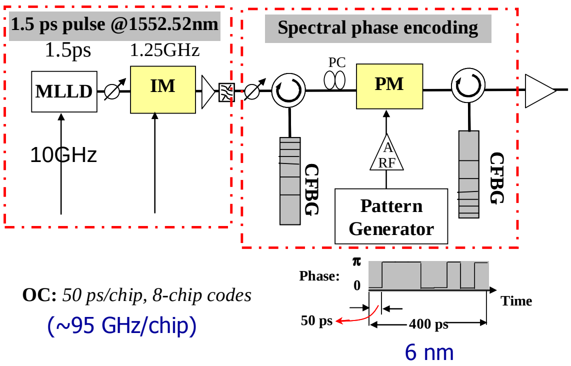

Figure 2: Experimental setup of the SPE

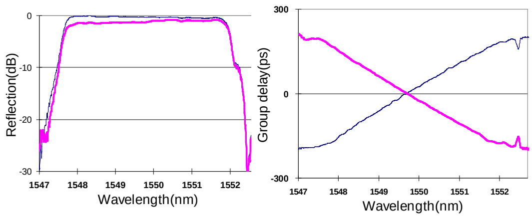

Figure 3: Spectral responses of the CFBGs

The decoding part has the same configuration as the encoding part with the PM driven by synchronously driven by $\overline{OC}$ (the complementary pattern of OC). Figure 4 shows the waveforms of the SPE encoded signals with different OC patterns OC1~OC4 and the decoded signal with decoder driven by $\overline{OC2}$. Good extinction ratio between auto- and cross-correlation verifies that the SPED scheme works well with CFBG. Comparing to optical fibres, SPED scheme using CFBG as the dispersive components has lower insertion loss, better flexibility and is more compact. The CFBG also function as bandpass filter to cut off the tails of the stretched signal discharging the needs for an addition optical filter.

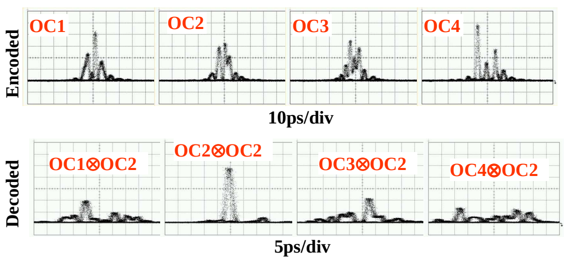

Figure 4: Waveforms of SPE encoded (upper row) and decoded (lower row) signals

Experiment with 2-D FBG

The two-dimensional (2-D, temporal-spectral) FBG array encoder can be regarded as nonlinear discrete dispersive component [12]. Using the 2-D FBG encoders as the dispersive components in the time domain SPE enables us to generate the novel reconfigurable coherent 2-D OC for the first time.

Figure 5(a) illustrates the principle of the proposed coherent 2-D SPE scheme and the proof-of-principle experiment setup. The 2-D FBG encoder stretches an input optical pulse into a multi-colour pulse train with 2-D OC pattern. The phase of each individual pulse (with different colour) is further modulated by the PM giving an additional SPE pattern to the pulse train. Figure 5(b) shows the spectral response of the 2-D FBG array encoder we used in the experiment. The spacing between adjacent wavelengths is 1 nm and chip-rate is 10 GHz/chip. The 2-D code pattern showing here is (λ1, λ3,λ5,λ2,λ4). Figure 5(c) shows the waveform and spectrum of the spread 2-D pulse train. The PM is driven by 10 GHz/chip, 5-chip BPSK SPE patterns with 1.25 GHz repetition rate to generate the coherent 2-D SPE signal. We used another port of the same 2-D FBG array to serve as the coherent 2-D decoder with an "all 0" SPE pattern. Figure 5(d) shows the measured auto-/cross-correlation waveforms with good extinction ratio.

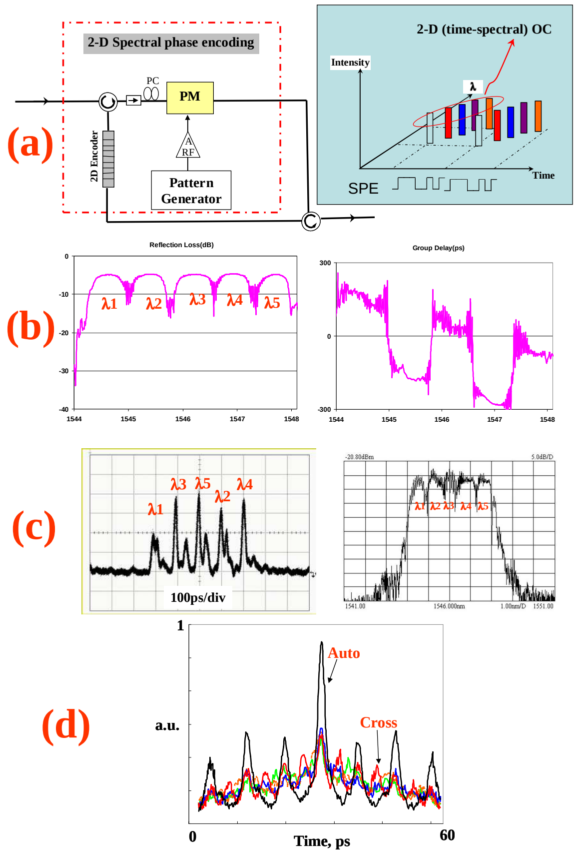

Figure 5: 2-D coherent SPE Experiment

Conclusions

Using CFBGs in time domain SPED has the advantages of lower insertion loss, better flexibility and higher compactness as compared to using optical fibre. The CFBG also function as bandpass filter to cut off the tails of the signal. The proposed reconfigurable SPED scheme with 2-D FBG array can generate/recognize novel coherent 2-D OC. This can be applied for 2-D coherent OCDMA, which has very large available code size.

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