Polarization spectral line-by-line pulse shaping

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Abstract: Spectral line-by-line pulse shaping is extended to full-vectorial capabilities for the first time to our best knowledge. We experimentally demonstrate polarization shaped optical waveforms extending a 50-ps time window.
OCIS codes: *(320.5540) Pulse shaping, (070.7145) Ultrafast processing.*

1. Introduction

Optical arbitrary waveform generations (OAWG) are enabled by applying spectral line-by-line pulse shaping on an optical frequency comb [1,2]. The most prominent advantage of such shaping regime is that the shaped waveforms could be with a temporal duration extending 100% duty cycle. Spectral line-by-line pulse shaping has been successfully applied to microwave/millimeter-wave photonics [3-5], as well as the generation and long-range fiber delivery of ultrahigh repetition-rate optical pulse trains [6]. In the above reports, however, only a single optical polarization has been utilized. On the other hand, polarization pulse shaping has been demonstrated, but only in the group-of-line regime thus provided very limited (~ps) time windows [7,8]. In this paper, we extend the line-by-line pulse shaping onto full-vectorial regime for the first time to our best knowledge. Polarization shaped optical arbitrary waveforms extending a 50-ps time window are experimentally demonstrated.

2. Experimental result and discussion

Figure 1 shows our experiment setup. A phase-modulated CW (PMCW) laser frequency comb with 20 GHz spacing (pulse period of 50 ps) is generated by injecting a 1 kHz-linewidth CW laser centered at 1545 nm into a low-V_π phase modulator [6]. The frequency comb is sent to a homemade reflective polarization line-by-line pulse shaper. The x- and y-polarized frequency comb lines are spatially separated by a Wollaston prism and the incident angles upon the Echelle grating are adjustable through the lateral positions of the telescope. A computer controllable 2 × 640 pixel liquid crystal modulator (LCM) array is positioned before the mirror (Fourier plane) for amplitude and phase controls. The amplitude and phase controlling voltages of our LCM are carefully calibrated. The current pulse shaper configuration is similar to that reported in Ref. [7]. However, in our shaper design, all the comb lines for both polarizations are clearly resolved and independently controlled using two LCM pixels to ensure clean line-by-line shaping regime. A short pulse erbium-doped fiber amplifier (EDFA) is placed after the output of the polarization line-by-line pulse shaper.

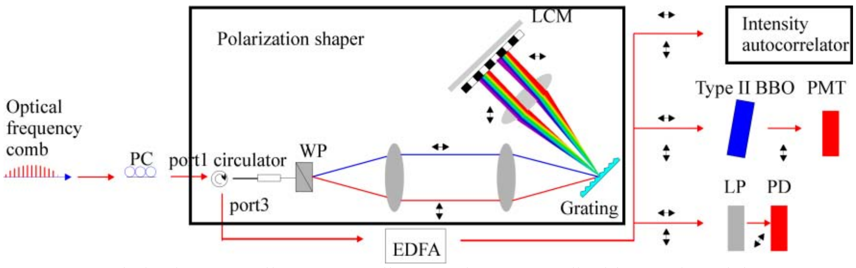

Fig. 1. Experiment setup. PC: polarization controller; WP: Wollaston prism; LCM: liquid crystal modulator; EDFA: erbium-doped fiber amplifier; PMT: photomultiplier tube; LP: linear polarizer; PD: photodetector.

Our initial procedures in characterizing the spectral phase difference between the two orthogonally polarized frequency combs are outlined as follows: (1) We first compensate all higher-order spectral phases of both the x- and y-polarized PMCW combs so that transform-limited (TL) pulses are generated. This is achieved by sending one polarized comb at a time into an intensity autocorrelator positioned at zero-delay to maximize the second-harmonic yield through an automated phase control process [6]. Figure 2 shows the phase compensation applied to the x-polarized comb spectrum in generating 1.8-ps transform-limited 20 GHz optical pulse train. The intensity autocorrelation trace of the pulse train is shown in the inset. (2) Secondly, the relative temporal delay (hence the linear spectral phase difference) between the two orthogonally polarized, transform-limited pulse trains needs to be determined. For this purpose, we use the pulse shaper itself as a precise delay-scanner with non-moving parts [9]. We send the combined beam (both polarizations) from the shaper output to a type II BBO crystal. A linear spectral phase scan (hence a tunable temporal delay) is applied onto the y-polarized comb while monitoring the resulting sum frequency generation (SFG) yield. The relative temporal delay of 15 ps is determined when the maximum SFG signal is obtained. We confirmed this relative delay using intensity cross-correlation, as shown in Fig. 3. (3) Lastly, the remaining absolute phase difference between the two polarized combs needs to be determined for complete knowledge over the polarizations of the instantaneous fields. We use amplitude control of the shaper such that only one spectral line (the initial CW laser line at 1545 nm) in each polarized comb is allowed to pass. The polarization controller before the polarization shaper input is tuned to ensure that the amplitude ratio between the two polarizations is exactly one. The combined x- and y-polarized 1545 nm beam is delivered to a linear polarizer positioned at 45 degree, and the resulting interferometric signal is detected by an InGas photodetector. Largest signal is anticipated when both 1545 nm fields are in phase. As shown in Fig.4, the absolute phase difference between the x- and y-polarized combs is found to be 5π/8.

With the spectral phase difference between the two polarized combs completely characterized, we now demonstrate the first (to our best knowledge) polarization shaped optical arbitrary waveform generations. Applying the linear and absolute spectral phase differences determined from the above procedures to the y-polarized comb, one obtains 45-degree linearly polarized pulse train. Figure 5 shows the instantaneous filed of the circularly polarized TL pulse when a π/2 relative phase is applied to all the y-polarized comb lines. Figures (6,7) are obtained when the y-polarized field is strongly chirped to fill the entire 50-ps window (100% duty cycle), while the x-polarized TL pulses are temporal delayed by -/+ 15 ps, respectively. These results are only achievable through clean line-by-line pulse shaping in both polarizations.

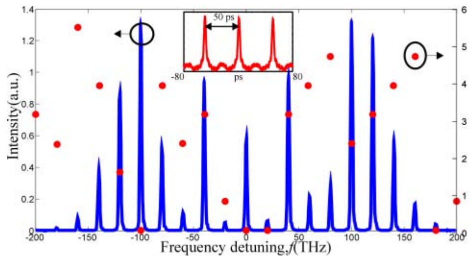

Fig. 2. Optical Frequency comb (solid) and the compensating phases (Red dot). Inset: Intensity autocorrelation of the pulse train

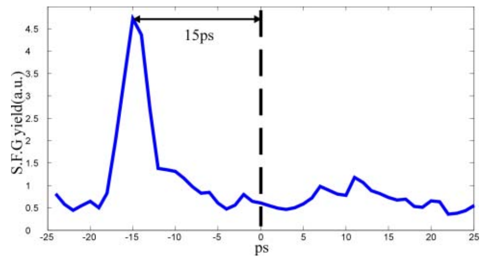

Fig. 3. Cross-correlation trace of x- and y- polarized wave

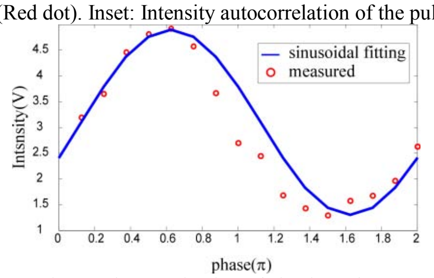

Fig. 4. Characterization of absolute phase

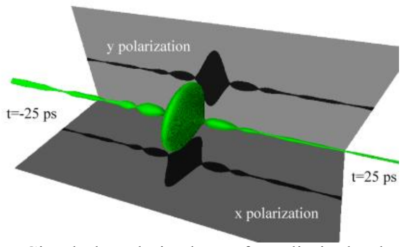

Fig. 5. Circularly polarized transform-limited pulse.

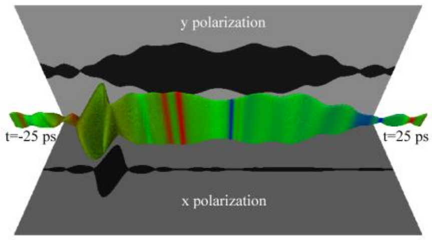

Fig. 6. Elliptical polarization near t=-15 ps time slice.

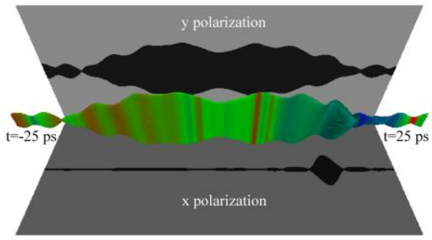

Fig. 7. Elliptical polarization near t=15 ps time slice.

In summary, full-vectorial optical arbitrary waveforms are experimentally demonstrated by applying polarization line-by-line pulse shaping to a 20 GHz PMCW frequency comb. This work was supported by the National Science Council in Taiwan under grants NSC 100-2112-M-007-007-MY3, 100-2221-E-007-093-MY3, and by the National Tsing Hua University under grant 100N2081E1.

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