Synthesis of arbitrarily polarized optical waveforms using vectorial temporal Talbot effect

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Abstract: Vectorial optical arbitrary waveform generation is experimentally demonstrated through polarization line-by-line pulse shaping. Temporal Talbot effect is extended into the vectorial regime, and the polarization shaped optical waveforms extending a 50-ps time window are synthesized.

OCIS codes: (320.5540) Pulse shaping, (070.7145) Ultrafast processing.

1. Introduction

Optical arbitrary waveform generation (OAWG) is enabled by applying spectral line-by-line pulse shaping on an optical frequency comb so that 100% duty cycle can be achieved [1-3]. However, in the above OAWG works, only a single optical polarization has been utilized. Polarization pulse shaping has been developed, however optical frequency combs were not used and the pulse shapers were not designed to operate in the line-by-line regime [4]. Temporal Talbot effect, in which the pulse train repetition-rate may be multiplied through the temporal self-imaging, has been investigated extensively with a single optical polarization [5,6]. In this paper, polarization line-by-line pulse shaping is implemented to achieve vectorial temporal Talbot effect for the first time to our best knowledge, where we exploit the periodic temporal phases for interesting field polarization synthesis. Our experimental results are measured are found in excellent agreements to the applied shaping controls.

2. Experimental result and discussion

Figure 1(a) shows the schematics of our experimental setup. A PMCW laser frequency comb with 20 GHz spacing (50 ps repetition period) is generated by injecting a 1 kHz-linewidth CW laser (NKT Adjustik) centered at λ_0 =1545 nm into a low-V_π optical phase modulator. 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 an Echelle grating are adjustable through the lateral positioning of the telescope [7]. A fiberized polarization controller is used to ensure balanced amplitudes between the two polarizations. A computer controllable 2 × 640 pixel liquid crystal modulator (LCM) array is positioned before the mirror to provide independent control to the amplitude and phase of each comb line for both polarizations.

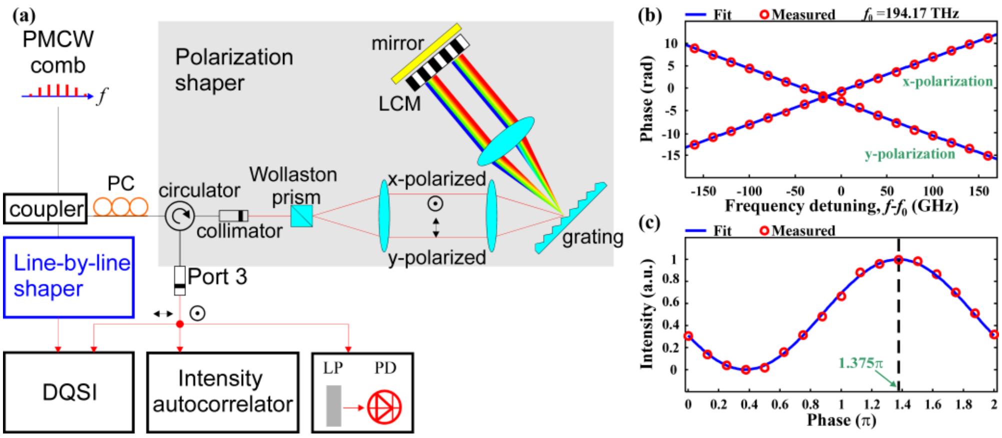

Fig. 1. (a) Experiment setup. PC: polarization controller; LCM: liquid crystal modulator; LP: linear polarizer; PD: photodetector. (b) Linear spectral phases measured by DQSI (open circles) for x- and y-polarizations. (c) Characterization of the absolute phase difference between x- and y-polarizations.

Prior to performing polarization pulse shaping, the spectral phase difference between the two orthogonal polarizations due to dispersion and the slight path difference must be careful characterized [7]. Our procedures in retrieving/compensating the three phase difference terms are described as follows: (1) First, nonlinear spectral phases of both the x- and y-polarized comb lines are compensated so that transform-limited (TL) pulse trains are generated. This is achieved by maximizing the second-harmonic yield of a single polarized comb at a time through an automated shaper LCM phase control process. (2) Secondly, the relative temporal delay is determined through a dual-quadrature spectral interferometry (DQSI) system [8] as depicted in Fig. 1(b). The relative temporal delay τ_{xy} =23.85 ps between the two polarizations is experimentally determined. A linear spectral phase of $\tau_{xy}\omega$ is applied to the y-polarized comb lines to ensure the two orthogonally polarized pulse trains have zero temporal delay. (3) Lastly, the absolute phase difference is determined. Our pulse shaper is programmed to block all the comb lines except the central one at λ_0 for both polarizations. The combined x- and y-polarized single comb line passes through a linear polarizer positioned at 45 degree. The resulting interferometric signal strength versus the extra phase added to the y-polarized comb line by the pulse shaper is shown in Fig. 1(c). The absolute phase difference of θ=1.375π is determined. After this procedure, all of the y-polarized comb lines are applied with θ=1.375π to eliminate the phase difference between the two polarizations.

Line-by-line polarization shaping is now implemented. Figures 2(a-c) show the measured (circles) and the LCM-applied spectral phases (line) phases of the shaped x- and y-polarized combs, respectively. The shaped waveform is then carefully characterized by the DQSI system [8]. In Figures 2(a,b) ,we apply periodic spectral phases of {0,π/2} and {π/2, π} [6] to the x- and y-polarized comb lines, respectively, and a large quadratic spectral phase is applied on the x polarization as shown in fig. 2(c). The first line-by-line polarization shaping example is to use the spectral phase application in fig. 2(a,b). Through this design, adjacent pulses will have alternating handedness since the pulse-by-pulse phase difference is [−π/2, π/2]. Figure 2(d) shows the resulting instantaneous electrical field. The intensity-rate doubling is evident: the temporal period is reduced to 25 ps. Temporal Talbot effect is now implemented into the vectorial regime. Although the pulse intensity rate can be multiplied through temporal Talbot effect, the temporal phase rate remains fixed and develops a deterministic periodical variation [7]. The handedness of the - 25 and + 25 ps pulses are both right-handed, while the 0 ps pulse being left-handed, and the pulses at time locations of -25, 0, and 25 ps are magnified within the insets. The instantaneous frequency of the waveform is represented by the color tone. In this example, the instantaneous frequency remains constant. The second example is to use the spectral phase application in Figs. 2(b,c). This results a linearly positively-chirped waveform filling the entire 50-ps window (100% duty cycle). Figure 2(e) shows the resulting instantaneous electrical field. The handedness of the - 25 and + 25 ps pulses are both right-handed, while the 0 ps pulse is linear polarization. The instantaneous frequency is dominated by the x-polarized up-chirped pulse, increasing linearly with time across the entire 50 ps period.

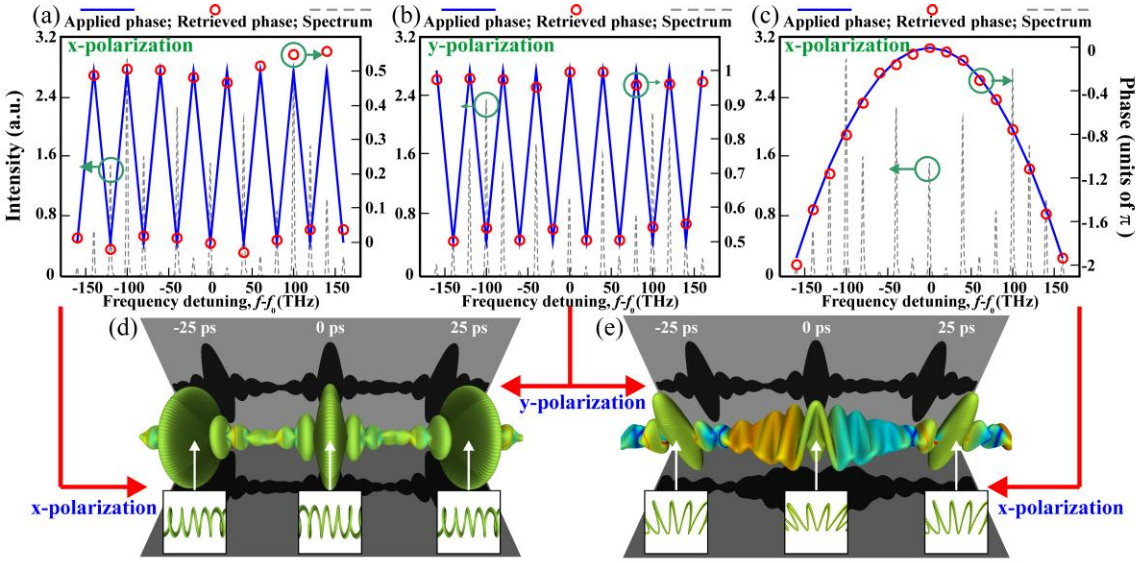

Fig. 2. (a-c) Characterization of the spectral phase for the x- and y-polarizations by DQSI (open circles), respectively. (d) Quasi-three-dimensional electric field representation with (a,b). (e) Quasi-three-dimensional electric field representation with (b,c). The color tone represents the instantaneous frequency of the waveform (blue and red for higher and lower frequencies).

3. Conclusion

In summary, polarization line-by-line pulse shaping is used to experimentally achieve vectorial temporal Talbot effect. 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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