Efficient Temporal Shaping of Ultrashort Pulses with Birefringent Crystals

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Abstract: A new and simple technique for temporal shaping of femtosecond and picosecond pulses with high efficiency is demonstrated. The pulse is divided into numerous pulses by a designed birefringent-crystal set. These divided pulses produce various shapes.

OCIS codes: 320.5540 Pulse shaping; 320.7080 Ultrafast devices

Shaping of short laser pulses is an area of active research. There is much interest in controlling pulse temporal shape and phase. The possible applications include coherent control of chemical reactions and pulse train generation for telecommunications, e.g. Our particular interest is a simple and robust means for shaping pulses that will drive a high-brightness electron source.

Here, we report an approach to temporally shape femtosecond or picosecond pulses, with high or low repetition rate, and high or low peak power. We employ a sequence of birefringent crystals to divide an initial pulse into sub-pulses (Fig. 1). The incident pulse has its polarization oriented at 45^0 angle with the optic axis of the first crystal. The orientations of the birefringent crystals at the odd-number positions are the same as that of the first crystal; and all those at the even-number positions are in the same direction as the polarization direction of the incident laser (Fig. 1). The divided pulses have alternating linear polarizations. Various pulse shapes can be obtained by varying the divided pulse number, the polarization mode delay, the energy distribution in the divided pulses, and initial pulse duration. With *n* crystals, the pulse shaper generates 2^n divided pulses. Those divided pulses produce various pulse shapes, such as a temporal square pulse, or pulse burst [1, 2]. The insertion loss of each crystal with antireflection coating is less than 0.2 %. The total loss of the crystal stack is negligible.

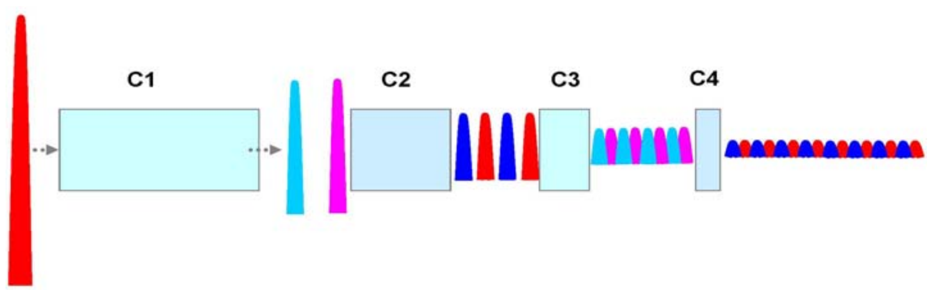

Fig. 1. Principle of pulse shaping. Each color of pulse presents for one polarizing orientation. The output pulse sequence has alternating linear polarizations

Experimental results on pulse shaping by crystal stacks verify the results of calculations. All the crystals in our experiments are *a*-cut YVO_4. The length of each crystal determines the polarization mode delay. We use four different length crystals for simulation and experiment: 8, 10, 15.4, and 22 mm. First, we demonstrate a few pulse shapes by changing the crystal lengths in a two-crystal stack. The seed pulse duration is about 2.6 ps. The cross-correlations for the pulse shaped by 8 mm and 15.4 mm crystals is shown in Fig. 2b, by 4.2 mm and 8 mm crystals in Fig. 2d, and by 10 mm and 22 mm crystals in Fig. 2f. The shaped pulses are measured by cross-correlation with the 2.6-ps pulse. Figures on the left side of Fig. 2 are the corresponding pulse shape by simulation. Overall, the experimental results agree well with simulation.

This method provides significant freedom to vary the pulse shape. Each crystal has two variables to change the pulse shape. Crystal length and orientation determine the delay and intensity distribution in the two divided parts, respectively. Extension to more crystals and generation of more divided pulses are straightforward. The simulation results of pulse shaping by 5-crystal stacks are shown in Fig. 3. First, we use 200-fs pulse to generate a 32-pulse burst by a 5-crystal stack (Fig. 3a). The last crystal length is about 1.06 mm, and the pulse spacing is about 800 fs. When the spacing reduces to 150 fs by another 5-crystal stack ending at 0.2 mm long crystal, the pulse shape converts into a square pulse with 4.7 ps duration (Fig. 3b).

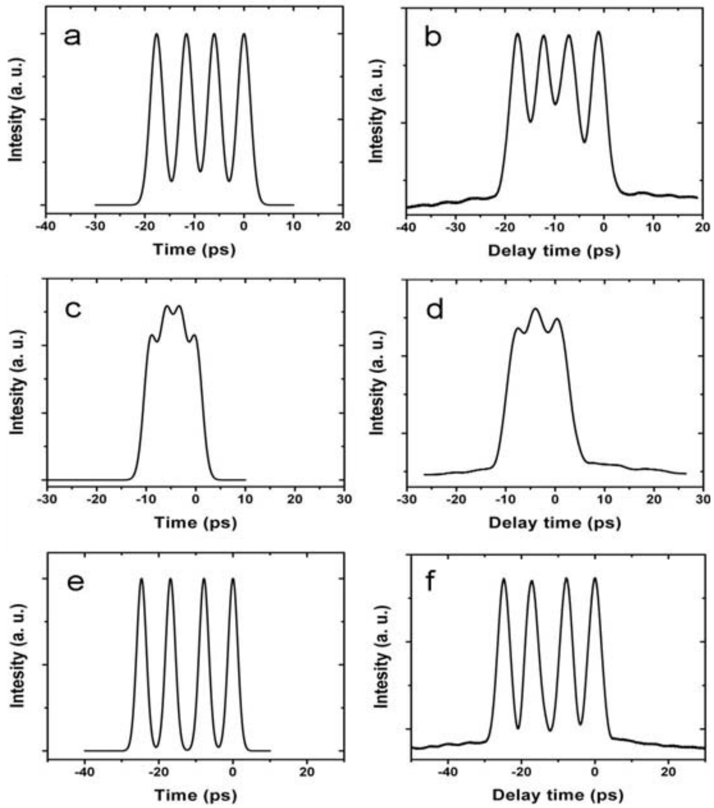

Fig. 2. Pulse shaping by crystal stacking. Left side: simulations. Right side: corresponding experimental results.

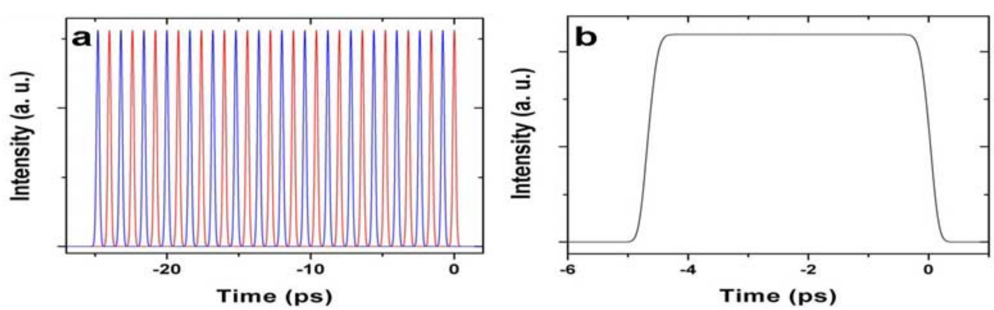

Fig. 3. Simulation results of pulse shaping by 5-crystal stacks: (a) pulse burst by 32 200-fs pulses with large spacing; (b) square pulse by 32 200-fs pulses with small spacing.

In summary, we propose a new approach to simple shaping of ultrashort pulses, based on pulse splitting in birefringent crystals. This method offers numerous advantages, including simplicity, robustness, high efficiency with both femtosecond and picosecond pulses, and compatibility with a wide range of repetition rates.

References:

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