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13. ABSTRACT (Maximum 200 words)

This DURIP equipment supplement provided the apparatus needed for development and execution of a unique method in femtosecond pulse shaping. In particular, the method allows a single laser beam with a single femtosecond pulse to be transformed into many spatially separate beams, each one with a specified sequence of femtosecond pulses.

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This DURIP equipment supplement provided the apparatus needed for development and execution of a unique method in femtosecond pulse shaping. In particular, the method allows a single laser beam with a single femtosecond pulse to be transformed into a many spatially separate beams, each one with a specified sequence of femtosecond pulses. In this "spatiotemporal" pulse shaping, a complex optical field can be generated with many ultrashort pulses that arrive at specified locations on a sample at specified times. From a fundamental point of view, this enables coherent optical control over material responses that move through a sample at light-like speeds, using some pulses to initiate the response at one sample location and other pulses, arriving at other sample locations at specified times, to manipulate the rapidly moving response. The method has been applied successfully to the manipulation of coherent polariton responses. These are very short, very fast electromagnetic/polar lattice vibrational responses that induce large fields and crystalline displacements wherever the go in the sample.

From an applications point of view, the method permits highly multiplexed generation of ultrahigh (THz) bandwidth optical signals. These can be made to arrive at specified addresses on a device at specified times. In the application demonstrated by us, the polariton responses can be viewed as THz-bandwidth signals. These signals are controlled and manipulated as they move at light-like speeds among different addresses on a device. Thus we have demonstrated extraordinarily high-bandwidth optical signal processing. Applications in high-bandwidth photonics switching, using semiconductor samples, are currently being pursued.

The attached figure 1 shows the automated femtosecond pulse shaping results. The pulse shaping principles are illustrated in figures 1a and 1b, the automated pulse shaper is illustrated schematically in figure 1c, and a spatially and temporally shaped output consisting of three separated beams, each with several pulses, is shown in figure 1d.

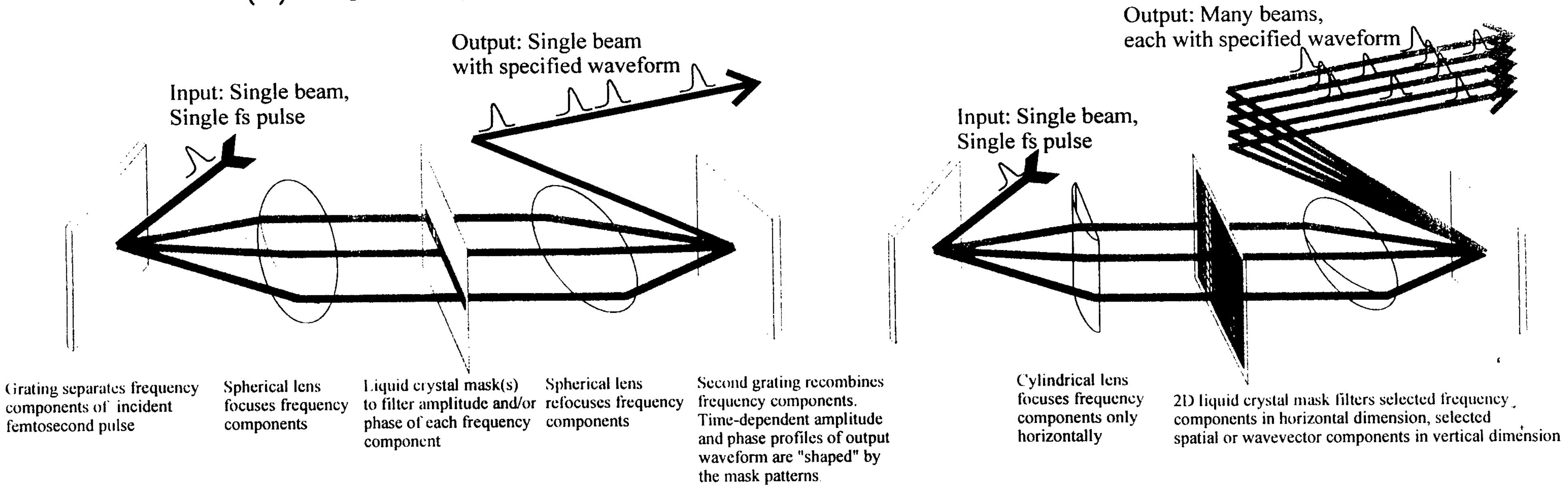
The attached figure 4 (both figures are taken from a recent ARO proposal) illustrates the use of the spatiotemporal pulse shaper for spatiotemporal coherent control over polaritonic signals moving at light-like speeds. Figure 4a shows the experimental arrangement. Figure 4b shows the output of the spatiotemporal pulse shaper, consisting mainly of 14 pulses, each separated spatially and temporally such that one after the other generates and repeatedly amplifies the propagating signal. This is analogous to a traveling wave amplifier for GHz electronics, but at THz frequencies and bandwidths. It is a first demonstration of what will be a broad range of ultrahigh-bandwidth electrooptical signal processing capabilities.

The results of this project have been submitted for publication, and additional submissions will be forthcoming.

Figure 1. Spatiotemporal femtosecond pulse shaping

(a) Temporal-only Pulse Shaper

(b) Spatiotemporal Pulse Shaper



Grating separates frequency components of incident femtosecond pulse

Spherical lens focuses frequency components

Liquid crystal mask(s) to filter amplitude and/or phase of each frequency component

Spherical lens refocuses frequency components

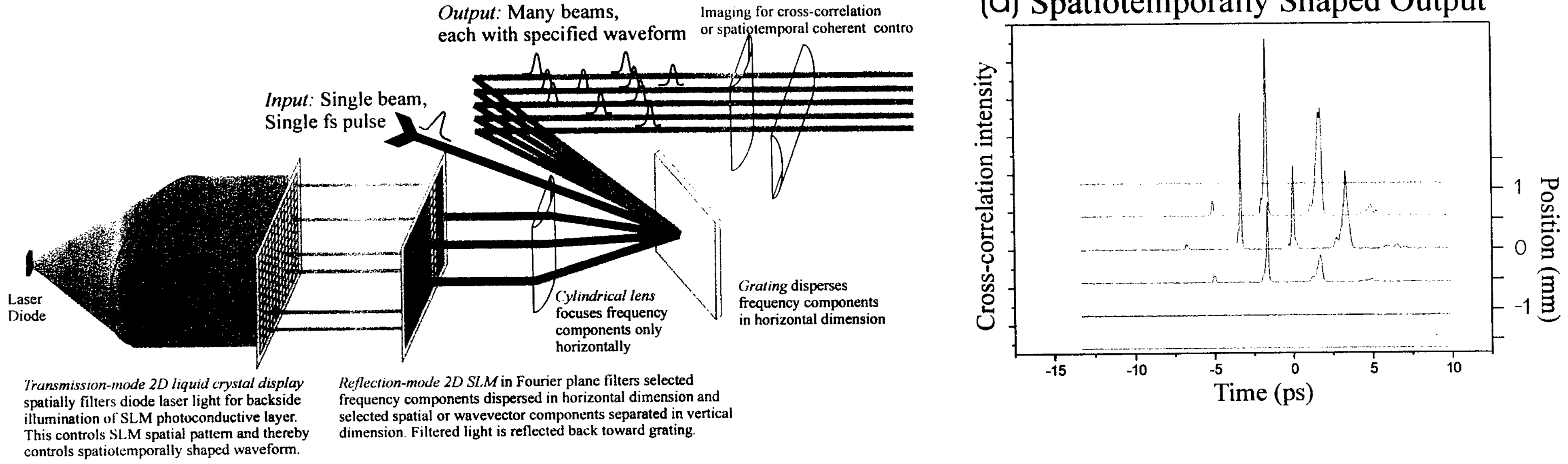
Second grating recombines frequency components. Time-dependent amplitude and phase profiles of output waveform are "shaped" by the mask patterns

Cylindrical lens focuses frequency components only horizontally

2D liquid crystal mask filters selected frequency components in horizontal dimension, selected spatial or wavevector components in vertical dimension

(c) Automated Spatiotemporal Pulse Shaper

(d) Spatiotemporally Shaped Output



Imaging for cross-correlation or spatiotemporal coherent contro

Cylindrical lens focuses frequency components only horizontally

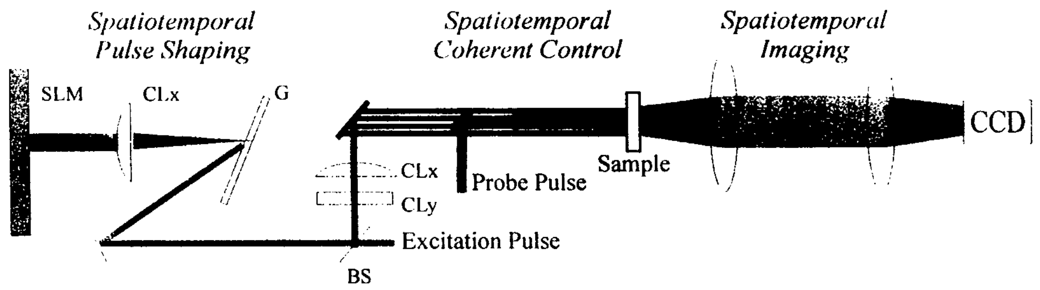
Grating disperses frequency components in horizontal dimension

Transmission-mode 2D liquid crystal display spatially filters diode laser light for backside illumination of SLM photoconductive layer. This controls SLM spatial pattern and thereby controls spatiotemporally shaped waveform.

Reflection-mode 2D SLM in Fourier plane filters selected frequency components dispersed in horizontal dimension and selected spatial or wavevector components separated in vertical dimension. Filtered light is reflected back toward grating.

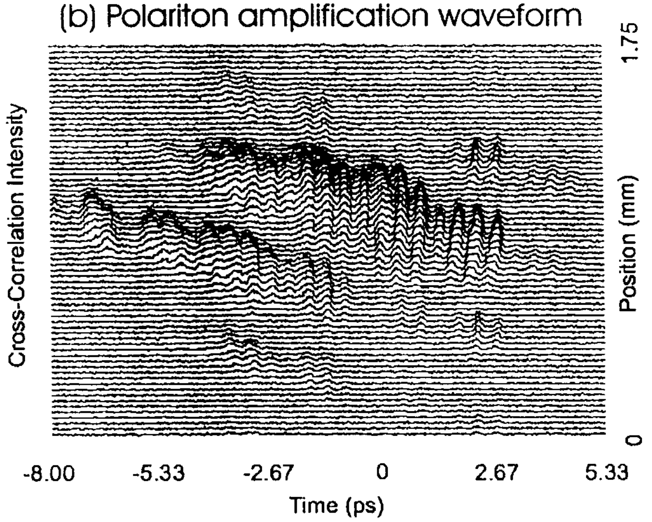
Figure 4. Spatiotemporal coherent control (automated)

(a) Automated spatiotemporal control system



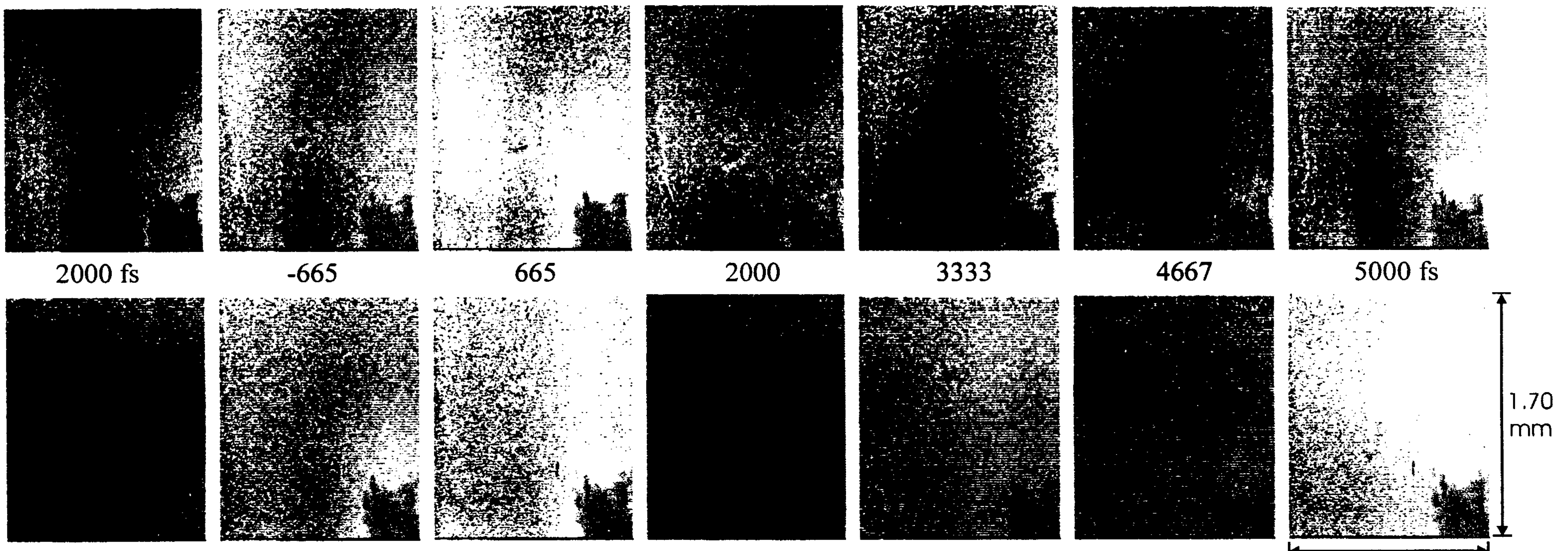
Preliminary results of an integrated system (a) for automated spatiotemporal coherent control. The waveform used (b, central region) has a series of more than 12 spatially and temporally shifted pulses. (Unwanted, weaker replica waveforms appear at shorter and longer times.) The pulses, focused to round spots, move along the $LiTaO_3$ sample (downward in part c) generating weak polariton "rings" (as in Fig. 2b) whose leading edges are amplified when the polariton group velocity is matched (top set of images).

(b) Polariton amplification waveform



(c) Automated spatiotemporal polariton control: Preliminary results

Excitation spots move along crystal at polariton group velocity: Coherent polariton amplification



Excitation spots move along crystal faster than polariton group velocity: No coherent amplification