Material Processing
Using Ultrashort Light Pulses with Tilted Front

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Abstract: Femtosecond laser writing in glass is controlled by the polarization plane azimuth and intensity front tilt of light pulse. Polarization dependent distribution of extraordinary modifications along the light propagation direction is observed.

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Strong dependence of the refractive index and absorption change in glass on the propagation direction [1] and polarization [2] of the ultrashort light pulses has opened new horizons in the modification of the transparent solids with ultrafat lasers. Here we provide further experimental evidence that glass modifications can be controlled by the mutual orientation of the polarization plane azimuth and the intensity front normal of the light pulse. Moreover polarization dependent distribution of modifications with unusual features along the light propagation direction is observed.

In experiment, we employed a mode-locked, regeneratively amplified Ti: Sapphire laser system operating at 800 nm with 70 fs pulse duration and 250 kHz repetition rate. A linearly polarized laser beam was focused via a 50X (0.80 N.A.) microscope objective at normal incidence and a depth of about 60 μm below the surface of the alumosilicate glass (composition SiO_2 64, Al_2O_3 17, B_2O_3 5, CaO 15 wt%) sample. We wrote a series of dots in the sample with a different polarization direction for each dot at the pulse energy of about 2.4 μJ. Inspection of the structures under optical microscope revealed that at certain orientation of polarization azimuth, a strong coloration of the irradiated region was accompanied by asymmetrically distributed bubbles at its boundary (Fig.1).

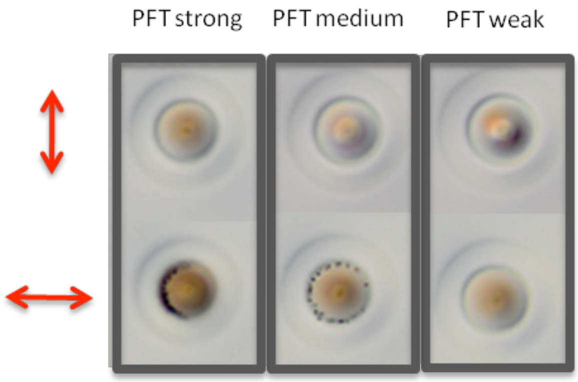

Fig. 1. Dots written with orthogonal polarizations and three different PFT values.

The spatiotemporal properties of the laser beam were characterized using a GRENOUILLE device. The measurements revealed Gaussian profile of the intensity, and a small pulse front tilt (PFT). The PFT can originate from independent (i) angular dispersion and (ii) simultaneous spatial and temporal chirp [3]. However, since in our experiment we did not observe astigmatic focal spots, which are conventionally caused by the angular dispersion, we believe that the latter contribution to the PFT is negligible. Being identically zero in the focus, the PFT is proportional to the beam diameter and can be significantly increased in the vicinity of beam waist. One can estimate that in our experiment, the tilt is as high as 20 fs/mm at 10 µm before the geometrical focus. The tilt angle can be further increased by plasma dispersion and reach tens of degrees in the regions where the strongest glass modification was observed.

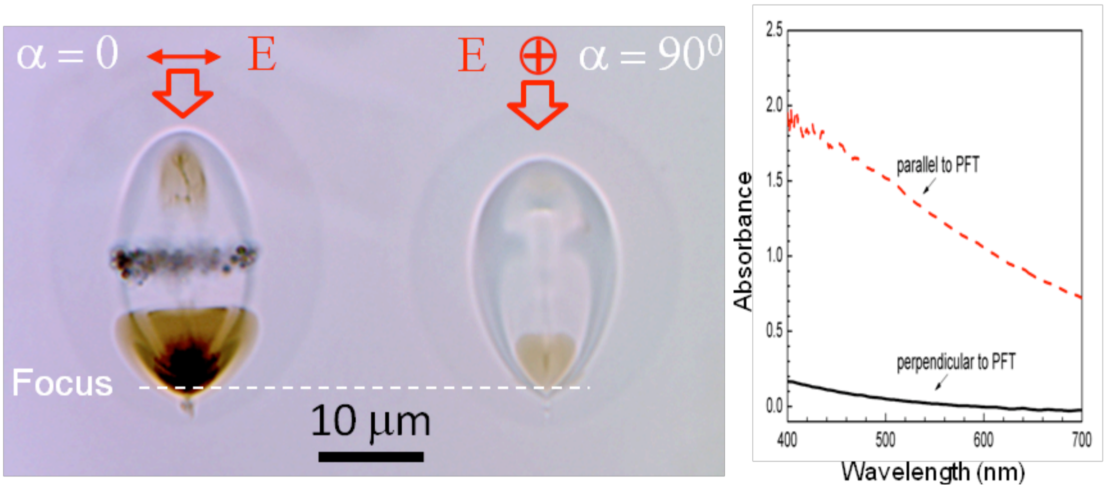

Fig. 2. Images of modified regions along beam propagation direction for writing beam polarised along (α = 0; left) and perpendicular (α = 90°; middle) to the pulse intensity front normal with corresponding absorption spectra (right). Number of pulses is 10^6.

Cross-sections along the beam propagation direction (Fig. 2) shows that the strongest modifications occur before the geometrical focus of the beam and that modification morphology differs dramatically for beam polarized parallel and perpendicular to the PFT Specifically, one can observe from Fig. 2 that when the beam was polarized along the PFT, the regions of strong coloration in the tail and head of the imprinted structure were accompanied with the bubble belt in the middle. An

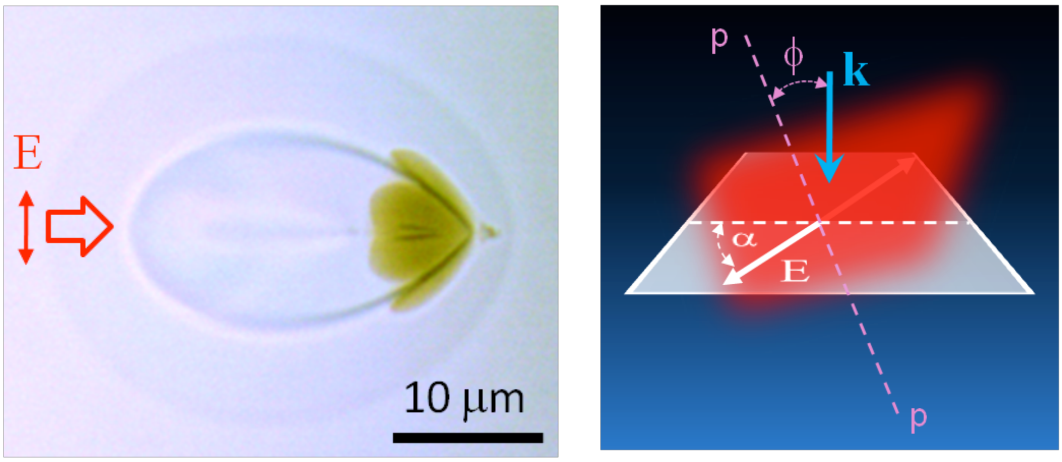

Fig. 3, Image of glass region modified with the beam polarised perpendicular to the PFT (α = 90°): Coloured flower-shaped region is formed near beam focus (left). Illustration of the tilted ultrashort pulse (right).

extraordinary, colored flower-shaped structure was also observed for the beam polarized perpendicular to the PFT (Fig. 3).

In conclusion we demonstrate that the stronger PFT in the ultrashort laser pulse, the stronger anisotropy in the light-affected area of the glass (Fig.1). The obtained results provided further proof that the tilt in intensity front of the pulse is responsible for the observed optical anisotropy.

References

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