

New phenomena in ultrafast laser micro-processing: from quill to non-reciprocal writing

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Modification of transparent materials with ultrafast lasers has attracted considerable interest due to a wide range of applications including laser surgery, integrated optics, optical data storage, 3D micro- and nano-structuring [1]. Three different types of material modifications can be induced with ultrafast laser irradiation in the bulk of a transparent material, silica glass in particular: an isotropic refractive index change (type 1); a form birefringence associated with self-assembled nanogratings and negative refractive index change (type 2) [2,3]; and a void (type 3). In fused silica the transition from type 1 to type 2 and finally to type 3 modification is observed with an increase of fluence. Recently, a remarkable phenomenon in ultrafast laser processing of transparent materials has been reported manifesting itself as a change in material modification by reversing the writing direction (Figure 1a) [4]. The phenomenon has been interpreted in terms of anisotropic plasma heating by a tilted front of the ultrashort laser pulse. Moreover a change in structural modification has been demonstrated in glass by

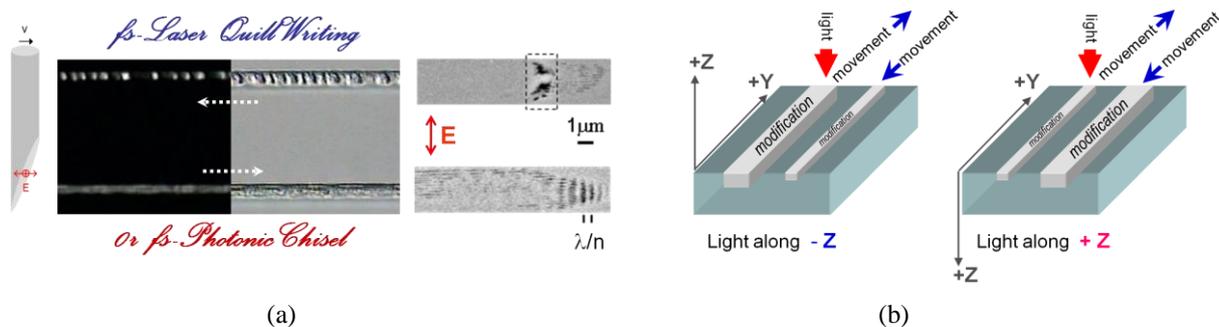


Figure 1 New phenomena in ultrafast laser writing. (a) Femtosecond laser quill writing in silica glass. (b) The illustration of non-reciprocal laser writing in lithium niobate - KaYaSo effect.

controlling the direction of pulse front tilt, achieving a calligraphic style of laser writing which is similar in appearance to that inked with the bygone quill pen [5]. It has also been a common belief that in a homogeneous medium, the photosensitivity and corresponding light-induced material modifications do not change on the reversal of light propagation direction. More recently it has been observed that in a non-centrosymmetric medium, modification of the material can be different when light propagates in opposite directions (KaYaSo effect, Figure 1b) [6]. In particular, when the direction of the femtosecond laser beam is reversed from +Z to -Z directions, the structures written in lithium niobate crystal when translating the beam along the +Y and -Y directions are mirrored. This is the first evidence of a new optical phenomenon of non-reciprocal photosensitivity. We interpret this effect in terms of light pressure and associated heat flow resulting in a temperature gradient in homogeneous media without inversion symmetry under uniform intense irradiation. Non-reciprocity is produced by magnetic field (Faraday effect) and movement of the medium with respect to the direction of light propagation: parallel (Sagnac effect) or perpendicular (KaYaSo effect). We anticipate that the observed phenomena will open new opportunities in laser material processing, laser surgery, optical manipulation and data storage.

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