Ultrafast light blade: Anisotropic sensitivity of isotropic medium to femtosecond laser radiation

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Material processing with ultrafast lasers has recently attracted considerable interest mainly due to a wide range of applications including laser surgery and 3D micro- and nano-structuring. However, we have recently demonstrated that in-depth investigation of the processes occurring in condensed medium in presence of intense ultrashort laser pulses opens new insight on the light-matter interaction at high intensities. In particular, we discovered that photosensitivity of non-centrosymmetric crystal is not necessary reciprocal [1], i.e. the light-induced modification depends on light propagation direction. We observed also strong dependence of the isotropic glass modification on the orientation of writing direction relative to the direction of pulse front tilt (quill writing effect) [2]. These effects indicate that at high intensities, a homogeneous illumination can produce essentially inhomogeneous modification in the medium, i.e. the presence of the hidden anisotropy in the light-matter interaction at high intensity. However until now this anisotropy manifested itself only when laser beam moves with respect to the sample. The question of fundamental importance is can this anisotropy manifest itself in the conventional material processing, i.e. when femtosecond light beam interacts with non-moving sample. One may recall that until now only two types of optical anisotropy have been identified. The first one is attributed to anisotropy of material structure being inherent, e. g. in crystals or externally produced e. g. by stress. Another type assigned to anisotropy of geometric structure, e. g. anisotropy of Fresnel reflections or form birefringence, is produced by macro or sub-wavelength scale interfaces and gradients of material. Here we demonstrate experimentally that uniform illumination an isotropic homogeneous medium can give rise to its inhomogeneous modification, i.e. the new mechanism of the optical anisotropy that manifests itself at ultrahigh intensities. Specifically, we observe dependence of the refractive index and absorption coefficient induced by intense ultrashort light pulse in an isotropic glass on the orientation of the polarization plane azimuth. This new phenomenon originates from the absorption anisotropy of electron plasma produced by the femtosecond light pulse with tilted intensity front [3]. Our results present the evidence of new type of collisionless heating mechanism [4] arising at the oblique interface produced by the pulse front tilt. We would like to point out that the observed anisotropic photosensitivity is intrinsic property of the light-matter interaction at high intensities. We anticipate that the observed phenomenon, which offers the orientation of a light polarization plane relative to the direction of pulse front tilt as a new tool to control interaction of matter with ultrashort light pulses, will open new opportunities in laser material processing, optical manipulation and data storage. We refer the observed phenomenon as ultrafast light blade, drawing an analogy between material modification produced by ulrashort light pulse with tilted front and cutting with a blade.

References

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