Photoinduced anisotropy and related phenomena in glass irradiated with ultrashort pulses

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New phenomena of light scattering and Cherenkov third-harmonic generation peaking in the plane of polarization during direct writing with ultrashort light pulses in glass have been reported. These observations were unexpected because the scattering of polarized light in the plane of light polarization in isotropic medium such as glass is always weaker compared to the orthogonal plane, since a dipole does not radiate in the direction of its axis. The phenomena were interpreted in terms of angular distribution of photoelectrons and sub-wavelength anisotropic index inhomogenities. Another experiments demonstrated uniaxial birefringence of structures in fused silica written by femtosecond light pulses. The index change for light polarized along the direction of polarization of writing beam was much stronger than for the orthogonal polarization. The origin of this anisotropic phenomenon remained a mystery. Recently we observed a further anisotropic property in silica after being irradiated by a femtosecond laser – strong reflection from the modified region *occurring only along the direction of polarization of the writing laser*. We show this can arise from a self-organized periodic sub-wavelength refractive index modulation. We speculate they arise from a mechanism associated with the creation of a hot electron plasma by multiphoton absorption of incident light. Anisotropic index inhomogeneities are then induced by electrons moving along the direction of light polarization. Self-organized nanostructures are in turn produced by a pattern of interference between the incident laser radiation and a plasmon-polariton wave generated within the sample. Positive feedback leads to exponential growth of the periodic nanostructures in the plane of light polarization, which become frozen within the material. The femtosecond-laser-induced birefringence is therefore likely to be caused by these laterally-oriented small-period grating structures. Birefringence of this nature is well known as 'form' birefringence. Our analysis suggests that this effect is also the primary cause of all anisotropic phenomena reported in the experiments on direct writing with ultrashort pulses in glass. The anisotropic phenomena and micro-reflectors described here should be useful in many monolithic photonic devices and can be harnessed for information storage, MEMS applications or quasi-phase matching where nanoscale periodic structuring is required.