Femtosecond laser nano-structuring in transparent materials: from bulk to fiber lasers

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Progress in high power ultra-short pulse lasers has opened new frontiers in the physics of light-matter interactions and laser material processing. Recently there has been considerable interest in the application of femtosecond lasers to writing inside transparent materials and in particular to fabrication of three-dimensional microstructures. The research in this area has lead to the discovery of the phenomena of anisotropic scattering and reflection of light from regions modified by laser irradiation that evidences the creation of periodic plain structures with the period smaller than the wavelength of light and oriented perpendicular to the laser polarization [1]. Self-organized nanostructures also explain the unusual negative birefringence of the regions subjected to femtosecond laser writing [2]. The emergence of periodic nanostructures was also observed under a scanning electron microscope [3-5]. Surface periodic sub-wavelength structures have been reported in many experiments on laser material processing. Our results provided the first evidence for periodic nanostructures in bulk transparent materials. Self-organized nanostructures are the smallest (with 20 nm thickness of plain regions) and the strongest (with -0.2 index change) periodic structures ever produced by light inside transparent materials. In this talk we review the results of experiments on nano-structuring with a regeneratively amplified Ti:sapphire laser (Coherent Rega) and with an amplified Yb fiber laser (IMRA-FCPA μJewel D-400) [6], as well as the results of theoretical studies of the mechanism of nanostructure formation based on two plasmon decay and bulk plasmon wave interference.

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