Self-organisation in glass by light: from second-order nonlinearity to 3D nano-structures

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The physics and applications of self-organised periodic structures in glass ranging from the second-order nonlinearity gratings produced by intense infrared irradiation to the periodic sub-wavelength structures induced by intense femtosecond light pulses are reviewed.

Summary

Glass dominates modern optical technologies. Nonlinear optical processes, such as second-harmonic generation and parametric frequency conversion, are technological very attractive and require a second-order optical nonlinearity - a $\chi^{(2)}$, which is normally absent in glass owing to its inversion symmetry. Thus, when light-induced frequency doubling was first discovered wide-ranging studies ensued into the mechanism and properties of this unexpected phenomenon. The mystery of self-organized $\chi^{(2)}$ gratings was finally solved on the basis of a new physical phenomenon - the coherent photogalvanic effect, consisting in quantum interference between light fields at two different frequencies, ω and 2ω, which excites a phase dependent current (coherent photocurrent). Coherent photocurrent creates quasi-phase matching $\chi^{(2)}$ gratings. Moreover in the experiments on electric-field second harmonic generation in optical fibres the first evidence of phase dependent modulation of a total cross-section of ionization due to quantum interference (coherent photoconductivity) in solid state materials has been obtained [1].

Another interesting field demonstrating unusual light-matter interactions and properties of materials is modification of index of refraction and direct writing of photonic structures by ultrashort light pulses in glass. A critical advantage of using femtosecond pulses relative to longer pulses for optical writing and data storage is that such pulses can rapidly and precisely deposit energy in solids. This is the principle of femtosecond photosensitivity and 3D direct writing of photonic structures ranging from 3D waveguides to embedded Fresnel zone plates. This research has led to demonstration of new phenomena – anomalous anisotropic light scattering and form birefringence in glass [2]. The anisotropic phenomena have been interpreted in terms of self-induced index nano-gratings in glass and self-organized form birefringence, which is a new manifestation of self-organization under intense irradiation. The observed self-organized periodic structures are the smallest (20 nm width) and the strongest (-0.2 index change) ever created by light in transparent materials. Moreover these are the first gratings created by light-matter (electron plasma) interference [3]. In the talk unusual behavior of glass subjected to intense light fields involving appearance of self-organised structures is reviewed.

References

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