Light craft: creating unusual properties in glass with light

Peter Kazansky
Optoelectronics Research Centre, University of Southampton,
Southampton, SO17 1BJ, UK

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-rangin 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 I review the craft of creating unusual properties in glass with intense light fields.

[1] Phys. Rev. Let. **78**, 2956 (1997)
[2] Phys. Rev. Lett. **82**, 2199 (1999)
[3] Phys. Rev. Lett. **91**, 247405 (2003)

•Professor Peter G. Kazansky was appointed in 2001 to a new chair leading "Physical Optics" group within the Optoelectronics Research Centre at the University of Southampton. He received a M.Sc. degree in Physics from Moscow State University in 1979 and a Ph.D. under supervision of Nobel Laureate for the invention of laser A.M. Prokhorov from the General Physics Institute in 1985. He was awarded the Leninskii Komsomol Prize in 1989 for the pioneering work on "Circular photogalvanic effect in crystals" (which concerns conversion of photon angular momentum to charge carrier momentum). From 1989 to 1993 he led a group in the GPI which unravelled the mystery of a new optical phenomenon – light-induced frequency doubling in media with inversion symmetry. He was awarded the title Senior Research Fellow in "Physical Electronics" in 1992. From 1992 he was awarded a Royal Society Fellowship at the ORC, where he is now pursuing his interests in new optical materials such as poled glasses, photosensitivity, femtosecond direct writing, nanotechnology, integrated atom optics and quantum information research. He is Vice-Chair of the TC-20 Technical Committee on Glasses for Optoelectronics of ICG, the International Commission on Glass.