Anisotropic micro-reflectors in glass by femtosecond laser machining

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Recently, the use of a focused femtosecond laser to directly write devices into the bulk of glass has become increasingly prevalent [1]. The physical damage created by such lasers, especially in the high power regime has been identified to display anisotropic properties such as anomalous anisotropic light scattering [2] and uniaxial birefringence [3]. So far, the microscopic processes underlying such anisotropies remain unclear. By writing embedded structures with a Ti:sapphire laser (repetition rate 250kHz, pulse duration 150fs, λ=850nm, and beam width ~1.5μm), we have identified a further anisotropic property in silica – strong reflection from the modified region occurring only along the direction of polarization of the writing laser. Our analysis suggests that this effect is also the primary cause of all previously reported anisotropic phenomena. Fig. 1, which shows a schematic of embedded diffraction gratings and an array of 'dots' written into a silica plate, demonstrates the geometry of the phenomenon. We believe that the anisotropic reflectivity can only be explained as a consequence of Bragg reflection from a self organized periodic structure, produced by interference between the incident laser radiation and a plasmon-polariton wave generated within the sample. This is demonstrated in the magnified region of Fig. 1 which shows the structure within a single 1.5μm 'dot'. Figure 2(a) shows a microscope image of the edge of an array of 'dots'. Here, the writing polarization is directed out of the page. The observed anisotropic reflectivity (1% per 1.5μm 'dot') can be compared to Figure 2(b) which shows no reflection from the same object, viewed from an orthogonal direction. The spectrum given in Fig 2(c) shows the peak of reflection to be 460nm, indicating that the self organized structures have a characteristic period of ~150nm, and modulating refractive index variation of amplitude $\Delta n \sim 10^{-2}$.

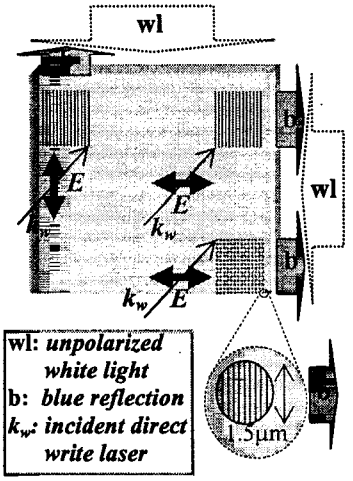

Fig.1. Anisotropic reflection from embedded structures. The magnified region illustrates the self-organized periodic structuring

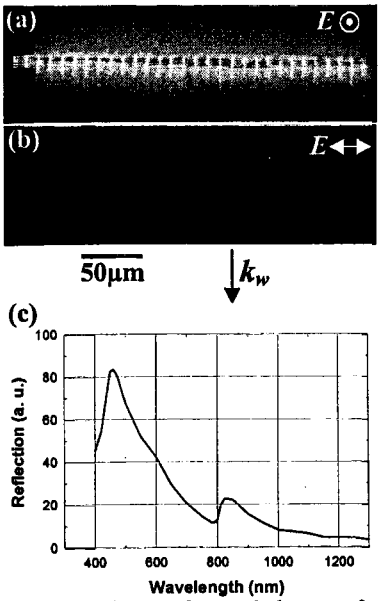

Fig.2. Reflection from a 2-d array of 'dots' in directions (a) parallel and (b) perpendicular to writing laser. (c) Spectrum of reflection.

[1] K.M. Davis, K.Miura, N. Sugimoto, K. Hirao, Opt. Lett. **21**, 1729-1731 (1996)

[2] P.G. Kazansky, H. Inouye, T. Mitsuyu, K. Miura, J. Qiu, K. Hirao, Phys. Rev. Lett. **82**, 2199-2202 (1999)

[3] L. Sudrie, M. Franco, B. Prade, A. Mysyrowicz, Opt. Comm. **171**, 279-284 (1999)