Functional Birefringent Elements Imprinted by Femtosecond Laser Nanostructuring of Multi-Component Glass

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A decade ago, a new type of self-organization process was observed in the bulk of SiO_2 glass after irradiation with ultrashort laser pulses [1]. Under certain irradiation conditions, highly ordered nanostructures with features smaller than 20 nm could be formed in the irradiated volume. The sub-wavelength arrangement of these structures results in form birefringence, which was recently exploited for demonstrating a variety of functional optical elements in silica glass [2]. Despite excellent physical and chemical properties of fused silica, the applications of this glass are limited due to the expensive manufacturing process associated with high melting temperature. Recently the evidence of laser-induced nanogratings in glasses other than SiO_2 was reported, including GeO_2 glass [3], binary titanium silicate glass (ULE, Corning) and multicomponent borosilicate glass (Borofloat 33, Schott) [4]. However, birefringence induced in borosilicate glass was more than one order of magnitude lower than in pure SiO_2 glass.

Here, we demonstrate functional optical elements imprinted by femtosecond laser nanostructuring in the bulk of multicomponent alumo-borosilicate glass. Optimised experimental conditions allowed reaching 200 nm retardance (an equivalent of a quarter-wave for 800 nm), which is comparable to the value induced in silica glass. As a demonstration, we imprinted a micro-converter for generating a radially polarized optical vortex in the bulk of AF32 glass. Additionally, we observed ultrafast laser induced birefringence in low-melting sodium borate glasses ($\geq$ 20 mol.% Na_2O), which have physical and chemical properties significantly different from high-silicate glasses.

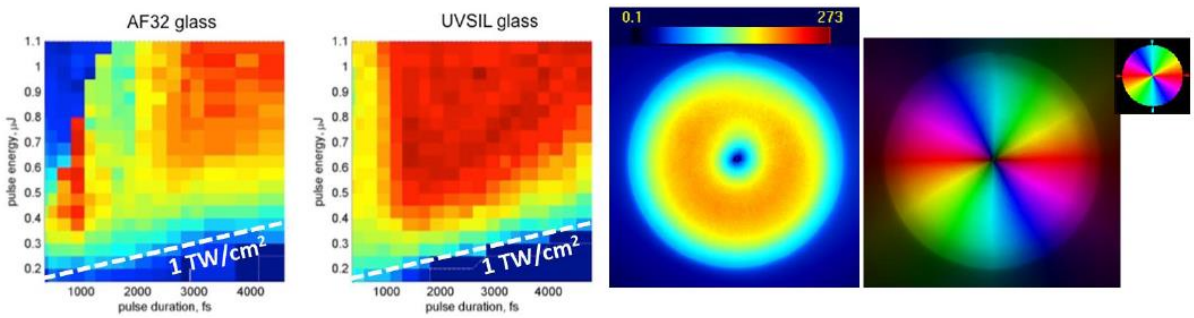

Fig. 1 Retardance as a function of pulse duration and energy measured for borosilicate glass AF32 and silica glass UVSIL. Quantitative birefringence measurements of 100 μm diameter converter imprinted in the bulk of AF32 glass.

Our preliminary results indicate that nanogratings in different glasses are formed above a certain energy threshold, which increases with the pulse duration, indicating that the threshold depends on the intensity and not on the amount of deposited energy, i.e. fluence. We estimated the intensity threshold of about 1 TW/cm^2, which is independent on the material composition (Fig. 1). However, the birefringence in multicomponent glasses could be observed only after depositing over 30 000 pulses. This could be related to lower melting temperature of borosilicate glass (working point temperature 1225°C) and sodium borate glasses (<800°C) as compared to fused silica (1800°C). This can also explain the absence of nanogratings and related birefringence in the mulicomponent glasses when the pulse energy was increased above energy threshold of 0.65 μJ. The presented results will help to elucidate the self-assembly process, its dependence on the physical parameters and extend the applications of ultrafast laser nanostructuring of glass.

References

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