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Ultrafast Laser Modification of Inorganic Glasses

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Consider the interaction between visible or near-infrared laser light with a “transparent” material, such as glass. Under normal conditions, i.e continuous low power illumination, the glass will transmit the light. However, when ultra-short pulses of modest energy of this same light (for example 100 fs, 1 μJ laser pulses) are tightly focused into a micron-size spot, very high, localized (in space and time) intensities, on the order of 100 TW cm^{-2} are obtained. Under these conditions the laser-materials interaction becomes highly nonlinear and can result in permanent changes in the structure of the glass. Since these high intensities are only achieved at the focal point of the laser beam, the effective nonlinear interaction and subsequent modification only occurs locally, i.e. within a confined region limited by the size of the focal volume. By moving the sample with respect to the laser focus it is possible to “write” 3-D patterns inside the glass. The structure of the modification patterns can differ from the unmodified material in a wide variety of properties including refractive index, absorption coefficient, nonlinear optical susceptibility, crystal structure, morphology etc. Applications of this so-called fs laser writing technique are in optical data storage, telecommunications and bio-sensing and –imaging. The experimental tools that are used for modifying the material can in a different implementation also be used to optically and spectroscopically characterize a material with high spatial resolution. In this talk I will review the basics of ultrafast laser modification of glass and present our results on optical waveguide fabrication in a variety of inorganic oxide glasses. I will discuss the behavior of the different glass systems and show how confocal laser fluorescence and Raman spectroscopy help us understand the relationship between the index changes and the associated changes in the atomic scale structure of the glass.