

Femtosecond direct writing of embedded photonic structures

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In the last few years, femtosecond lasers have proven to be of great utility for micromachining within the bulk of transparent materials and this processing technique has attracted much attention due to its simplicity compared to lithographic methods and its ability to write in three-dimensions [1]. When an intense femtosecond laser pulse is tightly focused into transparent material, high-order non-linear absorption allows the energy to be deposited predominantly within the focal volume producing a local permanent refractive index modification.

A regeneratively amplified mode-locked Ti:Sapphire laser (200 fs pulse duration, 250 kHz repetition rate) operating at wavelength tunable between $\lambda=800$ nm and $\lambda=850$ nm and focused by a 50 \times or 10 \times objective was utilized to effect all the writing processes. The samples were translated with a computer controlled stage relative to the laser focus. For the experiments fluence per pulse up to 74 J/cm² ($I \sim 4 \times 10^{14}$ W/cm²) and scan speeds of up to 400 μ m/s were utilized. Using this setup one and two-dimensional gratings (1 μ m up to 20 μ m period) embedded in silica glass plates and within the cleaved face of single-mode optical fibres have been written. In the latter case, the controllability of the power and direction of diffracted orders may offer new possibilities for optical routing. We have also written large diameter maskless birefringent Fresnel zone plates [2] embedded deep within silica glass substrates. This offers the possibility of writing multiple lens systems in three-dimensions producing rigid and environmentally tolerant devices.

Finally we have identified the 3 main properties (birefringence [3], anisotropic reflection [4] and negative index change) apparent in transparent materials after being irradiated by an amplified femtosecond laser system above a certain fluence threshold. Experimental evidences prove that those properties are correlated and a theoretical model has been developed to offer a consistent explanation.

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