PhD thesis:

Spatiotemporal shaping of ultrafast laser-induced shockwaves for material phase transformations

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Description: Today, we use lasers to generate conditions similar to those in hot cores of stars and planets on a tabletop optical experiment. To do so, we employ ultrashort laser pulses capable of generating extremely high optical intensities in the 10^{14} W/cm^2 range. At such intensities, an initially-transparent material transforms locally into a dense plasma. Strong pressure-temperature gradients build up inside the volume of the irradiated area that result in a violent decompression through emission of a shockwave [1]. Stress generated by the passage of the shockwave inside a material may permanently change its structure and laser-transform it in a new denser phase. A plethora of novel applications would then become possible (MEMS, MOEMS etc.) within a direct microfabrication technique with 3D abilities.

The object of this thesis is to use laser-driven shockwaves to modify fused silica glass. A spatial light modulator will be used to transform a Gaussian beam into a Bessel-Vortex beam with variable ring thickness and diameter. A simultaneous temporal control of the laser pulse delivery will allow optimal conditions to be met for undamped shockwaves to propagate into the solid and selectively modify matter into new phases. These new phases should allow among others increased refractive index engineering paving the way towards monolithic fabrication of photonic devices. The structures will be characterized by state-of-the-art techniques including transmission electron microscopy and X-ray diffraction in collaboration with academic collaborators in Australia and Japan. The recruited student will use an existing setup at LP3 as a starting block that is used for the generation and characterization of Bessel beams [2]. This setup uses the ASUR laser facility at LP3 delivering infrared (λ=800 nm) pulses with 30 fs pulse duration and a pulse energy of 15 mJ.

This project is an excellent opportunity to develop skills in a multidisciplinary field of Physics (Plasma Physics, Lasers, Thermodynamics, Mechanics etc.) and engineering. The student should have a strong background in Optics and/or Materials Science. A taste for experimental physics is necessary. Funding has already been acquired from the National Research Agency.

[1] O. Koritsoglou, D. Loison, O. Uteza, and A. Mouskeftaras, "Characteristics of femtosecond laser-induced shockwaves in air," *Opt. Express*, vol. 30, no. 21, p. 37407, 2022.

[2] X. Liu, R. Clady, D. Grojo, O. Utéza, and N. Sanner, "Engraving Depth-Controlled Nanohole Arrays on Fused Silica by Direct Short-Pulse Laser Ablation," *Adv. Mater. Interfaces*, vol. 2202189, p. 2202189, 2023.