Ultrashort vs. Shorter vs. Shortest:
The Impact of Pulse Duration on Direct Laser Photoinscription in Fused Silica

In tight focusing conditions, ultrashort pulses provide electric fields able to initiate the production of a (quasi) free carrier plasma even in wide bandgap dielectrics such as fused silica. As the plasma density reaches 10^{19}-10^{21} cm^{-3}, the lattice begins to soften. The plasma plays the role of an energy reservoir, driving structural changes including for instance point defect formation, microdensification, or thermoelastic stress. These modifications lead to a permanent refractive index in the irradiated volume.

In fused silica, a judicious choice of irradiation parameters (numerical aperture of the focusing unit, pulse duration, wavelength, repetition rate, etc...) enables the photoinscription of homogeneous, positive refractive index changes known as Type I modifications. These modifications are particularly appealing for the production of waveguide chips by simple translation of the sample with respect to the focus [1].

Direct laser writing (DLW) offers several advantages over traditional methods, including photolithography: it is inherently three-dimensional, eliminates the need for a cleanroom, and is well-suited for rapid prototyping. Nevertheless, to compete with established methods, the propagation (and coupling) losses of DLW-fabricated waveguides must be minimized. This problem is well identified and recently, losses as low as ~0.07 dB/cm have been reported by using advanced multipass schemes [2, 3] or UV femtosecond pulses [4].

In this talk, I will emphasize the role of the pulse duration on the plasma formation, the plasma dynamics, and the resulting irradiation products when operating in the Type I modification regime. In particular, we will compare the effect of 300 fs produced by a fiber laser (aka Ultrashort pulse) with those of with a few-cycle pulses (aka Shorter pulse) and a near single single pulse (aka Shortest pulse).

References:

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