Volumetric modification of fused silica with double laser pulses: the effect of pulse separation on energy deposition

Nadezhda M. Bulgakova[1,*], Vladimir P. Zhukov[2,3], Martin Zukerstein[1], Olga Fedotova[4], and Thibault J.-Y. Derrien[1]

[1] HiLASE Centre, Institute of Physics ASCR, Za Radnicí 828, 25241 Dolni Brezany, Czech Republic
[2] Federal Research Center for Information and Computational Technologies, 6 Lavrentyev Ave., 630090 Novosibirsk, Russia
[3] Novosibirsk State Technical University, 20 Karl Marx Ave., Novosibirsk 630073, Russia
[4] Scientific and Practical Materials Research Center, Belarus NAS, Brovky 17, 220072 Minsk, Belarus
*Corresponding author email: bulgakova@fzu.cz

Volumetric modification of dielectrics by ultrashort laser pulses is a complex phenomenon involving material photoexcitation and associated nonlinear processes. To achieve control over modification, it is necessary to gain a deep insight into the dynamics of laser-excited processes that can be realized using double-laser-pulse experiments with different time separations supported by numerical simulations. In this work, we investigate fused silica modification by double femtosecond 800-nm laser pulses separated in time in femto- and picosecond scale [1]. It is shown that the laser-generated free-electron plasma causes a shielding effect for the following pulse with a characteristic duration of ~600 fs after the pulse action. Within this time interval, the second pulse produces a reduced modification as compared to a longer time separation between pulses. For double pulses with different energies, it was found that the volumetric modification is stronger when a lower-energy pulse couples with material first (Fig. 1). This is explained by the combination of the effects of the re-excitation of self-trapped excitons, which are generated as a result of free electron recombination and associated light shielding. Experimental results are supported by numerical simulations of double laser pulse propagation in nonlinear media based on Maxwell's equations. Our findings offer a route for better controlling the inscription of 3D photonic structures in bulk optical materials.

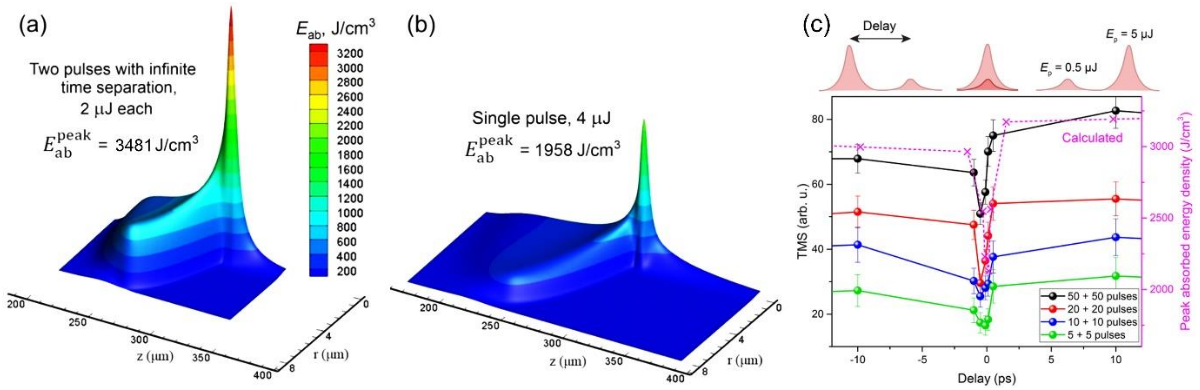

Figure 1: Calculated distributions of the absorbed energy density in fused silica after the action of two laser pulses 2 μJ each with infinite time separation (a) and one 4-μJ laser pulse (b). Other irradiation parameters and the color scale are the same. (c) Experimental data on transmission microscope signal (TMS) for double-pulse irradiation vs delay between two pulses (accumulation of 5, 10, 20, and 50 double pulses). Modeling data on the peak absorbed energy density are also given. Negative delay time is for the more energetic pulse coupling with the sample first.

References: [1] M. Zukerstein, V.P. Zhukov, et al. submitted to Optics Express.