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LASER ABLATION OF AMORPHOUS SiO_2 BY ULTRA-SHORT PULSES OF XUV FREE ELECTRON LASER

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The interaction of ultrashort laser pulse with dielectric materials involves the processes that can lead to surface ablation, resulting in minimal aside damage. For sufficiently high carrier densities (>10^{21} electrons/cm^3) dielectric breakdown occurs, eventually in the form of the ablation of the thin surface layer. The investigations realised in the last decade have lead to better clarity of the interaction mechanism by studying the influence of the pulse duration [1-6] and the material [7-10] on the ablation threshold. The differences in the results demonstrate that many questions referred to ablation of dielectric materials by ultrashort pulses remain open as before.

In this work we provide a research of ablation threshold value in the most widely studied dielectric material, fused silica. Structural modifications were induced with the intense XUV femtosecond pulses generated by the TESLA test facility free electron laser (TTF FEL) at DESY, Hamburg. The investigated samples were irradiated during a few following phases of the experiment with different wavelength of the radiation. The experimental data are quoted in Table 1.

Effects of the laser ablation were studied by means of the interference microscopy. Typical pictures of the modified surfaces are shown in Fig. 1 and Fig. 2. We started an analysis with the determination of the areas of the ablated regions by means of an integrating program. The threshold fluency was obtained from studies of the damage area as a function of the laser pulse energy. This investigation has been performed according to a procedure suggested by Liu [11].

For laser pulses with a Gaussian spatial beam profile, the laser fluence F_0 and the diameter D of the modified area are related by [12, 13]

$$D^2 = 2\omega_0^2 \ln(F_0 / F_{th}) \qquad (1)$$

where F_{th} is the fluence threshold value (threshold value is the value of energy density for this surface structure of the ablated area is modified) and ω_0 being the 1/e^2 beam radius.

Laser fluence can be calculated from the relation between Gaussian beam radius and the measured pulse energy

$$F_0 = 2E_{pulse}/\pi\omega_0^2 \qquad (2)$$

As a result of varying of the laser pulse energy at constant pulse duration different diameters of the damage spots are obtained. For a Gaussian shaped beam the dependence can be obtained from a plot of the squared outer damage diameter D^2 versus the incident energy of the laser pulse in logarithmical scale due to Eq. 1. From the slope of a linear fit we can calculate the value of ω_0. In this moment we can calculate the laser fluency F_0 on the surface. The threshold fluency F_{th} we determined via linear extrapolation of D^2 to 0.

Table 1. Wavelengths of the laser radiation generated during Phase 1 ÷ Phase 3 of the ablation experiment with TTF FEL.

	Phase 1	Phase 2	Phase 3
wavelength [nm]	32	13.2	7

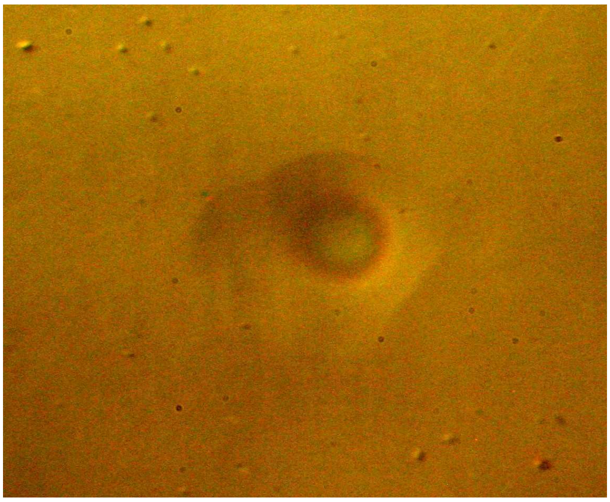

Figure 1. Typical shape of the crater created in fused silica by femtosecond ablation in single-shot regime.

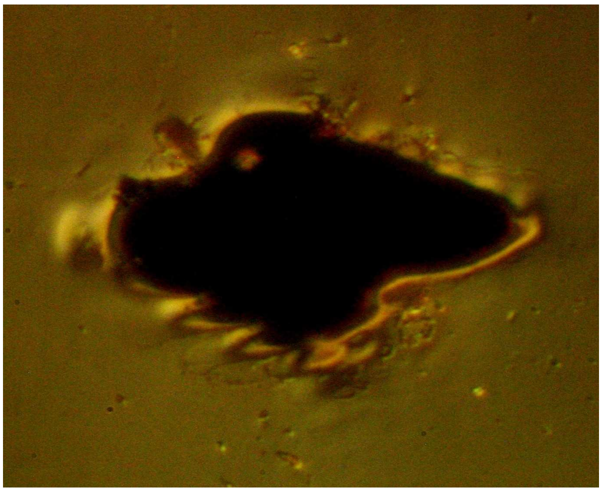

Figure 2. Typical shape of the crater created in fused silica by femtosecond ablation in multi-shot regime.

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