Evolution of optical properties of surfaces under influence of ultra-short pulses of intense EUV radiation

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Recent experiments at FLASH have shown that a multilayer mirror still reflects the damaging femtosecond pulse at fluences that far exceed the ablation threshold [1]. A natural question immediately arises: on what time scale will the optical properties still be preserved? To answer it a single-colour pump and probe transmission experiments was performed.

We investigated the change of a transmission through sample under influence of ultra-short pulses of intense EUV radiation. The wavelength was 13.5 ± 0.2 nm, pulse duration - 25 ± 5 fs and its intensity up to ~10^{14} W/cm^2. The irradiated sample was a thin (50 nm) silicon nitride foil covered on one side with MoSi multilayer mirror. The primary EUV beam excited the sample to maximal energy densities up to a few tens of eV/atom. But, since the sample thickness was comparable with absorption length, part (~35%) of the pulse energy was transmitted. It was next back-reflected by another multilayer mirror and passed again through the excited sample volume, this time as a probe beam with reduced intensity (~3% of the primary beam intensity). The distance between the sample and the back-reflecting mirror was adjustable, so the probe was delayed with respect to primary beam by a time in the range of ~350 fs to 2.8 ps. The probe beam intensity was measured with the EUV CCD camera (see Figure 1) placed far away from the sample. The same detector measured a part of the primary beam reflected from the sample. Since the intensity of this beam didn't depend on the sample excitation it could be used to monitor the incident beam intensity for the normalization pupose (as a reference).

After the irradiation the sample was studied using optical microscope. For high intensity pulses holes due to ablation were observed.

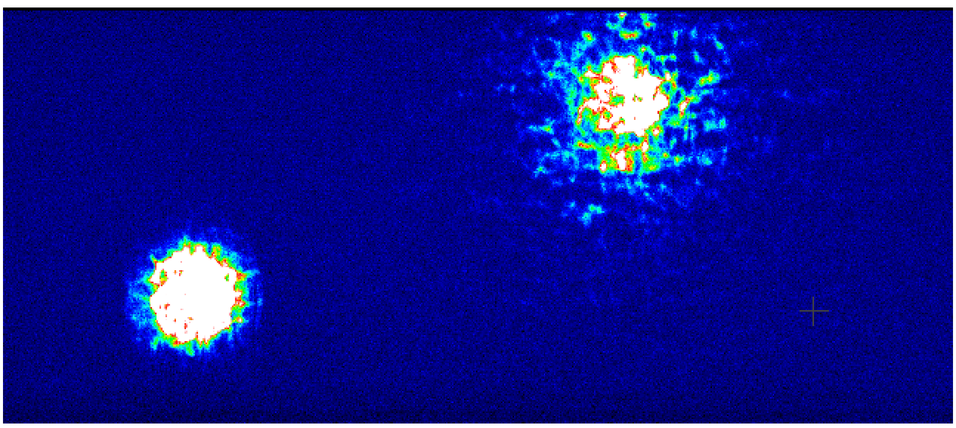

Figure 1: Pictures from the EUV CCD camera. The spot on the right side is a reference, while the spot on the left side is a probe signal. Time delay is equal ~350 fs.

The experiment was performed for various pulse energies (excitation energy densities) and time delays in the whole available range. The intensities of the transmitted probe beam were measured by integration of the CCD signal over the spot area. They were next normalized to the reference beam intensity, to obtain a signal proportional to the transmission of the excited sample volume.

The preliminary results are presented on the Figure 2. The main conclusion is that no significant changes of optical parameters over the whole measured time delay range were observed. A possible small trend (decrease of the mean signal from ~1.6 to ~1.4 [a.u.]) lies within error bars of the measurement. Also some outliers were observed, for which the intensities ratio was even lower then 1 (they are not shown on the figure 2). Most probably they are due to background reduction procedure and normalization of weak signals.

Another interesting observation is that at time delay equal ~ 1.7 ps low intensity (excitation to low for the ablation of the sample) data have similar values as the high intensity one. It means that the optical parameters probably don't depend on pulse intensity at that time.

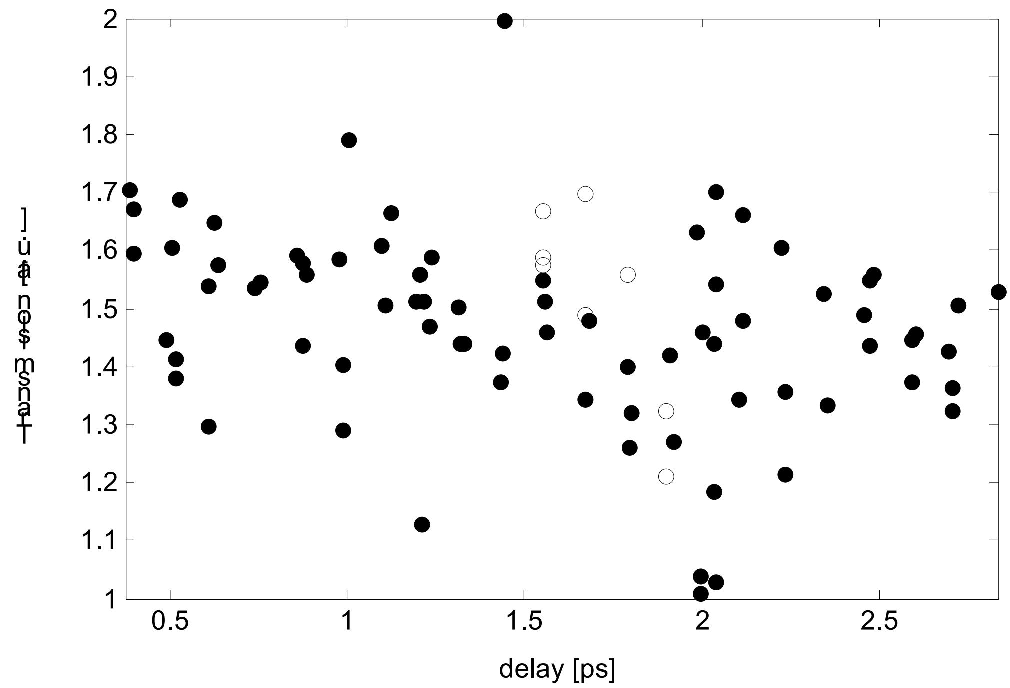

Figure 2: Transmission of the probe beam through the excited sample volume for various time delays. Two series of data are presented. Filled circles correspond to pulse intensities high enough for the damage of the sample. The empty circles correspond to low pulse intensities and excitations to low for ablation of the sample.

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References

[1] S.P. Hau-Riege et al., submitted to Phys. Rev. Lett., 2006