Optical characterization of FEL multilayer optics damaged by multiple pulse laser beam

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Fermi@Elettra is a Free Electron Lasers (FEL) user facility under construction at Sincrotrone Trieste in Italy. It will produce extremely high-intensity ultra short pulses of almost fully coherent and transform limited monochromatic radiation in the VUV/Soft X-rays range (12-413 eV, peak-power 1-5 GW) [1].
The damage on the FEL optics surfaces induced by the very high optical fluencies and short pulses duration is a challenging problem [2]. We performed some tests to understand the basic mechanisms responsible of the optics degradation.
A Si capped multilayer Mo/Si/B4C, optimized to work at 45° in the EUV spectral region, have been exposed in air to a multiple short pulse laser (= 400 nm, pulse duration ~ 200 fs at 100 Hz) with three different fluencies. Three different damages spots have been induced on the sample with energy of 50, 100, and 150 μJ for single pulse with an estimated spot dimension of about 200 μm. We have investigated the optical performances of the three different areas of the multilayer at the BEAR beamline @ Elettra[3,4]. The specular reflectivity at the Bragg peak at 100 eV, 800 eV, and 1600 eV drastically decreases between the first two expositions, and therefore a damage threshold between 160 and 320 mJ/cm^2 can be individuated. For the higher fluencies, the diffuse scattering increases with the rising of off-specular peaks, indicating the increasing of surface and interfacial roughness.
In parallel, measurements for surface, sub surface, and buried interfaces characterization (interdiffusion) have been performed by means of X-ray photoemission spectroscopy, X-ray Absorption Spectroscopy , and standing wave enhanced buried interfaces study (see for example [5]). AFM and microscopy measurements have also been done.

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