



## Formation of high-spatial frequency LIPSS on metals probed by fs-time-resolved small-angle X-ray scattering

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Fourth generation light sources, such as the European X-ray Free-Electron Laser (EuXFEL, Schenefeld, Germany) offer the unique capability to probe laser-driven structure formation at extreme scales in space and time. The extremely short probe wavelength allows to spatially resolve even the sub-100-nm sized *high-spatial frequency LIPSS* (HSFL).

Femtosecond time-resolved small-angle X-ray scattering (fs-SAXS) experiments have been conducted in transmission geometry on thin titanium films (100 – 300 nm) deposited on a silicon wafer frame array of thin Si<sub>3</sub>N<sub>4</sub>-membrane windows as substrate. These sample windows were irradiated with single or multiple linearly polarized 50 fs, 400 nm laser pulses (angle of incidence  $\theta \sim 10^\circ$ ) and probed in transmission under normal incidence with temporally delayed 25 fs, 1.5 keV X-ray pulses. At laser pump fluences exceeding the ablation threshold, the transient scattering signatures of HSFL and LSFL were identified for s- and p-polarized pump pulses and tracked for probe delay times up to a few nanoseconds.

The fs-SAXS patterns were compared to efficacy factor calculations of the optical absorption of a microscopically rough titanium surface using J.E. Sipe's first-principles theory of LIPSS. Additionally, numerical Finite-Difference Time-Domain (FDTD) simulations coupled to a two-temperature model (TTM), a solver of the Navier-Stokes equations (NSE), and the Equations of State (EOS) were performed to follow the material relaxation dynamics in momentum space.

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