



Nanoscale structural dynamics by extreme ultraviolet transient gratings

Bencivenga F^{(1)*}, Foglia L⁽¹⁾, Masciovecchio C⁽¹⁾, Mincigrucci R⁽¹⁾

(1) Elettra-Sincrotrone Trieste, Basovizza (TS), Italy

*Corresponding author's email: Filippo.bencivenga@elettra.eu

The coherent pulses of the FERMI seeded free electron laser (FEL) have permitted the development of the transient grating (TG) approach in the extreme ultraviolet (EUV) spectral range [1-3]. The implementation of FEL-pump/FEL-probe capabilities in EUV TG experiments allows to generate TG with spatial periodicities as short as 20 nm and probe the response on the investigated sample on ultrafast timescales [4].

The capability to generate spatial patterns of light on such a fine length-scale has relevant applications in probing dynamical processes on mesoscopic (10's of nm) scales, hardly accessible by other means. In this lecture we will provide examples of applications of this new experimental tool, in particular for nanoscale thermal transport in thin membranes of crystalline silicon and amorphous silicon nitride [4], where the thermal decay time of the nanoscale TG shows a marked deviation, with respect to the diffusive regime, in the crystalline sample. Conversely, in the amorphous sample the wavelength dependence of the thermal transport timescale is consistent with a diffusive behaviour. We will also highlight the possibility to use EUV TG to generate and detect the dynamics of bulk and surface phonons on previously inaccessible wavelength range [4-5].

We finally discuss on the potential of EUV TG in other contexts, such as, e.g., ultrafast magnetic dynamics at the nanoscale [6], as well as the ongoing development, which include the capability to use hard x-rays for TG excitations [7].

References

- [1] F. Bencivenga et al., Four-wave mixing experiments with extreme ultraviolet transient gratings, *Nature* 520 (2015) 205.
- [2] L. Foglia et al., First Evidence of Purely Extreme-Ultraviolet Four-Wave Mixing, *Phys. Rev. Lett.* 120 (2018) 263901.
- [3] A.A. Maznev et al., Generation of coherent phonons by coherent extreme ultraviolet radiation in a transient grating experiment, *Appl. Phys. Lett.* 113 (2018) 221905.
- [4] F. Bencivenga et al., Nanoscale transient gratings excited and probed by extreme ultraviolet femtosecond pulses, *Science Advances* 5 (2019) eaaw5805.
- [5] A.A. Maznev et al., Generation and detection of 50 GHz surface acoustic waves by extreme ultraviolet pulses, *Appl. Phys. Lett.* 119 (2021) 044102.
- [6] D. Ksenzov et al., Nanoscale Transient Magnetization Gratings Created and Probed by Femtosecond Extreme Ultraviolet Pulses, *Nano Lett.* 21 (2021) 2905.
- [7] J.R. Rouxel et al. Hard X-ray Transient Grating Spectroscopy on Bismuth Germanate, *Nature Photonics* 15 (2021) 499.