Nanoscale dynamics probed by extreme ultraviolet transient gratings

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FERMI is a worldwide unique free electron laser (FEL) source, designed to operate in the extreme ultraviolet (EUV) and soft x-ray range using an external laser seeding scheme. Such a scheme permits to generate ultrafast pulses with high brightness and coherence; moreover, it has allowed the development of special operation modes, such as multi-pulse/multi-wavelength FEL emission.

These capabilities have been applied in several contexts, ranging from coherent control in molecules [1] to EUV four wave mixing (FWM) [2-4]. In particular, non-collinear EUV FWM experiments carried out in the transient grating (TG) geometry are used to explore the so-called *mesoscopic* (10's of nm) length-scale range [4], hardly accessible by other means. Here we report on such novel experimental capabilities, which have been exploited for probing collective atomic dynamics at 10's of nm wavelengths and thermal transport processes down to the "single-digit" nm scale [4,5]. In such a regime we found that thermal transport in crystalline silicon is strongly non-diffusive, while in amorphous silicon nitride it is still compatible with a classical diffusive behaviour [4].

Applications of the EUV TG approach in other fields are also envisioned, as for instance in the study of mesoscopic structural relaxations in liquids and ultrafast magnetic dynamics at the nanoscale; the latter has been recently demonstrated [5,6]. We finally stress that these FWM experiments, carried out by exclusively using EUV pulses and time-resolved, represent an advance in the general context of developing the x-ray FWM approach, so far only theoretically conceived [7].

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