Structured ultrafast high-harmonic pulses

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Abstract

Coherent extreme-ultraviolet/soft x-ray pulses structured in their temporal (attosecond), spectral (line spacing) and angular momentum (polarization and topological charge) properties is nowadays possible thanks to high harmonic generation. In this talk we review our recent work in the generation and control of ultrafast structured harmonic pulses through the use of infrared driving beams with custom angular momentum properties.

Whereas angular momentum can be routinely transferred to visible/infrared (IR) light beams using waveplates, or spatial light modulators, among other techniques, it becomes a lot harder in the extreme-ultraviolet EUV/ x-ray regimes, where those techniques are inefficient. This challenging goal is very much worth the effort: imprinting spin (SAM) and/or orbital (OAM) angular momentum into the EUV/x-ray regimes will bring the applications of structured light down to the nanometric and ultrafast scales.

Among other x-ray sources such as x-ray free electron lasers or plasma-based soft x-ray lasers, high-harmonic generation (HHG) stands as a robust mechanism to generate highly spatially and temporally coherent radiation from the extreme-ultraviolet (EUV) to the soft x-ray regimes [1], with exquisite temporal accuracy in the attosecond regime [2]. Remarkably, such control is acquired through a highly nonlinear up-conversion process, where the properties of an infrared driving field are mapped into high-frequency harmonics. However, such mapping process is far from trivial. Fortunately, during the last decade it has been demonstrated that HHG offers a unique opportunity to provide high-frequency structured ultrafast pulses through such up-conversion mechanism.

In this contribution we will review the recent advances in the generation of structured coherent EUV/soft x-ray pulses through HHG. In particular, the use of structured driving beams with controlled SAM or OAM has opened exciting opportunities to harness the properties of the high-order harmonics in an unprecedented way [3].

One of the most appealing advances of HHG is the generation of high-order harmonics and attosecond pulses with controlled polarization—from linear to circular—due to their potential application in the study of chiral media and magnetic materials. Among a wide variety of different techniques [4], non-collinear HHG has allowed the generation of circularly polarized isolated attosecond pulses [5], which has also enabled to access the most fundamental dynamics of HHG through ellipsometry [6].

On the other hand, the use of driving field configurations with custom OAM is opening novel control opportunities over the properties of the high-order harmonics. The generation of attosecond vortices with controlled polarization [7]; high harmonic pulses with time-dependent OAM or self-torque [8]; attosecond pulse trains with time-ordered polarization states [9]; or low-divergence harmonic combs with controlled frequency line spacing extending into the soft x-rays [10], represent some of the most exciting advances. In addition, the perspective of the application of such structured schemes to HHG driven in solid systems [11], is opening very interesting avenues for the study of ultrafast electronic dynamics.

Achieving complete control over the generation of coherent ultrafast x-ray sources with custom angular momentum properties is nowadays possible thanks to HHG. It represents a significant advance towards the quest of capturing the fastest electronic and spin dynamics in a wide variety of materials.

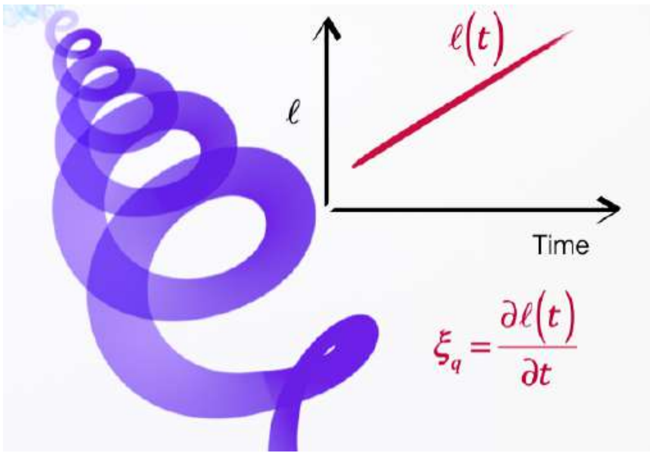

Figure 1: Representation scheme of an ultrafast pulse with self torque (dℓ/dt), carrying a subfemtosecond variation of its topological charge (ℓ) through the high-frequency EUV laser pulse [8].

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