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Multiscale modelling of HHG and its applications for phase-matching optimisation

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Synopsis We present a multiscale approach to model high-harmonic generation in gaseous media. Such a treatment is indispensable for a quantitative description of phenomena emerging from the interplay of the microscopic response of a single microscopic emitter, and the macroscopic profile of the driving beam propagating in a generating medium. In particular, we address phase-matching controlled by pre-ionising the medium.

High-order harmonic generation (HHG) is a workhorse tool of attosecond science. Our intention is to have a comprehensive computational picture of HHG in a gas phase. Such a picture requires to couple two scales: 1) The macroscopic model of the driving pulse strongly affected by a nonlinear propagation, 2) A single microscopic system – an atom or a molecule interacting with the pulse – described naturally by quantum physics.

We develop a fully numerical multi-scale model by coupling the numerical code for computing the non-linear pulse propagation [1], 1-dimensional Time-dependent Schrödinger equation [2], and diffraction-like XUV propagation based on Hankel transform [3]. Figure 1 illustrates the flowchart of the numerical model. This model is applied for the numerical treatment of HHG at ELI Beamlines [4]. It has been already used in [5,6].

In this contribution, we focus on the control of phase-matching in long media [5]. An external pre-ionisation mechanism allows for setting an optimal degree of ionisation to achieve ideal phase-matching along the propagation. In particular, we confirmed an 8-fold enhancement of H17 in krypton. This result was in good agreement between theory and experiments. We explain this scheme in more detail and complement our model with simple analytical considerations, which provide further insight into underlying physics.

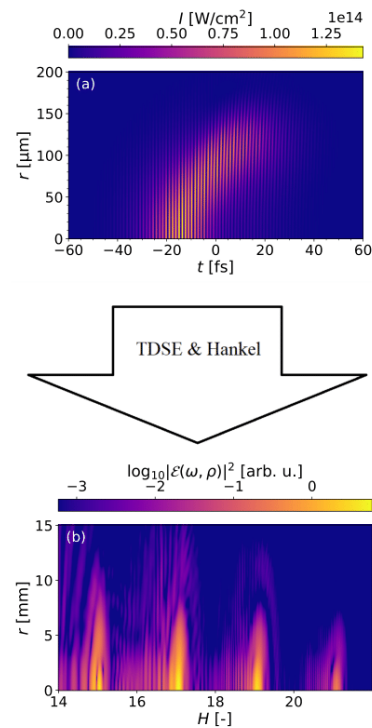


Figure 1. The flowchart of the multiscale model computation. (a) Shows a distorted Gaussian pulse (both in time and space) at 800 nm after the passage through a 15-mm long gas cell filled by Krypton (50 mbar). The field from the whole interaction volume is then processed to obtain a spatially resolved far-field (5 m) spectrum (b). This example corresponds to the HHG scheme from [6].

References

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