

Two-electron effects in HHG and strong-field physics

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This PhD project focuses on multielectron effects in HHG and related strong-field phenomena. The three-step model [1] provides a simple and intuitive picture of the process: a valence electron is i) ionised by the laser field, ii) accelerated back towards the parent ion, and iii) recombines, producing XUV radiation. A more accurate description, however, requires a quantum-mechanical treatment. The main directions of the project are: 1) microscopic studies, 2) numerical implementation of codes and their use on supercomputers, and 3) multiscale modelling including the effects of macroscopic laser propagation.

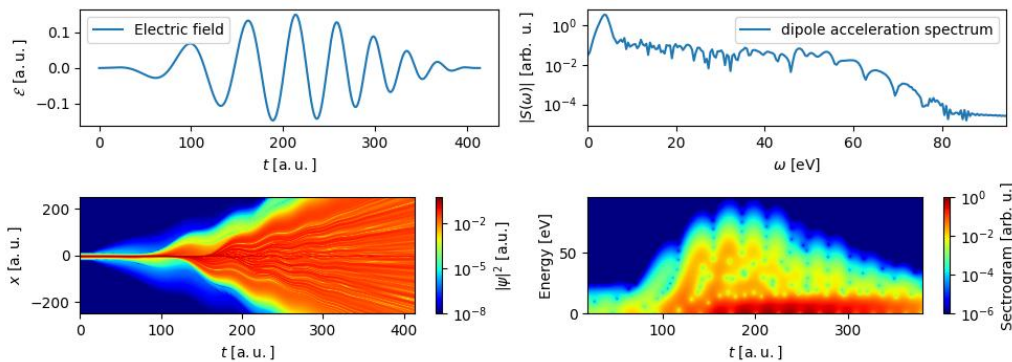


Figure: an example of diagnostic of a microscopic HHG process using single active electron approach in simplified 1D-geometry. The panel shows a sample electric field, the second panel shows the spectral content $|S(\omega)|$ of the produced radiation. The third panel shows the probability distribution given by the electron's wavefunction $|\psi(x,t)|^2$. The last panel shows the time-resolved energetic distribution (spectrogram) according to the spectrum $|S(\omega)|$.

In the microscopic part, we will use a fully numerical approach based on solving the TDSE. For a single electron, the geometry can be reduced to one dimension (1D). A computationally feasible extension is the 1D+1D geometry, which includes electronic correlation. Later, we aim to move towards the full 3D+3D case. The main physical topics of interest include HHG, and we will also extend the analysis to the ionisation process [2] and HHG in these regimes [3] and [4]. In addition, multielectron effects may play an important role in THz generation [5]. The student is expected to develop their own codes, integrate existing open-source tools [6]-[8], and benchmark and adapt them for our needs.

In the broader context of the project, the student will also become a member of the development team of the multiscale modelling package for HHG: <https://mma-hhg.github.io/> This will make it possible to use this toolbox to study macroscopic effects in the HHG process. The work will proceed in several steps. It will begin with a weighted coherent sum of the signals from neutrals and ions. Then, the multielectron TDSE will be used to provide a more accurate description and identify the intrinsic multielectron effects discussed above. Although HHG including ions has already been reported [3], its fully macroscopic description in more complex

scenarios remains challenging. The multiscale package will allow us to study and optimise [9] this case systematically, for example by examining XUV wavefronts [10].

The project will benefit from close collaboration with experimental teams working in HHG, both at the Department of Laser Physics and Photonics and at ELI ERIC [10], one of whose facilities is located near Prague. The work will therefore be well motivated and relevant for practical laboratory applications [11].

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