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PhD assessment report: Jan VABEK
'Multiscale approach to the description of high-harmonics generation in gases'

High harmonic generation (HHG) in gas phase media raised strong interests since 2001 with its first experimental demonstration as a source of attosecond pulses, the shortest flash of coherent light ever achieved. HHG results in gas from the interaction of a strong laser field and atoms. The phenomenon has been extensively studied experimentally and theoretically providing more and more insight in the phenomenological description of the process. The PhD thesis of Jan Vabek investigates the description of the HHG process with a multiscale approach. By multiscale approach, Jan Vabek intends to provide a full numerical description of the HHG phenomenon in gas phase, including full microscopic and macroscopic descriptions. The originality of the modelling approach lies as well in the implementation of a modular architecture of the modelling in response to the versatility these sources can now offer and with regards to a balance between accuracy of the description and computational cost. The work presented has also a viewpoint of offering open access calculation which now more and more in demand. The approach is original and required without any doubt a large range of skills and developments Jan Vabek clearly demonstrates, which was supported by the alliance of the two institutions, aka Prague and Bordeaux, for supporting the PhD work of Jan Vabek.

The PhD manuscript is presented in eleven chapters organised in Parts:

An introduction gives the motivation of the work presented and a state of art of multiscale modelling for HHG.

Chapter 1 provides the pre-request knowledge for the PhD manuscript and investigation presented.

Part1 comprises chapter 2 & 3 that describe the microscopic interaction of strong fields with single atom for HHG. Part 1 dedicates a non-exhaustive, yet necessary, description of the ionisation process incurred, and it describes the Strong field approximation model and its validity. Chapter 3 in particular shows a deep understanding on pros and cons of full 3D solvers.

Part2 comprises chapters 4, 5 & 6 and it provides a very clear macroscopic description of HHG. Chapter 4 focuses on the interplay of micro-macroscopic description. Chapter 5 explores the generation of HHG and the inherent propagation of the XUV light in thin targets. Chapter 6 gives the full multiscale model approach provided by Jan Vabek. This chapter is remarkably well written and provide a full insight in his approach to the next description of HHG.

The results obtained were compared to experimental results and prove to be very efficient on discovering new route to the generation with new control of the XUV wavefront and phase matching in long media. In the former, an emphasis is made on the novelty wavefront control can drive such as 'lens free' focusing of the HHG. The latter investigates the idea of pre-ionised media that would benefit to the phase matching and the HHG signal.

Part 3 is dedicated to exploration of numerical consideration in the proposed model. It comprises chapters 7 to 10 Chapter 7 re-visit the microscopic description 1D and 3D, including TDSE numerical methods, discretisation, convergence and time propagation. Chapter 8 and 9 explore the propagation of the driving field and the XUV field employing the famous Hankle transform for calculating the far field distribution. Chapter 10 is the convergence of all the modules developed and explore the synergy and the optimisation of the multiscale approach. Finally, Part4 presents the conclusions of the work and open to perspective suggested by the author.

The thesis manuscript offers appendices with great details and very useful to the understanding of the development and architecture choice.

As a conclusion, the work presented by Jan Vabek is of very good quality and interesting in many regards: from the description of HHG approach to the architecture of the code itself. The results show clear applications of such a code towards investigating new schemes for HHG. The results presented are original and consists of material already published or in term to be published. The manuscript is of good quality and properly organised. The use of the bibliography is also very much adequate and useful.

Therefore, I hereby acknowledge the quality of the work conducted by Jan Vabek in is PhD study and I recommend and authorised the PhD thesis of Jan Vabek to be defended further at a PhD defence in due time.

Dr Amelle ZAIR

10th of November 2022