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Referee report on PhD dissertation of Felipe Cajiao Velez

Mr Felipe Velez submitted the PhD dissertation on "Engineering and Control of Quantum Processes by Short Laser Pulses" that was written under supervision of dr hab. Katarzyna Krajewska. The auxiliary supervisor was dr Agnieszka Jaroń-Becker. The dissertation bases on two scientific articles, one in Phys. Rev. A journal, the other in J. Phys.: Conf. Ser., and on the results which have not been published so far. Mr Felipe Velez presented also his research in four international conferences.

The first chapter of the PhD thesis constitutes a short introduction to strong laser field phenomena. The aim of Chapter 2 is to introduce the formalism that allows for description of single-electron ionization of atoms by means of laser radiation and compare its prediction with other approaches. Mr Felipe Velez considers the so-called generalized eikonal approximation (GEA) that was introduced by prof. Jerzy Kamiński 30 years ago. Prof. J. Kamiński is also a co-author of all publications of Felipe Velez.

In Chapter 2 Mr Felipe Velez concentrates on the description of ionization of a Hydrogen atom by strong laser pulses. The generalized eikonal approximation is compared with the results obtained on the basis of the Keldysh approach. In the simplest version of the strong field approximation (SFA), the Coulomb interaction between the escaping electron and the parent ion is neglected. Mr Felipe Velez shows that the limiting case of the generalized eikonal approximation corresponds to a strong field approximation where the Coulomb interaction is taken into account within the first order of the Born approach. The comparison between the GEA and SFA is made in the case where a Hydrogen atom interacts with a series of a few short laser pulses. Such a perturbation results in an interference signatures in the energy spectra of ionizing electrons. In the considered problem the author applies also the saddle point approximation and tests its validity. The saddle point approach, that is a kind of the semiclassical approximation, allows one to interpret the ionization process as a result of interference of complex electronic trajectories. In

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my opinion, semiclassical approaches to single and multiple ionization processes, where on one hand one gains intuition from a classical picture and on the other hand obtains qualitative quantum predictions, is the optimal research direction to understand physics and discover new phenomena. The research of Felipe Velez goes in that direction. It is a pity he restricts himself to single electron problems that are quite well understood – for example the interference phenomena he observes have been already predicted, see e.g. Arbo et al. Phys. Rev. A 81, 021403 (2010). I wonder whether the GEA can be efficiently applied also to multi-electron processes? The results obtained in Chapter 2 by means of different methods are qualitatively the same but there are quantitative differences. I expect the GEA provides the most accurate predictions, however, that has not been tested in any nonperturbative numerical simulations.

In Chapter 3, the author switches to the problem of high-order harmonic generation in the interaction of atoms or molecules with strong laser radiation. The entire chapter is devoted to the introduction to the Lewenstein approach to the high harmonic generation phenomena. The original results of Felipe Velez are presented in Chapter 4 where the author analyzes high harmonic generation in the interaction of different isomers of C20 with a strong laser field. This is a very detail analysis performed in both length gauge and velocity gauge and for different orientation of the polarization axis of the incoming linearly polarized radiation with respect to the symmetry axes of the isomers. Also polarization properties of the generated harmonics are investigated. Similar analysis as for the C20 isomers is performed for N2 molecules too. Modulations of high harmonic spectra is explained in terms of interference effects related to multicentre nature of the systems and interferences of different electronic paths. Chapter 4 contains comprehensive analysis of the high harmonic generation for the C20 isomers. These results have not been published by the author at least at the moment when the PhD dissertation was submitted but maybe they are already prepared in the form of a scientific article?

I have two questions concerning this part of the thesis. The first is related to the discrepancy between the high harmonic spectra for the C20 ring isomer presented in Fig.4.5. Due to the symmetry of the isomer the spectra correspond to

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the same physical situation and they should be identical. The author writes that the discrepancy is related to a numerical error. However, the differences are visible in the logarithmic scale which means they are huge. It may question the validity of the approach. The obtained high harmonic spectra depend also on the gauge. The dependence on the gauge may happen when a perturbative approach is used but again one may ask which choice of the gauge is more trustworthy? The second question concerns the appearance of even harmonics in the spectra when atoms or molecules are displaced from the origin of the coordinate frame. It is very strange because for neutral systems dipole moment is independent of the choice of the origin. In any case the experimentally observed quantities can not depend on the choice of the coordinate frame.

Mr Felipe Velez wrote his PhD dissertation very carefully. It is hard to find any misprint – I could not. The author pays attention to all technical details of the applied approaches. He also provides very good background for the phenomena that are considered in the dissertation. It will definitely be a valuable source for anyone who would like to apply the eikonal approximation to strong field phenomena or to use the Lewenstein approach in an analysis of high-order harmonic generation. PhD dissertations that I had an opportunity to review usually concentrated on the results obtained by an author only. With respect to this the PhD thesis of Felipe Velez is a very nice positive exception. The author has broad knowledge about the strong field phenomena and he is able to forward his knowledge to others. Mr Felipe Velez should profit from the theoretical methods he has learnt. New scientific results have been already obtained and some of them are published. I am looking forward to seeing how he invests his knowledge in the future.

In conclusion, Mr Felipe Velez wrote a good PhD dissertation which meets all requirements needed for PhD degree and I recommend the dissertation for the defense in front of the respective committee.

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