Calculation of the strong field approximation term for the hydrogen atom excitation in intensive laser field

1. Introduction:

The problem concerns the theoretical study of laser-matter interaction, its mechanisms and manifestations. In the last three decades, we have witnessed incredible advances in laser technology and in the understanding of nonlinear laser-matter interactions, crowned recently by the award of the Nobel prize to Gérard Mourou and Donna Strickland. It is now routinely possible to produce few-cycle femtosecond (1 fs = 10^{15} s) laser pulses in the visible and mid-infrared regime. By focusing such ultrashort laser pulses on gas or solid targets, possibly in a presence of nano-structures, the targets are subjected to an ultra-intense electric field, with peak field strengths approaching the binding field inside the atoms themselves. Such fields permit the exploration of the interaction between strong electromagnetic coherent radiation and an atomic or molecular system with unprecedented spatial and temporal resolution. On one hand, High Harmonic Generation (HHG) nowadays can be used to generate attosecond pulses in the extreme ultraviolet, or even in the soft X-ray regime. Such pulses themselves may be used for dynamical spectroscopy of matter; despite carrying modest pulse energies, they exhibit excellent coherence properties. Combined with femtosecond pulses they can also be used to extract information about the laser pulse electric field itself. HHG sources therefore offer an important alternative to other sources of XUV and X-ray radiation: synchrotrons, free electron lasers, X-ray lasers, and laser plasma sources. Moreover, HHG pulses can provide information about the structure of the target atom, molecule or solid. Of course, to decode such information from a highly nonlinear HHG signal is a challenge, and that is why a possibly perfect, and possibly "as analytical as possible" theoretical understanding of these processes is in high demand. In this case, the Strong Field Approximation (SFA), which is the main theoretical tool here, and following approximations beyond SFA has to be carefully studied analytically and numerically.

2. Main part:

During the practice a student learns the main formulas, terms and units used in the laser-matter interaction physics. He also carries out independent calculations of the First Born (Dyson) term (FBA), which describes interaction of a finite in time laser pulse with the hydrogen atom and determines the population of an arbitrary hydrogen state at the end of pulse. To reach this objective, a student has to numerically calculate 3D integral with (highly) oscillating integrand. So, he has to study special numerical codes.

3. Description of the problem on the project:

See the page 3.

4. Requirements for the level of training of students:

Student has to know the main course of quantum mechanics, optics (including basic laser physics), has a practice in numerical calculations, and has a programming practice on Fortran and C++.

5. Recommended literature:

1. C. Joachain, N. Kylstra and R. Potvliege. Atoms in Intence Laser Fields (Cambridge university press, 2012).

2. K. Amini, et al. Symphony on Strong Field Approximation, arXiv:1812.11447v1 [quant-ph] 29 Dec 2018

3. A. Galstyan, O. Chuluunbaatar, A. Hamido, Yu.V. Popov, F. Mota-Furtado, P.F. O'Mahony, N. Janssens, F. Catoire, and B.Piraux, Phys. Rev. A 93, (2016) 023422.

4. Yu.V. Popov, A. Galstyan, F. Mota-Furtado, P.F. O'Mahony, and B.Piraux, Eur. Phys. Journal D 71 (2017), 93.

6. Number of project participants:

2 students are recommended.

7. Leader of project forom JINR:

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2. **Popov Yu.V.,** senior research of the BLTP, Candidate of Sciences in Physics and Mathematics