高次高調波によるアト秒 X 線パルスの増幅
Amplification of X-ray attosecond pulses

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研究成果概要

In 2021, as a continuation of our research performed in 2020, we have further investigated the amplification of attosecond pulses in helium. In 2020, the research was based on the single-electron numerical solution of the time-dependent Schrödinger equation (TDSE) for atomic processes in intense laser fields. The simulations performed with helium as amplifying medium provided interesting insight of the physical processes involved in the experimentally observed amplification around 100 eV, far from the ionization threshold of helium. An article reporting both theoretical and experimental results was published [C. Serrat, J. Seres, E. Seres, T-H. Dinh, N. Hasegawa, M. Nishikino and S. Namba, "Parametric attosecond pulse amplification from high order harmonic generation in He^{+} far from the ionization threshold.", Optics Express 28, 24243 (2020)].

In order to simulate propagation effects in parametric amplification process, during 2022 we have performed numerical simulations based on the single-atom response calculated by solving the 1D Schrödinger equation in the strong field approximation (SFA) in the nonadiabatic form, so that the full electric field of the laser pulse is used to calculate the nonlinear dipole moment. In these simulations, the generated HHG pulse train in Jet1 is calculated and used as seed XUV pulse together with the laser pulse in Jet2 considering different delays between them. Beyond the joint interaction of the laser and XUV pulse with the gas medium in Jet2, the propagation of them in the gas is also calculated. The HHG output from the first interaction in the Jet2 together with the seed and IR pulses are propagated and used as input for a second interaction with a second cell of He atoms. The process is repeated iteratively, so that propagation is described in a particle-in-cell simulation scheme. In order to fully consider the macroscopic effects associated to propagation, we have taken into account the regular phase mismatch associated to neutral gas and dispersion from the free electrons together with the geometrical phase mismatch due to the shape of the driving laser pulse, which arises primarily from the Gouy phase shift due to the focused laser beam. Neutral gas dispersion and absorption are calculated from the scattering cross sections (f_1 and f_2).

The simulations have ben compared with recently obtained results from the experiments and we have found a good agreement between theory and experimental measurements, demonstrating a new nonlinear effect on the parametric amplification produced by plasma dispersion. These results have been submitted for publication: J. Seres, E. Seres, C. Serrat, T. H. Dinh, N.

Hasegawa, M. Ishino, M. Nishikino, K. Nakano, and S. Namba, " Nonlinear propagation effect in x-ray parametric amplification during high harmonic generation.", (Submitted). https://arxiv.org/abs/2201.10966?context=physics

発表論文（謝辞あり）

"Nonlinear propagation effect in x-ray parametric amplification during high harmonic generation."
J. SERES, E. SERES, C. SERRAT, T. H. DINH, N. HASEGAWA, M. ISHINO, M. NISHIKINO, K. NAKANO, AND S. NAMBA
(Submitted).