Terahertz Emission of Atoms driven by Ultrashort Laser Pulses

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Synopsis Terahertz (THz) emissions of an isolated atom in an ultrashort (100 femtosecond) laser field are simulated by solving the time-dependent Schrödinger equation (TDSE). From numerical calculations, it can be concluded that continuum THz emissions occur more readily following transitions involving intermediate states above rather than those well below the ionization threshold of the system. The models are also used to describe the observed enhanced THz emissions with a superposed second order harmonic laser field or a spatially constant electric field. Strong field approximation is extended to analyze the general features of THz emissions resulting from continuum free-free transitions of an electron in strong laser fields.

Physical processes responsible for THz emissions have been studied extensively and most of the studies have been designed around a classical model, namely that transient electric currents are responsible for THz radiation both for laser-induced plasmas and laser-semiconductor interactions. Here we mainly talk about the THZ emission in the interaction of strong laser field and an atomic model by calculating the time-dependent Schröinger equation(TDSE) and get the results in accordance with the experiments.

It is first deduced from results with one-component laser fields that the excitations of electrons to continuum and high Rydberg states are essential for the generation of THz emissions as shown in Fig. 1. Transitions between the intermediate states lying above the ionization threshold of the atomic system are found to be much more effective for generating THz emissions than those states below the ionization threshold. This finding serves to enhance understanding of the behavior of an atom in intense laser fields since previous investigations often omit these continuum free-free transitions in the three-step model of HHG. Herein, an explanation, based on multiphoton transition processes, of how to substantially enhance THz emissions by mixing fundamental and second order harmonic laser fields[1] has been postulated. This mechanism, in light of a short-range shallow potential model, is shown to have all the usual low intensity four-photon mixing characteristics.

In support of the TDSE predictions about the THz emission processes, an analytical strong field approximation[2] is used to calculate the optical transition amplitudes between the continuum states. A biased electric field is also used to break the symmetry of the atomic system to facilitate the predominance of three-photon processes. This process enhances the THz emissions substantially and, consistent with previous studies, the dependence of the THz field strength on the applied electric fields is also predicted[3].

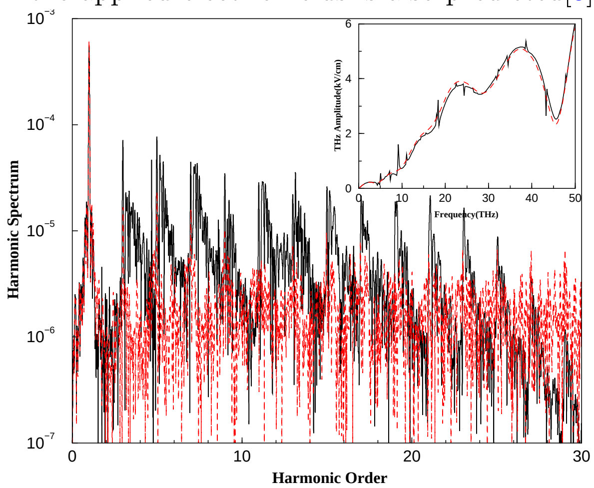

Fig. 1. The emission spectrum calculated from the whole states (solid line) and only the continuum states (dashed line) for the soft Coulomb potential. The spectrum in THz range is enlarged in the inset

References

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