Harmonic generation beyond the dipole approximation

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An atom interacting with an intense laser pulse emits high-order harmonics of the driving field. Termed high harmonic generation, this phenomenon has been actively studied in recent years. Many of the basic properties of high harmonic generation can be understood in terms of a three step model in which the electron ionizes by tunneling, oscillates in the laser field as a free electron and subsequently re-collides which the nucleus or atomic core [1].

At present, experimental studies of high harmonic generation by noble gases indicate that the shorter and more intense a laser pulse, the higher the harmonic order that can be produced. This is even true for pulses which are comprised of only a few optical cycles. It is therefore important to understand until what intensities this trend will continue. The magnetic field of the intense laser pulse will on the one hand tend to drive the oscillating electron away from the nucleus, thereby reducing harmonic generation efficiency. However, as opposed to the nonrelativistic case, relativistically driven free electrons can generate harmonics of the driving field without colliding with the nucleus.

We study the influence of the magnetic field and retardation effects on the generation of high-order harmonics by a single atom irradiated by an ultra intense ($> 10^{17}$ W cm^{-2}) laser field. Within the framework of the Klein-Gordon equation, we generalize non-relativistic models to account for both the coupling of the atom with the incident field beyond the dipole approximation and the relativistic dynamics of the electron in the laser field.

[1] For reviews, see C. J. Joachain, M. Dörr and N. J. Kylstra, Adv. At. Mol. Opt. Phys. **42**, 225 (2000); P. Salières, A. L'Huillier, P. Antoine and M. Lewenstein, Adv. At. Mol. Opt. Phys. **41**, 83 (1999); M. Protopapas, C. H. Keitel and P. L. Knight, Rep. Progr. Phys. **60**, 389 (1997).