Strong-field Below Threshold Harmonics

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Synopsis: We study the generation of below and near threshold harmonics in atomic gases, via calculations including single atom as well as macroscopic effects. Calculations in xenon indicate that the below threshold harmonics have multiple contributions, including one with a strongly intensity dependent dipole phase analogous to the well known long trajectory in above threshold high harmonic generation. We will also show preliminary results modeling absorption of the low energy harmonics in the presence of the strong IR field.

We study the production of below and near threshold harmonics excited in a gas of atoms by a short-pulse near-IR laser. Although the semi-classical model of high harmonic generation is not directly applicable to below threshold harmonics, results in xenon show that these harmonics still include a contribution with a strongly intensity-dependent dipole phase, analogous to the familiar long trajectory in above threshold harmonics [1]. Preliminary results modeling absorption of the below threshold harmonics in the presence of a strong IR field also allow us to explain the relative strengths of the harmonic orders.

Our method for calculating harmonic spectra by solving the coupled, non-adiabatic solutions of the single-atom time-dependent Schrödinger equation (TDSE) and the Maxwell wave equation for a gas of atoms is described in detail in [2]. However, the previously used approach of calculating the harmonic response via the strong field approximation (SFA) is insufficient for studying low energy harmonics where the atomic potential becomes increasingly important. We have instead developed a code which couples the solution of the wave equation to a direct numerical integration of the TDSE within the single active electron approximation [3]. This approach allows us to treat the laser electric field and the atomic potential on equal footing.

Calculations using this code in xenon with a driving wavelength of 1070 nm indicate that multiple generation processes contribute to the below and near threshold harmonics; one such process appears to be multi-photon in nature while another process is initiated by tunneling. The tunneling contribution, while strongly influenced by the atomic potential, still has an intensity-dependent phase that originates in laser-driven continuum dynamics similar to the above threshold harmonics.

The integration of the TDSE also provides information on single atom time-dependent ionization. This allows us to model the process of IR-assisted ionization due to absorption of below threshold harmonics. Figure 1 illustrates the effect this absorption has on the harmonic spectrum. In addition to studying the ionization process itself, we are able to more accurately model the relative strengths of the individual harmonics.

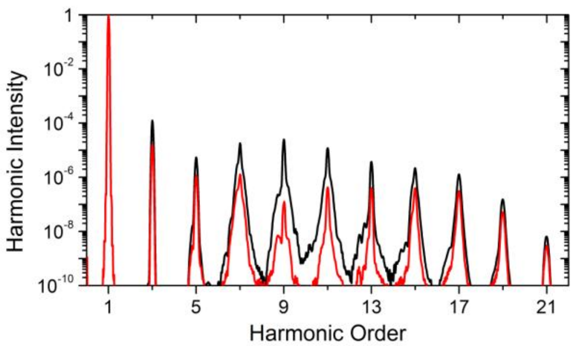

Fig. 1 (Color Figure) Harmonic spectrum in xenon with (red) and without (black) IR-assisted absorption of the harmonics.

References

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