Exploration of spectral and temporal fine structures of high-order harmonic generation[1]

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Synopsis We present an *ab initio* precision investigation of the time-frequency characteristics of high-order harmonic generation (HHG) calculated by solving accurately and efficiently the time-dependent Schrödinger equation by means of the time-dependent generalized pseudospectral method. We extend a new synchrosqueezing transform (SST) to obtain the time-frequency spectra of the HHG and the dynamical phase associated with the dipole-emission time profile. The SST time-frequency analysis allows us to explore the in depth dynamics and contributions of the multi-rescattering trajectories and resonant trajectories in HHG. It also exhibits the subtle details of the spectral and temporal fine structures of the HHG, providing novel insights regarding the dynamical origin of the HHG in below- and above-threshold regimes.

In the last several years, the study of high-order harmonic generation (HHG) is one of the most rapidly developing topics in strong-field physics [1]. Particularly, the HHG has been experimentally demonstrated to be a promising method to produce a unique source of coherent light in the extreme ultraviolet (XUV) and soft x-ray regions of the spectra, as well as for the generation of ultrashort attosecond laser pulse. The production of attosecond pulse represents a very important tool for the detection and control of the electronic dynamic behaviors [2]. Although the semiclassical three-step model can obtain the simple physical picture of the HHG, to account for the dynamical origin of HHG and attosecond pulse generation, it is necessary and valuable to also explore the spectral and temporal structures of the HHG from an *ab initio* simulations. This can facilitate the further experimental development of metrology for optimal control of attosecond pulse generation.

Recently, we have extended the synchrosqueezing transform (SST) method newly developed to explore the dynamical origin of the near- and below-threshold HHG simulated from an *ab initio* calculations [3] . By comparing with several other time-frequency transform methods, such as wavelet transform, the Gabor transform, and the Wigner-Ville transform, we find that the SST allows us to probe more deeply the delicate spectral characteristics in HHG, particularly for near- and below-threshold harmonics.

Figure 1 we present the SST time-frequency analysis of the HHG. For the comparison, the semiclassical simulation is also shown. It is clear that not only the semiclassical trajectories of the first returning are matched very well, but also the multi-rescattering trajectories are in good agreement with the SST time-frequency spectra.

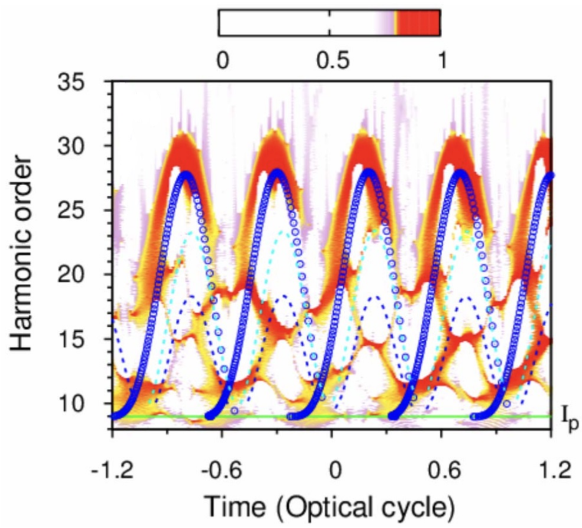

Figure 1. SST time-frequency spectra of above-threshold HHG in a 800-nm, 40 optical cycles, cosine-squared laser pulse with peak intensity $I = 1.5 \times 10^{14}$W/cm^2. The blue circles and the dashed lines indicate the semiclassical trajectories of the first returning and multiple returning, respectively, and the green vertical line indicates the corresponding ionization threshold marked by I_p.

References

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