Role of autoionizing states in resonant high harmonic generation and attosecond pulse production

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Although high-order harmonic generation (HHG) via interaction of intense laser pulses with gases provides a unique source of coherent femtosecond and attosecond pulses in extreme ultraviolet, the low efficiency of the process is a serious limit to its wide application. Using resonances of the generating medium is a natural way to boost the efficiency. Recently much attention has been paid to the role of resonances in HHG in gases and plasma plumes. It was shown that when the high-harmonic frequency is close to the transition to an excited quasi-stable state of the generating particle (in particular, to an autoionizing state (AIS)) the harmonic can be much more intense than the nonresonant ones.

The resonant HHG theory [1,2] generalizes the strong-field approximation to the resonant case. The theory shows that the interference of the non-resonant and the resonant terms leads to the Fano-like factor in the high harmonic spectrum. We compare this line shape with the XUV photoionization probability in the vicinity of the resonance.

Studies of the HHG using finely-tuned laser wavelength [3] show not only the resonant harmonic generation via AIS, but also a generation involving dressed-AIS that appears as two coherent satellite harmonics at frequencies ±2$ω\_{las}$ from the resonant one. Moreover, in the case of forbidden ground-AIS transition the emission at the frequencies ±$ω\_{las} $from the transition frequency can be observed.

Both simulation and experiment show phase-locking of the resonantly-enhanced high harmonics and strong influence of the resonance at the harmonic phases. Moreover, the phase properties of the dipole matrix element for the quasi-stable – ground state transition can be directly studied using resonant harmonic phase measurements. This can provide novel spectroscopic data, in particular, for the case of overlapping resonances.

The phase-locking of the resonant harmonics and relatively high conversion efficiency make them interesting for the attosecond pulse generation. The attosecond duration of the XUV pulse assumes broadband resonant enhancement; such enhancement due to a giant resonance was observed in Ref. [4,5]. We study theoretically [6] the effect of giant resonance on the phase difference between consecutive resonantly enhanced harmonics. We show that this effect leads to attosecond-pulse shortening in conjunction with the resonance-induced intensity increase of more than an order of magnitude.

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