Resonant High-Order Harmonic Generation and Attosecond Pulse Production

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Using the resonances of the generating medium is a natural way to boost the high-order harmonic generation (HHG) efficiency. Efficient generation of high harmonics with frequencies close to that of the transition from the ground to an autoionizing state (AIS) of the generating particle were experimentally investigated in plasma media [1] and in noble gases [2,3].

A number of HHG theories based on the specific properties of AIS were developed. These theories involve rescattering model in which the HHG is described as a result of tunneling ionization, classical free electronic motion in the laser field, and recombination accompanied by the XUV emission upon the electron's return to the parent ion. One of us suggested a four-step resonant HHG model [4] in which the first two steps are the same as in the three-step model, but instead of the last step (radiative recombination from the continuum to the ground state) the free electron is trapped by the parent ion, so that the system (parent ion + electron) lands in the AIS, and then it relaxes to the ground state emitting XUV. Basing on this model and HHG theory for the non-resonant case [5] we suggested the resonant HHG theory [6] considering an AIS in addition to the ground state and free continuum treated in [5]. The found intensity of the resonant harmonic can strongly exceed the intensities of the non-resonant ones, and the resonant harmonic line shape is described by a Fano-like factor. Moreover, our theory allows calculating the resonant harmonic phase. We show that there is a rapid variation of the phase in the vicinity of the resonance, in agreement with experiment [7]. The effect of the resonance on high-harmonic phases allows attosecond pulse shortening in conjunction with the resonance-induced intensity increase; moreover, the latter enhancement naturally provides XUV filtering needed for the attosecond pulse production [8].

Recent experimental and theoretical studies demonstrate important effect of the AIS dressing of the by the laser field [9] and coupling of the AIS and bound states with this field; the latter coupling leads to the manifestation of the so called dark AIS in the HHG spectrum [10,11]. Moreover, using higher-frequency fundamental field corresponding to multiphoton ionization regime leads to even more pronounced enhancing of the resonant harmonic [12] than for the tunneling regime.

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