Attosecond Pulses with Controllable Carrier-Envelope Phase via High-order Frequency Mixing

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The improvement of table-top attosecond sources in terms of brightness and pulse duration is of great interest and importance for an expanding field of application. Currently available table-top attosecond sources are based on the generation of high-order harmonics (HHG) of intense laser pulses during their interaction with a gaseous medium. However, the efficiency of the macroscopic HHG response is substantially limited by the phase matching of the process. Namely, the process is indissolubly connected to the photoionization of the medium, and the change in the refractive index due to the ionization leads to weaker phase matching. This limitation can be significantly softened for the high-order frequency mixing (HFM) process. This process occurs when two fields – at least one of which is intense and therefore causes photoionization of the gas – generate high-order mixed-frequency components. Here we study the attosecond properties of the coherent XUV generated via HFM analytically and numerically, focusing on the practically important case when one of the fields has much lower frequency and much lower intensity than the other one. We derive simple analytical equations describing intensities and phase locking of the HFM spectral components. We show that the duration of attosecond pulses generated via HFM, while being very similar to that obtained via HHG in the plateau, is shortened for the cut-off region. Moreover, our study demonstrates that the carrier-envelope phase of the attopulses produced via HFM, in contrast to HHG, can be easily controlled by the phases of the generating fields.