Polarization Control of High Harmonic Generation in a Pulsed Bicircular Laser Field

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The polarization properties of harmonics (such as the degree of circular polarization and the offset angle of the polarization ellipse) are determined by the laser-induced dipole moment $\vec{D}(\Omega)$. For instance, the degree of circular polarization of the harmonic with frequency $\Omega$ is

$$\xi = \frac{2 \text{Im} \left( \vec{D}_x(\Omega) \vec{D}_y^*(\Omega) \right)}{||\vec{D}_x(\Omega)||^2 + ||\vec{D}_y(\Omega)||^2} \quad (1)$$

Just recently, the generation of attosecond pulses with controlled ellipticity (close to circular) has elicited great practical interest. In order to generate such a pulse, the superposed harmonics should have the same ellipticity and comparable intensity, i.e. $\vec{D}_x(\Omega) \approx \pm i \vec{D}_y(\Omega)$, for a wide range of $\Omega$. This can be realized for a bicircular laser field with carrier frequencies $\omega$ and $2\omega$ having the same intensities and opposite helicities $[1]$. Based on the dipole selection rules, it was shown that harmonics with orders $(3n+1)\omega$ and $(3n-1)\omega$ are circularly polarized in opposite directions $[2–4]$. Thus, potentially, an attosecond pulse (or pulse train) can be obtained by summing harmonics from one group. It should be noted that the polarization properties and harmonic yields do not depend on the relative phase between two components if they are monochromatic fields or pulses with trapezoidal shape. This property reduces the ability to control the ellipticity of a generated attosecond pulse.

In this work we report an alternative way to control the ellipticity of an attosecond pulse, which is based on the use of two time-delayed short circularly polarized laser pulses with carrier frequencies $\omega$ and $2\omega$ having the same peak intensities and opposite helicities. The theoretical background of the proposed scheme is based on a recently developed theory of high harmonic generation in the adiabatic approximation. If two circularly polarized pulses are short enough, then in the framework of the developed approximation (cf. Ref. $[5]$) $\vec{D}(\Omega)$ can be presented in the following form (up to a common complex constant, which does not affect the results):

$$\vec{D}(\Omega) = \vec{K}_1(\Omega) + \vec{K}_2(\Omega)e^{i\Delta S}, \quad (2)$$

where $\vec{K}_1$ and $\vec{K}_2$ are real vectors, whose lengths depend only slightly on the time delay ($K_1 \approx K_2$); the angle between these two vectors is approximately $120^\circ$. The classical action difference $\Delta S = S_2 - S_1$ is between two neighboring events of ionization and recombination. Since $\Delta S$ is sensitive to the time delay, by varying the time delay between two pulses we can tune the components of $\vec{D}(\Omega)$ to those values that ensure a desired degree of circular polarization:

$$\xi \approx -\frac{\sin \Delta S}{K_1 + K_2 - \sqrt{3} \cos \Delta S}. \quad (3)$$

In this work we show that interference phenomena in high harmonic generation by a bicircular field can be used as an effective tool to the control polarization properties of high-order harmonics. We also provide the results of numerical solutions of the time-dependent Schrödinger equation, which are found to agree with results of the suggested theoretical model.

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References


