Generation of extreme-ultraviolet beams with time-varying orbital angular momentum
RESEARCH ARTICLE SUMMARY

ULTRAFAST OPTICS

Generation of extreme-ultraviolet beams with time-varying orbital angular momentum

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the mechanical torque exerted on matter by static-OAM beams. Extreme-ultraviolet (EUV) self-torqued beams naturally arise when the extreme nonlinear process of high harmonic generation (HHG) is driven by two ultrafast laser pulses with different OAM and time delayed with respect to each other. HHG imprints a time-varying OAM along the EUV pulses, where all subsequent OAM components are physically present. In the future, this new class of dynamic-OAM beams could be used for manipulating the fastest magnetic, topological, molecular, and quantum excitations at the nanoscale.

RESULTS: Self-torqued beams are naturally produced by HHG, a process in which an ultrafast laser pulse is coherently upconverted into the EUV wavelength of the extreme Breit-Wigner


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Модель

\[ \ell_q = n_1 \ell_1 + n_2 \ell_2 \]
Переменный угловой момент

Управляющее поле:

\[ U(\phi, t) = U_1(t)e^{i\ell_1\phi} + U_2(t)e^{i\ell_2\phi} \]

Амплитуда и фаза:

\[ |U(\phi)|^2 = |U_0|^2 \left\{ [1 - 2\eta]^2 + 4\eta[1 - \eta] \cos^2 \left[ \frac{(\ell_1 - \ell_2)\phi}{2} \right] \right\} \]

\[ \varphi(\phi) = [1 - 2\eta] \frac{\ell_1 - \ell_2}{2} \phi + \frac{(\ell_1 + \ell_2)}{2} \phi = [(1 - \eta)\ell_1 + \eta\ell_2] \phi \]

В приближении сильного поля (SFA), поле 17й гармоники:

\[ A_q(\phi) \propto |U(\phi)|^p e^{i\varphi(\phi)} = \left[ |U(\phi)|^p e^{i\varphi(\phi)} \right] = U_p(\phi) e^{i(q-p)\varphi(\phi)} \]

\[ A_q(\phi, t) \propto U_0^p(t) \sum_{r=0}^{p} \binom{p}{r} (1 - \bar{\eta}(t))^r e^{i\ell_1\phi} \bar{\eta}^{(p-r)}(t) e^{i(p-r)\ell_2\phi} \]

Средний момент:

\[ \langle \ell_q(t) \rangle = \sum_{r=0}^{p} \binom{p}{r} P_{l_1}^r P_{l_2}^{(p-r)} [r\ell_1 + (p-r)\ell_2] = q [(1 - \bar{\eta}(t))\ell_1 + \bar{\eta}(t)\ell_2] \]


Fig. 2. Azimuthal frequency chirp of self-torqued beams. Simulated spatial HHG spectrum along the azimuthal coordinate (\(\phi\)) when the time delay between the driving pulses is (A) 10 fs and (B) \(-10\) fs. The self-torque of light imprints an azimuthal frequency chirp, which is different for each harmonic, as indicated by the gray dashed lines (obtained from Eq. 6). The azimuthal frequency chirp serves as a direct measurement of the self-torque of each harmonic beam. The inset of (A) shows the intensity profile of the HHG beam, as well as the definition of the azimuth, \(\phi\).
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Fig. 3. Experimental scheme for generating and measuring light beams with a self-torque. (A) Two time-delayed, collinear IR pulses with the same wavelength (790 nm), but different OAM values, are focused into an argon gas target to produce harmonic beams with self-torque. (B) An EUV spectrometer, composed of a cylindrical mirror and flat-grating pair, collapses the HHG beam in the vertical dimension (lab frame y axis), while preserving spatial information, and thus the azimuthal extent in the transverse dimension (lab frame x axis). (Lower-right inset) The cylindrical mirror effectively maps the azimuthal frequency chirp into a spatial chirp along the lab frame x axis (i), which is then dispersed by the grating (ii).
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