Creating High-Harmonic Beams with Controlled Orbital Angular Momentum

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A beam of light with an angle-dependent phase $\Phi = \ell \phi$, where $\phi$ is the azimuthal coordinate, about the beam axis carries an orbital angular momentum (OAM) of $\ell \hbar$ per photon. Such beams have been exploited to provide superresolution in visible-light microscopy. The ability to create extreme ultraviolet or soft-x-ray beams with controllable OAM would be a critical step towards extending superresolution methods to extremely small feature size. Here we show that OAM is conserved during the process of high-harmonic generation (HHG). Experimentally, we use a fundamental beam with $\ell = 1$ and interferometrically determine that the $q$-th harmonic has an OAM quantum number $\ell$ equal to its harmonic order $q$. We also show theoretically how to couple an arbitrary low value of the OAM quantum number $\ell$ to any harmonic order $q$ in a controlled manner. Our results open a route to microscopy on the molecular, or even submolecular, scale.