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Extreme-ultraviolet scalar and vectorial vortices with very high topological charge

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Scalar and vectorial vortices are two paradigmatic beam structures carrying orbital angular momentum. On the one hand, a scalar vortex presents a twisted wavefront and homogenous polarization. On the other hand, a vectorial vortex combines a twisted phase and a spatially varying polarization. The topological charge in both scalar and vectorial vortices is the parameter characterizing the number of wavefront twists in one wavelength.

We demonstrate the up-conversion of scalar and vectorial vortices from the infrared (IR) to the extreme-ultraviolet (XUV) regime, by means of the conservation laws in high harmonic generation (HHG). For a scalar vortex, the topological charge in HHG scales linearly with the harmonic order i.e., $\ell_q = q\ell_1$ [1,2]. The analogous conservation law applies for a vector-vortex in terms of the Pancharatnam charge, ie. $\ell_{P,q} = q\ell_{P,1}$ [3]. In Fig. 1, we show the characterization of the 25th harmonic beam resulting from a vortex driver of $\ell_1 = 4$ (left) or from a vector-vortex driver of $\ell_{P,1} = 2$ (right). The experimental XUV beam (top row) is characterized using wavefront sensing metrology, which enables a full measurement of intensity and phase [2]. The theoretical beam (bottom row) is computed in the full quantum strong-field approximation and considers propagation effects in the transverse plane [2,3]. Our results demonstrate the up-conversion of scalar and vectorial phase singularities leading to very high topological charges in the XUV, up to $\ell_{25} = 100$. Such structured XUV beams may encourage advances in high-resolution imaging, attochemistry, or the fundamentals of intense laser-matter interactions.

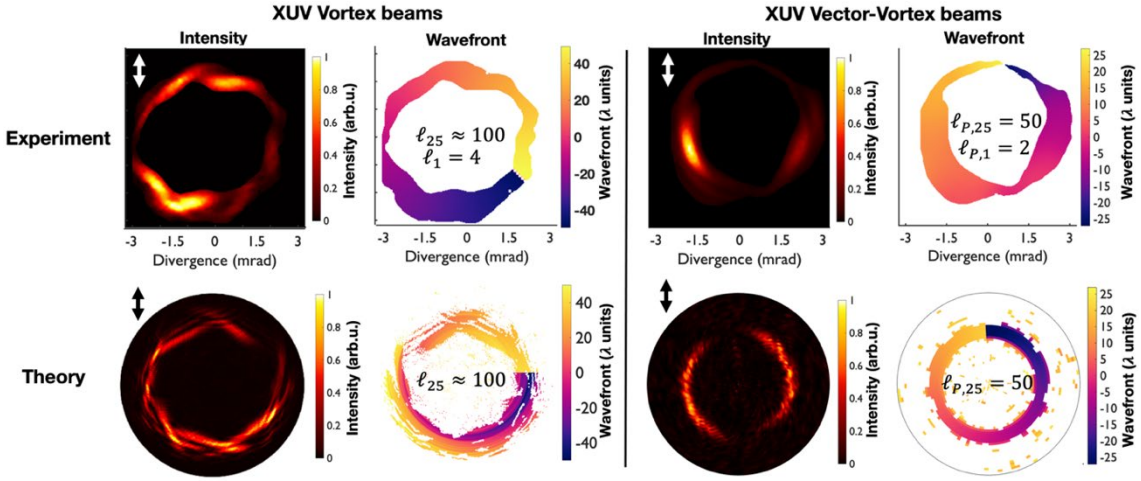

Figure 1. Characterization of XUV vortex and vector-vortex beams. We show the experimental (top row) and theoretical (bottom row) intensity of the vertical polarization projection and wavefront of the 25th harmonic beam. In the left panel, the HHG driver is a vortex of $\ell_1 = 4$, whereas in the right panel the driver is a vectorial vortex of $\ell_{P,1} = 2$.

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