Nonlinear up-conversion of scalar and vectorial vortices through high harmonic generation

Alba de las Heras[*,1], Alok Kumar Pandey[†2], Julio San Román[1], Tanguy Larrieu[2], Javier Serrano[1], Elsa Baynard[2], Guillaume Dovillaire[3], Moana Pittman[2], Charles G. Durfee[4], Luis Plaja[1], Sophie Kazamias[2], Olivier Guilbaud[2], Carlos Hernández-García[1]

[1] Grupo de Investigación en Aplicaciones del Láser y Fotónica, Departamento de Física Aplicada, Universidad de Salamanca, Pl. La Merced s/n, Salamanca E-37008, Spain

[2] Laboratoire Irène Joliot-Curie, Université Paris-Saclay, UMR CNRS, Rue Ampère, Bâtiment 200, Orsay Cedex F-91898, France

[3] Imagine Optic, rue Charles de Gaulle, 18, Orsay F-91400, France

[4]Department of Physics, Colorado School of Mines, Golden, Colorado 80401, USA

The nonlinear process of high harmonic generation (HHG) stands as a highly coherent tool to up-convert the properties of infrared/visible light into the extreme ultraviolet regime (XUV), or even into the soft x-rays. Thanks to HHG, we experimentally and theoretically report the generation of XUV scalar and vectorial vortices with very high topological charges [1,2]. On the one hand, scalar vortex beams present a homogenous polarization and a twisted wavefront along the azimuth, which encodes light's orbital angular momentum (OAM). The total wavefront twist, measured as the peak-to-valley wavefront value in one wavelength, points out the overall topological charge, ℓ, of the vortex beam. In HHG, the topological charge of scalar vortices scales linearly with the harmonic order i.e., $\ell_q = q\ell_1$ [1,3], which allows for the generation of high harmonic vortices with high OAM. On the other hand, vector-vortex beams merge a spatially varying polarization and a twisted wavefront, so their properties of spin angular momentum and OAM are intertwined. We demonstrate that the corresponding conservation law in HHG is ruled by the topological Pancharatnam charge, ℓ_P, satisfying $\ell_{P,q} = q\ell_{P,1}$ [2]. Additionally, the up-conversion of vector-vortex beams is far from trivial, since these beams are hybrid modes whose structure evolves during propagation [2].

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 [1]. The theoretical beam (bottom row) is computed in the full quantum strong-field approximation and considers propagation effects in the transverse plane [1,2]. 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.

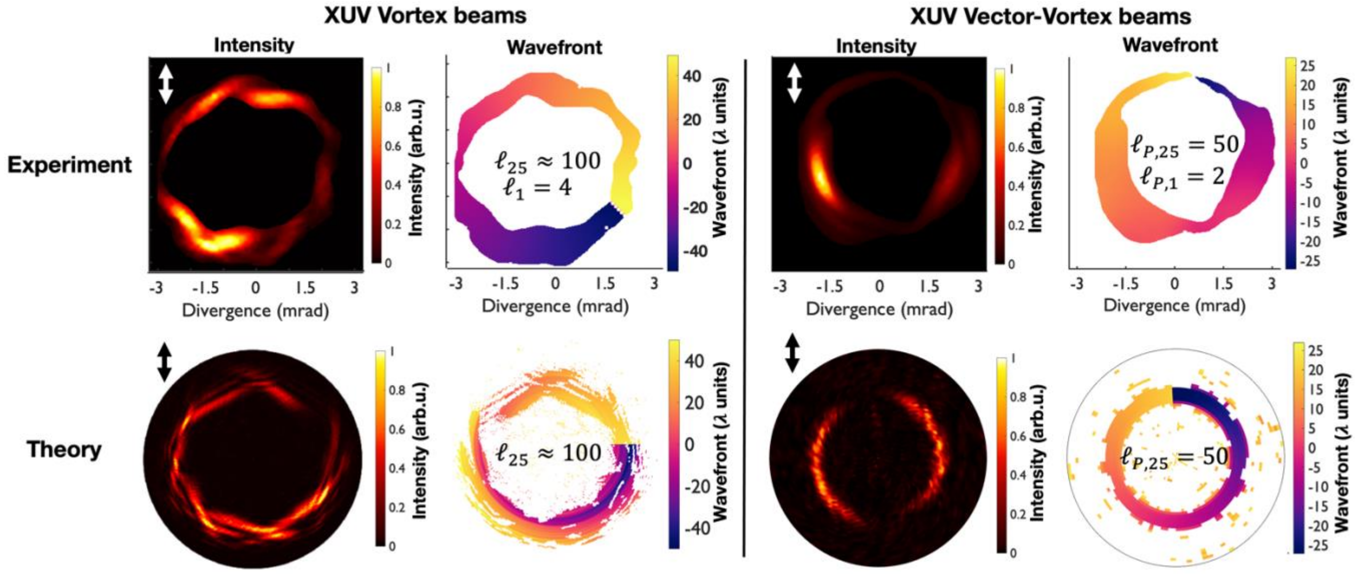

Figure 1 Characterization of XUV vortex and vector-vortex beams. We show the experimental (top row) and theoretical (bottom row) intensity of the vertical polarization projection and wavefront of the 25th harmonic beam. In the left panel, the HHG driver is a vortex of $\ell_1 = 4$, whereas in the right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

References

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*Corresponding author: albadelasheras@usal.es

†Corresponding author: alok- kumar.pandey@etu.univ-amu.fr