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Transfer of orbital angular momentum in high harmonic generation using two driving beams

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Light beams may carry both a spin and an orbital angular momentum (OAM). While the former is associated to their polarization state, the latter stems from the geometrical properties of their wavefront. In their prototypical form, beams with OAM have “donuts-like” intensity profile and helicoidal wavefront, carrying integral multiples of \hbar as angular momenta. Since their “rediscovery” in the late 90’s, beams with OAM of visible wavelengths have

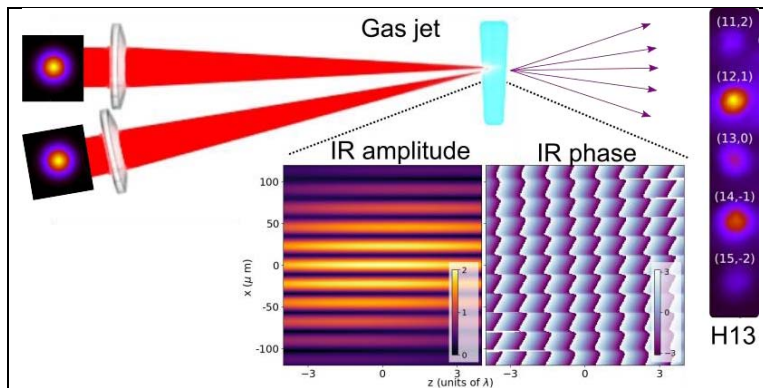


Fig. 1 Schematic of the experimental setup. Two intense femtosecond beams are crossing in a gas jet, where they create an “active” phase grating. This “active” grating both generates and diffracts high order harmonics. (right inset) Diffraction orders of harmonic 13 labelled by their corresponding parametric process.

found innumerable applications in quantum optics, microscopy or information transfer. A major recent development was the generation of such beams with much smaller wavelengths – in the extreme ultraviolet (XUV) – using synchrotron sources, free electron lasers as well as high harmonic sources (HHG). In this latter case, it creates ultrashort XUV sources of beams with OAM, suited for time-resolved applications at femtosecond and attosecond time scales. Remarkably, we showed that even though HHG is a non-perturbative process, the OAM transfer from the driving beam to the harmonics was purely parametric; i.e., the q -th harmonic – which can be thought as the

upconversion of q infrared photons – carries q times the OAM of the driver [3, 4]. However, this rule limits severely the flexibility in choosing the OAM of the XUV emission.

In this communication we present experiments that go beyond this simple scheme. If OAM transfer does behave in a parametric way, using two driving beams of different OAM should give us the control knob to fully tailor the harmonic emission. We show that this is indeed the case, using an extra “perturbing” beam to adjust at will the value of the OAM of the outgoing harmonics[2] (see figures). In a second part, we study how far this perturbative description can be taken. We observe that when increasing the perturbation, the yield of the higher perturbation orders can overwhelm the yield of the zeroth order. To explain this result, which seems to go against describing HHG as a parametric process, we derive a quantitative theory of HHG with two beams, based on the analysis of the wavefront of the global electric field at focus [1]. This reproduces the experimental results strikingly well, allowing us to gain a deeper understanding of the complex interplay of phenomena underlying the transfer of OAM in high-harmonic generation.

References

- [1] C. Chappuis, D. Bresteau, T. Auguste, O. Gobert, and T. Ruchon. High harmonic generation in an active grating. *arXiv e-prints*, 2018.
- [2] D. Gauthier, P. Rebernik Ribic, G. Adhikary, A. Camper, C. Chappuis, R. Cucini, L. F. DiMauro, G. Dovillaire, F. Frassetto, R. Généaux, P. Miotti, L. Poletto, B. Ressel, C. Spezzani, M. Stupar, T. Ruchon, and G. De Ninno. Tunable orbital angular momentum in high-harmonic generation. *Nature Communications*, 8:14971, apr 2017.
- [3] R. Généaux, A. Camper, T. Auguste, O. Gobert, J. Caillat, R. Taïeb, and T. Ruchon. Synthesis and characterization of attosecond light vortices in the extreme ultraviolet. *Nature Communications*, 7:12583, Aug 2016.
- [4] Romain Généaux, Céline Chappuis, Thierry Auguste, Samuel Beaulieu, Timothy T. Gorman, Fabien Lepetit, Louis F. DiMauro, and Thierry Ruchon. Radial index of laguerre-gaussian modes in high-order-harmonic generation. *Phys. Rev. A*, 95:051801, May 2017.

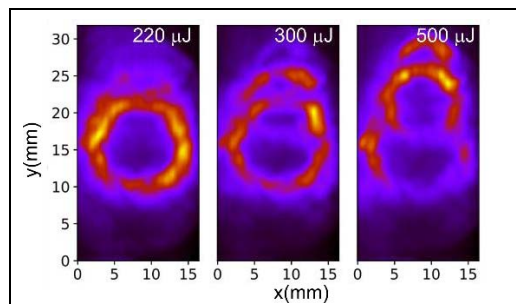


Fig. 2 Spatial profile of harmonics 13 when the horizontal beam carries an OAM $\ell_1 = \hbar$ while $\ell_2 = -2\hbar$ for different energies of the second beam. The diameters of the rings are in agreement with the conservation law of OAM. The yields are progressively moving towards higher order of diffraction as the perturbation increases, in agreement with the “active grating” theory. The zeroth order of the grating is located about $y=15$ mm.