Shaping high-order harmonic combs through phased-necklace drivers

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Precise coherent control over the frequency and divergence properties of high-frequency combs is fundamental for applications of high-harmonic generation (HHG) sources, such as high harmonic spectroscopy or imaging. During the recent years, manipulation over the angular momentum of the infrared driving beam has enabled exquisite control over the HHG to for example shape the polarization or orbital angular momentum (OAM) properties of the high-harmonic attosecond sources [1-3]. Here, we show that by harnessing the OAM of the driving beam, we can generate a transverse necklace-shaped beam that offers unique opportunities to manipulate the HHG process. In particular, it allows to create a spatial phased array of harmonic emitters that allow us to tune the frequency line spacing and the divergence of the emitted harmonic combs [4] (see Fig. (1)). This kind of control provides a new degree of freedom for the design of harmonic combs—particularly in the soft X-ray regime, where very limited options are available.

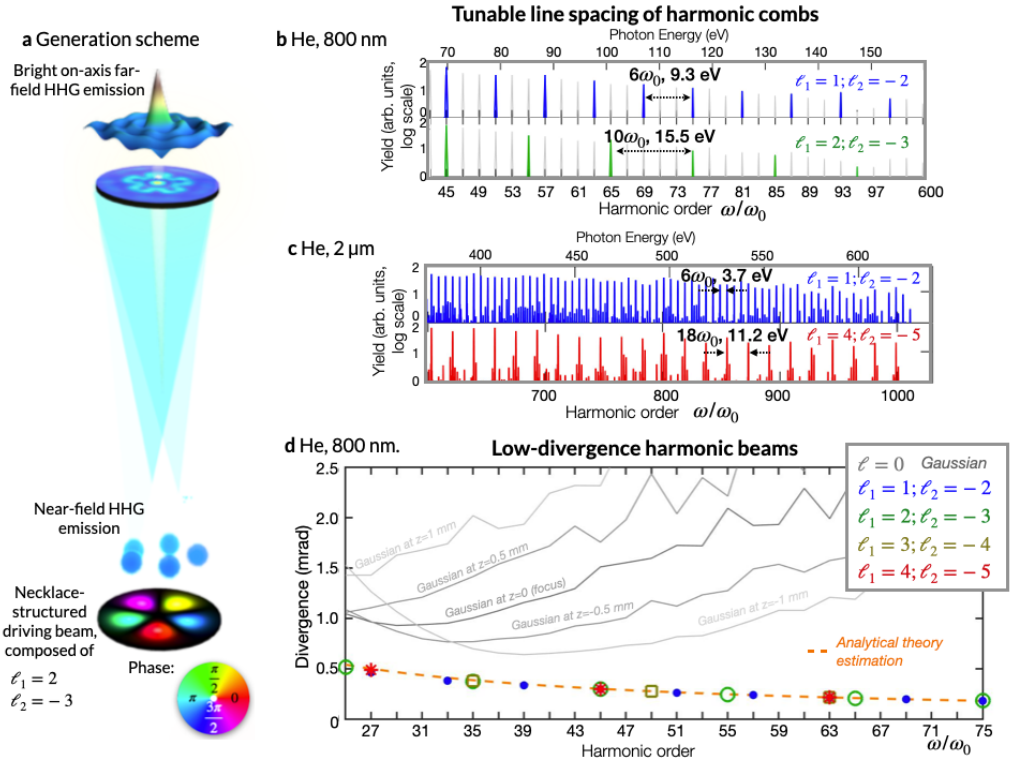

Figure 1: a) Generation scheme of necklace-structured HHG, where the driving field is composed of two collinear linearly polarized vortex beams with opposite—and different—OAM content (ℓ_1, ℓ_2) and same frequency (ω_0). Panels b) and c) show the tunability of the on-axis HHG spectra driven in He for 800 nm and 2 μm drivers, respectively. Panel d) shows the divergence of the on-axis harmonic beams which is lower than that obtained with Gaussian driving fields, and it also decreases with frequency.

[1] K. M. Dorney, et al. Controlling the polarization and vortex charge of attosecond high-harmonic beams via simultaneous spin-orbit momentum conservation. *Nat. Photon.* **13**, 123-130 (2019).

[2] L. Rego, et al., Generation of extreme-ultraviolet beams with time-varying orbital angular momentum. *Science* **364**, eaaw9486 (2019).

[3] L. Rego, et al. Trains of attosecond pulses structured with time-ordered polarization states, *Opt. Lett.* **45**, 5636 (2020).

[3] L. Rego, et al., Necklace-structured high harmonic generation for low-divergence, soft X-ray harmonic combs with tunable line spacing, arXiv:2107.12669 [physics.optics] (2021).