Acceleration of an isolated Attosecond Electron and Generation of Radiation Source driven by an ultraintense Spatiotemporal Vortex Laser

Fengyu Sun[1], Xinyu Xie[1], Wenpeng Wang[1], Stefan Weber[2] Yuxin Leng[1], Ruxin Li[1], Zhizhan Xu[1],
[1] State Key Laboratory of High Field Laser Physics and CAS Center for Excellence in Ultra-intense Laser Science, Shanghai Institute of Optics and Fine Mechanics (SIOM)
[2] ELI Beamlines facility, Extreme Light Infrastructure ERIC
e-mail (speaker): sunfengyu@siom.ac.cn

The feasibility scheme of achieving ultra-intense STOV lasers by using reflective and large-sized optical components (including reflective blazed gratings, cylindrical mirrors, and phase plates) is explored for the first time. The phase-locked acceleration of a relativistic isolated attosecond electron sheet is achieved by using such a relativistic STOV laser. The three-dimensional (3D) Particle-in-cell (PIC) results show that the unique phase singularity distribution of the STOV laser realizes the spatiotemporal regulation of the electron beam: in the longitudinal direction, the phase-locked acceleration of the electron beam is achieved; in the transverse direction, the transverse electric field of the STOV laser achieves electron beam focusing and constriction. Finally, isolated collimated electron sheets of ~GeV magnitude and ~600 attoseconds were obtained. Further, when the STOV laser is reflected by the planar target, the electron pulse collides with the reflected laser front, triggering a nonlinear Compton scattering process and generating an isolated ultrashort (~600 attoseconds), high-brightness (~3×10^{24} photons/s/mm^2/mrad^2/0.1%BW at 1 MeV) gamma-ray pulse. This scheme overcomes the shortcomings of the traditional Gaussian laser-driven radiation source, such as large divergence angles and the need for a complex dual-laser system. It also introduces the transverse orbital angular momentum into attosecond γ-ray pulses, opening up new avenues for applications such as ultrafast imaging, nuclear excitation, and detection.

References
[1] Fengyu Sun *et al*, Phys. Rev. Research. **6**, 013075 (2024)
[2] Fengyu Sun *et al*, Phys. Rev. Applied. **23**, L051003 (2025)

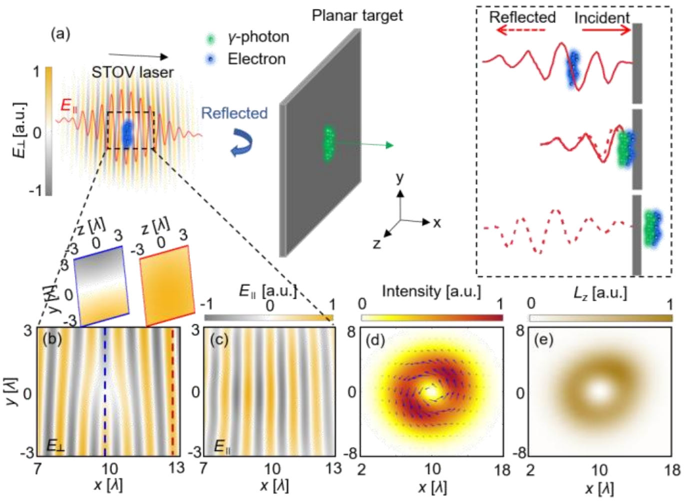

Figure 1. Schematic of an isolated attosecond γ-ray pulse generation. An IAES collides with the self-reflected STOV laser, triggering the NCS process, to generate the attosecond γ-ray pulse. (b) Vertical electric field and (c) longitudinal electric field distributions of the STOV laser. (d) The energy density of the STOV laser, with blue arrows indicating the circulating momentum flux. (e) TOAM density with the propagation term subtracted.