# Strong laser driven vortex Gamma photons and photonuclear reactions

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Vortex Gamma photons with intrinsic orbital angular momenta possess a wealth of applications in various fields—e.g., strong-laser physics, nuclear physics, particle physics, and astrophysics—yet their generation remains unsettled. Here, we investigate the generation of vortex Gamma photons via nonlinear Compton scattering of ultrarelativistic electrons in a circularly polarized laser pulse. We develop a quantum electrodynamics scattering theory that explicitly addresses the multiphoton absorption and the angular momentum transfer mechanism. In pulsed laser fields, we unveil the vortex phase structure of the scattering matrix element, discuss how the vortex phase could be transferred to the radiated photon, and derive the radiation rate of the vortex Gamma photon. We numerically examine the energy spectra and beam characteristics of the radiation, while also investigating the influence of finite laser pulses on the angular momentum and energy distribution of the emitted vortex Gamma photons [1].

Moreover, traditional photonuclear reactions primarily excite giant dipole resonances, making the measurement of isovector giant resonances with higher multipolarities a great challenge. Here, we also investigate the manipulation of collective excitations of different multipole transitions in even-even nuclei via vortex Gamma photons. We develop the calculation method for photonuclear cross sections induced by the vortex Gamma photon beam using the fully self-consistent random-phase approximation plus particle-vibration coupling (RPA + PVC) model based on Skyrme density functional. We find that the electromagnetic transitions with multipolarity $J < |m_\gamma|$ are forbidden for vortex Gamma photons due to the angular momentum conservation, with $m_\gamma$ being the projection of total angular momentum of Gamma photon on its propagation direction. Therefore, the giant resonances with specific multipolarity can be extracted via vortex Gamma photons. Moreover, the vortex properties of Gamma photons can be meticulously diagnosed by measuring the nuclear photon-absorption cross section. Our method opens new avenues for photonuclear excitations, generation of coherent Gamma photon laser and precise detection of vortex particles, and consequently, has significant impact on nuclear physics, nuclear astrophysics and strong laser physics [2].

References:

[1] Mamutjan Ababekri, Ren-Tong Guo, Feng Wan, B. Qiao, Zhongpeng Li, Chong Lv, Bo Zhang, Weimin Zhou, Yuqiu Gu, and Jian-Xing Li. Vortex γ photon generation via spin-to-orbital angular momentum transfer in nonlinear Compton scattering. Phys. Rev. D 109, 016005 (2024).

[2] Zhi-Wei Lu, Liang Guo, Zheng-Zheng Li, Mamutjan Ababekri, Fang-Qi Chen,

Changbo Fu, Chong Lv, Ruirui Xu, Xiangjin Kong, Yi-Fei Niu, and Jian-Xing Li. Manipulation of Giant Multipole Resonances via Vortex γ Photons. Phys. Rev. Lett. 131, 202502 (2023).