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Experimental demonstration of all-optical nonlinear Compton scattering using a multi-petawatt laser

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Progress in laser wakefield acceleration (LWFA) has led to the production of a multi-GeV electron beam from a cm-length plasma. Such beams are collocated together with high intensity laser pulses at petawatt (PW) laser facilities, allowing the study of laser-electron collisions in all-optical setups. This configuration opens up the possibility to test strong-field quantum electrodynamics (SFQED), in order to understand the behavior of charged particles under the influence of a strong laser field. In particular, experiments on nonlinear Compton scattering can reveal nonlinear features in high-energy gamma-ray emission spectra.

We present the measurement of high-energy gamma-ray beams generated from nonlinear Compton scattering experiments at the CoReLS 4PW facility. The gamma beams were produced during the collision of LWFA-accelerated electrons (E<3.5 GeV) and an ultrashort laser pulse (25fs) of intensity $I \approx 4 \times 10^{20}$ W/cm2, achieving a quantum nonlinearity parameter $\chi \approx 0.4 - 0.5$. The unprecedented properties of the gamma beams required the development of a novel detection technique based on a pixelated LYSO scintillation detector. Using this detection method, we observed broad gamma-ray spectra that can be parametrized by a critical energy >150 MeV, extending over hundreds of MeV. The beams have a low divergence (≈1 mrad), small source size and ultrashort duration, thus exhibiting an ultrahigh brilliance. Such high energy gamma beams open up new research possibilities in fundamental physics and nuclear photonics.

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