7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Nonlinear Compton Scattering between a Laser-Accelerated multi-GeV Electron Beam and an Ultrahigh Intensity Laser

Chang Hee Nam
Center for Relativistic Laser Science, Institute for Basic Science, Korea;
Dept. of Physics and Photon Science, Gwangju Institute of Science and Technology, Korea
chnam@ibs.re.kr

Ultrashort high power lasers, based on the chirped pulse amplification technique, have prompted the research on strong field physics. At CoReLS a 20 fs, 4 PW Ti:Sapphire laser was developed in 2017 [1] and applied for producing multi-GeV electron beams using the laser wakefield acceleration scheme. By tightly focusing this laser after wave-front correction, we demonstrated the record-breaking laser intensity of 10^{23} W/cm^2 in 2021 [2]. With an ultrahigh intensity laser, physical processes in strong field quantum electrodynamics (QED), such as electron-positron pair production from vacuum and light-by-light scattering, can be tackled. These processes were theoretically proposed a century ago, but could not be realized in experiments.

As part of strong-field QED research, we explored nonlinear Compton scattering between a multi-GeV electron beam and an ultrahigh intensity laser in an all-optical setup in Fig. 1. We generated a multi-GeV electron bunch with the CoReLS PW laser using the laser wakefield acceleration (LWFA) scheme. When a 5-cm gas cell of He, mixed with 3% Ne, was driven by a PW laser, an electron beam could be accelerated by the wakefield formed in the He plasma and stable electron beams of energy up to 3.5 GeV with an energy spread as small as 1% could be produced. We made this electron beam scatter with an ultrahigh-intensity laser beam, producing Compton gamma rays. As an ultra-relativistic electron beam sees the laser photon as a Lorentz-boosted hard x-ray photon, this scattering is a Compton scattering. In the lab frame, the Compton scattered photon becomes a gamma-ray photon.

The beam profile and energy spectrum of gamma rays from the Compton scattering were measured with two detectors made of scintillating crystals, as shown in Fig. 1. The gamma-ray signals from the Compton scattering were measured with LYSO scintillation detectors – a single crystal LYSO for imaging and a pixelated LYSO for energy spectrum. Using these gamma-ray detectors, we observed broad gamma-ray spectra extending over hundreds of MeV. We could confirm the nonlinear Compton scattering between a GeV electron and several hundred laser photons by obtaining the gamma-ray signal far exceeding the cutoff energy of the linear Compton scattering between an electron and one laser photon. In addition, the gamma-ray 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. We present our experimental results on NCS along with the analysis of measured gamma-ray signals.

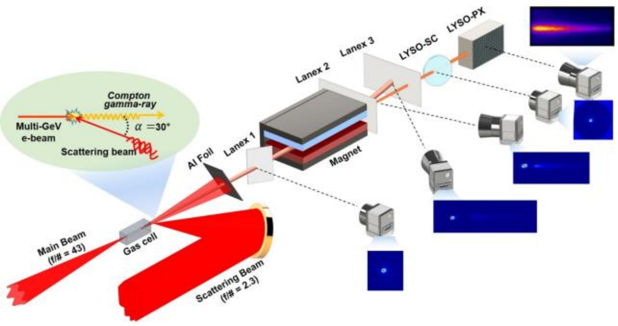

Fig.1 Experimental setup of all-optical nonlinear Compton scattering.

References

[1] J. H. Sung et al., "4.2 PW, 20 fs Ti:Sapphire Laser at 0.1 Hz," Opt. Lett. **42**, 2058 (2017).
[2] J. W. Yoon et al., "Realization of laser intensity over 10^{23} W/cm^2," Optica **8**, 630 (2021).