Generating ultrahigh brilliance quasi-monochromatic MeV γ-rays with high-quality LWFA electron beams

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Abstracts: *By designing a special cascaded laser-wakefield accelerator to generate high-quality monoenergetic e-beams, which were bound to head-on collide with the intense driving laser pulse via the reflection of a 20-um-thick Ti foil, as using a self-synchronized all-optical Compton scattering scheme, we has produced tunable quasi-monochromatic ultrahigh brilliance MeV γ-rays. This robust and compact ultrahigh brilliance γ-ray source may pave the way towards a variety of practical and research applications in x-ray radiology and photonuclear fields.*

Laser wakefield accelerators (LWFA) have achieved significant progress recently owing to the sophisticated injections, cascade and guiding technologies, and they can produce monoenergetic, energy tunable, GeV-class femtosecond e-beams with tens of pC charge over a distance of centimeter-scale, which hold the potential of becoming compact alternatives to conventional accelerators. The properties of the e-beams qualify them as a unique driver for the generation of compact, well-collimated, near-monochromatic, tunable, ultra-short and high peak brilliant x- and γ-ray sources up to a few MeV.

In this report, a cascaded laser accelerator (0.8mm+3mm) is designed to generate high-quality e-beams (~ 1% rms energy spread, ~ 50 pC at the peak energy, tunable from 200 to 500 MeV, < 0.4 mrad rms divergence). In order to reduce the difficulty of laser-electron temporal and spatial synchronization, we employed a self-synchronized all-optical Compton scattering scheme, in which the reproducible e-beams collide with the intense driving laser pulse via the reflection of a thin foil (20um Ti or 30um Al) in the naturally overlapped region. With the perfect combination of a cascaded laser-plasma accelerator and a plasma mirror, the photon yield was improved up to ~ 5×10^7 per shot and quasi-monochromatic γ-rays (tunable from 0.3 to 2 MeV) with a narrow bandwidth of ~ 14% (rms) have been achieved, corresponding to an ultrahigh brilliance of ~ 3.1×10^{22} photons s^{-1} mm^{-2} $mrad^{-2}$ 0.1% BW, which is one order of magnitude higher than ever reported value in MeV regime to the best of our knowledge.

The experiments were carried out at the SIOM 200TW laser system based on the chirped-pulse amplification (CPA) Ti:sapphire @ 1-Hz repetition rate with a duration of 33*f*s at a wavelength of 800nm. With careful design and sophisticated measurements, the e-beams and γ-rays were detected and analyzed respectively. Moreover, relevant particle-in-cell and Monte Carlo simulations showed good agreements with the experimental results and theoretical analysis. We anticipate that this ultrahigh brilliance and quasi-monochromatic MeV γ-rays enable many practical applications.