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High-flux ultrashort gamma-rays driven by petawatt laser in near-critical density plasmas

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Laser-driven gamma-ray source potentially offers a compact, ultra-short, and ultra-bright alternative to conventional gamma-ray sources based on large-scale particle accelerators. The nonlinear synchrotron radiation of direct laser-accelerated electrons in near-critical density plasmas recently has been proposed as a very efficient scheme to produce high-flux multi-MeV gamma-rays. However, there are still two critical issues that are required to overcome in this scheme. On one hand, the conversion efficiency of gamma-rays depends nonlinearly on the laser amplitude [1], such that it usually requires an intense laser with the intensity above 10^{22} W/cm^2 or even 10^{23} W/cm^2, which, however, holds little promise for the routinely available lasers. On the other hand, the broad divergence angle of the emitted gamma-rays leads to the rapid broadening of the source size and reduction of the peak brilliance, which restricts their usefulness in practical applications.

In this presentation, we propose a highly efficient gamma photon emitter obtained by irradiating a not-so-intense laser pulse on a miniature plasma device consisting of a plasma lens and a plasma mirror [2]. In this novel scheme, brilliant gamma-rays with very high conversion efficiency (higher than 1%) and spectral intensity (higher than 10^9 photons/0.1%BW/s) can be achieved by employing currently available lasers with intensity of 10^{21} W/cm^2. The practical effects of different nanostructures in the plasma lens and the oblique laser incidence are also discussed in this scheme [3]. In addition, we propose a novel scheme to manipulate the electron dynamics in near-critical density plasmas by exploiting an intense optical vortex [4]. In this way, the divergence of gamma-rays can be much reduced, which shows that in this scheme helical gamma-rays with very small divergence angle (less than 5^o) and ultra-high brilliance (~10^{24} photons/s/mm^2/mrad^2/0.1%BW) can be produced at a laser intensity of 10^{22} W/cm^2 [5]. In addition, very recently we propose a novel scheme for generating ultrashort gamma-ray pulse in attosecond domain by irradiating a circularly polarized vortex laser light onto a thin transparent foil [6]. In this scheme, an unprecedented gamma-ray pulse with ultrashort (~200 attosecond) duration and ultrahigh brilliance (up to 10^{27} photons/s/mm^2/mrad^2/0.1%BW at one MeV), which is comparable to the peak brilliance of X-ray free electron laser. Such high-quality gamma-rays generated in these schemes would find applications in wide-ranging area.

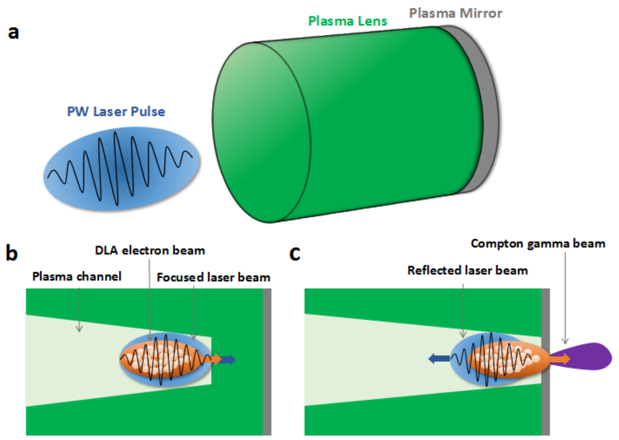

Figure 1. Schematic of the gamma photon emitter. (a) A high-intensity laser pulse is incident onto a bilayer plasma device consisting of a plasma lens and a plasma mirror. (b) At an early stage, the laser pulse (blue color) is strongly focused by the plasma lens (green color), and, meanwhile, a significant number of electrons (orange color) are confined in the laser-produced plasma channel (light-green color), and they are directly accelerated by the strong laser field. (c) At a later stage, the focused laser pulse (blue color) is reflected by the plasma mirror (gray color) and collides with the forward-propagating electron beam. Then the nonlinear Compton scattering process is induced and copious gamma photons (purple color) are emitted.

References

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