2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Novel large-energy terahertz radiation sources from intense laser-foil interactions

Yutong Li[1,2], Guoqian Liao[3], Weimin Wang[1], Zhengming Sheng[3,4], David Neely,[5] Paul McKenna[4] and Jie Zhang[3]

[1]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190

[2]School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100190

[3]Key Laboratory for Laser Plasmas (MoE) and Department of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240

[4]SUPA, Department of Physics, University of Strathclyde, Glasgow G4 0NG

[5] Central Laser Facility, STFC Rutherford Appleton Laboratory, Didcot, OX11 0QX

e-mail: ytli@iphy.ac.cn

Over the last decades relativistic electron beams from conventional accelerators have been applied to generate strong THz radiation through transition radiation [1], *etc*. Relativistic electron beams can also be generated in the interactions of intense laser pulses with low-density gas or high-density solid targets. With the energetic electron beam accelerated by wakefields in gas target, Leemans *et al*. have observed a ~0.3 μJ THz pulse through transition radiation [2].Compared with the gas targets, electron beams from solid targets have much higher charge, up to nC-μC. For a foil target, fast electrons transport forward through the target and will induce transition radiation when crossing the rear surface-vacuum boundary. Usually the bunch length of the fast electrons driven by a laser pulse in tens of femtosecond duration is of the order of ~10 μm, which is smaller than the wavelength of THz radiation. This will lead to the coherent transition radiation (CTR) [3]. One can expect that the THz radiation energy will be high due to the high charge and short bunch duration of the fast electron beam as well as the steep foil-vacuum boundary.

To verify this idea, we have carried out laser-foil experiments using a multi-TW femtosecond laser system at Shanghai Jiao-Tong University and the Vulcan PW laser system at the Rutherford Appleton Laboratory. For fs experiment, a *p*-polarized laser pulse in 30 fs and 2 J was incident onto solid targets at an incidence angle of 54 ° with a peak intensity of ~1.5×10^{19} W/cm^2. The laser prepulse contrast in the ns range is ~10^{-5}. Different types of targets were used in the experiment, including mass-limited metal targets with different sizes, polyethylene (PE)-metal double-layered targets and single PE targets.

In our fs experiment we demonstrated intense THz transition radiation of the laser-accelerated relativistic electron beams crossing the solid rear surface. The total THz energy from the rear of metal foils is estimated to be ~400 μJ/pulse, comparable to the energy level of the conventional accelerator based THz sources [4]. The corresponding energy conversion efficiency from the laser pulse energy on targets to THz radiation is ~2×10^{-4}. It can be well explained by the model of CTR considering the effects of diffraction radiation and formation zones[5].

In the experiments with the Vulcan ps laser system, we have much enhanced the THz pulse energy. According to the experimental measurements and calculated spatial distribution of THz radiation, the total energy of THz pulses emitted from the target rear, at a pump laser energy of ~60 J, is determined to be ~55 mJ within 3 THz. This corresponds to a peak power of ~36 GW and a laser-THz energy conversion efficiency of ~0.1%. To our knowledge, this is the highest THz pulse energy and peak power reported so far.

The laser-plasma-based THz transition radiation presented could be a promising compact strong-field THz source. Moreover, it may provide us a new tool to diagnose forward fast electrons in laser-plasma interactions.

References

[1] U. Happek, A. J. Sievers, and E. B. Blum, Phys. Rev. Lett. 67, 2962 (1991).

[2] W. P. Leemans et al., Phys. Rev. Lett. 91, 074802 (2003); C. B. Schroeder, E. Esarey, J. van Tilborg, and W. P. Leemans, Phys. Rev. E 69, 016501(2004).

[3] Ding W J, Sheng Z M and Koh W S 2013 Appl. Phys. Lett. 103 204107.

[4] Wu Z et al 2013 Rev. Sci. Instrum. 84 022701.

[5] Liao G Q et al 2016 Phys. Rev. Lett. 116 205003.

.