6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Generation of 10-MeV electron beams by 1-TW laser pulses in a thin, dense nitrogen gas cell

Po-Wei Lai[1], Dang Khoa Tran[1], Kun-Ni Liu[1], Xiang-Yuan Lin[2], Ming-Wei Lin[1,2], Hsu-Hsin Chu[3,4], Shih-Hung Chen[3], and Jyhpyng Wang[3,4,5]
[1]Institute of Nuclear Engineering and Science, National Tsing Hua University, Hsinchu, Taiwan
[2]Department of Engineering and System Science, National Tsing Hua University, Hsinchu, Taiwan
[3]Department of Physics, National Central University, Zhongli, Taiwan
[4]Center for High Energy and High Field Physics, National Central University, Zhongli, Taiwan
[5]Institute of Atomic and Molecular Science, Academia Sinica, Taipei, Taiwan
e-mail (speaker): bob9919@gapp.nthu.edu.tw

The rapid progress of high-average-power, diode-pumped laser technologies, capable of producing 100-mJ-level pulses at kHz repetition rates, motivates the development of high-repetition-rate laser wakefield acceleration (LWFA) driven by few-TW or even sub-TW pulses in a thin, dense gas target [1]. As the pump pulse undergoes self-focusing and self-modulation along with its propagation in a dense plasma, a greatly increased laser intensity thus can be realized to excite nonlinear plasma waves for electron acceleration. Meanwhile, using a nitrogen gas target enables ionization-induced injection [2] and consequently increases the output charge and improves its stability. In this work we investigate the performance of LWFA with 40-fs, 1-TW laser pulses irradiating at a dense, sub-mm nitrogen gas cell. The focal position of the pump pulse and the backing pressure of the gas cell were scanned to find the optimal condition for routinely generating electron bunches.

Figure 1(a) illustrates the experimental setup and Fig. 1(b) shows a 450-μm long target gas cell with a backing pressure of 1.3×10^5 Pa. Figure 1(c) illustrates the shadowgram and the lineout density profiles of the nitrogen plasma outside the gas cell. By computational fluid dynamics and particle-in-cell simulations, the peak density of plasma electrons inside the gas cell is estimated to be 5×10^{19} cm^{-3}. Under this condition, Fig. 1(d) shows typical profiles of output electron bunches measured with a LANEX screen, from which the vertical and horizontal divergences are estimated to be $\theta_y \approx 18 \pm 7.3$ mrad and $\theta_z \approx 20 \pm 5.7$ mrad in FWHM. The pointing distribution of 15 consecutive electron bunches shown in Fig. 1(e) gives the fluctuations of $\Delta\theta_y \approx 9$ mrad and $\Delta\theta_z \approx 14$ mrad. According to the images of output electrons dispersed by a 0.4-T magnet as shown in Fig. 1(f), these electron bunches were generated with an averaged peak energy $\approx 9.6 \pm 3.8$ MeV, energy spread $\approx 13 \pm 7.8$ MeV in FWHM, and bunch charge $\approx 25 \pm 14.6$ pC (> 3.5 MeV). These results provide valuable information for future development of few-TW LWFA that generates 10–20 MeV electron bunches with satisfactory beam properties for downstream applications.

References
[1] M.-W. Lin *et al*, Phys. Plasmas, **27**, 113102 (2020).
[2] M.-W. Lin *et al*, Phys. Plasmas, **27**, 013102 (2020).

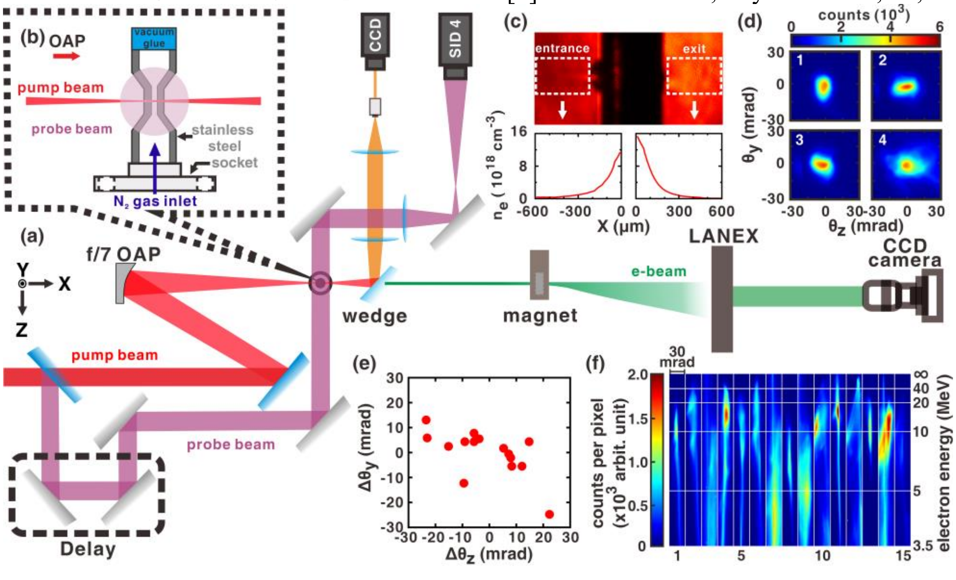

Figure 1. (a) Schematic diagram of LWFA experiment. (b) Structure of the gas cell with the paths of pump and probe beams. 1-TW pump pulses were applied with a backing pressure of 1.3×10^5 Pa, (c) a shadowgram and the corresponding line-out profiles of retrieved plasma density outside the gas cell. (d) Typical transverse profiles of output electron bunches. (e) Pointing variation and (f) images of the dispersed distribution of 15 consecutive electrons bunches.