Enhanced pointing and charge stabilities for electron beams from few-TW laser wakefield acceleration with a shaped sub-mm gas jet

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Invention a scheme of laser wakefield acceleration (LWFA) applicable with few-TW or even sub-TW pulses enables the high-repetition-rate generation of electron beams driven by modern diode-pumped lasers. It is a prerequisite here to create a dense target capable of providing a plasma electron density $n_e >> 10^{19}$ cm^{-3}, such that a high intensity can be resulted for the self-focused and self-modulated pump pulse to drive plasma waves for electron acceleration [1,2]. In addition, implementing a target with a shaped density profile can improve properties of output electrons, primarily for the enhanced charge stability and the reduced beam pointing fluctuation as demonstrated in this work.

Figure 1(a) illustrates the experimental setup in which 1-TW, 40-fs pulses were focused onto nitrogen gas jets for electron generation and pulses of the shadowgraphy probe beam were applied to measure density profiles of plasmas with a wavefront sensor. Gas jets were produced by a 178-μm diameter orifice as shown in Fig. 1(b), while a blade was placed with a height of 100 μm above the orifice and a coverage C = 0 % is defined when the blade edge is aligned with the back edge of the orifice exit. When 1-TW pulses were introduced to interact with gas jets produced with a backing pressure of 400 psi, the density profiles of nitrogen plasmas shown in Fig. 1(c) indicate that the shaped gas jet/ plasmas produced with C= 100 % exhibited an asymmetric density profile with a reduced length and a shortened density-down ramp when compared to the default one produced without using the blade. For the output electrons, the results shown in Figs. 1(d) and 1(e) indicate that using the shaped target can result in a greatly increased beam intensity and, more importantly, significantly reduced pointing fluctuations, which decreased from $\Delta\theta_y$ = 22.1 mrad and $\Delta\theta_z$ = 11.4 mrad for beams from default nitrogen jets to $\Delta\theta_y$ = 2.6 mrad and $\Delta\theta_z$ = 5.1 mrad for those from shaped jets. Meanwhile, as shown in Figs. 1(f) and 1(g) for the dispersed electron distributions, using the shaped jets can obviously improve the output beams for their charge stabilities. As the charge and associated deviation were estimated to be 4.9 pC and 134 % for electrons (> 3 MeV) generated from the default jets, an increased charge of 12.1 pC and an inhibited deviation of 10.7 % were acquired with the shaped gas jets, which greatly facilitates the downstream applications of few-TW LWFA with satisfactory beam properties

References

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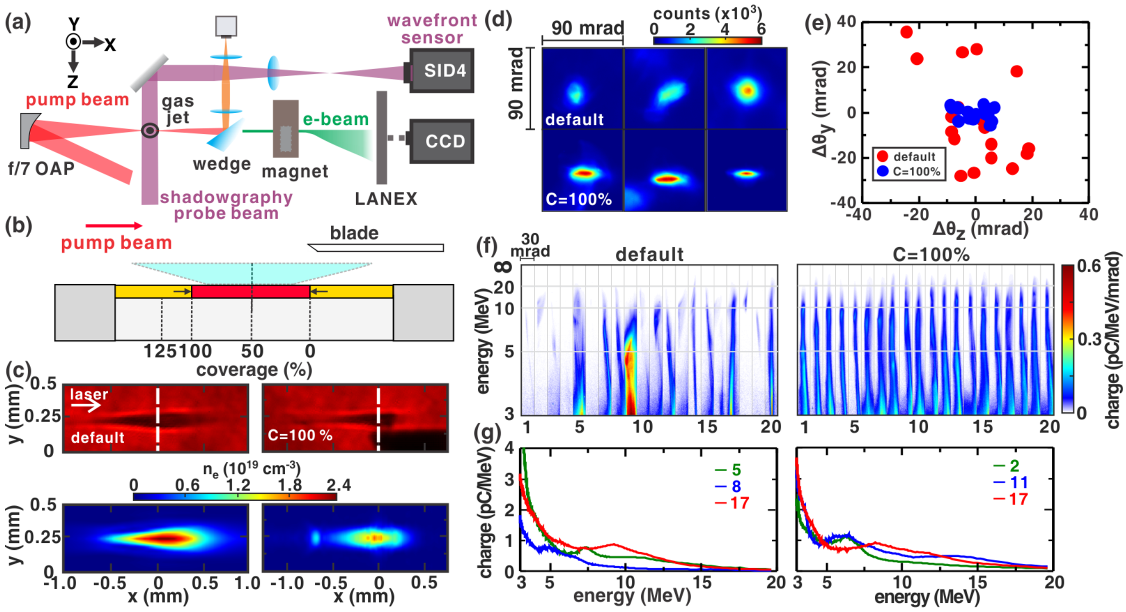

Figure 1. (a) Schematic diagram of LWFA experiment. (b) Illustration for the position of the blade edge relative to the orifice (nozzle) exit, (c) With 400-psi backing pressure fed to the nozzle, the shadowgrams and associated electron density distributions for the nitrogen plasmas produced with the default gas jet and the shaped one with the coverage C = 100 %. Corresponding (d) transverse profiles of output electron beams. Comparison for (c) pointing fluctuations and (f) images of dispersed distribution of 20 consecutive electron beams. (g) Representative energy spectra for results in (f).