Monoenergetic electron beam generation with ultrahigh intensity lasers

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Ultrashort relativistic electron beam generation from laser wakefield acceleration (LWFA) [1] is a rapidly growing research area that is expected to lead to a new generation of unconventional and compact (all-optical) high-energy particle accelerators. Quantum beams such as X-rays, THz radiation, positrons, and neutrons have been successfully generated based on laser-plasma electron beams [2]. These quantum beams are extremely short and naturally synchronized with the main laser beam. Those properties make them perfect for exploring the ultrafast phenomena through pump-and-probe experiments. Recently a great progress has been made in achieving good quality, self-injected electron beams from the LWFA scheme [3]. However, the electron beam quality was very much sensitive to experimental conditions, which naturally fluctuates shot to shot. Thus, the stabilization of the electron beam generation from the LWFA is currently a very important research topic. In this paper, we propose a method of employing a large laser focal spot to achieve stable electron beam generation. With typical parameters for the laser intensity and plasma density and long gas jet length of 4 mm, the large focal spot (several times larger than plasma wavelength) produced stable, well collimated, and high energy electron beam. On the of other hand, the plasma wavelength-long focal spot produced electron beams with the least quality. This is, to the best of our knowledge, the first experimental results that emphasize the importance of employing large laser spot size for the stable e-beam generation from the LWFA.

The experimental scheme is shown in Fig. 1. Up to 40 TW Ti: sapphire laser pulses were focused on a supersonic flow of helium gas jet. The laser pulse duration was 30 fs. The plasma density was $1x10^{19}cm^{-3}$ and it was measured by the Forward Raman Scattering (FRS) technique (0.5 TW 2 ps laser pulses were used for this purpose). The focusing mirror was changed (with one of different focal length) from one experiment to another to achieve different focal spot size. The (FWHM) laser spot sizes were 30, 25 and 10 micrometers for f/14, f/10 and f/2.5 focusing mirrors. The emitted electron beam energy spectrum was detected by an electron beam spectrometer. The spectrometer consists mainly of 6 cm-long permanent magnet (0.8 Tesla) that covers the energy range 20 MeV-300 MeV

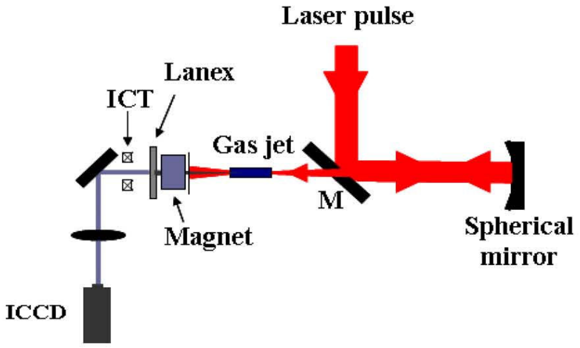

Fig. 1 Experimental scheme for the LWFA

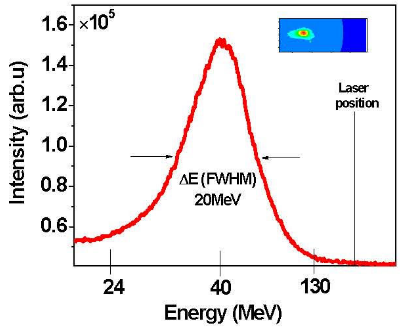

Fig. 2. Electron beam energy spectrum (monoenergetic) for the f/10 case, the beam charge was 20 pC

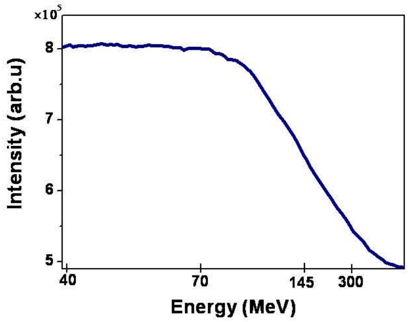

Fig. 3. Electron beam energy spectrum (flat-top) for the f/14 case, the beam charge was 20 pC.

Experimental results are shown in Figs 2 and 3, where the electron beam energy spectrum is shown for two focusing cases, namely, f/10 and f/14, respectively. Monoenergetic electron beam at 40 MeV with a FWHM of 20 MeV was produced in the f/10 focusing case. Flat-top energy distribution with a maximum energy of 300 MeV was produced in the f/14 focusing case. Physics beyond our experimental results and ways for achieving higher beam energies will be discussed.

References

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