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Detection and Characterization of GeV-class electrons from nonlinear laser wakefield

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Recently, monoenergetic electron beams are obtained with intense, short-pulse laser interacting with tenuous (underdense)[1, 2], a few centimeters plasma via laser wakefield acceleration (LWFA) mechanism [3]. Almost all the experiments utilize relatively long focal length focusing devices, of which the F-numbers (ratio of the focal length to the laser diameter) more than 10. The normalized peak laser field $a_0=eE/(mc\omega)$ is not greater than 5 usually, where $e, E, m, c,$ and ω are elementary charge, electric field of a laser, electron mass, speed of light, laser angular frequency, respectively. However, a large f-number detracts from the compactness of LWFA. Furthermore, a recipe for the generation of quasi-monoenergetic electron beans also requires not-so-strong laser intensities at vacuum as high as ~2. We investigated experimentally highly nonlinear regime around a_0~10. The nonlinear regime is not well explored recently and the benefits of the nonlinear regime might be its high gradient and a capability to accelerate high current electrons.

In several experimental campaigns conducted at KPSI, QST, we used J-KAREN-P laser [4, 5] with a relatively small f-number of 10. The peak laser power was 200-300 TW on target with an effective pulse duration of 30-40 fs. The focused intensity reached to 10^{20} W/cm^2 and the normalized laser field was ~10. We tried gas-jets with various sizes of 1 – 20 mm, ionization injection (Ne or N_2 doped with helium or hydrogen)[6], a shock injection with a movable razor blade. We developed a wide-range electron energy analyzer combined with the measurement of an input beam spatial distribution (see Fig. 1). By measuring the input beam angle offset, we can calculate the precise electron energy distribution. With this detector and after optimization of gas species, gas targets, group velocity dispersion, etc. We obtained GeV-class electron beams with good collimation with a high charge. A typical high energy shot is shown in Fig. 2.

In addition, we have developed a longitudinal beam monitor or electron bunch duration and timing monitor based on an electro-optical decoding method [7-9] but the measurable range was limited to ~30 fs. Here, we conducted the detection of coherent transition radiation, which is expected to have much shorter temporal information of the electron bunch. We will show the analyzed data in the presentation.

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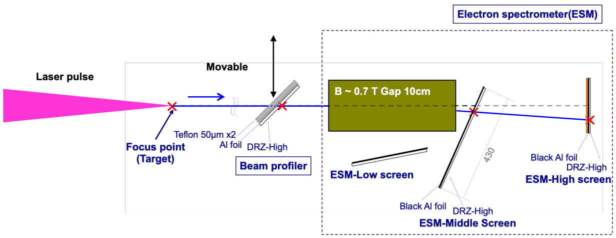

Figure 1. Experimental setup. A wide-range electron spectrometer with a beam profiler is shown.

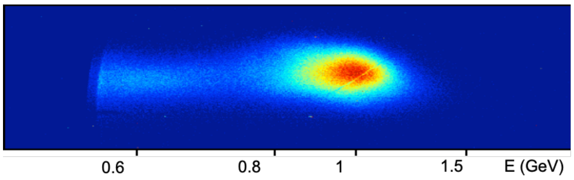

Figure 2. Typical high energy electron shot showing a quasi-monoenergetic peak in the ESM-High screen.

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