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Beam stabilization and control of laser wakefield acceleration by laser near field shaping

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Ever since laser wakefield acceleration (LWFA) concept was proposed by Tajima and Dawson in 1979 [1], a laser-plasma accelerator, which has an acceleration gradient that is thousand times higher than that of conventional accelerators, has been studied and developed as a next-generation compact accelerator [2]. The maximum energy of the LWFA electron beam have already achieved to be 8 GeV [3]. Recently, as one of the milestones in this research area, self-amplified spontaneous emission (SASE) free-electron laser (FEL) has been demonstrated by Chinese group [4], and seeded FEL has been demonstrated by a group of French and German researchers[5]. In Japan, we have a similar project to demonstrate FEL with wavelengths around extreme ultraviolet (XUV) and vacuum ultraviolet (VUV) in the JST MIRAI program [6].

The stability of electron beams is crucial for the practical application of laser-plasma accelerators, such as FELs. Here, we focus on the pointing stability. If the pointing of the beams is unstable, the electron beam cannot be transported to the beamline and guided to the undulator. The stability of the LWFA beams, including the pointing stability, can be improved by stabilizing the laser system and choosing appropriate injection methods. However, the cause of the instability of the LWFA electron beams still needs to be clarified. The typical pointing fluctuations of the electron beams observed in the experiments are three times larger than those of the driving laser pulses.

We have performed LWFA experiment with near field shaping of high intensity laser pulse for stabilization and control beam direction. The experiment have been performed with J-KAREN-P laser system which is a high-contrast petawatt-class Ti:Sapphire laser system at KPSI[7].

In our experiment, we succeeded in stabilizing the electron beams by simply placing an aperture in the laser transport line before the focusing element, that is, an off-axis parabolic mirror (OAP) as shown in Figure 1. Shaping the near-field profile (NFP) of the laser pulse with the aperture removes the outer part of the laser pulse with unstable wavefront and intensity. This improves the quality and stability of the focusing laser pulse, and thus, the electron beam generated by this laser pulse also becomes stable. This simple method is expected to be a key technique for realizing an ultracompact accelerator with LWFA, in the future[8].

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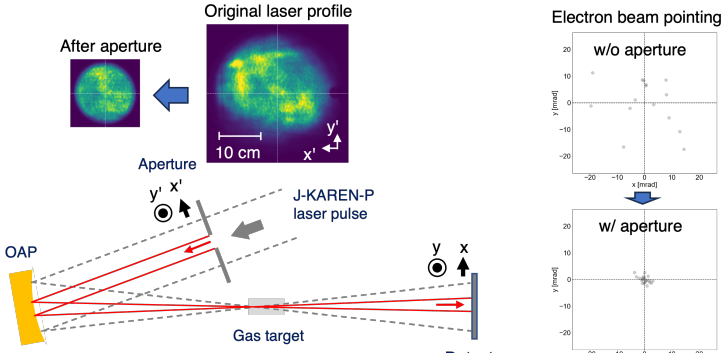

Figure 1 LWFA beam stabilization by near field shaping of high intensity laser pulse