Laser-Plasma Acceleration Research at PAL

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Laser-plasma accelerators have been the most promising candidates for future compact accelerators which can be used for next-generation free-electron lasers (FEL). However, their poor stability and reproducibility limit the applications of the laser-plasma accelerator. Photocathode RF gun is a good candidate for stable electron generation and has been utilized as a major injector for X-ray free-electron laser at PAL (PAL-XFEL) because they provide electron beams with low emittance[1,2].

The Injector Test Facility (ITF) at PAL was built to develop the photocathode gun in 2012 and the results of photo-injector research contributed to successful commissioning of PAL-XFEL in 2016. Since then, the ITF has been refurbished for the purpose as Electron Linear Accelerator for Basic Science (e-LABs). The e-LABs facility consists of two beamlines with separate two RF electron guns. The first beamline is dedicated to MeV ultrafast electron diffraction (UED) research, and thus it was designed for generation of a few of MeV electron bunches. The second is a multipurpose beamline capable of delivering 70 MeV electrons in maximum. This conventional photocathode RF guns separate electron beams with good qualities such as energy jitter of 0.01% and emittance of ~0.5 mm mrad which are required for user facilities.

The plasma acceleration with external injection using these good quality electron beams from RF photocathode gun is very prospective research[3]. Compared to other LPA techniques that accelerate the electrons in plasma wakefield, electron beams from photocathode RF gun are used as an injector for LPA, resulting in better beam quality. Figure 1 shows the planned experimental scheme of the second beamline at e-LABs for plasma accelerator with the external injection method. Generated electron beams from the photocathode gun are accelerated to 70 MeV through a short linear RF accelerator, then the beams are focused to tens of micrometer by the plasma lens. Tightly focused electron beams can be inserted into the laser wakefield driven by an intense laser pulse, leading to acceleration to high energy. If the electron beams have 3 GeV, they can be used to produce soft X-ray FEL[4,5]. For this external plasma accelerator, we have developed a capillary plasma source considering diverse purposes, for example, plasma lens and plasma acceleration shown in Figure 1[6]. The capillary block is made of a sapphire since it can provide a long-lived stable plasma source. Furthermore, we are preparing the laser upgrade to a few hundred TW system to realize the high-energy laser-driven wakefield acceleration and bunch compression for shorter electron bunches for the beam-driven wakefield acceleration and beam injection.

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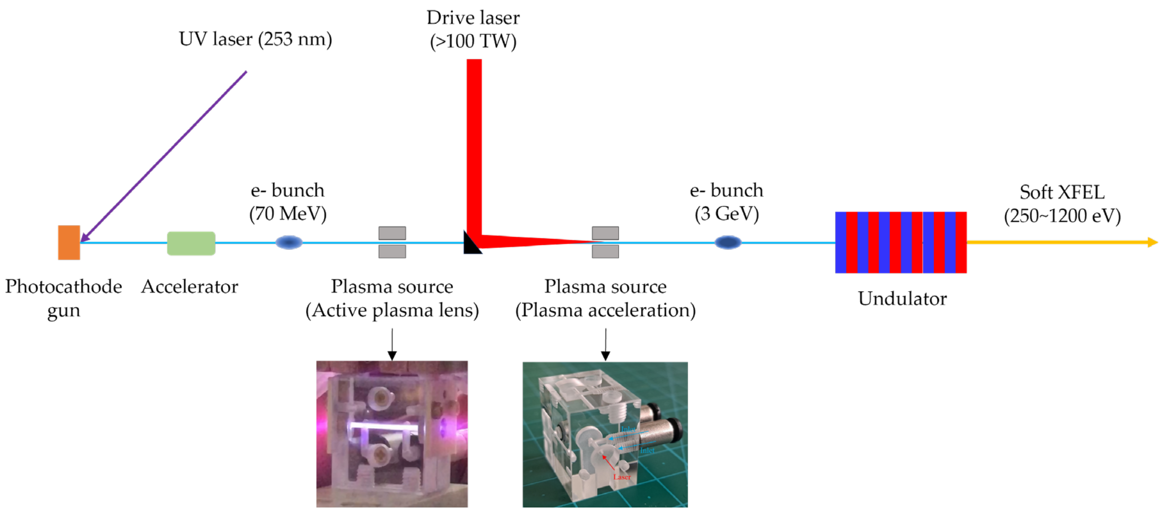

Figure 1. Schematic diagram of plasma accelerator based XFEL researh at e-LABs, PAL. The developed one-body capillary plasma sources can be used for plasma lens and plasma electron acceleration in laser-plasma acceleration research.