4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Femtosecond electron pulses driven by intense laser irradiation on foil target and its application

Shunsuke Inoue, Masaki hashida
Advanced Research Center for Beam Science, Institute for Chemical Research, Kyoto University
e-mail (speaker): sinoue@laser.kuicr.kyoto-u.ac.jp

Irradiating a solid target with an intense laser pulse drives high-energy radiation such as electrons, ions, and X-rays. These radiations have the characteristics of short pulse and high brightness because they are accelerated on a temporal and spatial scale, closing with the pulse width and spot size of the laser pulse. Studies have been conducted on applying laser-driven radiations as a probe pulse with short pulse width and high brightness. For example, laser-driven short-pulse X-rays have succeeded in capturing ultrafast structural changes in substances as a tabletop-sized femtosecond X-ray light source[1]. Using charged particles driven by intense laser as a probe pulse enables measuring ultrafast time-varying electromagnetic fields, which are difficult to observe with other methods. In proton radiography using a laser-accelerated proton beam, it has been reported observation of the spatial distribution of electromagnetic fields that change within a few picoseconds[2]. Since the laser-accelerated electrons can have a pulse width of less than a picosecond, in contrast, laser-accelerated electrons have a feature that they can observe an electromagnetic field that changes faster. Also, since electrons are much lighter than protons, they are highly sensitive to electric fields of small amplitude that cannot be measured with proton beam. We are focusing on this laser-accelerated short-pulse electron and are developing a high-intensity short-pulse electron source[3]. In this presentation, we will introduce the characteristics of this laser-accelerated short-pulse electron and the ultrafast transient electric field measurement using it.

Figure 1 shows a schematic of the experimental setup and a phase of laser-accelerated electron pulse. The experiments were conducted using a Ti:sapphire CPA laser system at Kyoto University. An intense laser pulse (center wavelength: 810 nm; pulse width: 40 fs; pulse energy: 400 mJ; repetition rate: 5 Hz) was split into two pulses. One pulse was provided for accelerating the electron pulses, and the other was provided for as pump pulse at the compression point, after passing through a delay line. An electron pulse was accelerated directly by the laser pulse (intensity: 1×10^{18} W cm^{-2}) striking aluminum foil, the thickness of 11μm. As the electron pulse was accelerated while the laser pulse was interacting with the Al foil, the width of the electron pulse was considered to be comparable to that of the laser pulse[4]. From the laser-irradiated Al foil, electron pulses with a broad energy spectrum were emitted toward omnidirectional. A part of them was injected into a phase rotation system composed of a magnetic lens, dipole magnets pair, and quadrupole magnets. After passing through this phase rotation system, the electron pulse traveled to a compression point to its shortest pulse width. At the compression point, we obtained a high-brightness probe pulse with features such as pulse width: 89fs, energy: 370 keV, charge: 20 fC.

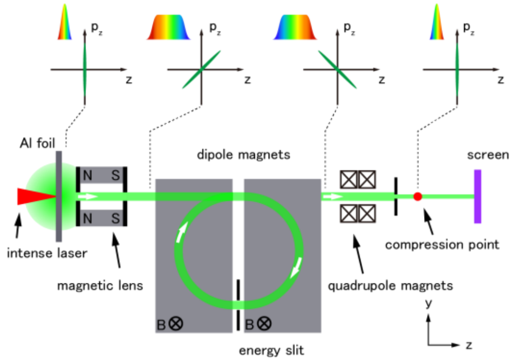

Figure 1. Schematic of experimental setup.

With these electron pulses as the probe for electric fields, the spatial distribution of the electric field generated by the interaction between the femtosecond laser pulse and the solid was measured, with a time resolution of hundreds of femtosecond. Figure 2 shows the snapshot of the electromagnetic field induced by irradiating a 40 fs laser pulse at the intensity of 1014w/cm2 on a tungsten wire. Without the pump laser pulse, an electron backlight image of the tungsten wire was captured. With the pump pulse, as the electron pulse was deflected by the electromagnetic field created by the laser plasma, the backlight image of the electromagnetic fields can be obtained. Over during the several hundred femtoseconds from the laser pulse is irradiated, a semi-sphere shaped shadow image was captured. It is considered that this shadow was created by the electrons emitted from the tungsten wire due to the laser irradiation. The size of this shadow gradually increased with time, which indicates the electrons emitted from the wire gradually increased.

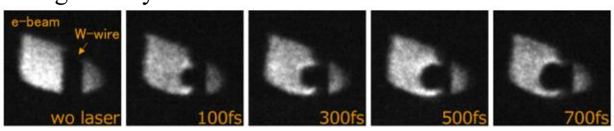

Figure 2. Snapshots of the EM field by fs-laser plasma.

References

[1] Germán Sciaini, Appl. Sci. 9, 1427 (2019).
[2] L. Romagnani et al., PRL 95, 195001 (2005).
[3] S.Inoue, et al., PRAB, 21, 041302 (2018). S. Tokita et al., Sci. Rep. 5, 8268 (2015). S. Tokita et at., PRL 255001 (2011).
[4] S.Inoue, et al., PRL 109 185001 (2012)

Acknowledgements

This work was supported by the MEXT Quantum Leap Flagship Program (MEXT Q-LEAP; Grant No. JPMXS0118070187), a Grant-in-Aid for Scientific Research (C) (Grant No. 18K11918), the Matsuo Foundation, and the AMADA Foundation.