Laser Driven Particle Accelerators and their Application to Science, Industry and Medicine

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We are investigating the laser driven charged particle acceleration to develop a particle accelerator using an intense lasers with a focused intensity of >>10^{18} W/cm^2. To monitor energy spectra as well as plasma parameters under the repetitive operation, we are using real time detectors. The proton energy of ~MeV is stably obtained for applications.

Key Words: Ultra-high intensity laser, Laser produced plasma, Laser driven acceleration

1. Introduction

Currently a table top femto-second Titanium Sapphire laser having typically a 10 Hz repetition rate becomes popular for many fields especially in the laser driven proton sources. A laser pulse with an ultra high contrast ratio irradiates a thin-foil target resulting in a high energy and a high intensity collimated proton beam. 1) On the other hand, a proton beam with the energy of 50 MeV has been obtained with a sub-kJ laser. 2) We hope that such a high energy proton beam will be obtained with a repetitive table-top laser in near future.

The laser driven accelerators have significant features such as delivering an ultra-short and high intensity (high peak current) pulse, having a very small source size (low emittance), as delivering an ultra-kJ current) pulse, having a very small source size (low emittance), a well collimated diverging beam as well as wide energy spread (a chirped proton pulse). Some of them are advantages and also disadvantages for specific applications. Taking into account such issues, the development is extensively going on to realize real applications for industries and medicine using laser driven accelerators.

2. Activities of the experiments

We have performed series of experiments on proton generation with thin foils at APRC, CRIEPI in Japan as well as APR in Korea. 3, 4, 5) We have analyzed these experimental results. 6) We have also performed preliminary application experiments. For example, Figure1 shows the result of proton shadowgraphs of the Cu mesh having a periodically structured pattern. The pulse duration of the Titanium Sapphire laser called JLITE-X 7) at APRC is 50-300 fs at full width at half maximum (FWHM), the pulse energy is 200 mJ, and the contrast ratio of the pre-pulse which is due to the leakage from the regenerative amplifier, to the main pulse is 10^{-7}. The p-polarized laser pulse with ≥50 μm diameter at the 45 degrees incident angle is focused with an off-axis parabolic mirror with a focal length of 646 mm onto the 5 μm thick Tantulam tape target which is operated at 1 Hz repetition rate. The target driven supplies fresh surface to the focal spot at every shot. We are investigating the laser driven charged particle acceleration to develop a particle accelerator using an intense lasers with a focused intensity of >>10^{18} W/cm^2. To monitor energy spectra as well as plasma parameters under the repetitive operation, we are using real time detectors. The proton energy of ~MeV is stably obtained for applications.

Based on the successful proton imaging experiment, we have tried to obtain simultaneous imaging of test samples by protons and X-ray. The experimental result is shown in Fig.2. Details of the experimental conditions and results can be found in Ref.8. Another interesting combination is protons and Tera-hertz (THz) radiation. We have characterized the simultaneous emission of protons and THz radiation from a metal thin tape target. Details can be found in Ref.9. Such techniques will contribute to the development of unique pump-probe technique or multiple beam imaging system with high time resolution.

For this purpose we need a high quality, intense and high energy proton beam. One of the examples of such a proton beam is shown in Fig.3. The special resolution of the mesh image is ~10 μm which shows point proton source and laminar proton flow. This source is applicable to the proton radiography. The conversion efficiency (laser energy into the total proton kinetic energy) is ~3% which is high enough to make radiography for single laser shoot. The maximum energy
In summary, we are investigating the proton generation processes as well as developing its applications. Protons with MeV energy range are stably obtained. We plan to develop laser-driven proton source for medical applications. Towards the medical applications, we put the suitable targets which might be a unique contribution to the industries or sciences.

is 4MeV. Details can be found in Ref.10.

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References


Fig. 1 (a) A Cu mesh is backlit with a single laser produced proton beam. (b) The magnified backlit image of letter, ‘L’ is (a). The scale corresponds to the CR-39 detector plane which corresponds to 63 μm on the object (the mesh) plane. The letter, ‘L’ is clearly visible. (c) Close look up of the proton shadow graph around letter, ‘L’. An etch pit of the proton (radius of ~5 μm) is visible.

Fig. 2 Simultaneous imaging of a mesh by MeV protons (a) and keV X-ray(b).

Fig. 3 a) Transverse intensity profile of the proton beam (>0.8 MeV) recorded on CR-39. The white region corresponds to the proton bombards. b) The proton shadowgraph of the Cu 20 μm mesh.