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Pre-pulse-shape control for efficient laser ion acceleration

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We have investigated the laser acceleration and its application to laser driven neutron source. When a thin film is irradiated with a high-intensity laser of more than 10^{18}W/cm^2, the electrons are accelerated to the relativistic regime and then the strong electrostatic field can be excited due to charge separation between expanding electron cloud and ions at rest to accelerate ions to the MeV region. This ion acceleration mechanism is Target Sheath Normal Acceleration (TNSA)[1], and much research has been intensively done over the past 20 years. Yet, the TNSA mechanism has not been fully understood, and many unexplained physical processes remain, especially regarding the interaction between the laser and the target thin film. Currently, the mainstream of research on laser acceleration in the world is toward high contrast and high intensity, and the contrast, that is, (main laser peak intensity / pre-pulse intensity) has reached a level exceeding 10^{11}. The main laser intensity also exceeds 10^{20} W/cm^2, and the intensity level to reach 10^{23} W/cm^2 has been achieved by ELI-NP in Europe. Laser acceleration research using such high-spec ultra-high-intensity lasers with ultra-high contrast ratio has produced many results such as high-energy ion acceleration. On the other hand, NIF-ARC ultra-high intensity laser experiment at LLNL in USA, a larger amount of proton acceleration than theoretically expected was confirmed experimentally at a laser intensity of 10^{18} W/cm^2 level [2]. The intensity of 10^{18} W/cm^2 is accessible at the general university laboratory, representing that its regime still has much potential to be optimized to achieve efficient ion acceleration.

In our previous studies, it has been found through theory and experiment that the initial target condition immediately before high-intensity laser irradiation, that is, the change in the initial target condition due to pre-pulse irradiation has a significant effect on the TNSA mechanism [3]. Our recent experiments with the T6-laser at Kyoto University demonstrated the enhancement of the ion acceleration efficiency and ion energy. We have found that the appropriate weak nano-second low-intensity pre-pulse enhances the absorption of the femtosecond main pulse laser and increases the slope temperature of the relativistic electron. It is also found that keeping the condition of the sharp density gradient of the rear side of the target is necessary for the efficient ion acceleration. In Fig. 1(a), we show our experimental highlight, where the presence or absence of 1000 Å aluminum coating on a 10 mm thick polyethylene (CH) target. TNSA ion acceleration was performed under the condition that the pre-pulse intensity was varied in five steps (condition 1 to 5), keeping the main intensity identical to 10^{19} W/cm^2. The energy of the accelerated protons was measured using CR39.

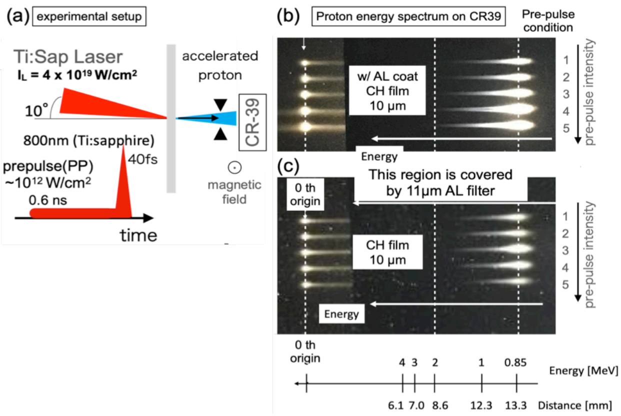

Figure 1 (a) Schematic of the experiment and observed proton spectrum (b) w/Al coat (c) w/o Al coat

The experimental results showed that the accelerated proton energy spectrum with and without aluminum coating changed significantly. Without aluminum coating (Fig.1(b)), TNSA ion acceleration was suppressed when the pre-pulse (PP) level if (Condition 3) was exceeded. On the other hand, in the aluminum-coated target shown in (Fig1(c)), both the number of protons and the maximum energy increase monotonically as the pre-pulse intensity increases. This experiment shows the importance of shine-through control when the transparent target is used for TNSA. Our Experimental results show the increased number of accelerated protons and maximum energy by applying pre plasma under the condition where the density gradient at the rear side of the target is kept to be sharp. The ionization process of the dielectric material by pre-pulse Data is currently being analyzed in terms of the ionization process of the body, and the interaction between the laser and the target.

References

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