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Characterization of Laser-induced Ion Acceleration by Modulation of Spectrum Generated during Laser-Plasma Interaction

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After the development of ultrahigh intensity short pulse laser, laser-induced ion acceleration has been considered an area of challenging laser-matter interaction physics with strong potential for applications. High energy ion beams can be utilized to laser-induced nuclear fusion, proton radiography, laboratorial astrophysics, and cancer therapy. By driving nanometer scale targets with ultraintense laser pulses with peak intensity over 10^{22}W/cm^2, protons/ions can be accelerated by the light-sail (LS) radiation pressure acceleration (RPA) mechanism and the highest ion energy could reach more than 1 GeV in simulation [1].

The LS RPA occurs when a thin layer of electrons from a solid metal or polymer is pushed by the radiation pressure of a high intensity laser pulse. Due to strong laser intensity, the radiation pressure of the laser light gives the momentum to the electrons in a target plasma, accelerating them to high energy. The remaining ions in the target are eventually accelerated also by the Coulomb force between the electrons and ions. On the other hand, the laser pulse that gives pressure to the electron layer is reflected with a spectral shift by Doppler effect. The amount of spectral shift by the Doppler effect is determined by the velocity of the reflecting surface; thus, measuring the laser spectrum reflected from the target material can be used as another evidence of RPA and the energy of electrons.

In this presentation, the investigation of spectral modulation will be discussed from the experiment of proton/ion acceleration using the 20 fs, 4 PW Ti:Sapphire laser at Center of Relativistic Laser Science (CoReLS) [2]. A double plasma mirror (DPM) system was used to enhance the contrast of the laser and to prevent damage of an ultrathin target before the arrival of the main pulse. Ultrahigh intensity laser pulse with very high contrast was focused with an off-axis parabola (OAP) on the target surface with focal spot size of 1.6 - 3.3um, as measured with a focal spot monitoring (FSM) system in the target chamber. The normal direction of the target had an angle around 5 degree from the laser direction in order to prevent damage of the beamline and the laser system by back reflection. Thin polymer target [3] was used with the thickness from 20nm to 100nm. Laser polarization was changed by using a quarter waveplate to convert linear polarization to circular polarization.

Accelerated ion spectrum by the laser pulse was measured by a set of Thomson parabola spectrometers (TPS's). TPS's were installed at the direction of 0 degree (laser direction), 30 degree and 150 degree (rear side) at the end of the chamber. A set of optical fiber were installed to measure the laser spectrum with optical spectrometers, after interacting with the target, in the front and rear sides to measure transmitted and reflected laser spectra from the target.

Dependence between ion energy spectrum and various experimental parameters, such as laser energy, target thickness, and laser polarization, was investigated. And also, correlation between the accelerated ion energy spectrum and measured spectral modulation will be discussed.

References

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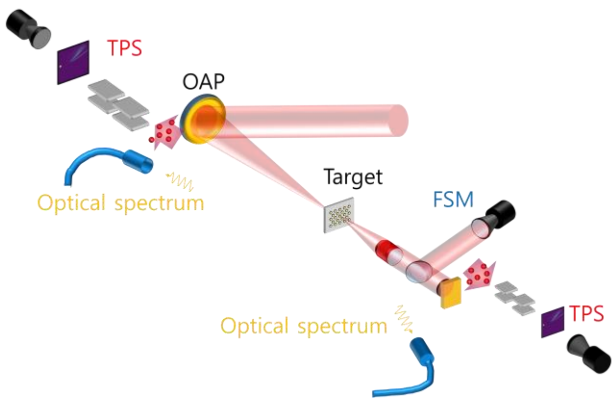

Figure 1. Scheme for the experimental setup of the target chamber. The focal spot monitor (FSM) can be moved vertically in order to clear the path between the target and the Thomson parabola spectrometer (TPS).