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Ion acceleration experiments with high contrast high intensity laser system "J-KAREN-P" -- Extremely strong quasi-static electric field---

M. Nishiuchi[1], H. Sakaki[1], N.P. Dover[1], Ko. Kondo[1], J. K. Koga[1], H. Kiriyama[1], Y. Watanabe[2], M. Kando[1], and K. Kondo[1]

M. Hata [3],N. Iwata[3], Y. Sentoku[3]

[1]*Kansai Photon Science Institute, National Institutes for Quantum and Radiological Science and Technology (QST)*

[2]*Department of .Advanced Energy Engineering Scienmve, Kyushu University*

[3] *Graduate School of Engineering, Osaka University*

nishiuchi.mamiko@qst.go.jp:

Energetic ion beams produced by the high peak power laser pulse and dense matter attracts many field of interests because of their characteristics, such as, short-pulse at source, low emittance, high current, and so on. The acceleration of highly charged heavy ions is of great interest for applications in nuclear physics, for example, in experiments involving heavy nucleus -nucleus collisions. It is crucial to achieve as high as possible an ion charge state in the earliest stage of the acceleration process for increasing the efficiency of the downstream accelerator while decreasing its size and running cost. In addition, the ion energies cannot get higher at the early stage of acceleration in the conventional accelerator system, thus, the space charge effect is severe especially in the acceleration process of heavy ions, which leads the problem of emittance growth. The heavy ion beam produced by the high peak power laser interaction with target shows, on the contrary, more than 10MeV/u energies together with highly charged states [1,2] from the very beginning, which is extremely beneficial beam for the accelerator.

However, high intensity laser pulse interaction with solid density target, the real laser matter interaction is not so simple as the idealized high peak power laser pulse with Gaussian-like temporal and spatial distribution solely interacts with idealized solid density target. Especially the temporal distribution of the laser pulses alters the target condition significantly.

Recently short-pulse petawatt-class high peak power laser systems are able to deliver laser pulses with intensities of ~10^{22}Wcm^{-2} for real experiments. J-KAREN-P laser system at the Kansai Photon Science Institute [3-7] is one of those rare laser systems in the world which can provide real high laser intensity pulses on target for the experiments with the good laser contrast condition and almost diffraction limited focal spots. During the commissioning phase in the last few years, ion acceleration experiments have been carried out extensively and cleared out the effects of how the temporal distribution of the laser pulse effects onto the laser matter interaction, thus, how it effects severely onto the laser intensity, energy and pulse duration scaling of the ion acceleration regime [7-9].

Even though the laser-driven ion beam has beneficial characteristics, there still exists a long way before it is really applicable to the real application. Even the beam accelerated by the "simplest" acceleration scheme of Target Normal Acceleration scheme is not fully controlled yet. It is also true that the details of the sheath field parameters are not yet successfully measured.

Aiming at the controling of the laser-driven ion acceleration scheme, we for the first time measure the sheath field strength by using the charge state of the ions as a probe. The J-KAREN-P laser pulse with the energy of 10J, duration of 40fs was focused down to an almost diffraction spot size to be maximum peak intensity of ~3x10^{21} Wcm^{-2} onto the 500 nm Silver target. We carefully chose the laser pulse shape so that the contaminant layer was removed at the timing of the main pulse interaction with the target without significant deformation. With the condition, the field ionization by the sheath itself dominates any other ionization processes and highly charged silver ions with maximum charge states of +40 ± 2 with the energies of more than 10MeV/u are detected with the Thomson Parabola spectrometer, indicating field strength of ~100 TV/m was established at the target rear side. The PIC simulation (PICLS [10]) combined with the hydro-dynamical simulation (FLASH2D [11]) well-reproduces the experimental condition.

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