1st Asia-Pacific Conference on Plasma Physics, 18-22, 09.2017, Chengdu, China

Laser Plasma based Micrometer Size Mono-energetic Heavy Ion Accelerator

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The interaction of intense, ultra-short lasers with matter has been a fascinating area of research in recent times because of the highly nonlinear, non-perturbative physics that it offers as well as its potential towards realization of table top particle accelerators offering key breakthroughs in the areas of fusion research, surface science, advanced accelerator concept, and many more. The interaction of such a laser pulse with thin foils, in particular, has been explored extensively [1] for achieving a "table-top accelerator" source of protons and lighter atoms. Conventionally, the ion acceleration in thin foil targets is attributed to the Target Normal Sheath Acceleration (TNSA) mechanism [2], in which the multi-MeV energy "hot electrons" generated during ultra-high intensity laser - matter interaction produce an electrostatic sheath field of ~ TV/m magnitude at the foil-vacuum interface. This sheath field ionizes and subsequently accelerates the hydrocarbons contaminant present on target surface. Even if higher-Z atoms are present on the surface, the lighter species get preferentially accelerated due to lower mass and possess a continuous energy distribution. This makes it difficult for the practical application of such ion beams, which require narrow energy spread. With the focused intensity of present day lasers routinely crossing the relativistic barrier, schemes have been proposed based on the radiation pressure of the laser pulse [3] to accelerate lighter ions (e.g. H^+, C) by using few nanometer thick foils as target. However, none of the mechanisms has been so far successful to accelerate heavier ions and that too with a narrow energy spread.

We report, the initial experimental results on accelerating heavy ions (e.g. gold) based on the interaction of intense, ultra-short laser pulses with nano-composite target consisting of 3-8 nm Au nano-particles embedded in 100 nm thick carbon layer deposited on Si substrate. The inset of Figure 1 shows the ion emission spectra recorded using Thomson Parabola Ion Spectrograph (TPIS) from Au nano-composite target from the front side. One can see that all the charge states of Au ions have same kinetic energy and exhibit mono-energetic feature. On the other hand, Si^{1+} ions show a continuous energy distribution. From the derived energy spectra in fig. 1it is evident that for various charge states of Au possess the same kinetic energy, thereby ruling out the possibility of Coulombic acceleration. We believe that it is the kinetic pressure of the expanding bulk plasma pushes the AuNP as a whole and yield a mono-energetic expansion. The initial results will be presented, and our current understanding of the mechanisms involved will be discussed. These above experimental results can be important for different applications like compact plasma based ion sources, as injector to conventional accelerators, inertial confinement fusion studies, and shock related studies.

References:
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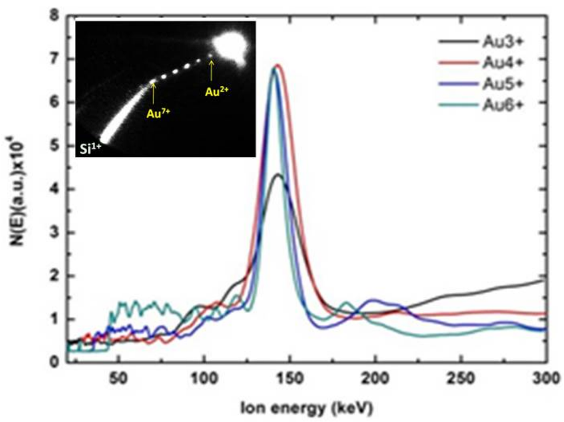

Figure 1: The derived ion energy spectra recorded with TPIS from nano-composite sample. The inset shows the raw TPIS picture.