Charge State Distributions of Ions Accelerated in Shortpulse-Laser-Plasma Interaction ◇

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We report on ion acceleration from thin foils irradiated by ultrashort (350 fs) high-intensity (6×10^{19}W/cm^2) laser pulses. The ions are accelerated from the target rear side normal to its surface, which for protons can be well-explained by the target normal sheath acceleration (TNSA) mechanism [1]. In recent experiments acceleration of heavy ions up to 5 MeV/u could be demonstrated making use of resistive heating in order to remove the hydrocarbon contaminants on the target surfaces [2]. Nevertheless, the real dynamics of the acceleration process, and especially the origin of the different charge states and their energy distribution are not yet understood.
In last years annual report [3] we discussed source size measurements and charge state distributions of ions accelerated from high intensity laser irradiated thin foils. Referring to the homonymous publication [4], in this report we will discuss the conformance of the observed charge state distributions with the equilibrium distributions [5] in more detail. The experiments were performed at the LULI 100TW laser where we used 25μm tungsten foils with a mixture of beryllium, oxygen, and argon on their rear side. Water and hydrocarbon contaminants were removed by resistive heating (1200°C). The laser was focused to the target front side to a spot size of 6μm full width half maximum resulting in an intensity of 6×10^{19}W/cm^2. The ion spectra were recorded by a Thomson parabola spectrometer with a 300μm pinhole placed $\sim$ 1m in the target rear side normal direction.

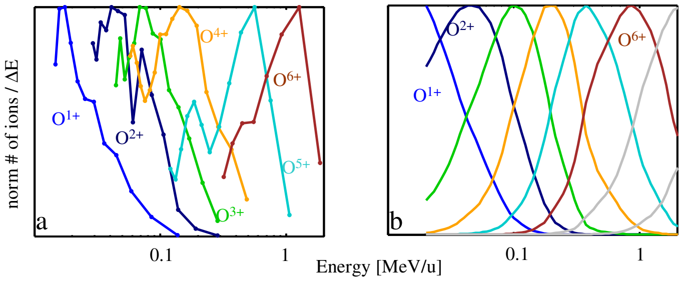

Fig. 1: Typical oxygen charge distribution (a) and equilibrium charge state distribution [5] (b). Each charge state spectrum was normalized to its maximum.

A typical spectrum of oxygen ions observed in a single shot is shown in Fig.1a. Each charge state spectrum was normalized to its maximum. For the absolute scale refer to refs. [3,4]. The same normalization was applied to the equilibrium charge state distribution (Fig.1b), which is obtained when a continuous spectrum of arbitrarily charged oxygen ions pass sufficient matter of solid density, e.g. a thin ($\lesssim$ 20nm) carbon foil. The fraction of the ions in each charge state at different energies was calculated using the mean charge states and distribution widths tabulated in [5] for different incident energies, namely 0.02, 0.04, 0.1, 0.2, 0.4, 1, 2 and 4 MeV/u. The similarity of the two charge state distributions is obvious, indicating that electron capture and loss processes are in equilibrium for the case of laser accelerated ions. The importance of this observation is founded by the fact that recombination up to now was considered to play a minor role during and after the TNSA process. For a quantitative comparison we assumed the tabulated mean values and distribution widths as unknown fit parameters (2 parameter × 8 energy values). The fitted quantities were compared to the tabulated values for carbon foils (Fig.2). The mean charge states are close to the values tabulated in [5] as already discussed in [3,4]. The distribution widths obtained from the fit are a factor of $\sim$ 1.5 lower than the values from [5], whereas the energy dependence is similar. Without showing the data, it should be mentioned that all the discussed characteristics are also true for the observed beryllium and argon charge distributions.

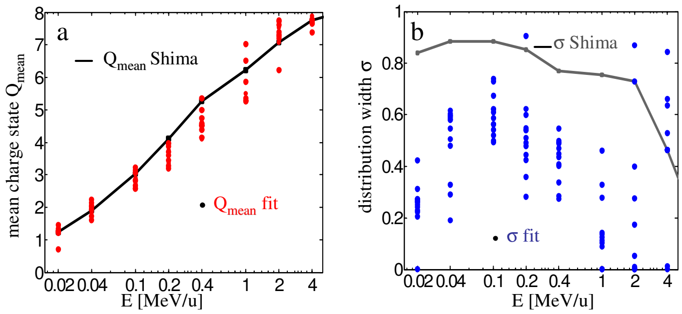

Fig. 2: Mean charge states (a) and charge distribution widths (b). The values obtained from the fitting procedure (dots) are compared to the tabulated values for oxygen ions passing a carbon foil [5].

Future campaigns at the TRIDENT-laser (Los Alamos National Labs) and the PHELIX-laser (GSI, Darmstadt) are planed to further investigate the physical origin which is responsible for the observed charge state distributions.

References

[1] S.C. Wilks *et al.*, Phys. Plasm. **8** (2001) 542
[2] M. Hegelich *et al.*, Phys. Rev. Lett. **89** (2002) 085002
[3] J. Schreiber *et al.*, MLL Jahresbericht (2003) 62
[4] J. Schreiber *et al.*, Appl. Phys. B **79** (2004) 1041
[5] K. Shima *et al.*, At. Data & Nucl. Data Tables. **51** (1992) 173

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