Energy loss measurements of heavy ions in dense weakly coupled plasma generated by volumetric heating with hohlraum generated x-rays

A. Ortner[*1], A. Blazevic[2], M. Basko[7], S. Bedacht[1], W. Cayzac[2], A. Frank[5], S. Faik[6], D. Kraus[3], T. Rienecker[6], G. Schaumann[1], D. Schumacher[2], An. Tauschwitz[6,8], F. Wagner[1], and M. Roth[1]*

[1]Technical University Darmstadt, Germany ; [2]GSI, Darmstadt, Germany; [3]UC Berkeley, USA ; [6]University Frankfurt, Germany ; [7]KIAM Moscow, Russia ; [8]HIC for FAIR, Germany

In two experimental campaigns in 2012 precise measurements of the energy loss of Ca ions in dense, partly ionized carbon plasma have been carried out. An unexpected hight increase of the stopping power in this weakly coupled plasma ($\Gamma \approx 0.5$) has been measured. This was the first time, that ion stopping in such a plasma was measured.

A 1 ns long, frequency doubled ($\lambda = 527$ nm) laser pulse with a total energy of 150 J is converted in a spherical cavity into X-rays with a radiation temperature of $T_r \approx 100$ eV. This Plackian radiation heats up a secondary cylindrical hohlraum to a radiation temperature of $T_r \approx 30$ eV. These soft X-rays are then used to heat volumetrically two thin carbon foils into a dense plasma state. A weakly coupled carbon plasma with an electron temperature of 5 eV to 15 eV and electron density of up to $5 \cdot 10^{21}$ cm^{-3} and an ionization degree of 2^+ to 4^+ is generated. The properties of the primary as well as of the secondary hohlraum have been extensively studied by RALEF2D hydro-simulations [2, 3] and characterized in several experimental campaigns [4]. It has been shown, that no gold from the walls of the cylindrical hohlraum flows into the ion path for about 5 ns, which allows us to study the interaction of an ion beam in a pure carbon plasma.

Fig. 1 shows the experimental setup used at the Z6 target area at GSI. The radiation temperature is measured with an X-ray streak spectrometer [4] and the electron density of the carbon plasma is characterized with a multi-frame interferometry. The ion energy loss is determined by a time of flight measurement of the delayed ion bunches. Details about the experimental setup and the double hohlraum targets can be found in [5].

* a.ortner@gsi.de

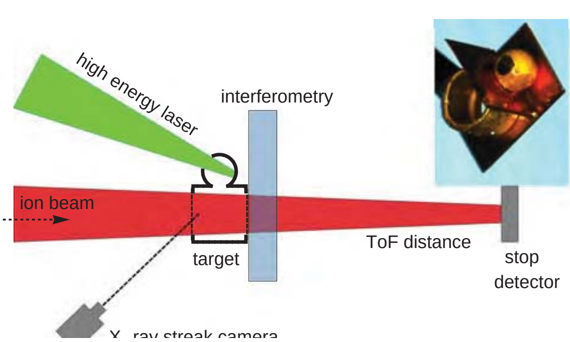

Figure 1: setup of the ion energy loss experiment

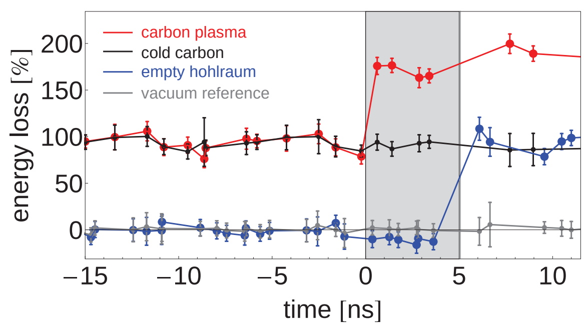

Figure 2: Energy loss results compared with an empty hohlraum, cold carbon and vacuum measurements. $t = 0$ ns indicates the beginning of the laser pulse. The gray area the 5 ns time probing window.

The experimental results are shown in Fig. 2 and compared to measurements of the ion bunch delay in cold carbon of the same areal density as well as to vacuum and to a empty hohlraum shot. The scale of the y-coordinate is normalized to the energy loss in cold carbon. As it can be seen on the "empty hohlraum" - measurement, the gold plasma coming from the wall, at earliest affects the ion bunches after 5 ns. In plasma an increase of the energy loss of $+70$ % is observed. Presently, our theoretical model basing on the CaSP code for the stopping-power calculation and on a newly developed Monte-Carlo code for the charge-state determination, cannot explain such a strong increase [6]. A crucial point to validate this theoretical approach is to compare the calculated charge state distribution with experimental data. For this reason, we will carry out a beam time in september 2014 where we will focus on the measurement of the charge state distribution of the outcoming ion beam after interacting with the plasma column.

References

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