Ion energy loss at maximum stopping power in a laser-generated plasma*

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Ion stopping in plasma is relatively well-understood for projectile velocities much higher than the thermal velocity of plasma electrons ($v_{ion}/v_{th} >> 1$), but large uncertainties remain for the region of maximum stopping power, where $v_{ion}/v_{th} \approx 1$. This parameter region, of crucial importance for ICF, is very difficult to model theoretically [1] and, to our knowledge, no experimental data exists in order to benchmark the existing theories and numerical codes. The purpose of this work, led in collaboration with the CEA and CELIA in France, is to carry out such measurements, and the first campaign was conducted in 2012.

100 μg/cm^2 carbon foils were irradiated from both sides with frequency-doubled pulses from the PHELIX and *nhelix* laser systems, as in [2]. The generated hot (200 eV) and dense (10^{20-21} cm^{-3}) plasma has been well-characterized by using multi-frame interferometry [3] and hydrodynamic simulations with the RALEF2D code [4], both approaches being consistent with each other [2,3]. The plasma was fully ionized and ideal (coupling coefficient $\Gamma \approx 0{,}01$). The projectile energy was $0{,}5$ MeV/u, and carbon ions were employed, as they are expected to be fully stripped in plasma in these conditions, according to Monte-Carlo calculations. In this way, no charge variation affects the stopping power and only the Coulomb logarithm of the interaction is expected to play a role. Theoretical calculations of the stopping power of C^{6+} in a fully ionized carbon plasma reveal discrepancies reaching $30\,\%$ between the various approaches.

The experimental setup is shown in Fig.1. The ions were decelerated to $0{,}5$ MeV/u by using a graphite foil of 45μm thickness. This led to a beam straggling of $10\,\%$ in energy and 1-2° in angle, as calculated with the TRIM and Geant4 codes. The decelerating foil was positioned only 10 mm from the plasma target, allowing about $90\,\%$ of the ion beam to interact with a transversally homogeneous plasma according to TRIM and RALEF2D results, while keeping the foil outside of the laser beam path. To avoid the overlapping of consecutive ion beams, a time-of-flight distance of only 50 cm had to be used.

A new 15×15 mm^2 large and 13 μm thick polycrystalline CVD-diamond detector was therefore specially developed for the experiment, allowing to register $10\,\%$ of the beam. Due to their proximity to the plasma, the detector and the signal transmission line had to be properly shielded against X-rays and EMP. In particular, a 2 mg/cm^2 gold foil on the beam path blocked most of direct X-rays without stopping the ions.

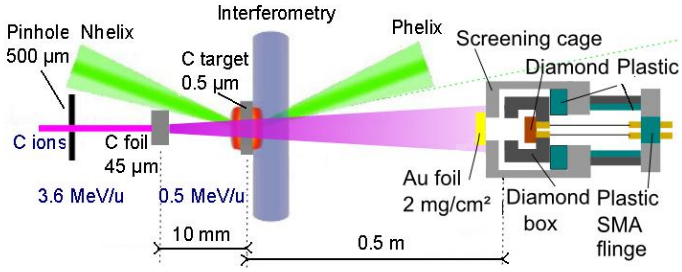

Figure 1: Experimental setup.

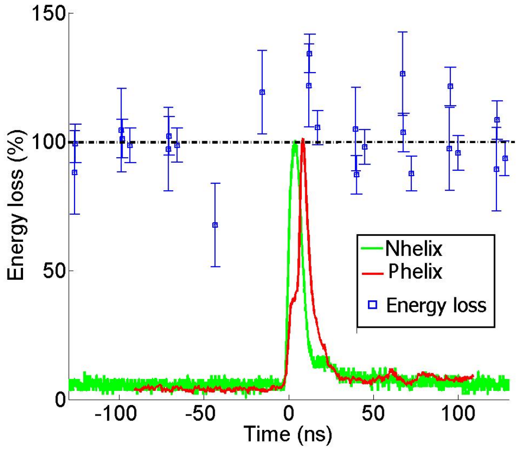

Figure 2: Energy loss as a function of time. $100\,\%$ corresponds to the energy loss in the solid foil.

First data was successfully gathered, and preliminary results are shown in Fig.2. An increase in energy loss in plasma of $34\,\%$ in relation to the cold target is observed.

References

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