First Energy Loss Measurements for C-ions in Shockwave-driven, Non-ideal Plasmas

K. Weyrich[1], H. Wahl[2], A. Golubev[3], A. Kantzyrev[3], M. Kulish[4], S. Dudin[4], D.H.H. Hoffmann[1,2], B. Sharkov[3], V. Mintsev[4]
[1]TU Darmstadt, [2]GSI Darmstadt, [3]ITEP Moscow, [4]IPCP Chernogolovka

Strongly-coupled, non-ideal plasmas with Γ-parameters ≥1 in the density regime up to 10^{22} e^-/cm^3 and temperatures between 1-10 eV and their interaction with heavy ions beams are of interest for basic research in ICF and laboratory astrophysics. Especially a deviation from the Z_{eff}^2 behaviour of the energy loss of the ions in the plasma is expected [1]. At the Z6 experimental area at GSI non-ideal plasmas can be created by shockwaves originating from the detonation of a high explosive, 360 mg Nitropenta (NP) or 55 g RDX. The shockwave compresses Xe-gas in a glass-tube and a plasma layer is formed infront of the schockfront that propagates through the target [2]. The experimental set-up completed in summer and commissioned in a test beam-time in August 2001 ressembles the one used at the ITEP Moscow for measurements with proton beams [3].

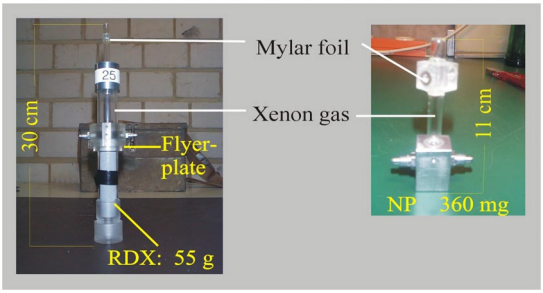

Fig. 1: Two target versions: the large design with RDX and detonator (left), the small design were the shockwave is detonator-driven only (right)

A beam-time with first results on shockwave-velocity and energy loss of C-ions with 5.9 MeV/u in a Xe-plasma was carried out in November 2001. For this beam-time a modified version of the large 55 g RDX containing target [2] with flyer-plate shown in fig. 1 (left) was used for practical reasons, easier alignment and no time-consuming cleaning of the chamber and vacuum-components from soot. The modified target in fig. 1. (right) consists mainly of the upper part of the large target: the small glass tube and the cube with the foil windows for beam passage and an aluminum body with gas inlets and the detonator glued into the lower end. Due to the small diameter of the gas filled section a flyer-plate is not neccesary to provide a plane shockwave in the Xenon gas. The detonator containinig 360 mg NP is here the source for a high-pressure pulse coupling as a shockwave into the Xe-gas.
Hence, it was neccessary to guarantee that the detonator really explodes and is not only destroyed by deflagration. This demands a rise-time for the high voltage pulse delivered to the detonator of less than 0.5 µs with a peak height ≥ 2 kV and as consequence a low-inductivity circuit. The realization of the ignition machine which provides this pulse uses a triggered spark gap as high voltage switch (thyratrons can not handle the fast current rise) and was built at the TU Darmstadt.
The main features to analyse the data of the measured energy loss as function of the plasma free electron density n_e and temperature T_e are the shockwave velocity and initial Xe-gas pressure from which these two parameters can be calculated by a code developed at the ICP, Chernogolovka. The shockwave velocity was diagnosed by two methods, with a streak camera recording the light emission from the passage of the shock front through the glass tube. Additionally there is a fiber-optical system, consisting of 4 fibers with 300 µm core-diameter which are placed equidistantly in the fiber-holder along the glass tube Each fiber is connected to a photodiode and the signals from the photodiodes are recorded with a TDS 744 oscilloscope. The time-delay between the recorded light-signals on the oscilloscope enabled an online estimation of the shockwave velocity.

Target-Nr.	Pressure (bar)	v_{sh} (mm/µs)	v_{sh} (mm/µs)
6	0.2	2.95	3.03
9	0.4	2.92	2.94
10	0.67	3.14 streak	3.13 fibers

Table 1: Xe-pressure and shockwave velocity diagnosed with a streak camera and by the fiber optical system

Table 1 shows the measured shockwave velocity and the original Xe-gas pressure in the target. Both measuring methods are in good agreement for the resulting shockwave velocities between 2.9-3.15 km/s, which are weakly pressure dependend.

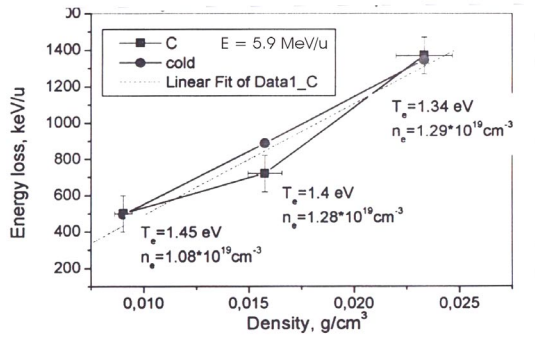

Fig. 2: Energy loss of C-ions in cold Xe-gas and plasma

Fig. 2 shows the measured energy loss in cold Xe-gas and the Xe-plasma for the 3 targets in table 1 and the resulting free electron densities and temperature. The temperature T_e varies between 1.3 eV and 1.4 eV, while n_e is between 1.1-1.35*10^{19} cm^{-3}. Non-idiality parameters are ~ 1. Nevertheless the measured energy loss in the plasma in this first experiment deviates within the error bars not from the one in the cold gas, which is due to the low ionisation degree of less than 10 %, thus the energy loss is still mainly determined by the bound electrons.

References

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