

Energy Loss of 5.9 MeV/u and 11.4 MeV/u C-ions in Shockwave-driven, Non-ideal Plasma

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For strongly-coupled plasmas a deviation from the Z_{eff}^2 behaviour of the energy loss of ions, as known in weakly coupled plasmas, is expected [1]. Strongly coupled plasmas are characterized by a Γ -parameters ≥ 1 . Interaction of heavy ions with strongly-coupled plasmas and possible non-ideality effects in the density regime up to 10^{22} e-/cm³ and temperatures between 1-10 eV are of interest for basic investigations in the warm dense matter regime and laboratory astrophysics. Such conditions can be realized in shockwave-driven plasmas, as they are investigated at the Z6 experimental area at GSI since 2001. The shockwave that creates the plasma is driven by the detonation of a high explosive, and compresses gas (Xe or Ar) in a glass-tube. In front of the shockfront, a plasma layer propagates through the target. For details of the experimental principle and first results of the interaction with C-ions see [2].

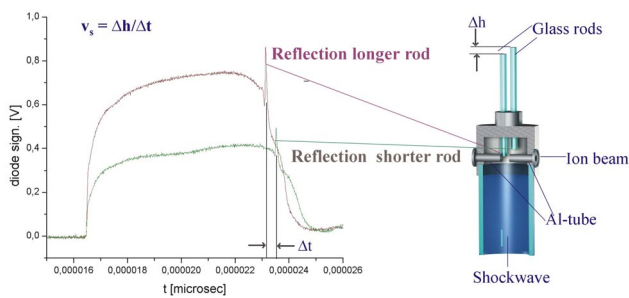


Fig.1: Measurement of the shockwave velocity in Ar-plasma

A new type of plasma targets was developed with a one-tube head replacing the 2-stages-type or detonator-driven type described in [2]. Two small Al-tubes intrude into the head, leaving only a 4 mm gap as interaction zone to avoid edge effects at the tube-wall and minimize straggling.

For diagnosing the plasma parameters the shockwave velocity was measured as shown in fig. 1. Two glass rods penetrate with different length into the target head and are connected to optical fibers. The light emitted from the travelling shockfront is transmitted via the optical fibers and recorded with photodiodes. At the surface of the rods the shockwave is reflected which is seen as a peak in the light signal. The shockwave-velocity, therefore, is calculated from the timely distance of the peaks and the difference in rod-length. Shockwave velocity and initial gas pressure are the needed input parameters for determining the plasma parameters. Codes developed at the ICP in Chernogolovka based on spectroscopic data, which give as a result the plasma free electron density and temperature, whereas the Γ -Parameter follows, enable this. The measurements revealed for an Ar-plasma free electron densities between $0.26 - 1.5 \cdot 10^{20}$ cm⁻³ for initial Ar-pressures between 0.2 - 3 bar and Γ -parameters between 0.6 - 1.3. Figures 2 and 3 show the

measured energy loss for two ion energies, 5.9 MeV/u and 11.4 MeV/u, of ¹²C-ions for plasma and cold gas of the same particle line density (the compression factor plasma to cold gas is ~ 10). Even if the plasma values seem to be enhanced, in the range of the error bars no difference between the energy loss in gas and plasma can be detected. An enhancement of the energy loss in plasma above the one in cold gas is known from several measurements in ideal plasmas in the density regime of $10^{16} - 10^{21}$ cm⁻³.

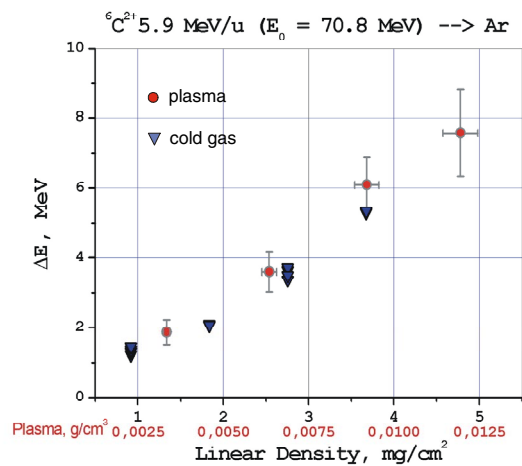


Fig 2: ΔE of 5.9 MeV/u C-ions in Ar-plasma and gas

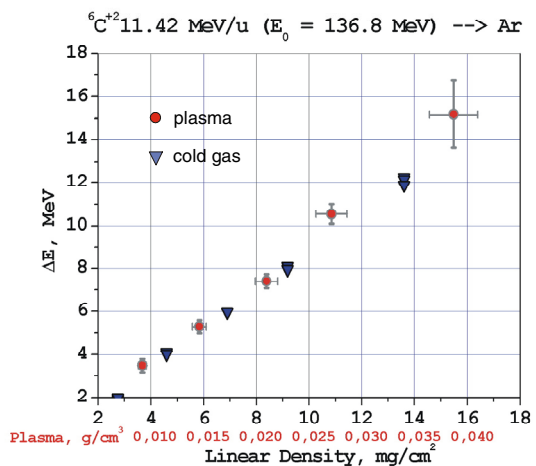


Fig 3: ΔE of 11.4 MeV/u C-ions in Ar-plasma and gas

Further investigations are necessary to decide, if this result has to be explained by the fact that the energy loss is dominated by the still bound electrons as in cold gas or if here a different behaviour in non-ideal plasmas is indicated.

References

- [1] G. Zwicknagel et. al., Phys. Rep. 309 (1999) 117
- [2] K.Weyrich et. al., GSI-Report, GSI-2001-6, Nov. 2002