Simulation of Hydrogen Metallization Experiment Using the SIS-200

N. A. Tahir[1], A. Kozyreva[1], D. H. H. Hoffmann[1,2], A. Shutov[3], J. A. Maruhn[4], P. Spiller[2], U. Neuner[2], A. Tauschwitz[2], J. Jacoby[2], M. Roth[2], R. Bock[2], H. Juranek[5], R. Redmer[5]

[1]TU Darmstadt, [2]GSI Darmstadt, [3]ICPR Chernogolovka, [4]Universität Frankfurt, [5]Universität Rostock

This contribution presents two-dimensional hydrodynamic simulations of a cylindrical multi-layered target that contains a layer of frozen hydrogen and is irradiated by a uranium beam. These simulations have been done using the BIG-2 [1] computer code. The beam-target arrangement is shown in Fig. 1. The target is 3.0 mm long and the radius of the hydrogen layer is 0.5 mm whereas the outer target radius is 3.0 mm. The right face of the cylinder is irradiated with the SIS-200 beam. The beam consists of 10^{12} particles of U 400 MeV/u and the pulse length = 50 ns. The beam spot has an annular shape (ring shape). The inner radius of the focal spot ring is also 0.5 mm while the outer radius is 2.0 mm. This avoids direct heating of the hydrogen region. The range of 400 MeV/u uranium ions in solid cold lead is 4.25 mm. The energy deposition is therefore approximately uniform in the lead shell because the Bragg peak lies outside the target.

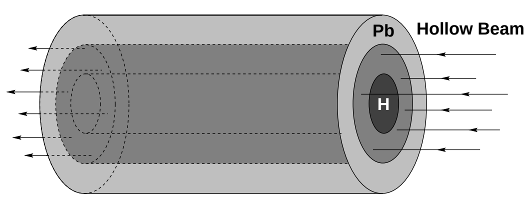

Figure 1: A Multi-Layered Cylindrical Target Driven by 400 MeV/u Uranium Beam

Figure 2 shows the density vs radius at L = 1.5 mm (middle of the cylinder) in the hydrogen region at different times during the implosion. It is seen that at t = 100 ns, a shock has entered into the hydrogen region and the shock front is at r = 150 μm. Moreover the hydrogen-lead boundary has moved from an initial position of 500 μm to about 350 μm. The shock converges at the cylinder axis at t = 115 ns and a return shock developes that is seen moving outwards at t = 120 ns. The return shock is again reflected at the hydrogen-lead boundary that continues to move inwards slowly. As a result of this multiple shock reflection and slow adiabatic compression, the hydrogen layer is compressed to physical conditions predicted for hydrogen metallization. These include a density of about 1 g/cm^3, a pressure of above 3 Mbar and a temperature of a few 0.1 eV. The SESAME equation-of-state data is used for hydrogen.

In Fig. 3 we plot the density, pressure and temperature vs radius in the hydrogen region at L = 1.5 mm at t = 170 ns. It is seen that the density is about 1 g/cm^3, the average temperature is about 0.2 eV while the pressure is above 5 Mbar. These conditions exist between t = 160 ns - 200ns which provides with enough time for experimental investigations. For details see Refs. [2,3].

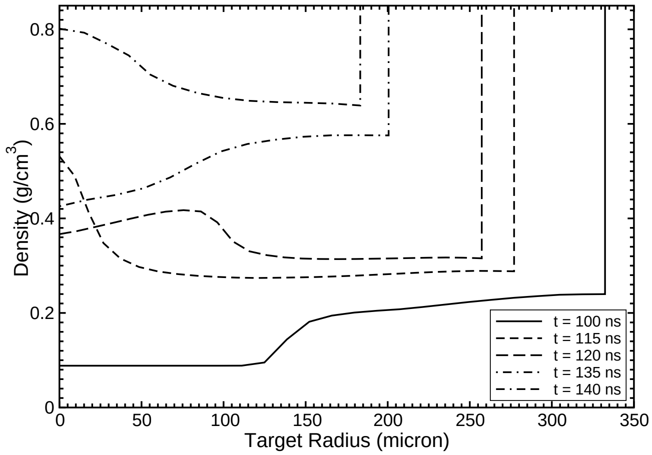

Figure 2: Density vs Target Radius at L = 1.5 mm

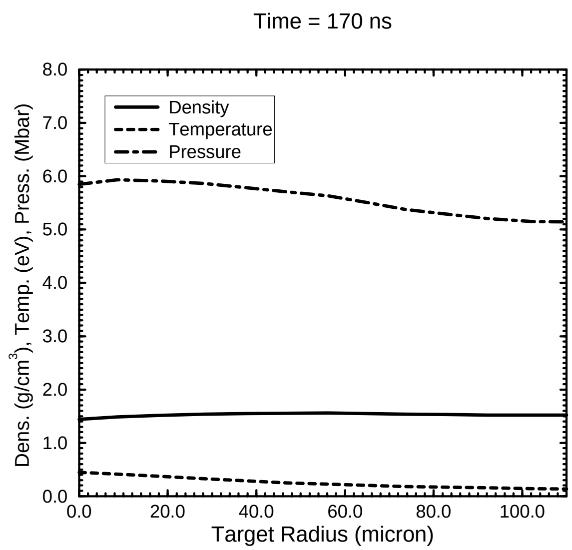

Figure 3: Density, Temperature and Pressure vs Target Radius at $L = 1.5\,\mathrm{mm}$ and at $t = 170\,\mathrm{ns}$.

References

[1] V. E. Fortov et al., Nucl. Sci. Eng. 123 (1996) 169.

[2] N. A. Tahir, D. H. H. Hoffmann, A. Kozyreva, A. Tauschwitz, A. Shutov, J. A. Maruhn, P.Spiller, U. Neuner, J.Jacoby, M.Roth,R. Bock, H. Juranek and R. Redmer, Phys. Rev. E 63 (2001) 016402.

[3] N. A. Tahir, D. H. H. Hoffmann, A. Kozyreva, A. Tauschwitz, A. Shutov, J. A. Maruhn, P.Spiller, U. Neuner, J.Jacoby, M.Roth,R. Bock, H. Juranek and R. Redmer, Contrbu. Plasma Phys. (2001) In Print.

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