Schlieren investigations on pressure waves induced by the heavy ion beams in solid targets

C. Constantin[1], E. Dewald[2], C. Niemann[2], S. Udrea[1], D. Varentsov[1], U.N. Funk[1], D.H.Hoffmann[1]
J. Jacoby[2], U. Neuner[2], P. Spiller[2], A. Tauschwitz[1]
TU-Darmstadt[1], *GSI-Darmstadt* [2]

The intense relativistic heavy ion beams generated in the heavy ion synchrotron (SIS) of GSI offer the possibility to study the matter under extreme conditions. This is a subject of many on-going experiments at HHT area of GSI, such as investigations on the hydrodynamical evolution and cold compression of the matter supressed to the high energies delivered by the ion beam. The adiabatical cold compression of solid state matter is relevant for equation of state (EOS) studies including phase transitions to metallic state [1]. In one of these experiments a $^{83}Kr^{36+}$ ion beam with $2 \cdot 10^{10}$ particles/pulse, 300 MeV/u energy and 700 ns pulse duration was stopped in a solid layered target which is described in the graphic below (fig.1).

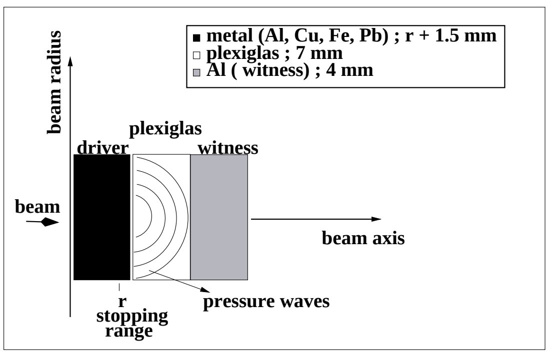

Figure 1: The target design: metal driver, 7 mm plexiglas window, 4 mm Al witness for observing the reflexions on interfaces between different materials.

After the beam is stopped in the driver pressure waves are launched and propagate in the plexiglas. To visualise and characterise them a schlieren technique was employed. Schlieren method is based on the bending of light rays when passing through refractive index gradients perpendicular to the optical path. The perturbances induced by the pressure waves in the target create regions of density gradients which will deflect some rays of the initially parallel laser beam towards the higher densities; these rays will no longer follow the parallel beam which is blocked by a beam stop put in the focus of the laser beam. They will pass near by and will be recorded on the detectors.The time resolved detection in this case was done by a streak camera working in a 10 μs streak time mode. The time resolution given by the streak slit width was of 180 ns and a very strict focusing on the target insured the space resolution. A framing camera was mounted together with the streak camera for two dimensional visualisation of the shock front. The 2D pictures so obtained showed a spherical wave expanding in time. From the streak pictures it was possible to determine the propagation velocity, which was found to be slightly higher than the speed of sound in plexiglas (2.6 km/s). The velocity and the consequently determined pressure values [2] depend on the heavy ion beam energy deposition in the driver material. For the Kr ion beam and all four materials this values are tabulated below (table 2).

species	driver	velocity [km/s]	pressure [Gpa]
$^{83}Kr^{36+}$	Al	2.82	0.26
	Fe	2.74	0.21
	Cu	2.70	0.16
	Pb	2.92	0.40

A typical behaviour for shock waves is to split whenever an interface between two materials with different acoustic impendences is encountered [3]. Due to this fact multiple pressure waves could be seen in the experimental pictures together with their reflections on the plexiglas boundaries (fig.2). Future experiments will consist in several optimizations regarding the target geometry and moddeling of the shock front, i.e. to obtain planar shock waves, much more effective also from the investigation point of view. As a result, also an increase in the compression factor (around 0.04 in the actual conditions) is expected. The experimental set-up will be oriented towards absolute measurements of three main parameters: velocities of the shock wave propagation, pressures behind the shock waves and densities in the sample material. These results would constitute reliable benchmarks for the theoretical simulations and EOS studies.

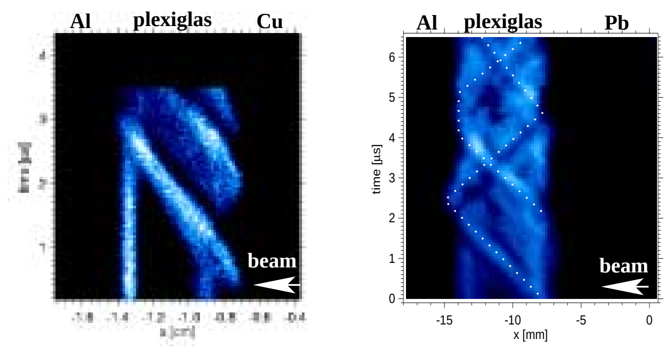

Figure 2: Experimental picture of a Pb-plexiglas-Al and Cu-plexiglas-Al target shooted with a Kr ion beam.

Acknowledgments: We thank BMBF for supporting this work.

References

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