

# Multiple shockwaves driven by heavy ion beams in solid matter

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At the high energy density experimental area (HHT), strongly coupled plasmas are created by the interaction of the SIS heavy ion beams with solid targets. Presently, the generated plasmas have densities close to the solid state, large volumes of several mm<sup>3</sup> and temperatures up to 1 eV. Besides experiments of direct matter heating by heavy ion beams, a complete study of the low entropy shock compression of solid matter driven by the ion beams was performed, with relevance for the equation of state of matter at low temperatures, astrophysics and others [1]. In these experiments layered metal-plexiglass targets were used [2], whereby the fine focused ion beam (FWHM < 0.5 mm) is fully stopped in different metal absorbers and the induced shocks are investigated in a plexiglass layer. The shock dynamics was studied time and space resolved by two-dimensional schlieren measurements performed simultaneously with a framing and a streak camera (Fig. 1).

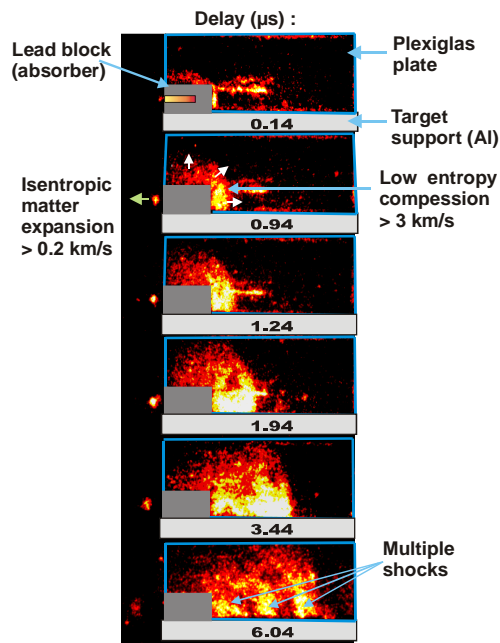


Fig.1 Two-dimensional schlieren multi-framing pictures of the weak shockwaves induced by an <sup>197</sup>Au<sup>65+</sup> beam (300 MeV/u, 700 ns pulse).

The obtained pictures are mapped in density gradients induced in the transparent regions and besides the shockwave dynamics they show the isentropic expansion of the Pb target heated directly by the ion beam. Furthermore, the improved resolution and target design as compared to [2] allowed the measurement of the shock velocity variation along the plexiglass window (Fig.2). The highest shock velocity in plexiglass, was obtained for the Fe absorber (4 km/s) and was considerably higher than the sound speed at room temperature (2.6 km/s). As expected, much lower shock velocities were obtained for the Pb absorber for an unfocused ion beam (Fig. 2). The corresponding pressures in the shock are proportional to the measured velocities and were estimated for PMMA from empirical data

[2] to values considerably higher than 14 kbar which corresponds to 3.4 km/s.

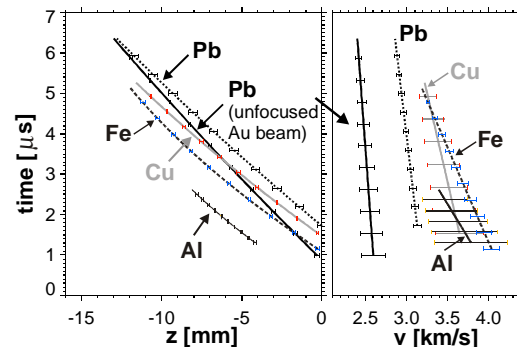


Fig.2 Axial shock expansion and the corresponding shock velocity in plexiglas for different absorber materials.

Another interesting point is that the velocity decrease is the highest for Al and the lowest for Pb, showing that the radii of the spherical shock front (Fig.1) is larger e.g. for Pb than for Al. This can be explained by the fact that the shape of the shock front is determined by the hydrodynamics of the heated matter in the Bragg peak region, which is very pronounced for Pb and reduced for Al and Fe due to their high melting points or binding energy. The shock time history and density gradients were measured locally in plexiglass, along the ion beam axis, by laser deflection measurements, method which measures directly the deflection of a laser beam due to transversal refractive index (density) gradients (Fig. 3).

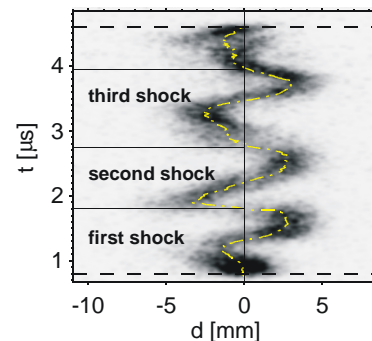


Fig.3 Typical streak picture obtained with laser deflection measurements for an Fe-Plexiglas-Al target [1].

As schlieren, this method showed that the shock frequency and strength depends on the absorber material. Along with schlieren and laser deflection, interferometric and pressure gauge measurements were employed to measure directly the induced densities and pressures. Metal-cryogenic crystal layered targets will be employed in the near future in similar experiments. (Funded by BMBF)

## References

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