Isentropic Compression of Iron with PHELIX*

B.F. Ionita[1], D.H.H. Hoffmann[1], A. Ortner[1], S. Udrea[1], F. Wagner[1], V. Bagnoud[2], A. Blazevic[2], A. Frank[2], D. Varentsov[2], K. Weyrich[2], N. Amadou[3], and E. Brambrink[3]

[1]TUD, Darmstadt, Germany; [2]GSI, Darmstadt, Germany; [3]LULI, Paris, France

Laser-driven isentropic compression is an important technique to reach high-pressure low-temperature states, which are of interest for planetary physics (especially the relatively poorly known multi-Mbar range of the phase diagram of iron found in Earth's interior). This technique requires relatively long compression times (>10 ns), times which can be achieved with the PHELIX laser.

The experimental setup deployed in this work is shown in Fig. 1: thin iron foils (10-50 μm) were compressed isentropically by irradiating with a flat-top PHELIX beam (15 ns, ~150 J @2ω, Ø1 mm), while velocity on the free surface was recorded simultaneously by two line VISARs [1,2] (Fig. 2), with spatial resolution of ~20 μm (Fig. 3a).

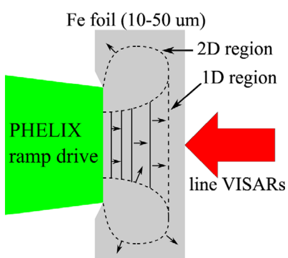

Figure 1: Experimental principle.

The velocity interferometers were equipped with fused silica etalons of 15.04 mm and 50 mm, corresponding to velocity sensitivities of 3415 m/s/fringe and 1027 m/s/fringe, respectively, using the frequency doubled beam (532 nm) of nhelix as diagnostic laser.

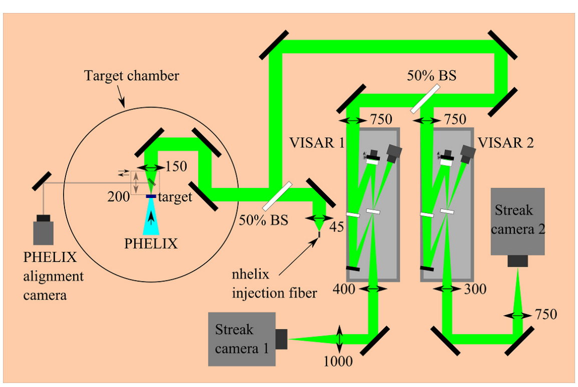

Figure 2: Optical schematics of the dual line VISAR setup in the Z6 experimental area.

Raw interferometric data obtained with the system are shown in Fig. 4b. A smooth fringe shift indicates shock-less compression, as expected for isentropic compression.

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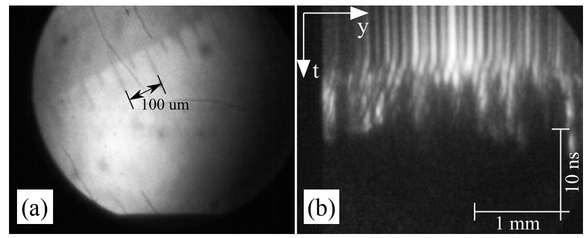

Figure 3: (a) Spatial calibration; (b) raw interferogram.

Surface velocity profiles were obtained by tracing the fringe shifts, from which particle velocity was determined as half of the surface velocity, given that expansion takes place in vacuum (therefore no impedance matching). Pressure was further derived from an iron isentrope starting at room conditions.

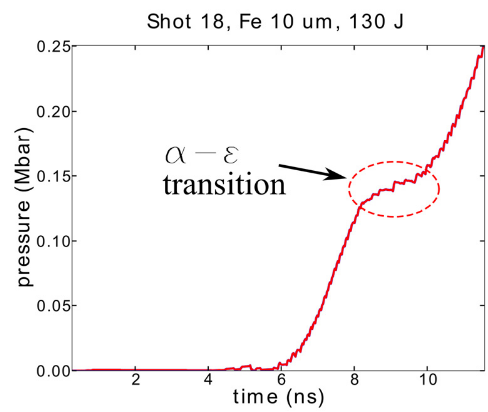

Figure 4: Pressure temporal profile with α–ε phase transition plateau.

In Fig. 4, the plateau on the profile between 8 and 10 ns is related to the well known α–ε phase transition in iron at ~130 kbar, its length and starting velocity comparable to other results [3]. The study of dynamics of phase transitions [4] can be thus studied.

The shape of the temporal intensity profile of PHELIX as well as its spatial intensity profile will be optimized in future experiments to increase the maximum reachable pressure to several Mbar.

References

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