Imaging Interferometer for Pressure Measurements in Ion-Beam Driven HEDP Experiments*

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The relatively poorly explored near critical region of Pb ($T_c \approx 5500$ K, $p_c \approx 2.3$ kbar) was reached at HHT using sub-microsecond SIS-18 uranium beams at 350 AMeV and ~$3 \cdot 10^9$ particles/pulse, with a sub-millimetre spot on target, leading to uniform isochoric heating, evaporation and expansion of the material across a gap (Fig. 1a).

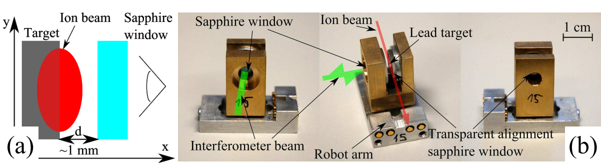

Figure 1: Target - ion beam - diagnostics configuration: (a) experimental principle; (b) target holder.

The behaviour of Pb during isentropic compression on the front surface of a sapphire window (Fig. 1) was analyzed using a fast multi-channel pyrometer [1] and a specially developed imaging displacement interferometer (Fig. 2), designed to permit for the first time simultaneous temperature and pressure measurements (Fig. 3) by integrating the light collection optics for both systems on the pyrometer head. The specularly reflecting sapphire surface is imaged on a 50% beam-splitter through a doubly afocal system in order to keep the optical front flat. It is further relayed to the surface of the reference mirror which can be tilted remotely to allow for fringe tuning, and to an alignment camera and a streak camera, at a final resolution of ~50 µm. The imaging capability is used to solve fringe movement uncertainties.

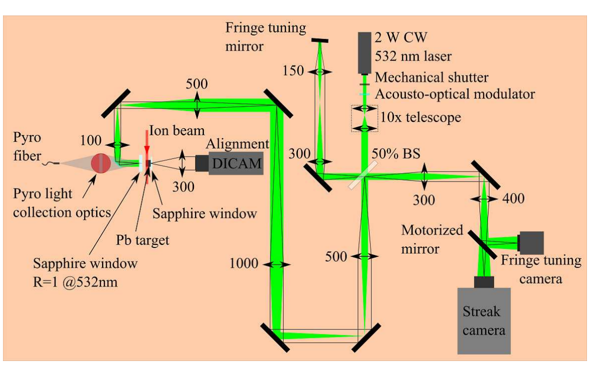

Figure 2: Optical schematics of the diagnostic devices.

Pressure is calculated as the product of acoustic impedance of sapphire and particle velocity (half of the surface velocity obtained through time derivation of the measured displacement, given no impedance matching).

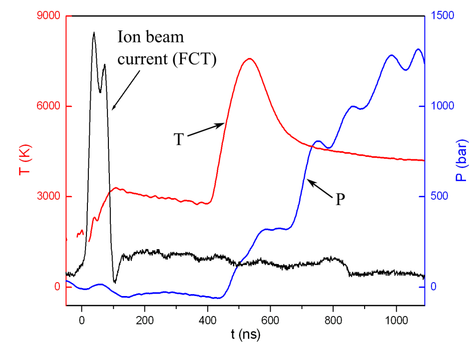

Figure 3: Simultaneous temperature (red), pressure (blue) and ion beam intensity (black) temporal profiles.

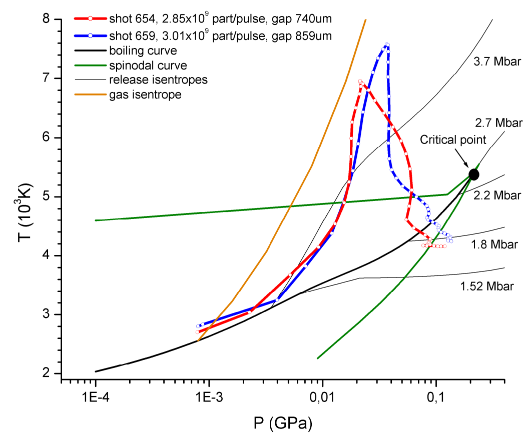

Figure 4: Explored region of the T-P phase diagram.

Two obtained temperature-pressure curves are shown in Fig. 4, as they start from a point on the boiling curve, approximately follow the 3.7 Mbar release isentrope [3] until it intersects the spinodal curve, afterwards kinematic effects govern the dynamics of the superheated material, to finally reach an area near the boiling curve.

Using higher intensities up to ~$5 \cdot 10^{11}$ particles/pulse available at FAIR, the near critical region of other metals, especially refractory ones (e.g. Ta, Ti, W) can be probed.

References

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