Progress on HEDP/WDM experiments at GSI*†

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During the past year, significant progress has been achieved in experimental investigation on heavy-ion beam generated high-energy-density (HED) states in matter (warm dense matter, WDM). The main aims of the HEDP/WDM experiments performed at the HHT area of GSI were commissioning of recently developed diagnostic instruments and methods for the future HEDgeHOB experiments at FAIR; tests of different beam-target configurations for EOS studies; optimization of transport, focusing and diagnostics of intense heavy ion beams; obtaining new data on thermophysical properties and hydrodynamic response of various materials in HED states near boiling curve, two-phase liquid-gas and the critical point regions. In particular, HED properties of lead, tin, copper, aluminum, tungsten, tantalum, sapphire and uranium dioxide have been studied using the ”plane-HIHEX” beam-target design concept (see Fig. 1).

In this beam-target configuration, solid or porous sample foil is placed along the elliptically-shaped ion beam, at the origin. Two sapphire plates are located parallel to the foil from both sides at variable distances, limiting the target expansion and defining the final volume. In order to avoid undesirable direct heating of the sapphire plates by the beam, a thick tungsten slit collimator is installed in front of the sample. The physics package is placed inside a solid brass container with additional sapphire windows at each face. The HIHEX design allows one to study 1D quasi-isentropic expansion of uniformly heated target material into a buffer gas or vacuum.

In the performed experiments, electron-cooled beam of $^{238}\mathbf{U}^{73+}$ ions with initial ion energy of 350 AMeV has been used. The intense, up to $2.5 \cdot 10^9$ ions/bunch, ion pulses have been compressed in time down to $\sim 110\,\mathrm{ns}$ (FWHM) and focused at the target to a spot of $\leq 300\,\mu\mathrm{m}$ diameter. The beam intensity and the pulse shape has been measured by current transformers installed in front of the target chamber whereas the upper limit for the focal spot size has been determined by recording beam-induced scintillation of argon gas at ionic lines.

A motorized achromatic 1:1 imaging system collects the light emitted by beam-heated target and transmits it to a fast radiation pyrometer and a streak-spectrometer via $400\mu\mathrm{m}$ quartz fiber lines. Using this advanced light collection system and an improved fast 12-channel pyrometer, the color temperatures up to 12000 K during direct ion-beam heating

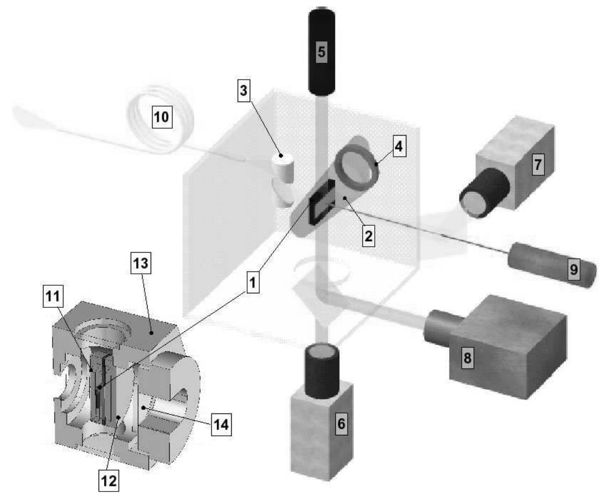

Figure 1: Scheme of the HEDP diagnostic instruments at HHT and plain-HIHEX target design: 1 – sample foil, 2 – ion beam with elliptic focal spot, 3 – pyrometer/spectrometer light collection system, 4 – beam current transformers, 5 – backlighting laser or Xe flash lamp, 6,7 – fast amplified CCD cameras (beam/target optical diagnostics and alignment), 8 – streak camera (target expansion shadowgraphy), 9 – displacement interferometer or VISAR system (pressure measurements), 10 – quartz fiber lines to pyrometer and streak-spectrometer (target temperature, spectroscopy), 11 – (gold-coated) sapphire plates, 12 – tungsten slit collimator, 13 – brass container, 14 – sapphire windows.

of tungsten targets have been recorded in the performed experiments. Target pressure is determined by measuring displacement history of the gold-coated outer surface of the sapphire plate (see Fig. 1). For this purpose, a modified 90° Michelson interferometer or an all-fiber VISAR system is used, registering pressures in the kilobar range at the moment of impact. The target expansion velocity is measured by visible backlighting/shadowgraphy system consisting of a diode laser or Xe flash lamp, interference filters and an electronic streak camera. The expansion velocities of more than $2\,\mathrm{km/s}$ has been detected for lead targets. In addition, the evolution of the electrical conductivity has been measured using a four-probe contact technique for lead and aluminum targets in plane and cylindrical (wires) geometries.

The obtained data on HED properties of various metals in hot expanded liquid, two-phase liquid-gas and near-critical states is currently being analyzed and prepared for publication. It is also planned to compare the experimental data with full-scale 3D hydro-simulations taking into account radiation transport phenomena.

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