Warm dense matter analysis

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Application Note

Introduction
Matter at high energy-densities is being investigated at the Extreme Matter Institute EMMI and the GSI Helmholtz Center for Heavy Ion Research, Darmstadt, Germany. The regime of strongly coupled, partly degenerate plasmas, also known as Warm Dense Matter, challenges both its theoretical and experimental access. These conditions can be found in the interior of giant planets or during the implosion process in the inertial confinement approach to nuclear fusion.

One way to generate Warm Dense Matter in the laboratory is the approach of isochoric heating via laser-generated hot electrons. A relativistic laser pulse creates energetic electrons within a target which penetrate and heat the irradiated sample within a time that is much faster than the hydrodynamic response time of the target. That way, energy is injected into the solid density target transforming it into a state of high energy-density.

Experimental Setup
In a recent experiment, we irradiated cryogenic Argon droplets with laser pulses of 2.5 J energy at intensities of around 10^{19} W/cm^2 [1]. The 2p-1s emission excited by the energetic electrons within the droplet target was spectrally dispersed by a Highly Oriented Pyrolytic Graphite (HOPG) crystal. See figure 1 for a schematic of the experimental setup.

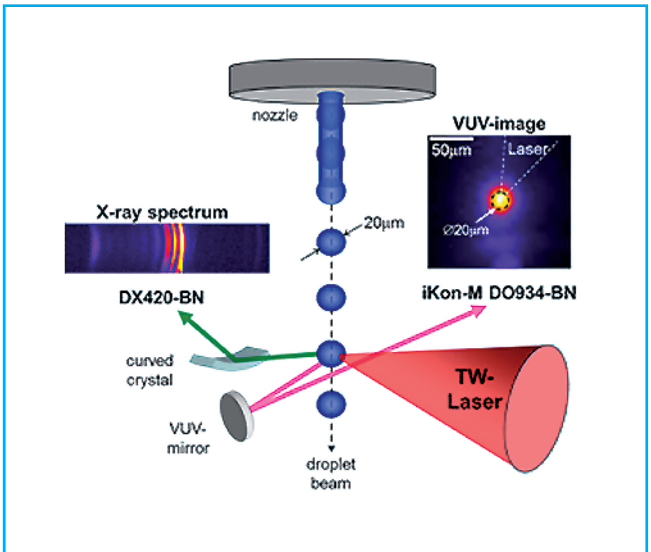

Fig. 1: Experimental setup. The cryogenic Argon droplets are irradiated with relativistic laser pulses to generate high energy-density matter.

Results and Discussion
An Andor DX420-BN in-vacuum camera was used to detect the obtained spectrum at around 3 keV photon energy. The camera with its elongated CCD chip (1024 pix x 255 pix) was operated at +5 °C, a temperature sufficient to yield low background count levels without risking immediate icing of the chip in case of vacuum issues. The geometry of the spectrometer in combination with the specified quantum efficiency of the camera allowed for an estimate of the number of detected photons for each acquisition. The single shot acquisitions were triggered using a TTL signal 3 ms before the laser pulse with a subsequent acquisition time of 1 s. In addition the self-emission of the heated droplets was imaged in the VUV regime around 13.5 nm onto a second Andor camera (DO934P-BN) to get an upper boundary for the target dimension after the heat up has finished. Figure 2 displays the integration of the cameras into the setup.

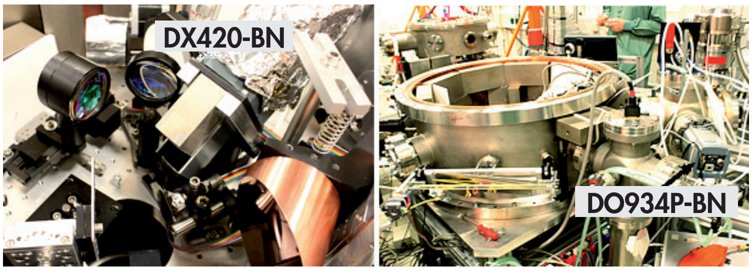

Fig. 2: Photographs of the setup with the employed scientific CCD-cameras.

Analysis of the recorded data not only confirmed the rapid heat-up process but let us also conclude that the Ohmic return current drawn by the laser-generated electrons that penetrate the target accounts for a significant fraction of the energy density reached in the irradiated samples.

References
[1] R. A. Costa Fraga, A. Kalinin, M. Kühnel, D. C. Hochhaus, A. Schottelius, J. Polz, M. C. Kaluza, P. Neumayer, and R. E. Grisenti, Rev. Scient. Instr. 83, 025102 (2012)

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