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A platform for observing phase-transitions and measuring temperature of ion-heated samples

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The graphitization-threshold of diamond is of significant interest for nanodiamond synthesis from laser-shocked plastics, for particle detectors, and for the application in diamond anvil cells.
We report on experiments conducted at the HHT facility (GSI), in which a monocrystalline diamond target was volumetrically heated using a uranium ion beam. The PHELIX laser enabled measurements of X-ray Thomson scattering (XRTS) and X-ray diffraction (XRD) from the heated sample.

By comparison to density functional theory molecular dynamics simulations, the increase of diffuse elastic scattering can be leveraged to asses the sample's bulk temperature. We show that this method provides good agreement with the expected heating up to $\sim 2000\text{K}$. Above this threshold, a rapid increase in the elastic scattering intensity is observed, which cannot be attributed to increased lattice movement alone. Instead, the data suggest a fundamental change in the target's integrity. Although macroscopic fracture is clearly evident, we argue that it is not sufficient to account for the observed signal. Rather, a thermally driven graphitization process provides the best explanation for the measurement.

Building on these findings, we outline the next steps in the experimental campaign, substituting the carbon targets by silicon. As heating is increased for comparable ion numbers while the temperature of the phase transition is reduced, we do not rely on the Bragg peak for triggering the phase transition, resulting in a more homogeneous probing area. This allows constraining temperature not only by XRTS, but also from the thermal expansion visible in the spatially resolved XRD. By varying probing time and heating, we seek to obtain insight into the super-heating dynamics of the material.

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