In-situ Pulse Laser Heating in Diamond Anvil Cells

with time-resolved temperature measurements

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Application Note

The ICCD detector iStar DH320T-18U-73 and the spectrograph Shamrock SR-303i-A-SIL from Andor Technology are integrated as a part of the online laser heating system at the Extreme Conditions Beamline P02.2 at PETRA III synchrotron light source in Hamburg.

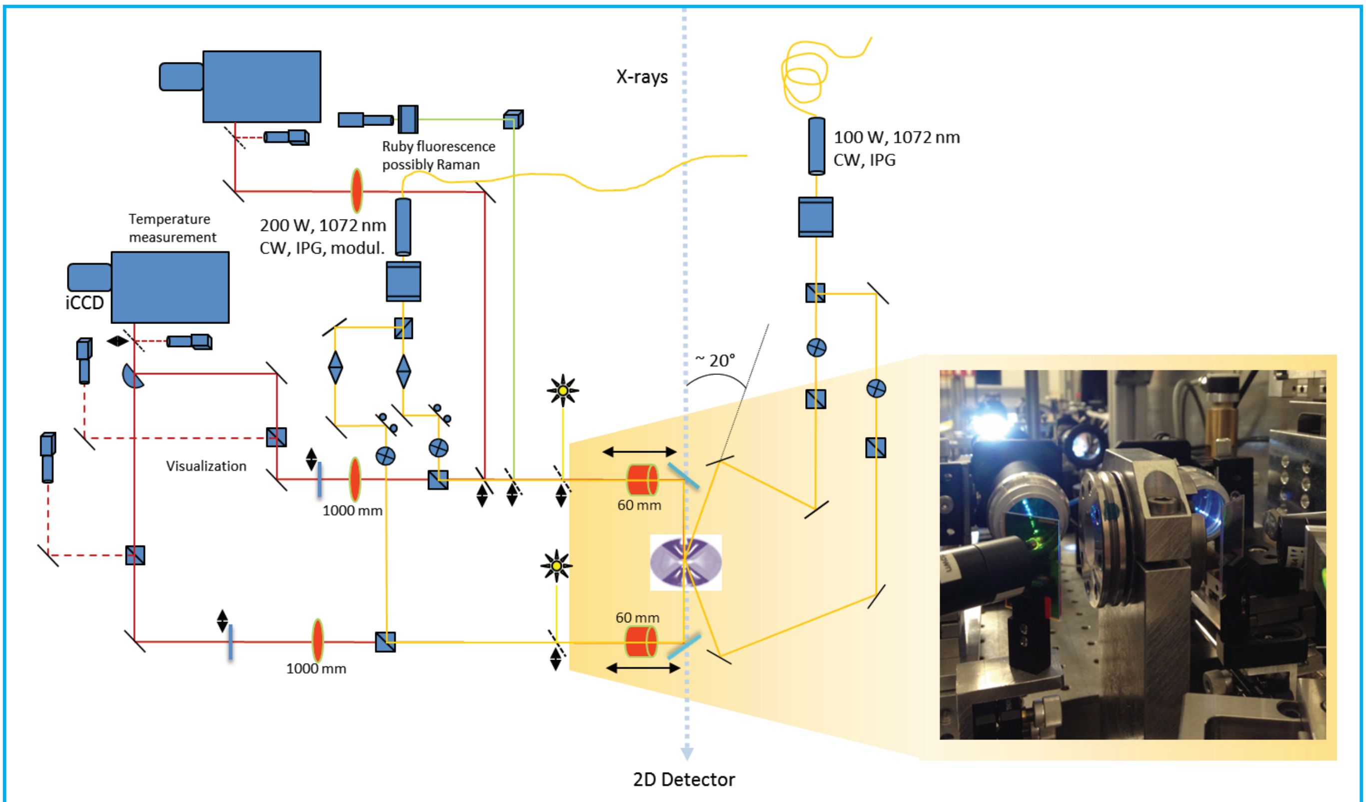

Figure 1: Setup for in-situ laser heating in the DAC. Yellow lines depict laser beams focused onto the sample, thermal radiation is collected via optics to the spectrograph and ICCD for temperature determination.

Research here is focused on the investigation of matter at high pressures (tens to hundreds of gigapascals) generated in diamond anvil cell (DAC); by adding temperature to the system one opens up largely unexplored pressure-temperature phase space.

Because of small dimensions of the samples (order of several tens of micrometres in lateral dimensions, few micrometres in thickness), and the proximity of highly thermally conductive diamonds, reaching temperatures above 2000 K requires tightly focused laser beams. There are two 1064 nm fibre lasers installed to heat the sample in-situ while probing it by x-ray diffraction technique. Temperatures of hot parts of the sample are measured from both sides using spectroradiometric fits to emission in typical spectral range of 600 – 800 nm.

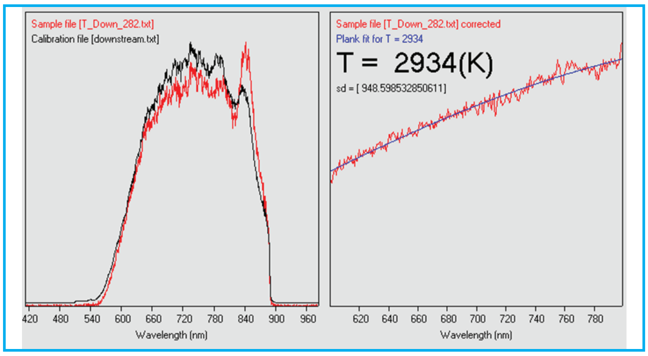

Figure 2: Left: Intensity spectra of a calibration lamp at 2865 K (black) and from the hot sample (red). Right: Corrected sample spectrum for the system transfer function (red) and fit to a Planck function (blue) that determines the temperature.

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An important upgrade of the system is the possibility to perform these experiments on shorter time scales.At pressures over one megabar (100 GPa, i.e. pressures in the core of the Earth), the risk of sample contamination and diamond damage is increasing during continuous laser heating. Therefore, we had built a pulse laser heating system where the laser pulses are synchronized to x-ray detector, x-ray shutter and temperature measurement. The laser pulses may vary from microsecond duration to several hundreds of milliseconds, depending on the scattering power of the sample. For shorter laser pulses (microseconds), the diffraction and emission signals have to be integrated over several thousands of cycles.

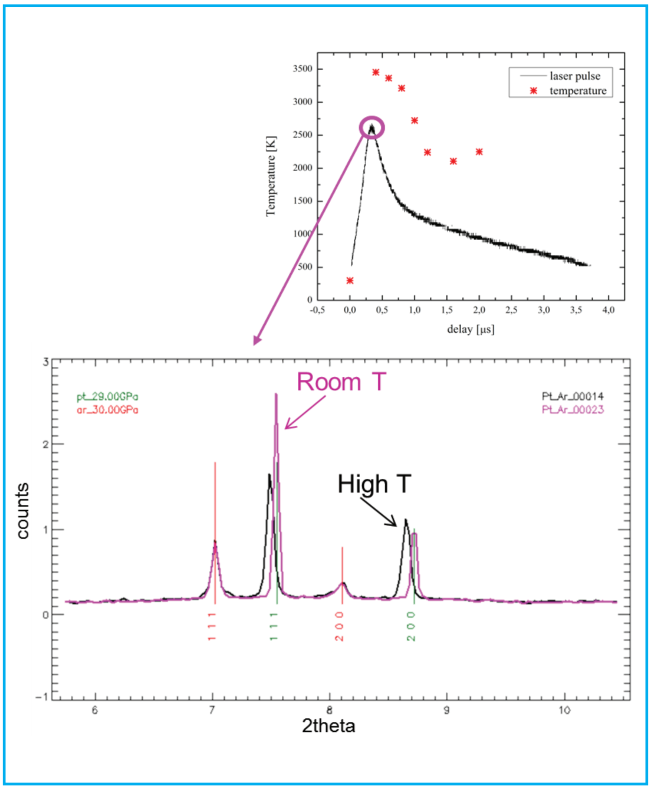

Figure 3: Pulse laser heating of pressed platinum sample in DAC. Temperature has been measured over a half microsecond intervals at different time delays across the 4 microsecond laser pulse duration (top). Simultaneously, an x-ray detector had collected diffraction data during one microsecond window. To collect enough intensity, the resulting diffraction pattern and emission were integrated over 80.000 shots with a repetition rate of 10 kHz. The lower plot shows diffraction peaks of platinum (green lines) at room temperature (pink) and at the highest temperature (black), exhibiting peak shift due to thermal expansion.

Depending on the application, one can rather opt for longer (millisecond) laser pulses, where one shot is sufficient to acquire all relevant information.

References

H.-P. Liermann, W. Morgenroth, A. Ehnes, A. Berghäuser, B. Winkler, H. Franz, E. Weckert (2010) The Extreme Conditions Beamline at PETRA III, DESY: Possibilities to conduct time resolved monochromatic diffraction experiments in dynamic and laser heated DAC. J. Phys., Conf. Ser. 215, 012029

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