Low-temperature High-pressure Sample Environment for Single Crystal and Powder X-ray Diffraction -for I15 beamline of Diamond Light Source

Bishnupada Ghosh*[1,2], Xiaojiao Liu[1], Egor Koemets[1], Allan Ross[1],

Mahmoud Abdellatief[1], Dominik Daisenberger[1], Annette K.Kleppe[1] and Nicola Casati[2]

1. Diamond Light Source Ltd, Harwell Science and Innovation Campus, Didcot OX11 0DE, United Kingdom
2. Center for Photon Science, Paul Scherrer Institut, CH-5232 Villigen, Switzerland

Abstract

A low-temperature cryostat for high-pressure single-crystal and powder X-ray diffraction is currently in an advanced stage of commissioning in parallel at the Extreme Conditions beamline I15 at Diamond Light Source (DLS, UK) and at the ADDAMS beamline at the Paul Scherrer Institute (PSI, Switzerland). The I15 beamline operates in the high-energy range of 20–80 keV and ADDAMS beamline offers 5-40 keV. Both provide focussed and collimated X-ray beam well suited for high-pressure diffraction studies.

The cryostat for diamond anvil cells (DACs) is a custom-built cryogen flow system from DAC Tools (www.DACTools.com), using a controlled flow of liquid nitrogen or liquid helium to access cryogenic temperatures. Temperature control is achieved via heaters and sensors located near the sample and cold finger. A double-membrane DAC arrangement enables fine in-situ pressure control. The system provides optical access for pressure determination via ruby fluorescence. Sample temperatures as low as 11 K and 80 K can be achieved using liquid helium and liquid nitrogen, respectively. Cu-Be made mSSDAC-80-BeCu diamond anvil cells from DAC Tools (www.DACTools.com) are being used for efficient cooling and better thermal stability.

This capability will provide a powerful platform for structural investigations of pressure and temperature-tuned phenomena such as superconductivity [1], charge density waves [2], and structural phase transitions, as well as materials relevant to extreme planetary environments, including icy moon hydrospheres [3–4]. High-pressure, low-temperature phase boundaries can also be accurately mapped. The ability to perform experiments under cryogenic conditions further suppresses unwanted chemical reactions and diffusion processes, which is particularly important for reactive systems such as alkali metals and hydrogen-rich compounds.

The cryostat is being optimized for reliable, user-friendly operation and seamless integration with beamline instrumentation. This poster presents the current configuration and highlights recent results from commissioning activities, with a focus on developments at DLS, demonstrating the current performance and potential of the system for advanced high-pressure, low-temperature diffraction studies.

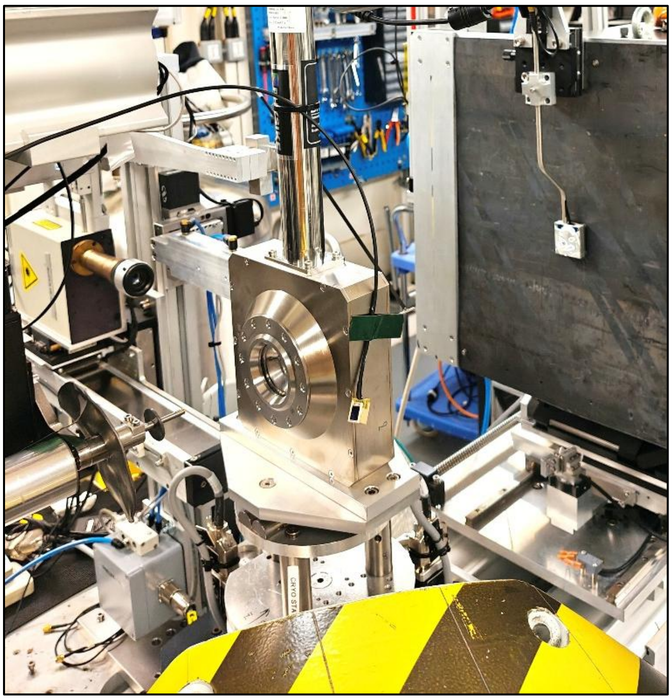

Figure 1: Cryostat on the diffractometer of I15 beamline

References

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[3] Journaux et al., PNAS **120**, 9 (2023)

[4] Yamawaki et al., Physica B **344**, 260 (2004)