2023 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Super high-pressure x-ray diffraction & imaging of samples in the Diamond Anvil Cell

Helmholtz Centre, division:

DESY-FS

Project leader:

H. P. Liermann

Contact Information of Project Supervisor: (Email, telephone)

hanns-peter.liermann@desy.de, +49 (0)40 89985722

Web-address:

https://photon-science.desy.de/facilities/petra_iii/beamlines/p022_extreme_conditions_beamline/index_eng.html

DESY Group:

FS-PETRA-D

DESY-OCPC Programme Coordinator (Email, telephone and telefax)

Frank Lehner; frank.lehner@desy.de; +49 40 8998 3612

Description of the project (max. 1 page)**:**

The study of hierarchical structures using x-ray diffraction and x-ray imaging techniques is a new frontier in the field of high-pressure physics. Ongoing projects have shown that the combination of these techniques at the Extreme Conditions Beamline P02.2 at PETRA III is providing a deep insight into the inner working of systems compressed using Diamond Anvil Cells (DACs) and might open up an entire new branch of high-pressure physics research (1). Until now only partially coherent phase contrast imaging (PCI) with x-ray diffraction have been combined, which has turned out to be very suitable to study the kinetics of phase transitions during dynamic pressurization and heating. However, this technique is not really applicable to super-high-pressure samples compressed in multi-megabar cells (e.g. conventional or toroidal DACs, Jenie et al. 2018, Dewale et al. 2018, Glazyrin et al. 2022) because the samples are just too small for x-ray PCI. Alternatively, one can use Scanning Transmission X-ray Microscopy (STXM) with a submicron diffraction beam to gain an inside to the sample and pressure distribution of very small sample commonly encountered in a toroidal or double stage DAC (Glazyrin et al. 2022). However, the spatial resolution of this technique is currently limited (e.g. Wang & Li, 2022). By combining STXM with coherent diffraction imaging (CDI) to reconstruct a complex transmission function of an object from a series of sample-position dependent diffraction images using computational iterative phase retrieval algorithms (Wang & Li,2022) the spatial resolution of the sample can be significantly improved. This approach has never been tried in a DAC or a tDAC, because in most cases the coherence of the source was too low.

Beamline P02.2 has developed over the last 5 years a submicron beam at 25.6 keV (Glazyrin et al. 2022) partially in the framework of a previous OCPC project, which the beamline is continuously improving in collaboration with the former Verbundforschungs Prokject of the BMBF (PI.: N. Dubrovinskaia) and the imaging group at PETRA III. The setup is now extensively used at P02.2 for the study of samples at super-high-pressure. However, the spatial resolution of the setup is not going to improve until the advent of PETRA IV and the new Extreme Conditions Time Resolved XRD & Imaging Microscope (ExTReM). Fortunately, it will be possible to improve the spatial resolution somewhat by combining STXM with CDI by means of STXM ptychography at P02.2. By comparing it with the setup at P06 nano probe (which is not optimized for high-pressure research in the DAC) the participants of the project will gain extensive experience in setting-up the technique at ultra-low emittance sources such as PETRA IV or the High-Energy Photon Source (HEPS) for the study of samples at ultra-high pressures in the DACs and tDAC. Among a variety of scientific fields and disciplines the project will contribute to studies of amorphous solids density under high pressure etc. This project will hence provide the beamline staff a deep understanding in the implementation of STXM ptychography in order to prepare for its usage at Extreme Conditions Time Resolved XRD & Imaging Microscope (ExTReM) of PETRA IV as well as the high-pressure beamline at HEPS that we are planning to collaborate with.

References:

Jenie et al. (2018) Nat. Comm., 9, 3563 (2018) doi: 10.1038/s41467-018-06071-x |
Dewaele et al. (2018) Nat. Comm., 9, 2913. doi: 10.1038/s41467-018-05294-2.
Glazyrin et al. (2022) J. Synchrotron Rad. (2022). 29, 654–663. doi: 10.1107/S1600577522002582
Wang & Li (2022) Spectrosc. 2022, 43(1), 84-9. doi: 10.46770/AS.2022.00

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

We want to strengthen the collaboration with the high-pressure beamline at the High-Energy Photon Source (HEPS) in Beijing, China. In 2019 we started a collaboration with the lead scientist of the high-pressure beamline, Dr. Li Xiaodong, and Dr. W. Dong was hired in the OCPC project to work on the development of super-high-pressure technology and diffraction setup at beamline P02.2, mutually benefitting both of our beamlines. Several publications have originated from this collaboration and Dr. W. Dong has gone back to China since and is now a staff member at the High pressure beamline, using the experience gained to help design and build the high-pressure beamline at HEPS. We want to build on this collaboration and extend this project by combining the existing high-pressure technology and x-ray diffraction beamline at P02.2 to include x-ray imaging and in particular - ptychography. This technique has not been used in high-pressure physics but will be one of the more prominent techniques available at ultra-low emittance sources such as PETRA IV and HEPS. In the last 5 years we have already shown the strength of the combination of x-ray imaging and diffraction by implementing Phase Contrast Imaging at P02.2. Adding ptychography will be an extension of these efforts paving the way for new technical capabilities of the Extreme Conditions Time Resolved XRD & Imaging Microscope (ExTReM) at PETRA IV.

Required qualification of the postdoc:

- PhD in Physics, Geophysics, Mineralogy
- Experience with 3rd generation light sources and micron focusing in particular at high-pressure diffraction beamlines
- Additional skills in preparation and assembly of double stage or toroidal Diamond Anvil Cells
- Language requirement: Good spoken and written English