2025 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Exploring phonon polaritons in van der Waals materials and their heterostructures.

Helmholtz Centre and/or institute:

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Project leader:

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

Phonon polaritons (PhPs) hold great promise for applications in molecular sensing, sub-wavelength imaging, high-speed photodetector and other technologies due to their strong light-matter coupling and sub-wavelength energy confinement. Van der Waals (VdW) materials serve as an ideal platform for studying phonon polaritons. By stacking and assembling, the structure of vdW materials can be further enriched, resulting in the hybridization of PhPs. Additionally, by combining phase-change materials, the dynamic modulation of PhPs in vdW materials is enabled, as the properties of phase-change materials can significantly be altered through external stimuli. Rapid development of the new class of materials strongly depends on the advances in the analytical techniques for their precise characterization.

In this project, we aim to develop a platform for detailed characterization of excitable polariton modes in vdW materials, providing an analytical tool required for designing nanophotonic devices with novel functionalities. For this we plan to combine synchrotron infrared nano-spectroscopy and far-field infrared spectroscopy techniques. Leveraging the broadband, high spectral irradiance and stability of synchrotron light, synchrotron infrared nano-spectroscopy provides a qualitative tool to probe and characterize the multispectral phonon polaritons of vdW materials with a spatial resolution of about 20 nm. Furthermore, far-field infrared spectroscopy enables a wide range of external field modulation techniques, including high pressure, high and low temperatures, and magnetic or electric fields, allowing exploration of the tunability range of PhPs within a single material. Using the complimentary approach of near- and far-field spectroscopies, we will develop the methodology for precise characterization of PhPs in vdW materials and their heterostructures, which is crucial for the design of nanophotonic devices with novel functionalities.

The infrared beamline IRIS at BESSY II, equipped with an IR scattering-type scanning near-field optical microscope (s-SNOM), allows for the infrared spectroscopy and imaging experiments to be performed with nanoscale spatial resolution down to 10 nm in the broad spectral range of 350-3500 cm^{-1}. The IRIS group has extensive expertise in the near-field infrared experiments on a range of different materials.

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

National Synchrotron Radiation Laboratory (NSRL), the first national laboratory in China now operates a fully upgraded soft X-ray synchrotron radiation facility close to the 3rd generation level. It hosts ten experimental stations, including those for Infrared Spectroscopy and Microspectroscopy, Soft X-ray Microscopy, Photoemission Spectroscopy, Catalysis, enabling cutting edge research across physics, chemistry, life and materials sciences, medicine, and more. In particular, the infrared (IR) beamline by utilizing the high brightness of synchrotron radiation source, develops various far field spectroscopic techniques under special conditions such as imaging microscopy at extreme environments (low temperature, high pressure, and magnetic fields), and in situ/operando studies. It conducts research in areas including quantum materials, metal-insulator phase transitions, optical properties of materials, in situ chemical reactions (photoelectrocatalysis), polymer materials, biomaterials, geosciences and environmental science, paleontology, and archaeology.

By combining the expertise of IRIS and NSRL IR beamline research groups, we aim to make the exploration of PhPs in vdW materials and their heterostructure possible through complementary use of synchrotron-based near-field and far-field infrared spectroscopy techniques, thereby facilitating the design of advanced tunable photonic materials.

Required qualification of the postdoc:

- PhD in physics, chemistry or a related field
- Experience in the field of infrared spectroscopy under the range of different environmental conditions (high pressure, temperatures), and data analysis of spectroscopic infrared data
- Experience in the experiment design and operation of infrared experimental set-ups, particularly at the synchrotron light sources
- Skills in use of various software such as MATLAB, SolidWorks, and Igor
- Language requirement: English