# Coherent Diffraction Imaging with Electrons and X-rays

The travel costs will be covered by the PSI

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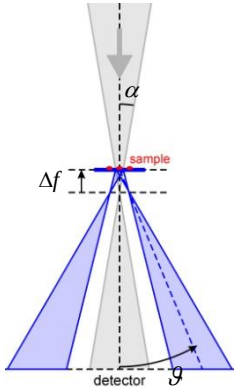
We develop novel high-resolution 3D imaging techniques with coherent waves (electrons, X-rays) for imaging 2D materials (graphene, etc) and nanostructures. We have a number of exciting research projects which include but are not limited to: imaging, diffraction, holography, ptychography, wavefront modulation, etc. The projects include experiments, theory, simulations and data analysis, involving iterative phase retrieval methods and machine learning techniques. Some (but not all) projects are listed below. For details, please contact Tatiana Latychevskaia (tatiana.latychevskaia@psi.ch)

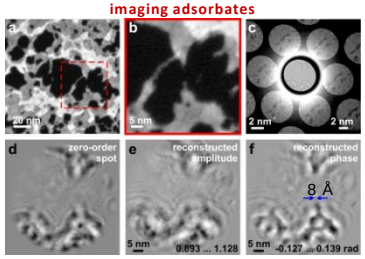
## Convergent Beam Electron Diffraction (CBED)

Sara Mustafi, Ding Peng
in collaboration with Sarah J. Haigh[1,2] and Kostya S. Novoselov[1,3,4]
[1]National Graphene Institute, [2]Department of Materials, University of Manchester, UK;
[3]Department of Materials Science and Engineering, [4]Centre for Advanced 2D Materials, National University of Singapore

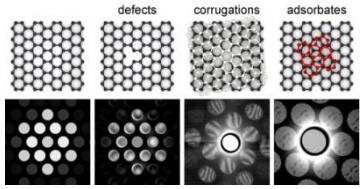


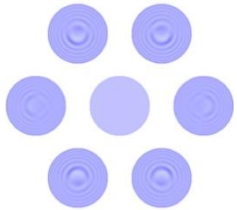

**Experimental projects**
- preparation of clean graphene
- imaging and characterization of graphene
- deposition of nano-particles on graphene

imaging adsorbates




imaging defects

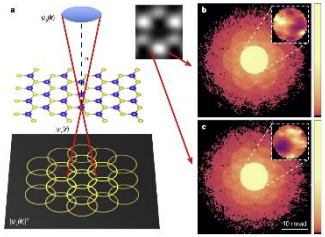


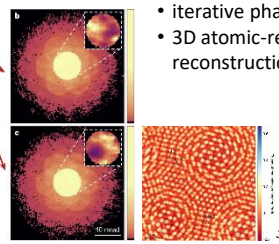



PNAS 115 (29) 7473-7478 (2018)
Front. Phys. 14 (1), 13606 (2019)
Ultramicroscopy 212 112976 (2020)
Ultramicroscopy 28 (8), 2140001 (2021)
Phys. Rev. B 105, 184113 (2022)
Carbon 201, 244–250 (2023)
Surf. Rev. Lett 2140001 (2021)

**Theory and simulations projects**
- simulation of CBED patterns of graphene with defects, adsorbates, etc
- iterative phase retrieval
- 3D atomic-resolution reconstruction

### Ptychography



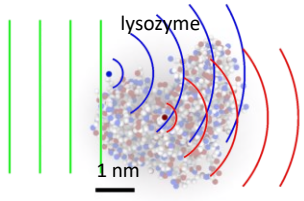


Jiang et al, Nature 559 (2018)

## Theory, algorithms and simulations

waves scattering, propagation and diffraction for light, X-ray and electron waves

**Waves scattering**
- elastic
- inelastic
- coherence




**What can be reconstructed from an intensity measurement?**
- sample 2D projection?
- 3D reconstruction?
- at what resolution?

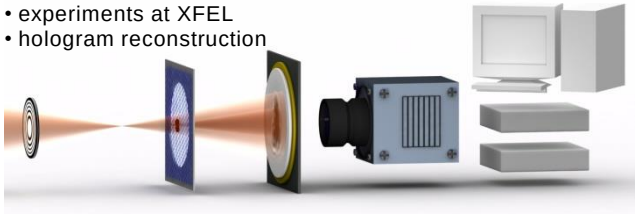
**Waves propagation in matter**
effects of:
single scattering (Kinematic)
multiple scattering (Dynamical)

**Algorithms for**
ptychography, tomography, holography, coherent diffraction Imaging (CDI)

## Holography with X-rays

in collaboration with Kirsten Schnorr and Christoph Bostedt, Maloja X-FEL, PSI

**Experimental projects**
- sample preparation
- experiments at XFEL
- hologram reconstruction

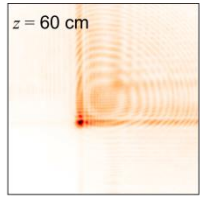


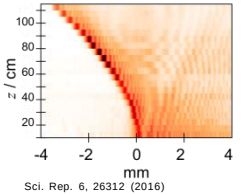
**Theory and simulations projects**
simulation and reconstruction of X-ray holograms

## Wavefront modulation

**Experimental projects**
- creating bending and Airy light beams
- creating beams with orbital angular momentum (OAM)
- imaging and characterisation of the created beams

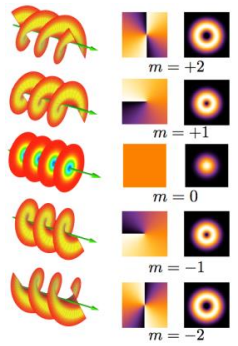
bending light Airy beams

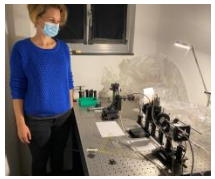



Sci. Rep. 6, 26312 (2016)
Appl. Opt. 55, 6095–6101 (2016)

Light optical beams with Orbital Angular Momentum (OAM)



Alice Kohli
in optical lab at the PSI

**Theory and simulations projects**
- simulation of optical masks for wavefront modulation
- evaluating the properties of the created OAM beams

## Dammann Gratings

in collaboration with Dr Christian David and Dr Joan Vila Comamala (PSI)
https://www.psi.ch/de/lxn/new-x-ray-optics-and-applications

Availability of Free Electron Lasers offer new unprecedented possibilities for coherent imaging of organic and inorganic structures, and time-resolved phenomena. Experimental characterization of an X-ray beam parameters, in particular, its coherence, is important for both optimization of the imaging conditions and data interpretation. Towards this goal, we are planning to design and fabricate dedicated diffractive optical elements.

The tasks of this Master project include: simulation of diffractive optical elements (Dammann gratings) and measuring their properties using light optical setup.