Coherent Diffraction Imaging and Holography

PSI Center for Life Sciences

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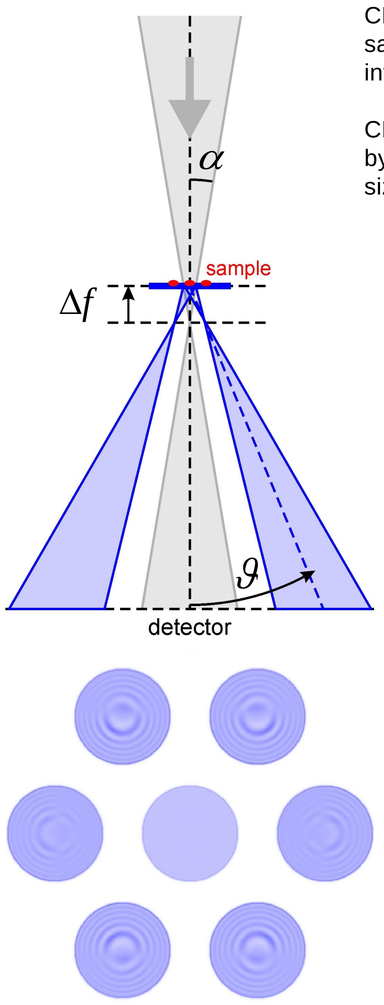
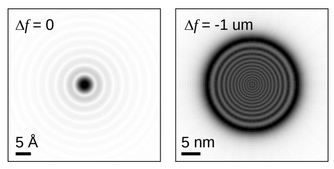
imaging of 2D crystals (graphene, MoS_2, etc) by convergent beam electron diffraction (CBED)

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

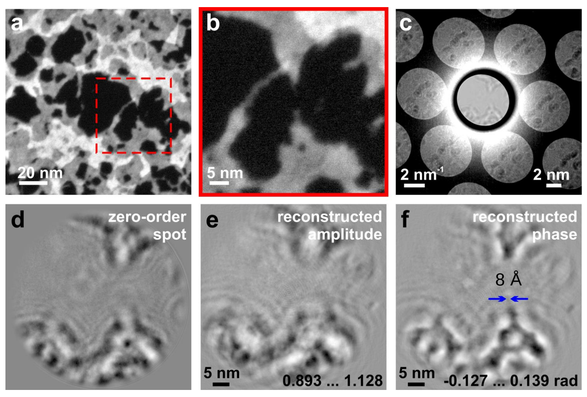


CBED patterns are real-space and diffraction patterns of the sample simultaneously. They contain plenty of structural information, the challenge is to reconstruct this information.

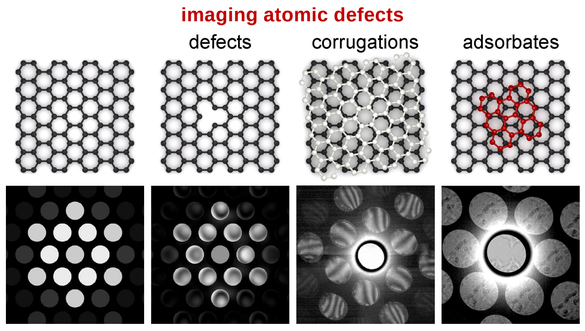
CBED is a **radiation dose** adjustable technique:
by choosing the sample position at different defocus Δf, the size of the probed area (and thus the dose) is regulated:



imaging adsorbates



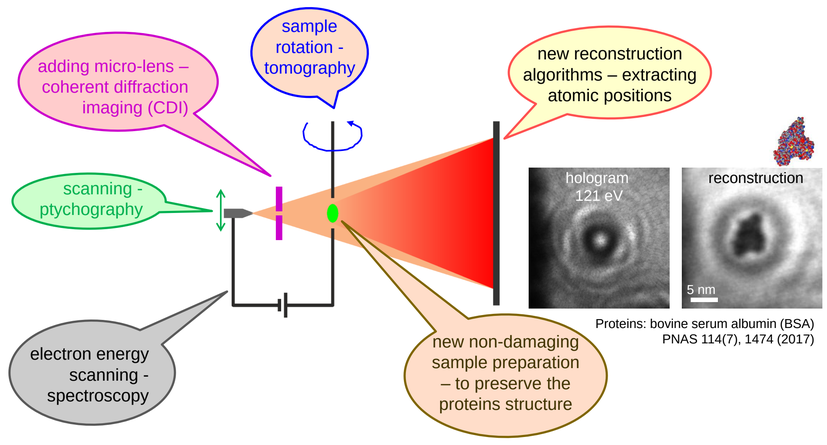
imaging atomic defects



PNAS 115 (29) 7473-7478 (2018)
Front. Phys. 14 (1), 13606 (2019)
Ultramicroscopy 212 112976 (2020)
Ultramicroscopy 219 113020 (2020)
Surf. Rev. Lett. 28 (8), 2140001 (2021)
Phys. Rev. B 105, 184113 (2022)
Carbon 201, 244–250 (2023)

low-energy electron holography (LEEH)

advantages
can be used for imaging individual macromolecules
low radiation damage to specimen
high sensitivity to local potentials
disadvantages
requires very thin samples
short inelastic mean free path (IMFP) (~ 5 Å)

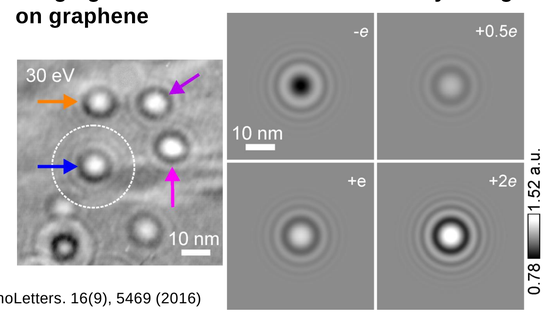


Proteins: bovine serum albumin (BSA)
PNAS 114(7), 1474 (2017)

Experimental projects:
• installing and operating the custom-built low-energy electron microscope at PSI
• sample preparation (2D crystals, macromolecules, etc.) and characterisation
• recording of low-energy electron holograms

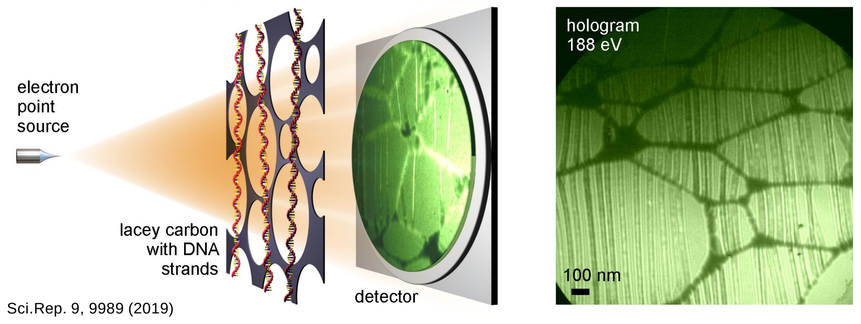
Theoretical and simulation projects:
• development of theoretical models of low-energy electron scattering in matter
• simulation and reconstruction of low-energy electron holograms

Imaging adsorbates with sub-elementary charge on graphene



NanoLetters. 16(9), 5469 (2016)

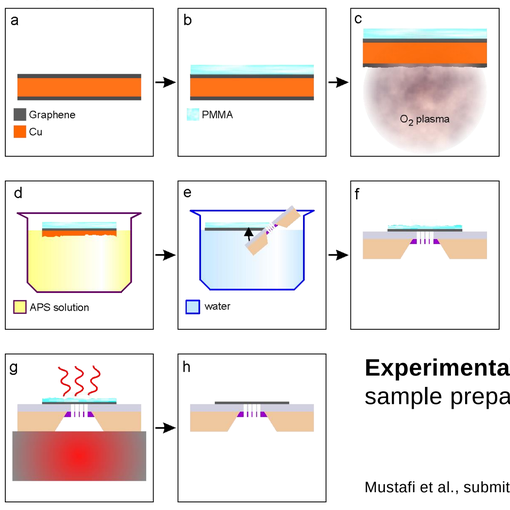
Imaging individual biological (DNA) macromolecules



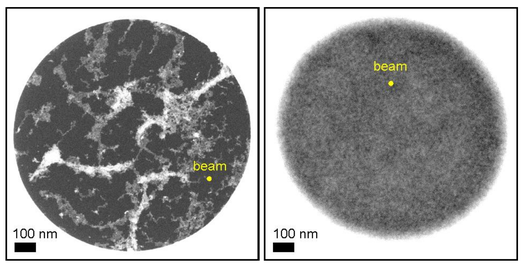
Sci.Rep. 9, 9989 (2019)

making atomically clean graphene

Sample preparation



High-angle annular dark-field (HAADF) imaging in transmission electron microscope (TEM) at ScopeM ETH

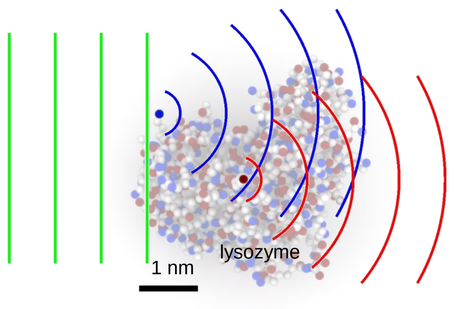


Experimental project:
sample preparation and characterisation at ScopeM ETH

Mustafi et al., submitted (2025)

theory and simulation of electron scattering and propagation

Electron scattering
• elastic
• inelastic
• single scattering
• multiple scattering
• coherence



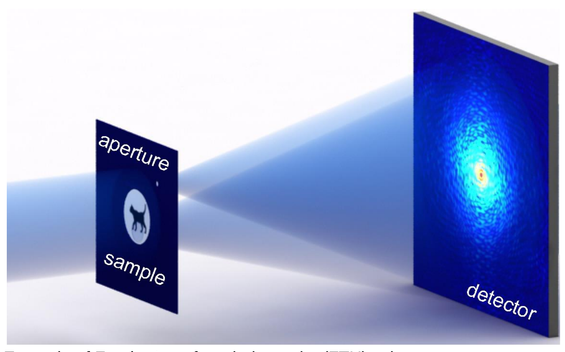
Simulations for
• holography
• ptychography
• tomography
• coherent diffraction imaging (CDI)

imaging with X-rays

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

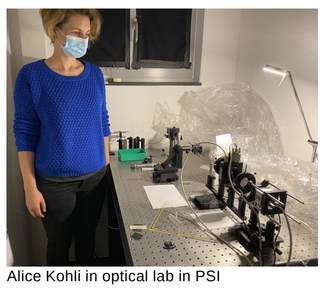
• development of theory
• simulation of holograms
• reconstruction of holograms

X-ray scattering
• theory and simulations of X-rays scattering and imaging of biological macromolecules



Example of Fourier transform holography (FTH) scheme, Photonics 10(2) 153 (2023)

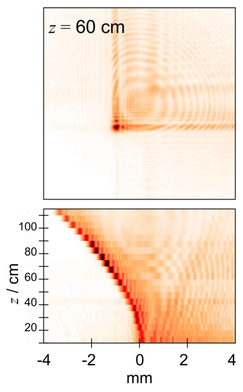
light optical wavefront modulation



Alice Kohli in optical lab in PSI

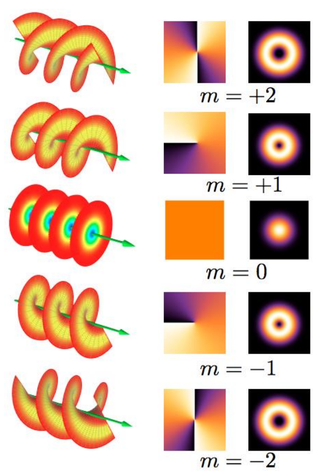
Experimental projects
• creating of the bending beams, Airy beams, and beams with orbital angular momentum (OAM)
• characterisation of the beams
• imaging with the beams

Airy beams bend as they propagate



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

optical angular momentum (OAM)



Schweizerischer Nationalfonds

The travel costs to PSI will be covered by PSI.

Universität Zürich[UZH]