RESONANT COHERENT X-RAY IMAGING OF QUANTUM SOLIDS

Project Description

In this project, we will be developing and using methods to study the dynamics of translation-symmetry broken electronic phases using coherent soft x-ray light. This involves a combination of implementing existing methods in challenging geometries (Bragg mode soft x-ray ptychography) and working with entirely new methods currently under development in our group. The project is directed by Riccardo Comin at MIT (which will be the primary affiliation for this position). Because the bulk of the experimental work will involve measurements at beamline 7.0.1.1 of the Advanced Light Source (ALS), the full-time location of work is at Lawrence Berkeley National Lab, in the team of Sujoy Roy. Analysis code will be written in python, extending existing python-based work previously developed in the group.

The project will focus on improving our understanding of the real-space organization of electronic and magnetic domains in systems with collective electron phases. The ultimate goal is to use coherent X-ray imaging to visualize electronic textures with sub-20 nm resolution in quantum materials hosting charge-density-wave and antiferromagnetic order. This development is unprecedented in nature and very timely as it addresses new scientific opportunities unlocked by the order-of-magnitude improvement in the X-ray coherence of newly upgraded light sources.

One the one hand, this will require working with ptychography in the Bragg geometry to study the amplitude and phase of the antiferromagnetic (AFM) order parameter in typical correlated electronic materials hosting AFM phases - rare earth nickelates and some magnetic Van der Waals materials. As the project progresses, we will transition to using Randomized Probe Imaging (RPI), a single-frame method, to study the intrinsic dynamics of these order parameters as they approach the relevant phase transitions. The use of RPI and its combination with X-ray Photon Correlation Spectroscopy will be further explored to realize new methods for performing single-shot spatiotemporal imaging with sub-20 nm and sub-ps spatial and temporal resolutions. Because the nature of this data is unusual, this project will additionally require working on new analysis methods to take advantage of the real-space nature of the resulting data.

Techniques to be used/developed

- Resonant 2D Bragg-mode ptychography with soft x-rays.
- Resonant Bragg-mode RPI with soft x-rays.
- X-ray photon correlation spectroscopy.
- Analysis methods for studying correlations in time dependent real-space images of complex-valued order parameters.

Materials to be studied

- 2D magnetic Van der Waals materials, in particular transition metal halides and chalcogenides.
- Multilayer magnetic thin films.
- Rare earth nickelate ($RENiO_3$) thin films.
- Quasi-1D charge-density-wave systems (ZrTe3, TaTe4, etc.)

Preferred background/experience

- X-ray lensless imaging experiments and phase retrieval algorithms.
- Resonant soft X-ray scattering/spectroscopy.
- Study of nanoscale spatial textures in collective electronic and magnetic phases of complex materials (including CDW, AFM, skyrmions, etc.).
- Strong proficiency with scientific python frameworks and pytorch is ideal.