REFLECTION AND SPATIOTEMPORAL SOFT X-RAY IMAGING OF COMPLEX SYSTEMS

Project description and objectives

The primary objective of this project is to develop innovative methods for coherent soft X-ray lensless imaging in reflection (Bragg) geometry and single-frame mode. The approach will involve implementing existing methods in a relatively unexplored scattering geometry (Bragg mode soft X-ray ptychography) and building upon new single-frame imaging methods recently developed by our team for spatiotemporal imaging. This project is a collaboration between the group of Riccardo Comin at MIT (which will be the primary affiliation for this position) and the team of Sujoy Roy at the Advanced Light Source (with the primary work location being beamline 7.0.1.1).

The core goal of this project is to develop ptychography in the Bragg geometry for phase-contrast imaging of nanoscale inhomogeneities (down to the 10-20 nm scale) in a wide variety of materials including quantum, magnetic materials and functional materials. One of the methods that will be used is Randomized Probe Imaging (RPI), a single-frame method developed by our team [A. Levitan, et al., Opt. Express 28, 37103 (2020)]. Additionally, this method will be employed for single-shot experiments at XFELs to demonstrate spatiotemporal imaging with sub-20 nm and sub-ps spatial and temporal resolutions.

This project represents a new frontier in X-ray studies of complex materials, providing opportunities for new scientific discoveries that leverage the superior performance and coherence of diffraction-limited storage rings worldwide.

Project Goals

The specific goals of this project are to:

- Develop ptychography in the Bragg geometry for phase contrast imaging of nanoscale inhomogeneities in complex materials.
- Develop Randomized Probe Imaging (RPI) for single-shot spatiotemporal imaging with sub-20 nm and sub-ps spatial and temporal resolutions.
- Use these methods to study the structure and dynamics of quantum materials.

Project Impact

This project will have a significant impact on the field of X-ray studies of complex materials at the nanoscale. The development of new methods for coherent soft X-ray lensless imaging in reflection (Bragg) geometry and single-frame mode will enable the study of nanoscale inhomogeneities in complex materials with unprecedented spatial and temporal resolution. In the future, the advancements facilitated by this line of inquiry will create novel opportunities to visualize, describe, and understand the structure and dynamics of complex systems, resulting in groundbreaking discoveries in the fields of condensed matter physics, materials science, and biology.

Techniques to be used/developed

- Resonant 2D Bragg-mode ptychography with soft x-rays.
- Resonant Bragg-mode RPI with soft x-rays.

Preferred background/experience

- X-ray lensless imaging, including CDI, ptychography, and/or holography.
- Knowledge and experience in the use of phase retrieval methods.
- Preferred but not essential:
    - Resonant soft X-ray scattering/spectroscopy.

- Knowledge of scipy-based toolsets and pytorch.