My research aims to study electron-phonon coupling using Resonant Inelastic X-ray Scattering (RIXS) as a tool to shed light on the underlying mechanism of high-temperature superconductivity, and dark matter detection.

Project 1: Charge and lattice dynamics in cuprate superconductors

High-temperature superconductivity is often accompanied by competing phases. In cuprates, it is believed that charge density wave (CDW) intertwines with or competes against the superconductivity phase, but the underlying mechanism is not yet fully understood.

On the other hand, a possible interaction between CDW excitations and phonons was observed in a previous study, where the phonon intensities were found to exhibit sharp peaks at the CDW's wavevector. While phonons play an important role in conventional superconductors according to BCS theory, CDWs participate in unconventional high-temperature superconductors by interacting with superconducting phase as mentioned before, and possibly with phonons. The observed elusive relation among phonons, CDWs, and superconductivity underscores the significance of electron phonon coupling.

Therefore, we propose a study on electron-phonon coupling in cuprate, as well as the interplay between phonons and CDW excitations, thus the name ``Charge and Lattice dynamics'' in this project.

Project 2: Electron-phonon coupling in KTO and STO

Superconductivity has been recently discovered on the LAO/KTO interface and on EuO/KTO interface. However, unlike LAO/STO interface where the superconductivity was found in all directions, the LAO/KTO interface exhibits a strong orientation dependence of critical temperature. Specifically, superconductivity was found on LAO/KTO(111) at T = 2 K, on LAO/KTO(110) at T = 0.9 K, but not on LAO/KTO(001) even at a low temperature T = 25 mK.

The orientation-dependent superconductivity observed in LAO/KTO may be attributed to the interaction between electrons and phonons. To gain a deeper understanding of the underlying difference between LAO/STO and LAO/KTO interfaces, it is necessary to quantitively and experimentally compare their electron-phonon couplings.

Therefore, we propose a study using resonant inelastic x-ray scattering to extract and compare their electron-phonon coupling in different directions.

Project 3: Sub-MeV Dark Matter Detection

The concept of dark matter has long been shrouded in mystery in the field of physics. Despite numerous efforts to study and to detect dark matter, the exact mass of the dark matter particle remains unknown. Different experimental tools have been utilized to cover a range of masses for dark matter detection, including phonon-based technique, which can be used to detect the sub-MeV dark matter (10 keV - 1 MeV).

In the dark matter model, dark matter particles interact with phonons, in a similar manner to electrons. As such, it would be useful to experimentally measure the electron-phonon coupling in the material being used for dark matter detection.

According to a recent research, sapphire is a suitable material for several reasons. (1) The anisotropic property of sapphire allows for the differentiation of dark matter particles from other particles. (2) Sapphire is an insulator with minimal screening effects which could potentially hinder the interaction between phonons and dark matter particles; (3) Sapphire is a polar material that is expected to interact strongly with dark matter, facilitated by dark photon mediation.

Therefore, we propose to conduct a resonant inelastic x-ray scattering (RIXS) study on sapphire to experimentally extract the electron phonon coupling. By accurately measuring this coupling, we expect to facilitate the detection of dark matter on sapphire.

Shortened version:

My research leverages Resonant Inelastic X-ray Scattering (RIXS) to explore electron-phonon coupling, focusing on its role in high-temperature superconductivity and dark matter detection.

**Project 1: Charge and Lattice Dynamics in Cuprate Superconductors** High-temperature superconductivity in cuprates features a complex interplay between charge density waves (CDWs) and superconductivity phases. Notably, an intriguing interaction between CDW excitations and phonons has been observed. Since phonons are key in conventional superconductors and CDWs in unconventional ones, understanding this electron-phonon coupling is crucial. Our study will examine the dynamics between phonons, CDWs, and superconductivity in cuprates, providing insights into their intricate relationship.

**Project 2: Electron-Phonon Coupling in KTO and STO** Recent discoveries of superconductivity at LAO/KTO and EuO/KTO interfaces, particularly the orientation-dependent critical temperature at LAO/KTO interfaces, suggest a significant role of electron-phonon interactions. Unlike the isotropic superconductivity at LAO/STO interfaces, LAO/KTO interfaces show a marked orientation dependence. We aim to use RIXS to quantitatively compare electron-phonon couplings at these interfaces, enhancing our understanding of their distinct superconducting behaviors.

**Project 3: Sub-MeV Dark Matter Detection** The elusive nature of dark matter, especially its unknown mass, remains a major challenge in physics. Phonon-based techniques have potential in detecting sub-MeV dark matter (10 keV - 1 MeV). Our research hypothesizes that dark matter particles interact with phonons similarly to electrons. We propose a RIXS study on sapphire, chosen for its anisotropic properties, minimal screening effects, and strong expected interaction with dark matter. By accurately measuring electron-phonon coupling in sapphire, we aim to advance the detection of dark matter.

This research promises significant contributions to the understanding of high-temperature superconductivity and dark matter, employing cutting-edge RIXS techniques to unravel complex electron-phonon interactions.