PHYSICS COLLOQUIUM:
Electronic dissipative forces in structural phase transitions

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Date:
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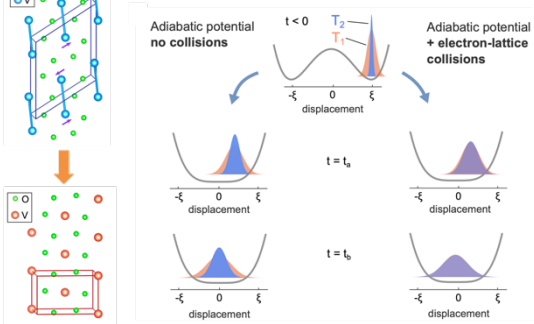
Time:
10:30 AM-11:20 AM

Location:
GRAN 135

Abstract:

Femtosecond laser pulses provide a promising strategy to control quantum phases of matter with potential to realize “properties on demand” [1]. While laser pulses can distort the lattice into novel structures with exotic properties not accessible in equilibrium, probing those transient structures remains a challenge. X-ray free electron lasers hold promise to revolutionize our ability to control materials by visualizing the atomic and electronic structure of these transient states as they transform.



After a brief introduction to ultrafast x-ray scattering and X-ray free electron lasers, I will present results that demonstrate a strong electron-phonon interaction and breakdown of the Born-Oppenheimer approximation during the photoinduced insulator-metal transition of VO2. We used ultrafast X-ray diffuse scattering [2,3] at the Linac Coherent light Source (LCLS) at SLAC to study the dynamics of the lattice long-range order and its fluctuations at all length-scales across the photoinduced transition in VO2. We adjusted the sample temperature to control the pre-existing lattice disorder and atomic velocities before ultrafast photoexcitation across the transition with a laser pulse. The x-ray diffuse intensity is sensitive to the lattice disorder and fluctuations and their dynamics, which we recorded with femtosecond time resolution. The diffuse intensity reveal that the fluctuations characteristic of the rutile metal develop equally fast ~ 120 fs independently of the initial sample temperatures (either 100 or 300 K). This contrasts strongly with analogous measurements in other order-disorder transitions such as ultrafast melting, where the disorder develops significantly more slowly at lower temperature [5]. We conclude that, due to a breakdown of the Born-Oppenheimer approximation in the transient metal, additional non-conservative forces in the form of electronic collisions and friction are responsible for the increased lattice disorder. We illustrate the lattice disorder with a simple molecular dynamics model of particles coupled to a Langevin bath that has a time dependent temperature. Electronic dissipative forces in structural phase transitions

References
[1] Basov, D. N., Averitt, R. D. & Hsieh, Nat. Mater. 16, 1077–1088 (2017), [2] S. Wall et al, Science 362, 572 (2018), [3] M. Trigo et al, Nat. Phys. 9, 790 (2013), [4] de la Peña Muñoz et al, Nat Phys 19, 1489 (2023), [5] X. Wang et al, Phys. Rev. Lett. 124, 105701 (2020).

About The Speaker:

Mariano Trigo is a Staff Scientist in the Stanford Institute for Materials and Energy Sciences and PULSE Institute at SLAC National Accelerator Laboratory. He received his PhD in Applied Physics from The University of Michigan and joined SLAC in 2010 after a postdoc at Stanford University. He uses x-ray free electron lasers and ultrafast pulses to study quantum materials. At SLAC he has developed new techniques to study the fluctuations and collective modes of materials as well as their interactions using x-ray free electron lasers.

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