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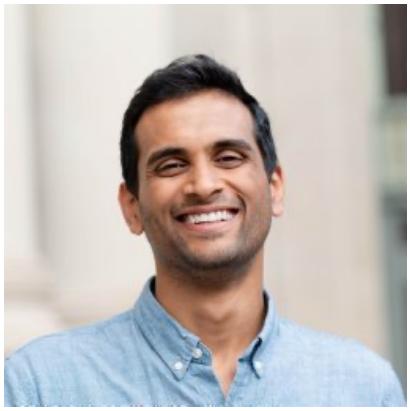
Decoding light-driven quantum materials

Abstract: Driving quantum materials with intense optical pulses offers a powerful means to control their behavior, leading to remarkable emergent phenomena such as photoinduced magnetic, ferroelectric, and superconducting phases. However, such phenomena are usually transient, limited to the sub-picosecond duration of the optical pulse or decaying shortly thereafter. Advancing the design and control of light-driven quantum materials therefore requires targeted strategies to achieve long-lived, metastable phases. In this talk, I will describe how symmetry protection leads to electronic metastability in a prototypical cuprate ladder material, $Sr_{14}Cu_{24}O_{41}$. This finding is enabled by femtosecond resonant x-ray spectroscopy, which provides unprecedented access to correlated electronic phenomena far from equilibrium. Our measurements show that the metastability is driven by a transfer of holes from chain-like charge reservoirs into the ladders. This ultrafast charge redistribution arises from the optical dressing and activation of a hopping pathway that is otherwise forbidden by symmetry. Relaxation back to equilibrium is hence suppressed once the optical pulse ceases. Remarkably, we find that this trapped nonequilibrium electronic distribution hosts a propagating, collective charge mode that is absent at equilibrium, representing a possible precursor to superconducting pairing. Our results demonstrate how dressing quantum materials with electromagnetic fields can provide a rational design strategy for nonequilibrium phases of matter.

1. H. Padma, et al. Symmetry-protected electronic metastability in an optically driven cuprate ladder, *Nature Materials* 24, 1584 (2025)
2. H. Padma, et al. A light-induced charge order mode in a metastable cuprate ladder, *arXiv*:2510.24686 (2025)

Bio: Hari Padma is an experimental condensed matter physicist and the Frederick Reines Assistant Professor of Physics at Case Western Reserve University. Prior to joining the faculty at Case in 2026, he was a Postdoctoral Fellow in the Department of Physics at Harvard University. He earned his Ph.D. in Materials Science and Engineering from Penn State University in 2021. His research addresses fundamental problems in quantum materials, with a focus on probing and controlling nonequilibrium electronic phases using advanced ultrafast optical and x-ray techniques.



HARI PADMA
Case Western Reserve University

Date:
Thursday May 21, 2026

Time:
10:00am – 11:00am

Location:
ASRC Auditorium
85 Saint Nicholas Terrace
New York, NY 10031

Host:
Andrea Alù, Director, Photonics Initiative, ASRC, CUNY GC

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