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Title: Polaritonic worldline metrology on quantum materials

Abstract: Polaritons - hybrid quasiparticles arising from the coupling of light and matter - propagate through space and time, carrying rich information about the underlying electronic system. In this talk, I will introduce a newly developed experimental approach that allows direct visualization of polariton dynamics in both space and time. By mapping the polaritonic worldline - the spacetime trajectory of a polariton, we establish worldline metrology, a framework that quantitatively reveals key material properties such as electronic spectral weight and relaxation rate. I will discuss plasmon-polariton dynamics in strongly interacting Dirac fluids, where electron-hole collisions lead to pronounced renormalization of polariton propagation. I will then highlight the spacetime duality of polariton loss: by tailoring the temporal profile of photonic excitation, spatial decay can be fully suppressed, enabling spatially sustained propagation. If time permits, I will also touch on quantum electrodynamics in graphene-hBN multilayer cavities, where ultrastrong light-matter coupling can be achieved deep in the sub-diffraction regime with full in situ magnetic tunability.