PHYSICS COLLOQUIUM:
Engineering heterostructures in 2 – D solids to define new localized quantum states with quantum coherent properties

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About The Speaker:

Dr. Alexander Weber-Bargioni is a scientist at the Molecular Foundry (Lawrence Berkeley National Laboratory) where he directs the nanoscale imaging and manipulation facility. He believes that collaborative, multidisciplinary research is the most effective path to high impact science, which he demonstrated by building a thriving quantum materials research program in a user facility environment. Dr. Weber-Bargioni explores quantum phenomena in matter with a specific interest in quasiparticle coherence and entanglement, addressing fundamental questions in condensed matter physics and advancing next generation materials for quantum information science. To this end, his group develops scanning probe and photon based characterization techniques to visualize quasiparticle excitations at their native length and time scales in low dimensional material systems. He did his postdoc at the Molecular Foundry, (2008-2010), received his PhD in physics from the University of British Colu mbia (2007) and graduated from the University of Konstanz with a Vordiplom (bachelor) in physics. For his scientific vision, research and community engagement he has received numerous awards, including the DOE Early Career award, the Bavarian Guest Professor award, the R&D 100 award, and the LBL Director's Award of Excellence. Dr. Weber-Bargioni recharges by exploring the world on his bicycle and backcountry skis, spending time with his daughter and wife in the mountains, and making artisanal olive oil at his family's Tuscan olive farm.

Abstract:

We explore how atomically sharp hetero structures such as 2-D stacks, 1-D boundaries within a 2-D material, and 0- D vacancies and substitutes in 2-D materials create new protected states that host quasiparticle excitations using photo low temperature Scanning Tunneling Microscopy, near field optical microscopy, and low temperature time resolved optical spectroscopy. The concept of quantum coherence is well established in fields such as atomic physics and quantum optics. In solid state systems, quantum coherence plays a critical role defining new phenomena such as coherent quasiparticle transport or coherent emission. However, in the solid state, the meaning of quantum coherence of a quasiparticle excitation is often not straightforward due to undefined decoherence channels, coherence time noise and the difficulty to directly access their associated quantum properties experimentally. While environmental effects are difficult to characterize in 3D systems, coherent quasiparticle transport or emission in 2D solids can be directly and non-destructively analyzed, manipulated experimentally and fully captured with ab-intio methods. Understanding how atomically precise heterogeneities in 2-D solids can create localized and protected states that host quasiparticle excitations and how to control their interaction with their environment is at the core of my research interest. In the first part of my presentation I will focus on coupled excitonic quasiparticles. We explored the formation and recombination channels of interlayer excitons formed in WS2 / WSE2 stacks and as that may relate to the recently reported formation of excitonic Bose Einstein Condensates. In combination of coupling excitons to plasmonic cavities we map out the local emission of dark excitons with preliminary evidence of measuring their coherent transport. We were also able to show strong coupling between excitons and plasmon polaritons to form a new quasiparticle excitation in for of a plexcitons and report on their transport properties as well. In the second part of my presentation I will focus on next generation quantum emitters in 2-D hosts characterized by photo STM with atomic resolution an ab initio greens function approach simulations. We show how 2-D MoSe2 and 2-D WS2 carry a zoo of intrinsic point defects that modify substantially electronic properties, such as individual S vacancies that create two level systems within the band gap with extremely high spin orbit coupling. These S defects can be artificially induced, and mediate single photon emission via optical stimulation as well as electric stimulation. We show how C-H for S or Se substitutes in 2-D WS2 and 2-D WSe2 form locally charged hydrogen-like states. Upon deprotonation the localized carbon radical hosts a localized deep in gap state with a net spin and electron-phonon coupling that bears strong similarities to NV color centers in diamond, but in this case with atomistic control.

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