Quantum Science and Technology Mini-Symposium
Room B110-112 - Session QS+EM-TuM

SiC, Diamond and Related Materials for Quantum Information Sciences

Moderators: Erin Cleveland, U.S. Naval Research Laboratory, **Cheng Gong**, University of Maryland

8:40am **QS+EM-TuM-3 Topology, Superconductivity and Unconventional Quantum Criticality in Monolayer WTe2*, Sanfeng Wu,*** Princeton University **INVITED**

Quantum critical points associated with quantum phase transitions are highly intriguing states of matter; yet they are difficult to study. An example is the superconductor to insulator or metal transition in two dimensions (2D), a topic that has a long history in condensed matter research, but many problems remain unsolved. In this talk, I will discuss our recent experimental finding of a quantum critical point in monolayer tungsten ditelluride (WTe2), a unique 2D crystal in which topology, strong correlations and superconductivity all occur in a single material. We directly measure superconducting quantum fluctuations, whose behaviors are so anomalous that an unusual explanation beyond the conventional Landau-Ginzburg-Wilson paradigm is required.

9:20am **QS+EM-TuM-5 Robust Cavity Emitter Coupled System Based on Lifetime-Limited Emission in H-BN*, Sanchaya Pandit,*** Department of Mechanical and Material Engineering, University of Nebraska - Lincoln*; Y. Wang,* Department of Electrical and Computer Engineering, University of Nebraska - Lincoln

In the field of quantum information technology, it is essential to reach a strong coupling regime, where the coupled systems exhibit quantum coherent oscillations. The ability to control the interactions between the single photon emitter and the cavity mode allows for the manipulation of the photon's quantum state, which is crucial for many quantum applications. Quantum emitters based on defect centers in hexagonal boron nitride (h-BN) have emerged as prominent light sources for integrated quantum photonic applications. Especially, the defect centers with single photon emission around 635 nm have been demonstrated to exhibit lifetime-limited linewidth even at room temperature. This work explores the monolithic integration of this type of h-BN emitters with the whispering gallery mode (WGM) in the microdisk cavity. By optimizing the cavity design, strong coupling between the emitter and cavity has been predicted analytically. Furthermore, coherent manipulation of photon based on cavity-emitter detuning, and spatial position of emitter has been explored and visualized as vacuum Rabi splitting and Rabi oscillation through the Quantum toolbox in Python (Qutip) simulation. The robust cavity design and methodology developed will provide valuable guidelines for the realization of scalable and integrated quantum photonic circuits based on h-BN defect centers.

11:00am **QS+EM-TuM-10 Collective Excitations in Topological Materials*, Stephanie Law,*** Pennsylvania State University **INVITED**

Topological insulators (TIs) are materials that have a bulk band gap crossed by surface states with linear dispersion. These surface states are present at the physical boundaries of the material, and host two-dimensional, massless electrons that are spin-momentum locked. When they couple to a photon, these electrons form the basis of Dirac plasmon polaritons (DPPs) with resonances in the THz spectral range.

In this talk, I will first discuss our efforts to grow TI materials by molecular beam epitaxy (MBE). The TI materials of interest are Bi2Se3, BixSb1-x, and MnBi2Se4. These are all two-dimensional materials, meaning that they exhibit a layered structure with van der Waals (vdW) bonding between each layer. Due to the relativley weak interlayer bonding, these materials grow by van der Waals epitaxy, which has unique opportunities and challenges. I will show our results on growing these materials on passivated substrates (e.g. Al2O3) and unpassivated substrates (e.g. GaAs and Si).

I will then discuss our efforts to excite plasmonic excitations in these materials. The frequencies of the DPPs are predicted to depend both on the wavevector of the excitation as well as on the film thickness when the film is much thinner than the wavelength of light. In this regime, a DPP is excited on the top surface and on the bottom surface of the film simultaneously. These excitations couple, leading to an acoustic and an optical mode. By mapping this relationship, we have shown conclusively that we are able to excite DPPs in TI thin films. These resonances have mode indices of a few hundred, much higher than what is observed in traditional plasmonic systems, implying that light is strongly confined in these materials. We attribute the large mode index to the fact that we are exciting a coupled optical mode and that the bulk permittivity of the TI is also large. Unlike most materials, the large mode index does not lead to a decrease in lifetime. Instead, the lifetime of the mode determined by the full width at half maximum is a few hundred femtoseconds. We attribute this relatively long lifetime to the spin-momentum locking of the surface state electrons, which reduces their probability of scatting. We have also demonstrated coupling of the DPPs in the plane using a stripe array as well as coupling out of plane by growing a layered structure. Finally, we have created a multilayer structure comprising alternating layers of a TI and a normal insulator, leading to a Dirac hyperbolic metamaterial in the THz.

11:40am **QS+EM-TuM-12 Novel Particles in 2D Materials Detected with Quantum Interference and Raman.*, Kenneth Burch,*** Boston College **INVITED**

The pursuit of new quasi-particles is driven by the quest to uncover novel phases of matter, emergent phenomena. These may also serve as a foundation for future technological innovations. In this presentation, I will elaborate on our utilization of Raman spectroscopy to identify emergent particles in 2D materials. Firstly, I will delve into our endeavors to identify fractional spin excitations in RuCl3. Subsequently, I will highlight our recent breakthrough in discovering the Axial Higgs mode, which results from Quantum Geometry and a charge density wave. This discovery was facilitated by Raman's unique ability to detect the particle's symmetry and employ quantum interference to unveil its Axial properties.

Author Index

Bold page numbers indicate presenter