PCSI
Room Ballroom South - Session PCSI-2WeA
Applications of 2D Defects and Interfaces

Moderator: Ania Bleszynski Jayich, University of California, Santa Barabara

4:15pm **PCSI-2WeA-28 Hexagonal Boron Nitride for Quantum and Nonlinear Optics*, Alexander Solntsev,* *I Aharonovich,* University of Technology Sydney, Australia **INVITED**

Photonic integrated circuits that process information encoded in particles of light are poised to revolutionize information processing, communications and sensing. A promising, emerging class of quantum technologies is based on solid-state, on-demand, single photon emitters (SPEs) coupled to optical resonators and waveguides that serve as building blocks for high density, on-chip quantum photonic circuits [1]. Nevertheless, despite years of research, existing systems are inadequate for real-world applications, and there is a significant effort to find high-performance emitters hosted by materials that enable integration in photonic devices. Recently, the SPE family expanded upon the discovery of quantum emitters in two-dimensional (2D) materials [2]. These materials are atomically thin and hence offer new possibilities for scientific exploration and device engineering. Later, hexagonal boron nitride (h-BN) emerged as a compelling 2D host of SPEs offering bright single photon emission and robust operation [3].

Another important sphere of 2D material applications is nonlinear optics (NLO). Most widely used integrated photonic platforms do not possess quadratic optical nonlinearity, which significantly limits NLO applications such as wavelength conversion and all-optical switching. Integrating 2D materials with strong NLO response into photonic circuits resolves this problem [4]. Here, h-BN is particularly well positioned, since unlike other popular 2D materials, it offers both significant NLO susceptibility and transparency in the visible range. This presentation will focus the latest advances in h-BN nonlinear and quantum optics.

[1] P. Lodahl, S.Mahmoodian, & S. Stobbe, "Interfacing single photons and single quantum dots with photonic nanostructures," Reviews of Modern Physics 87, 347-400 (2015).

[2] "Single photons for all," Nature Nano., 10, 481-481 (2015).

[3] T. T. Tran, K. Bray, M. J. Ford, M. Toth, & I. Aharonovich, "Quantum emission from hexagonal boron nitride monolayers," Nature Nano. 11, 37-41 (2016).

[4] A. Autere, H. Jussila, Y. Dai, Y.Wang, H. Lipsanen, Z. Sun, "Nonlinear Optics with 2D Layered Materials," Adv. Mater. 30, 1705963 (2018).

4:45pm **PCSI-2WeA-34 Detection of Thermodynamic "Valley Noise" in Monolayer Semiconductors: Access to Intrinsic Valley Relaxation Timescales*, Mateusz Goryca,*** National High Magnetic Field Laboratory*; N Wilson,* University of Washington*; P Dey,* National High Magnetic Field Laboratory*; X Xu,* University of Washington*; S Crooker,* National High Magnetic Field Laboratory

The new class of atomically-thin transition-metal dichalcogenide (TMD) semiconductors such as monolayer MoS_2 and WSe_2 has focused broad attention on the concept of "valleytronics", founded on the idea of encoding information in an electron’s valley degree of freedom. The key parameter for any valleytronic technology is the intrinsic timescale of an electron’s inter-valley relaxation, and recent optical pump-probe studies have shown long (exceeding microseconds at low temperatures) valley relaxation of resident carriers in monolayer TMDs [1,2]. However, a significant drawback of all such experiments is that they are by design perturbative: they require optical pumping to intentionally drive the electrons out of equilibrium. Such pumping inevitably introduces so-called "dark" exciton states, whose presence can mask carriers' intrinsic valley relaxation.

Here we present a completely alternative approach, based on the idea of passively "listening" to the random spontaneous scattering of carriers between *K* and *K'* valleys in strict thermal equilibrium. We demonstrate that the stochastic *valley noise* is measurable by optical means and encodes the true intrinsic timescales of valley relaxation, free from any pumping or excitation [3].

Using this new fluctuation-based methodology we measure very long valley relaxation dynamics of both electrons and holes in a single electrostatically-gated monolayer of WSe_2. Valley noise frequency spectra reveal long intrinsic valley relaxation with a single sub-microsecond time scale. Moreover, they validate both the relaxation times and the spectral dependence of conventional pump-probe measurements, thereby resolving concerns about the role of dark excitons and trions in studies of long-lived valley relaxation.

[1] J. Kim *et al.*, Science Advances **3**, e1700518 (2017).

[2] P. Dey *et al.*, Phys. Rev. Lett. **119**, 137401 (2017).

[3] M. Goryca *et al.*, arXiv:1808.01319 (2018).

5:00pm **PCSI-2WeA-37 The Electronic Structure of 2D Materials*, Justin Wells,*** Norwegian University of Science and Technology, Norway **INVITED**

The electronic bandstructure contains complete information about the occupied electronic states which exist in a material. i.e. intrinsically it includes information on doping, Fermi velocities, confinement, the orbital nature of the bands, spin-coupling and all possible interactions. Measuring the electronic bandstructure is possible using techniques derived from photoelectron emission spectroscopy; and due to the exceptionally short probing length, this works particularly well for 2D materials and surface phenomena.

In this talk, I will describe some recent examples from our own research. In particular, I will describe how certain materials allow a smooth 3D to 2D transition, such that the role of dimensionality can be disentangled. Specifically, I will discuss the unusual phonon mediated scattering/coupling in graphene/graphite [1-3], the spin texture of monolayer transition metal dichalcogenides (TMDCs), and how the origins of this are derived from local symmetry breaking in the parent bulk compounds [4,5]. Finally, I will discuss the 3D to 2D transition in group-IV semiconductors (silicon and diamond) created as a result of a high-density dopant plane within the bulk material (see figure), and the implications of this confinement for the ultimate miniaturisation of classical and quantum devices [6-8].

[1] Mazzola *et al*., PRL **111**:216806 (2013)

[2] Mazzola *et al*., Phys. Rev. B **95**:075430 (2017)

[3] Hellsing *et al*., (2018) arxiv.org/abs/1808.08620

[4] Riley *et al*., Nature Physics **10**:835 (2014)

[5] Bahramy *et al*., Nat. Mater **17**:21 (2018)

[6] Miwa *et al.* PRL **10**:136801 (2013)

[7] Cooil *et al.,* ACS Nano **11**:1683 (2017)

[8] Mazzola *et al.* PRL **120**:046403 (2018)

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