Quantum light sources in low-dimensional Van der Waals materials and their heterostructures

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Single photon sources are basic building blocks for the future quantum technologies such as quantum computing, quantum sensing, metrology and secure quantum communication. The recent discovery of quantum emitters and spin quantum defects in two-dimensional (2D) materials emerged as a promising platform for the next generation of integrated photonic devices for quantum photonic technologies.

In contrast to their 3D counterparts, two-dimensional materials (2DMs) which shows several advantages over the state-of-the-art QEs: (i) atomic thickness and absence of dangling bond results **efficient extraction** of the light, (ii) quantum emission from SPEs can be tuned using external electric field, strain or creating novel artificial VDW stacking (for example, Moiré superlattice). and (iii) straightforward means for interfacing with integrated electronic or photonic circuits, possibly allowing a more versatile quantum photonic platform.

SPEs formed in 2D materials come in two varieties. Defect centers in hexagonal boron nitride similar to color centers in diamond, emit single photons at room temperature. However, these emitters show difficulty of deterministically inducing emitters at desired wavelengths or spatial positions. The other option for 2D single photon sources is emitters in transition metal dichalcogenides which emit only at liquid helium temperatures yet allow precise spatial positioning and exhibit a reduced range of emission wavelengths. For example, Single photon emitters (SPEs) have been detected in various 2D materials, covering wavelengths from ultraviolet to telecommunications ranges. Research has demonstrated SQEs emitting at rates exceeding 10 MHz and achieving 95% single-photon purity in hBN and WSe_2. By applying strain and defect manipulation, these emitters can be arranged in arrays, while nanophotonic integration further amplifies their brightness.

Strain and defect engineering in 2D materials can result in mid gap energy states in the electronic structure of the material, leading to the creation of single and entangled photon sources. The wavelength can vary from visible to near IR depending on the material's selection. Once the photo-emitters are generated in the 2D materials, they can be transferred onto almost any arbitrary substrates including silicon photonic circuits (waveguides, couplers, Mie resonator, plasmonic antenna, photonic crystal cavities, etc.), making them an even more versatile and robust candidate for on-chip photon sources.

In this project, the candidate will contribute to investigate sources of single and entangled photons in 2D van der Waals materials, at near-infrared wavelengths, potentially useful for quantum communications. Key challenges will be understanding the nature and origin of the single and entangled photon emission in this family of materials and tailoring their properties to their potential usage in quantum communications.

PhD candidates with suitable knowledge in **quantum physics/optics** who keen to research in quantum communications. This project will involve **design, fabrication and characterization** of quantum optoelectronic devices using low dimensional materials as a solid-state host. Therefore, this research project is mostly experimental one. However, an inclination for theory or simulations will be positively considered.