

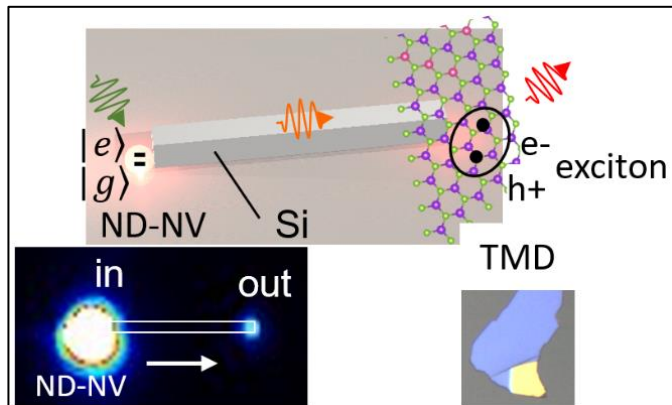
Quantum Excitronics : Excitation of Single Excitons in TMD-Type Materials Using Diamond Nanoparticle-Based Photon Sources

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Introduction and context - In order to face the future challenges in communication and data processing, integrated optics and in particular nanophotonics offers deep integration at the nanoscale and is an appealing approach that might lead to disruptive technologies.

In this context, Transition Metal Dichalcogenide (TMD) monolayer [1] have gained significant attention in the field of optoelectronics due to their unique opto-electronic properties. These materials exhibit stable excitons (a neutral electron-hole particle), which are crucial for applications in quantum technologies. Nevertheless, future exciton-based devices, require precise control over the generation and manipulation of individual excitons.

We propose here an innovative approach to achieve such a control, by using colored centers in diamond nanoparticles as an intermediate source of single photons [2]. These diamond-based photon sources are integrated at the end of silicon nanowires [3], which allows to decouple the processes of photon generation, propagation, and subsequent excitation of excitons within the TMD materials. This internship offers an exciting opportunity to engage in cutting-edge research at the intersection of quantum technologies, nanomaterials, and optoelectronics. By working on the excitation of single excitons in TMD materials using single-photon sources, the M2 student will contribute to the development of next-generation quantum devices and gain valuable hands-on experience in experimental physics and nanotechnology.



Internship Objectives - The main objective of this internship is to study and characterize the excitation of single excitons in TMD-type materials using single-photon sources derived from colored centers in diamond nanoparticles. The internship will involve a combination of experimental work and optical characterizations (at low temperature) to reach this goal.

The key tasks and objectives are:

- **Preparation of the sample and preliminary characterization:** Optical characterization of diamond nanoparticles with colored centers (NV - Nitrogen Vacancy) already coupled to silicon nanowires [3] / TMD subsequent and controlled deposition on the same sample
- **Optical Characterization of the exciton excitation:** : Investigation of the excitation mechanisms of single excitons in TMD materials using single photons emitted by the diamond nanoparticles by performing low-temperature (4K - allowing for the suppression of thermal effects and enhanced resolution in the detection of the excitonic state) optical characterizations (photoluminescence, time-resolved measurements, Fourier plane imaging, correlation measurement), to analyze the behavior of single excitons in the TMD materials.
- **Analysis of results:** Detailed analysis and comparison of the optical properties of the TMD materials in the classical and quantum regimes. The emitted photons and the resulting excitonic behavior will be analyzed using various techniques, including spectroscopy, to understand the efficiency and dynamics of exciton generation.

Expected Results and Impact - The outcome of this project is expected to provide insights into the possible excitation of excitons in TMD by single photons and their interaction. This work will contribute to the development of novel optoelectronics devices, particularly in the field of quantum information processing.

References: [1] G. Wang et al. Rev. Mod. Phys. 90, 021001 (2018). [2] C. Bradac et al. Nat. Comm. 10, 5625 (2019). [3] M. Humbert et al. Phys. Rev. Applied 17, 014008 (2022).

Keywords, areas of expertise	Quantum technologies, single photon, colored centers, nanodiamond, TMD monolayer, exciton, time-resolved optical microscopy, photon correlation, numerical simulation of optical properties.
Required skills for the internship	The candidate will be involved in the experimental aspects of the optical characterization of optical excitation of TMDs (down to single photon excitation), and to the theoretical aspects of such coupling (electrodynamics simulation). Autonomy, dynamism, scientific curiosity and rigor are the key words to carry out this project. Basic understanding of optics and materials science, especially related to semiconductors (TMD) materials. Familiarity with laboratory work. Knowledge or experience in optical spectroscopy techniques, especially for low-temperature measurements.