Exploring quantum defects in 2D materials with ultrafast optical coherent microscopy

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Scientific context. Quantum emitters in two-dimensional (2D) semiconductors layered materials are growing rapidly as one of the most promising building-blocks for next generation quantum technologies [1,2,3]. Additionally such qbits systems are of great interest for fundamental quantum optics experiments. Indeed, these optically active defects or confined exciton inherit exceptional properties from their 2D hosts, which exhibit a high mechanical flexibility, easy integration into photonic chips, and capacity to be stacked with other 2D materials (2DM) to form innovative device architectures.

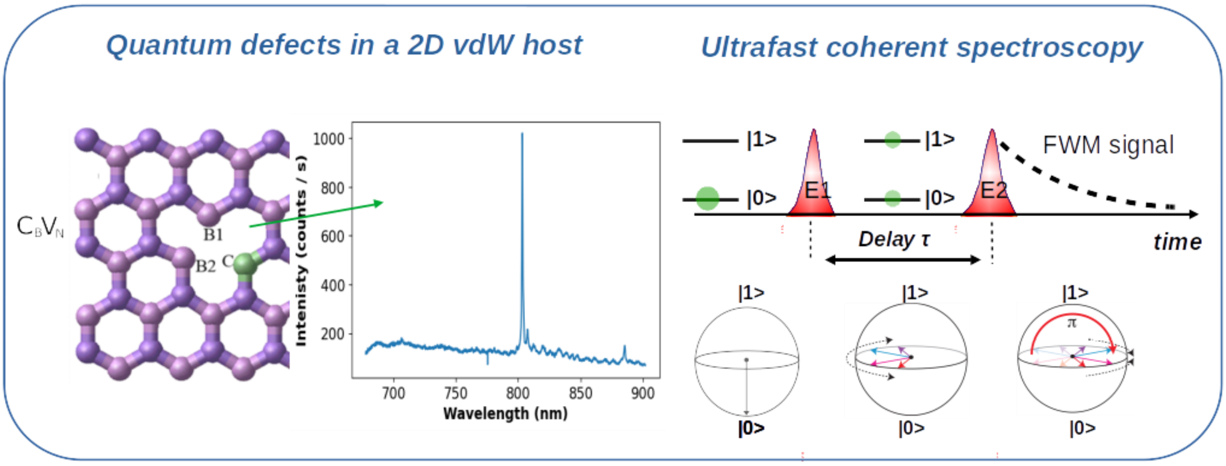

Figure: *Illustration of quantum defect in hBN 2D lattice. Optical signature from a single radiative defect obtained by micro-photoluminescence in a home-made hBN sample. (Right) Scheme of the time-resolved experiment in four-wave mixing configuration (FWM), see also ref [4,5]. The first pulse creates a quantum superposition between the excited and the ground states of the excitonic system. This superposition evolves freely in time, then the second pulse probes the quantum state of the system with a time resolution of about 100 fs. Below is the corresponding evolution of quantum states represented in the Bloch sphere.*

Project. In the team, important progress has been made on one hand concerning the processing and identification of radiative defects in van der Waals 2D semiconductors such as hexagonal Boron Nitride [6], and on the other hand, in the development of a cutting-edge experiment that combines optical microscopy and ultrafast non-linear coherent spectroscopy (see fig.) [5]. The latter allows to optically probe and manipulate quantum superpositions of states at the single-system level with spatial (~ 500 nm) and temporal resolution (100 fs) [4,5]. In this context, we are looking for a motivated student to investigate the light-matter interaction mediated between radiative defects or confined excitons in 2D hosts, coupled to photonic nanostructures, in order to tailor their optical properties. The PhD project comprises multiples aspect. 1) Synthesis of new-generation 2D materials. 2) Static characterization of quantum emitters using micro-photoluminescence spectroscopy, ranging from cryogenic to room temperature. 3) Study of the quantum properties using state-of-the-art time-resolved experiment mentioned above. 4) Understanding and modelling of the mechanisms of decoherence of confined excitonic systems surrounded by photonic and 2D crystalline environments.

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[5] R. Chowdhury et al. Robust coherent dynamics of homogeneously limited anisotropic excitons in two-dimensional layered ReS2 https://arxiv.org/abs/2411.13695
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