Strain effects on the electronic states of 2D excitons probed by magneto-optical spectroscopy

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Excitons dominate the emission spectra of two-dimensional semiconducting materials, like monolayers (MLs) of transition metal dichalcogenides (TMDs). Therein, strong carrier confinement and reduced dielectric screening make excitons stable up to room temperature with binding energies exceeding several hundreds of meV [1]. Excitons in TMD MLs feature several interesting characteristics. They can form very stable multi-excitonic and charged exciton complexes [2]. They can act as information carriers via their valley quantum number addressable using circularly polarized light [3]. They can be spatially localised by defects hence behaving as emitters of single photons [5].
These features can be controllably modified or induced by strain thanks to the high structural responsivity of MLs to mechanical deformations [6]. The latter couple to the material's electronic properties that are eventually reflected in the optical characteristics of the excitonic emission, such as energy and circular/linear polarisation. Especially relevant is how those characteristics can be altered and probed by external magnetic fields in combination with strain fields.

In this talk, we report on Zeeman splitting measurements in mechanically deformed WS_2 MLs in form of micro-domes and discuss the deep influence that strain plays on the exciton magnetic moment. Indeed, strain causes a hybridization of *k*-space direct and indirect excitons resulting in a sizable decrease in the modulus of the gyromagnetic factor of the ground-state exciton [7]. Since MLs are often unavoidably subjected to strain, this aspect ought to be considered when regarding excitons as valley-carrying bits. We also show that Zeeman splitting measurements can be conveniently exploited to understand the origin of the mechanism underlying the presence of single-photon emitters in TMD MLs [5]. As a matter of fact, a doubling of the gyromagnetic factor of localised *vs* free excitons in WS_2 confirms the participation of electrons belonging to the dark conduction band in the generation of single photons from exciton localisation centres in WS_2 micro-domes.
Those described above are prominent examples highlighting the relevance of magnetic fields in the physics of two-dimensional semiconductors.

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References.

[1] Z. Jiang *et al*., Phys. Rev. Lett. **118**, 266401 (2017).
[2] X. Chen, *et al.*, Nat. Commun. **14**, 8233 (2023).
[4] R. Rong *et al*., Adv. Sci. **10**, 2206191 (2023).
[5] S. Cianci *et al*., Adv. Opt. Mater. **11**, 2202953 (2023).
[6] E. Blundo *et al*., Appl. Phys. Rev. **8**, 021318 (2021).
[7] E. Blundo *et al*.,. Phys. Rev. Lett. **129**, 067402 (2022).