Strain-induced exciton transfer among quantum emitters in two-dimensional materials

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Monolayer Transition-Metal Dichalcogenides (ML-TMDs) are two-dimensional semiconductor materials exhibiting unique optical and electronic properties. In addition to their easiness in fabrication, ML-TMDs can withstand large strain without breaking, being then feasible to exploit deformations to control their transport and optical properties. Furthermore, localized excitons in ML-TMDs provide single photons with high brightness [1]. Since both impurities and spatial strain gradients induce quantum emitters (QEs) in ML-TMDs [2], the dynamic control of the strain field enables engineering the QEs' properties and exploits their full potential for quantum technologies.

Our piezoelectric device bursts into this context: it is a gold-covered piezoelectric material with a micro-pillars array enclosed by dry-transferred ML- WSe2. The QEs nucleation sites are arranged around the pillars, providing control of their position over a few microns [3]. Furthermore, by deforming the piezoelectric substrate we can induce external strain fields to the QEs. We demonstrated that the QEs energy can be precisely tuned across a spectral range as large as tens of meV without changing the multi-photon emission probability [4]. We also observed that the external strain field reversibly modifies the QEs brightness. This feature can be explained in a disordered potential landscape scenario, where different QEs originate from different strain-induced potential wells in the material's bandgap. To confirm this hypothesis, we performed theoretical simulations based on an exciton diffusion model. We found good agreement between the theory and the experimental results, confirming that strain is a valuable tool for brightening specific emitters and validating this physical picture[4]. We also investigated the QEs response in an external magnetic field in the Faraday configuration. Measuring the g-factor of several single-photon lines as a function of the applied external stress, we found that despite changes in energy up to 10 meV, the variations in the g-factor always remain between the experimental errors [5], ensuring the robustness of the QEs magnetic response.

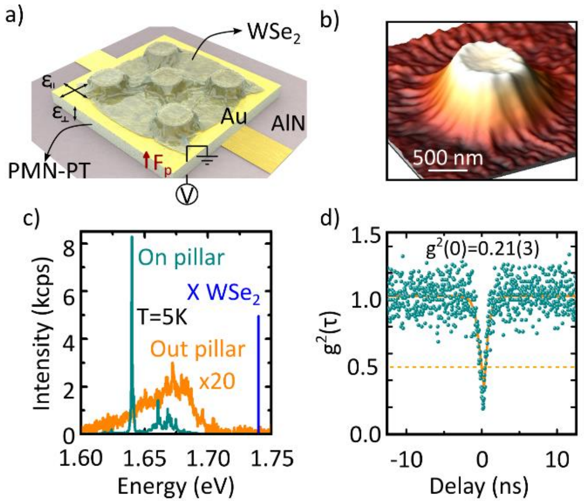

Figure 1: a) Sketch of the device, a PMN-PT piezoelectric plate featuring pillars over which a WSe_2 ML is transferred. The top and bottom surfaces of the plate are gold-coated. The application of an electric field F_p along the poling direction produces the out-of-plane ($\varepsilon_\perp$) and in-plane ($\varepsilon_\parallel$) deformation of the attached ML. b) AFM image of one specific pillar. c) Micro-PL spectra recorded outside (orange line) and at the edge (dark-cyan line) of a pillar. The emission energy of the WSe_2 ML 2D-neutral-exciton is indicated with a blue vertical line. d) Second-order autocorrelation measurement obtained on a single QE. The single photon emission nature is confirmed by the low-value $g^{(2)}(0) = 0.21(3)$.

References

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