Quantum emitters from electrostatically strained WSe_2 monolayers suspended over nanocavities

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Tungsten diselenide (WSe_2) monolayers are promising hosts for quantum emitters due to their intrinsic dark exciton state, which hybridizes with defect states under tensile strain, resulting in localized defect emission. To date, strain engineering has focused primarily on creating static strain via techniques such as draping WSe_2 monolayers on patterned substrates or indentation with an atomic force microscope, which suffers from poor control over strain. In this study, we employ an electrostatic straining approach demonstrated for monolayer WSe_2 suspended over micron-scale cavities in a patterned substrate. In this approach, a back-gate voltage applied to the silicon substrate below the cavity induces a downward deflection of the suspended WSe_2 monolayer due to the capacitive interaction between the monolayer and substrate.[1]

Here, we investigate scaling of the cavity to nanoscale dimensions, allowing the distance between emitters to be smaller than the wavelength of light and enabling the study of cooperative emission behaviors from coupled emitters such as those leading to superradiant emission. This collective emission from coupled emitters has been previously observed in laterally arranged quantum dot ensembles, but not in highly scalable WSe_2-based quantum emitters. By performing electrostatic straining on a WSe_2 monolayer suspended over 100-nm diameter cavities, monolayer deflections of 2 nm (V_g = 10 V) and 3.5 nm (V_g = 27.5 V) were observed, corresponding to 0.2 and 0.4% increase in tensile strain, respectively. Initial studies of photoluminescence from a WSe_2 monolayer suspended over 10 cavities showed a linear (rather than saturating) behavior of localized emitter intensity as a function of increasing excitation power, a distinct characteristic of cooperative emission. Second-order photon correlation measurements showed an emitter antibunching behavior of $g^{(2)}(0) = 0.24 \pm 0.03$, indicative of high-purity emitters, which can be attributed to the effective exciton funneling on nanoscale cavities. Current studies are focused on the electrostatic biasing of the suspended WSe_2 monolayer, which could enable precise strain modulation and enhanced coupling of emitters for possible observation of additional cooperative emission phenomena. This can be beneficial for the development of highly scalable and tunable coupled quantum emitters from strained WSe_2 monolayers for potential applications in quantum information processing, quantum laser technology, and quantum computing.

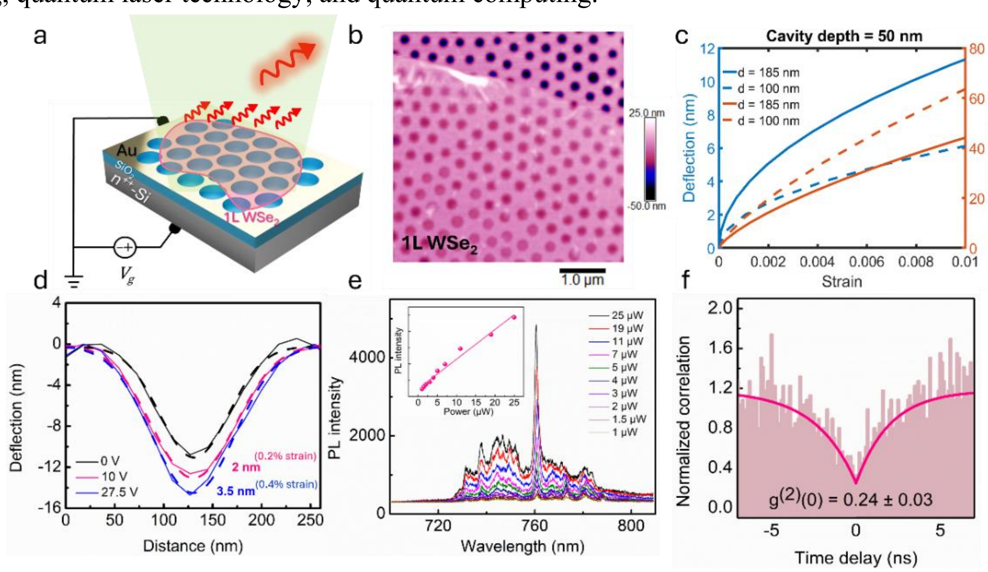

Figure 1 a. *Schematic diagram of electrostatic straining approach.* ***b.*** *AFM topographic image of WSe_2 monolayer suspended over nanocavities.* ***c.*** *Model calculations of deflection and applied bias as functions of strain.* ***d.*** *Monolayer deflection at different applied voltages.* ***e.*** *Power-dependent emitter intensity at increasing excitation power.* ***f.*** *Second-order photon correlation, showing a strong antibunching behavior with $g^{(2)}(0) = 0.24 \pm 0.003$.*

Reference

1. Wu, F.C.M. *et al. Nano Letters* **25** (27), 10983-10989 (2025).

Supplementary Pages

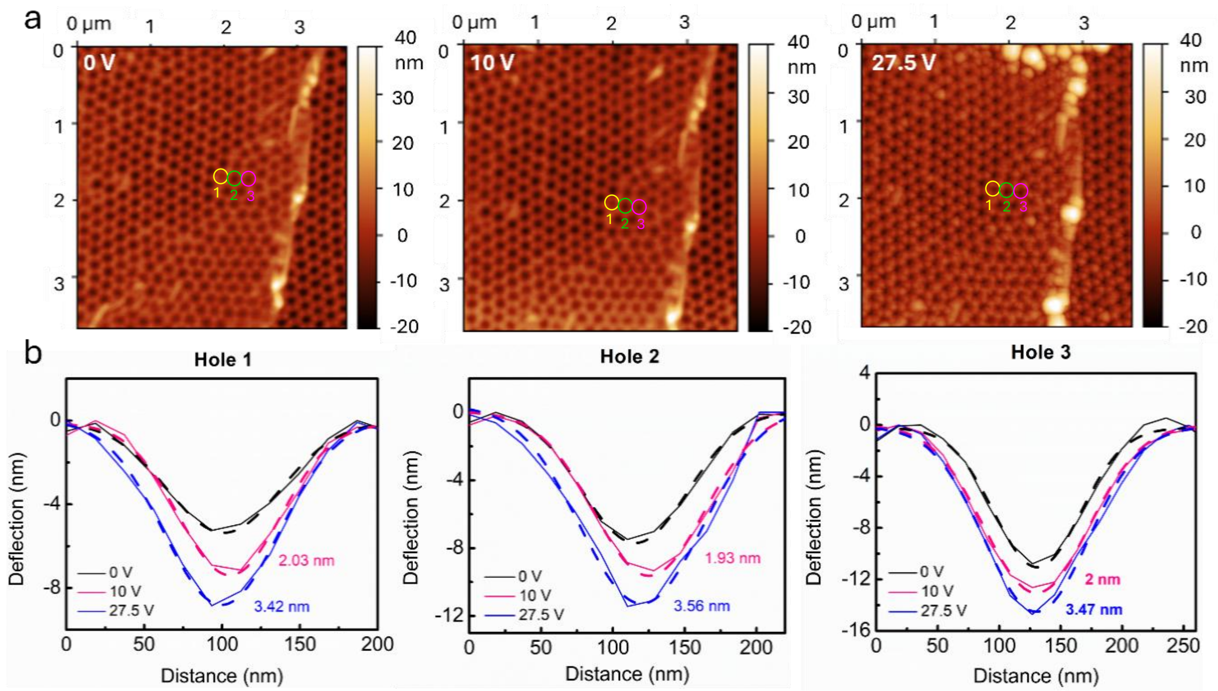

Figure 2 *Electrostatic deflection of suspended* WSe_2 *monolayer on nanocavities at different bias voltages.* ***a.*** *AFM topographic images of suspended* WSe_2 *monolayer over nanocavities at bias voltages of 0 V, 10 V, and 27.5, showing monolayer deflection at increasing bias voltages.* ***b.*** *Deflection profile of* WSe_2 *monolayer at three different cavity sites, showing 2 nm and 3.5 nm deflection at 10 V and 27.5 V, respectively.*

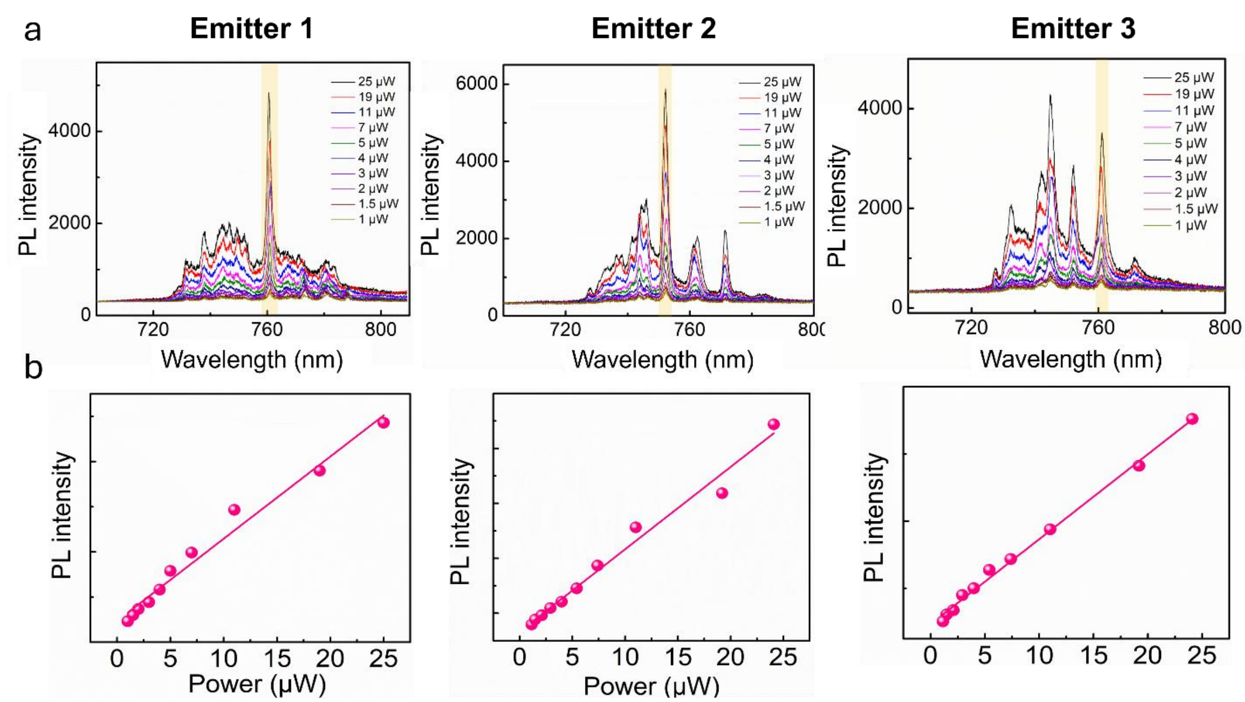

Figure 3 *Power-dependent emitter intensity at different laser excitation powers.* ***a.*** *Photoluminescence intensity spectra at T = 4 K of* WSe_2 *monolayer on nanocavities measured at different excitation powers for three different sites across the sample, showing sharp localized emitters.* ***b.*** *Linear behavior of emitter intensity at increasing excitation power, showing a distinct characteristic of cooperative emission.*

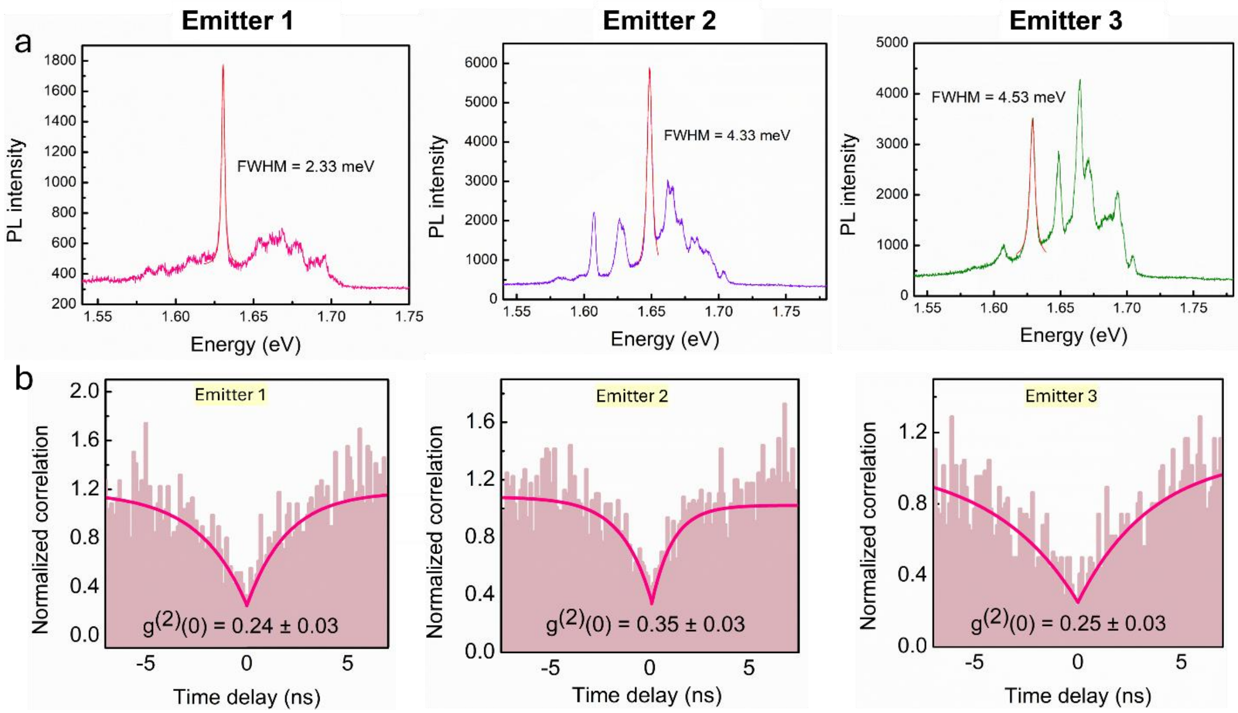

Figure 4 *Second-order photon correlation measurements of three chosen emitters.* ***a.*** *Photoluminescence intensity spectra at T = 4 K of suspended* WSe_2 *monolayer over nanocavities showing sharp localized emitters with emitter linewidths ranging from 2–4.5 meV. b. Second-order photon correlation measurements of the chosen emitters in* ***(a)****, showing a strong antibunching behavior with* $g^{(2)}(0) = 0.24–0.35$.