Eclectically driven photon emission from individual atomic defects on monolayer tungsten disulfide

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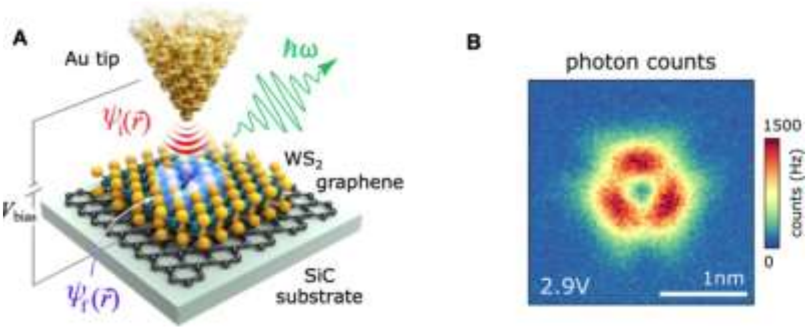
Atomistic point defects, such as NV centers in diamond and point defects in silicon carbide, are a powerful platform for creating next-generation solid state quantum emitters. In particular, the use of two dimensional (2D) materials is of interest due to their high photon extraction efficiency, synthetic flexibility, and tunability through gating and substrate engineering. Recently, single photon emitters have been observed in hBN as well as semiconducting transition metal dichalcogenides (TMDs), however the atomic scale origin of the emission is still actively debated. Furthermore, the ability to create identical emitters with the required spatial precision and specificity is currently lacking. These challenges prevent the systematic development and deployment of quantum emitters in 2D materials.

Here we use scanning tunneling microscopy light emission (STM-L), scanning tunneling spectroscopy (STS), and noncontact atomic force microscopy (ncAFM) to correlate photon emission with the atomic and electronic structure of individual defects in monolayer WS2. [1,2] With a gold coated STM tip, we observe single photon emission from intrinsic tungsten substitutes and deliberately created sulfur vacancies by tip induced electroluminescence. We are able to tune photon emission by the applied bias and map photon emission with atomic resolution. There is a correlation between the bias onset for photon emission and the energy of the lowest unoccupied in gap states observed in STS. In addition, the photon maps closely resemble the in gap defect atomic orbital resonances. This indicates that the luminescence arises from the inelastic tunneling of the electrons from the continuum of tip states into the in-gap defect states. Inelastic charge-carrier injection into localized defect states of 2D materials thus provides a powerful platform for electrically driven, broadly tunable, atomic-scale single-photon generation.

References

[1] B. Schuler et al., ACS Nano 13, 10520 (2019)
[2] B. Schuler et al., Sci. Adv. Vol. 6, no. 38, eabb5988

Figures



A. Scheme of experimental configuration. B. Spectrally integrated photon map of a sulfur vacancy defect.