Tunable and Deterministic Single Photon Emitters in Bilayer WSe_2 with Quantum Phonon States

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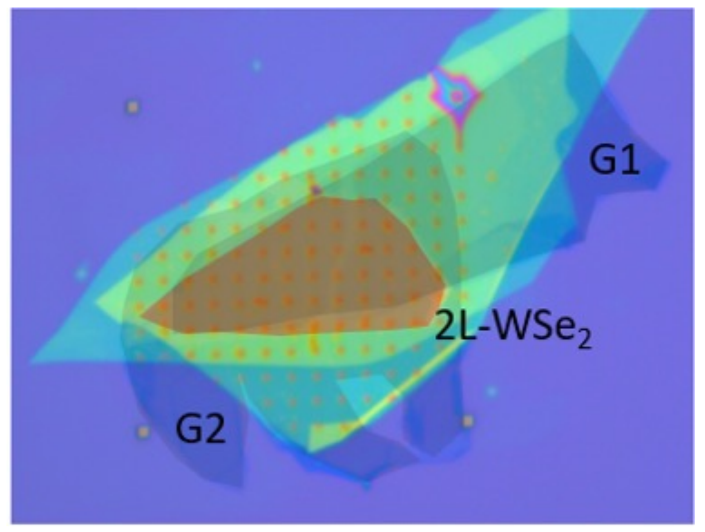
Importance of Single Photon Emitters

On-chip single photon emitters are highly desired for quantum information processing:

- ✓ Weak interactions with the environment
- ✓ Low transmission loss through waveguides
- ✓ Easily integratable with existing infrastructure



2D materials for Quantum Applications

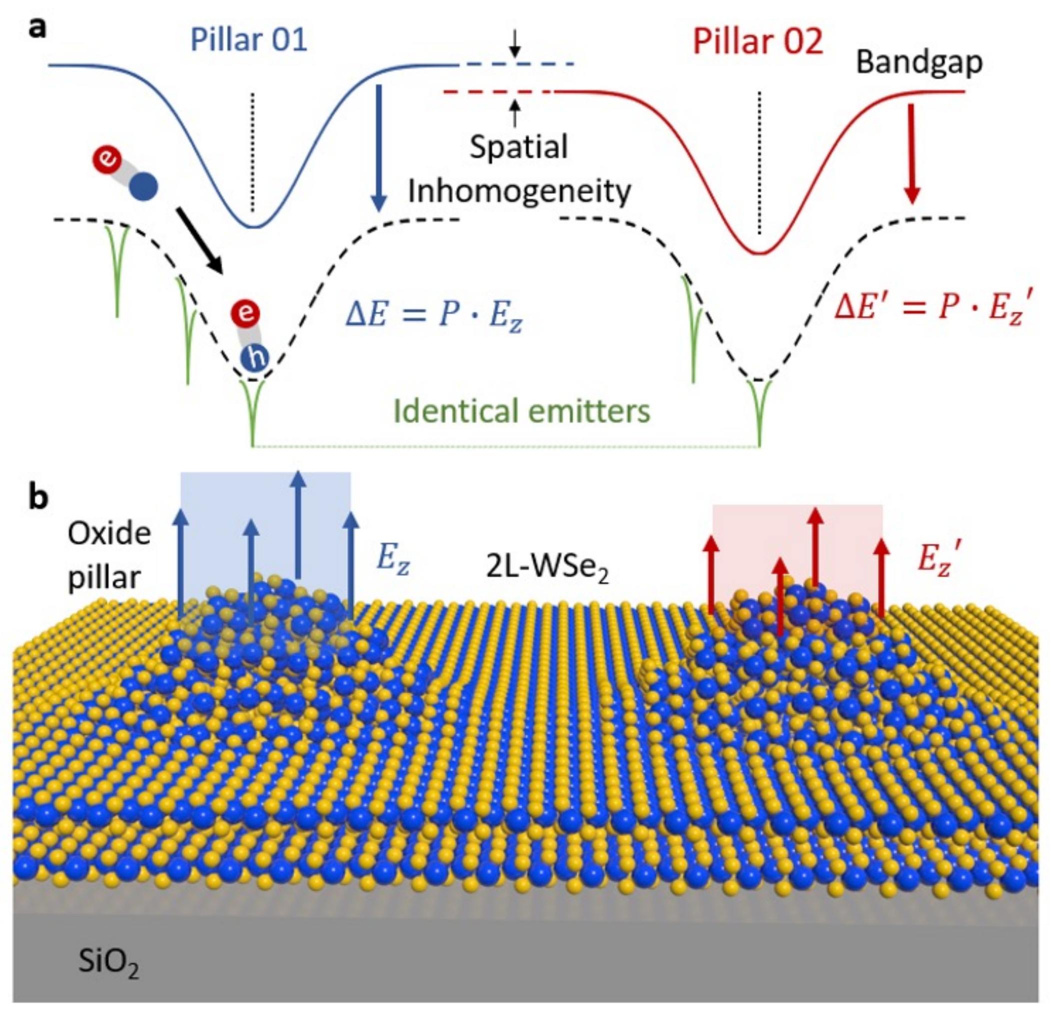
Reduced dimensionality leads to useful quantum effects & symmetry breaking

- ✓ Valley degree of freedom
- ✓ Strong control of optical & electronic properties
- ✓ Strong exciton binding energies
- ✓ Strain and defect induced single photon emitters

SPEs in 2D materials

- ✓ Can be deterministically created with >95% yield
- ✓ Location of emitters at interface of emitters offers easy and efficient integration
- ✓ Purity and brightness on the scale of other SPE platforms
- X Spectral inhomogeneity prevents identical emitters

Engineering Tunable Emitters in 2D

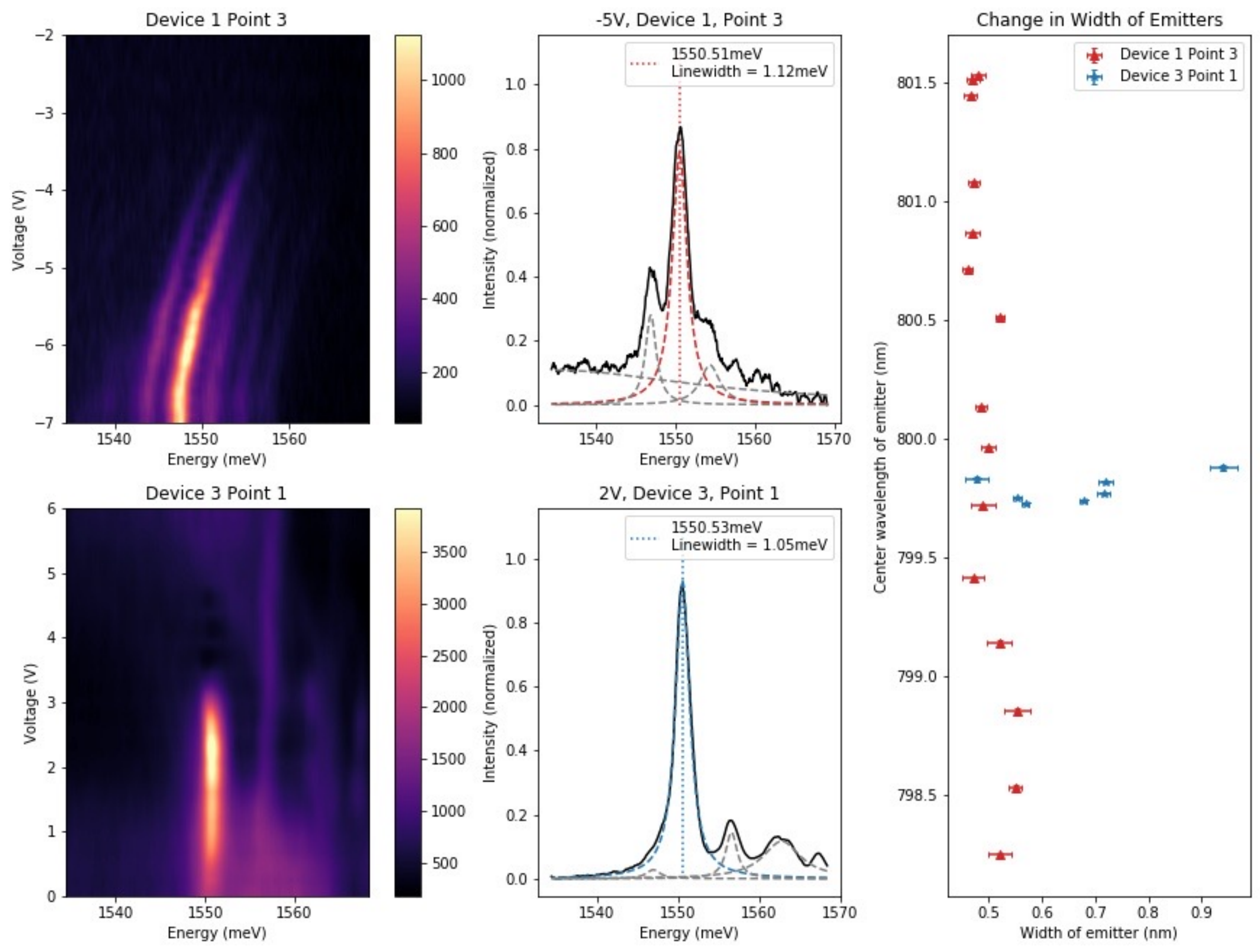


- Interlayer excitons have out of plane electric dipole
- Energy can be shifted using quantum-confined Stark effect

✓Energy tunable indirect defect-bound interlayer excitons

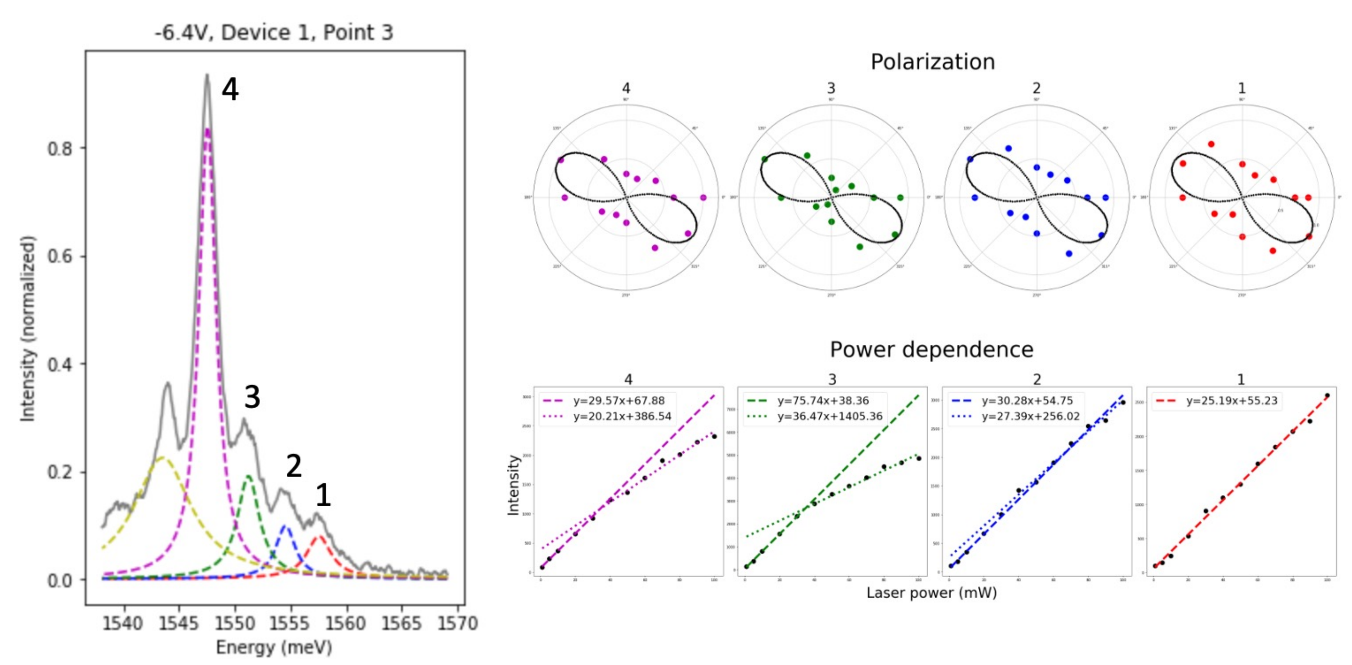
✓Linewidth tunable defect-bound intralayer excitons

Properties of Tunable Emitters



- Tune multiple emitters to the same energy and linewidth in step towards creating identical single photon emitters
- For interlayer excitons, linewidth of emitter stays constant throughout energy modulation
- For intralayer excitons, energy of emitter stays constant while linewidth is tuned

Quantum Phonon Sideband



- Series of peaks are turned on at the same voltage in many devices
- Energy spacing between peaks is fixed through modulation
- Same linear polarization indicates they originate from same source

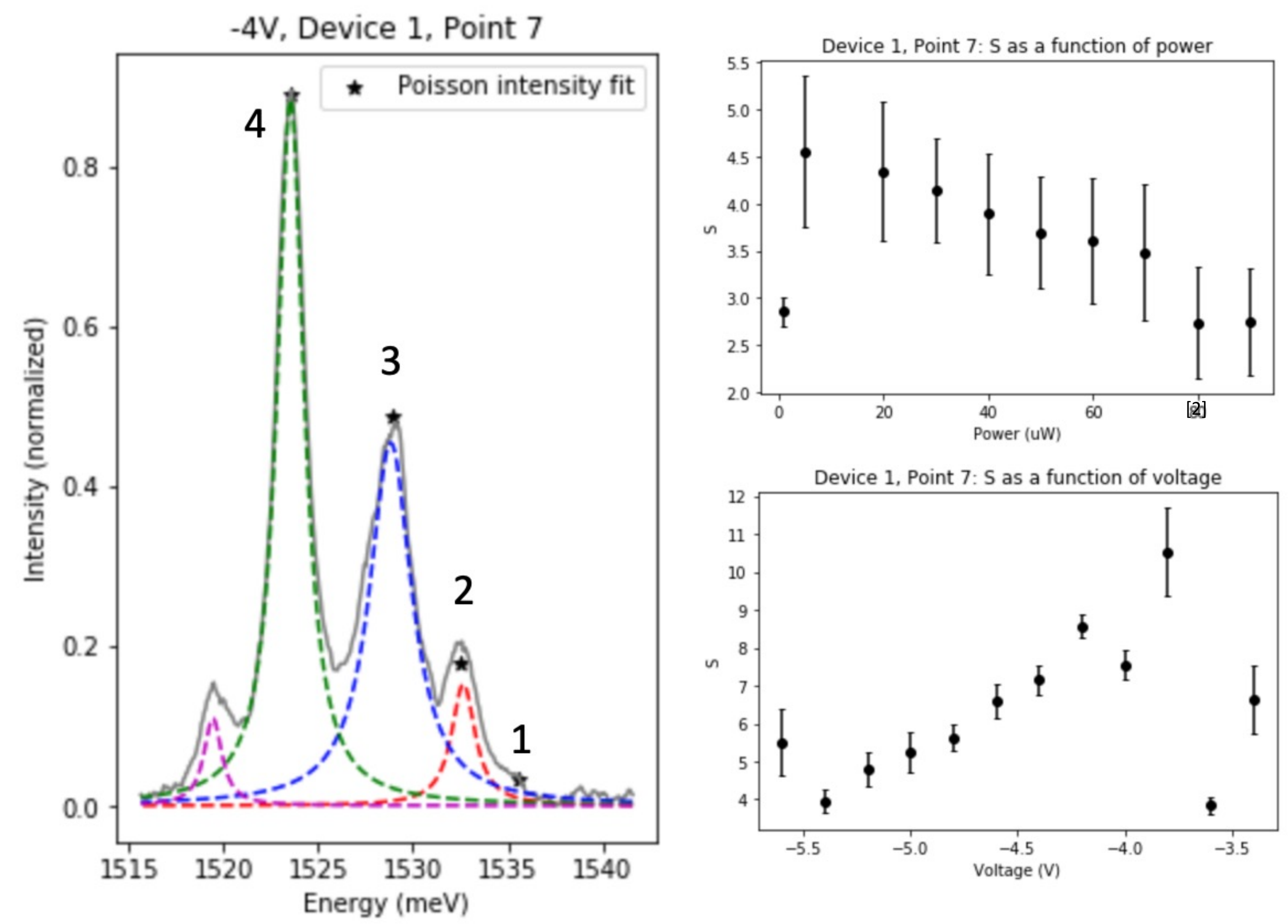
Exciton-Phonon Coupling

Franck-Condon integral for overlap of the vibrational states in the ground and excited states gives:

$$(\langle 0|n\rangle)^2 = e^{-S}\frac{1}{n!}S^n ,$$

i.e. the intensity of the nth order phonon side band can be described with Poisson distribution

S is Huang-Rhys parameter that describes exciton-phonon coupling of localized states



- Coupling parameter can be varied by modulating pump power, voltage
- Spacing between these states remains fixed
- Different phonon sideband modes can be selectively enhanced

Future Work

Integration with a waveguide

- Fabricate two heterostructures, tune two separate emitters to the same energy
- Couple them together on chip using MZI structure

Integration with photonic cavity:

- Selectively enhance each quantum phonon mode
- Tunability resolves engineering problem for designing photonic cavities for emitters with spectral inhomogeneity

Substitute in twisted bilayer WSe2

- Under a magnetic field will have single photon emitters that are valley polarized
- Creates tunable 2 level quantum system

ELECTRICAL & COMPUTER ENGINEERING

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