Fluorescent Defects in Hexagonal-Boron Nitride

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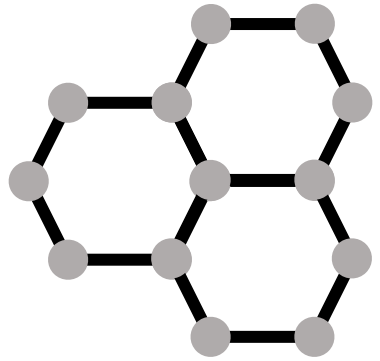
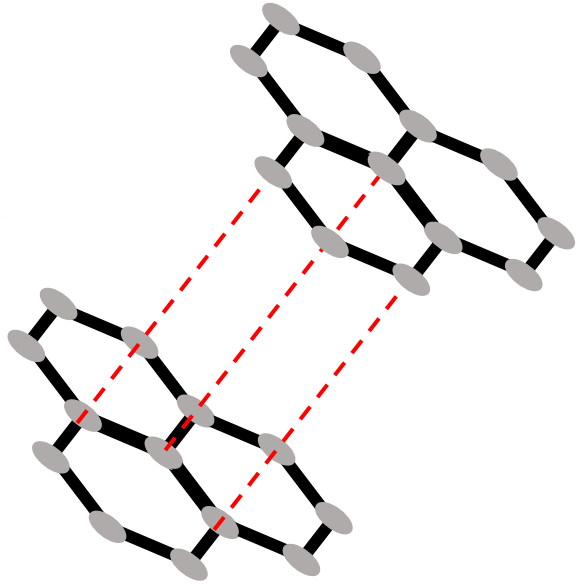
van der Waals Materials

- A type of material, commonly made up of many 2-Dimensional layers
- Atomic bonds within a single layer are strong
- Different layers are held together by weak van der Waals forces
- These forces can be overcome without breaking atomic bonds, allowing layers to be separated

Single graphene layer

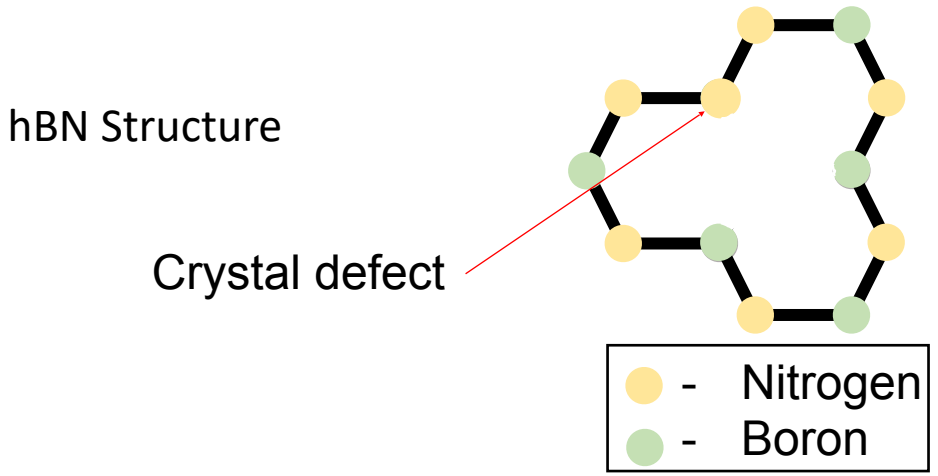


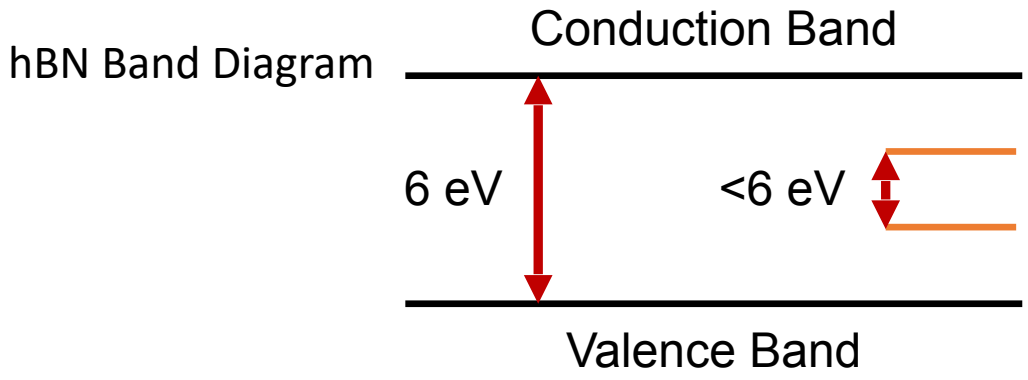
Multiple graphene layers held together by van der Waals forces



Hexagonal Boron Nitride (hBN)

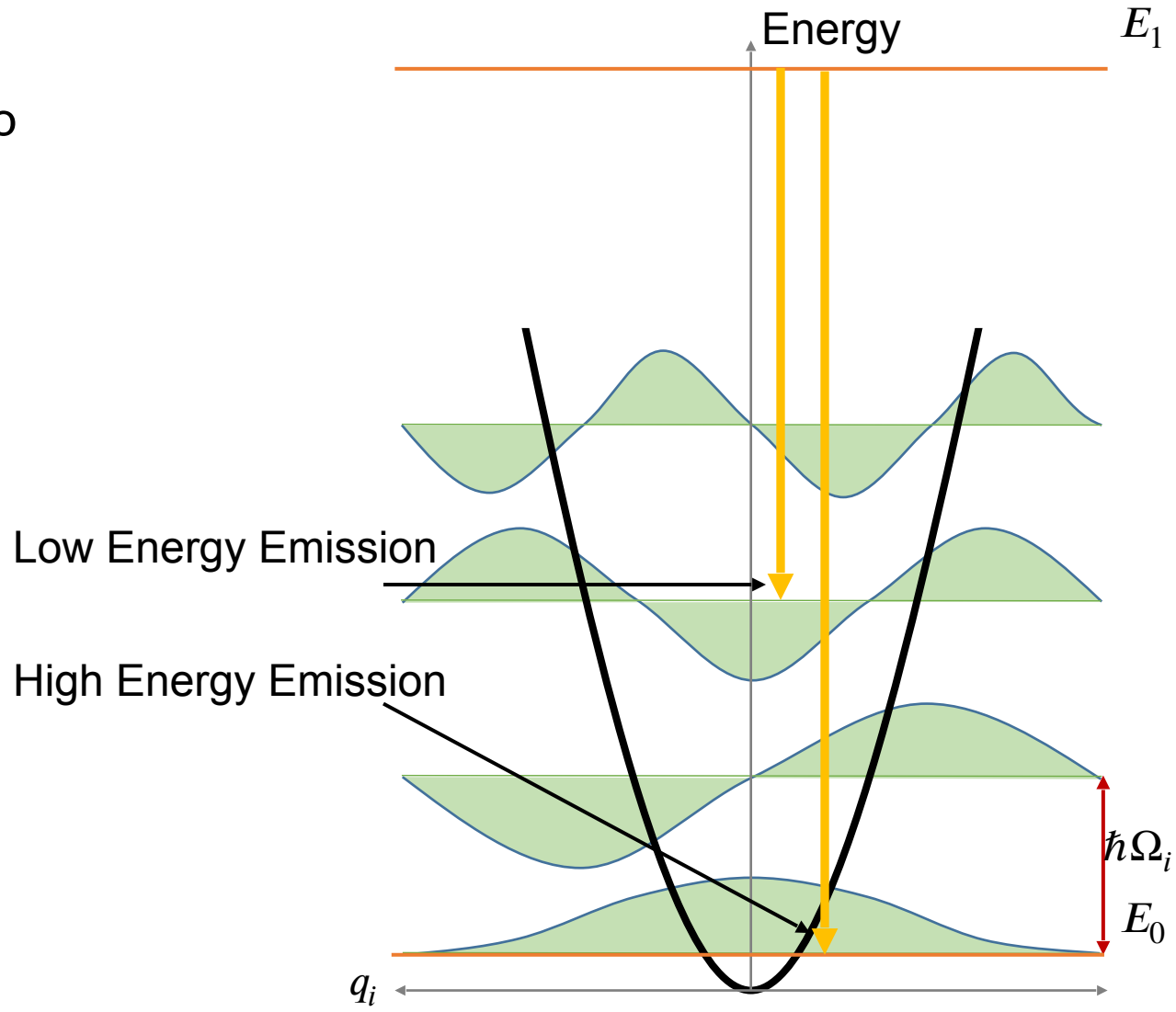
- A van der Waals material with similar structure to graphene
- hBN is an insulator, with a bandgap of ~6 eV
- Nitrogen-based defects can occur, creating low-energy trapped electron states
- Electrons excited to the higher energy state emit a photon when they decay to the lower energy state





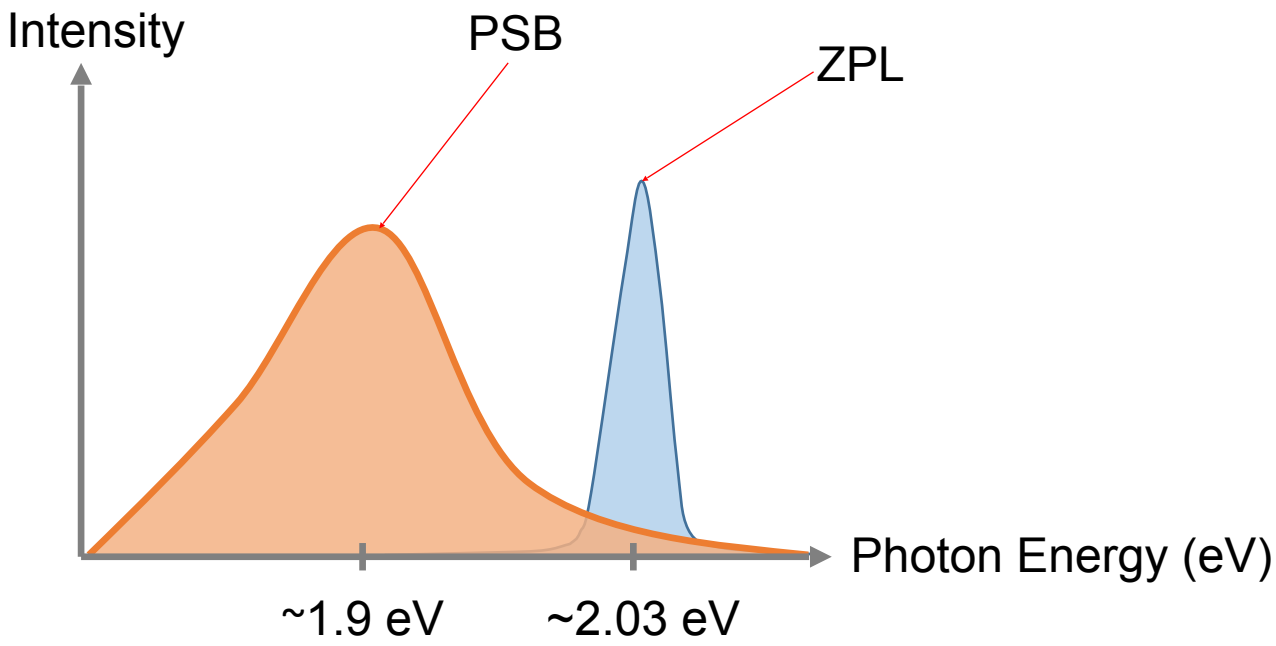
Zero Phonon Line and Phonon Sideband

- Electrons moving from a high energy state to a ground state can give off vibrational energy, in the form of phonons, in addition to photons
- Electrons that emit zero phonons emit photons with the maximum possible energy
- Electrons that emit phonons emit photons with lower energy
- High energy emissions form the Zero Phonon Line (ZPL), low energy emissions form the Phonon Sideband (PSB)



ZPL and PSB Measurement Expectations

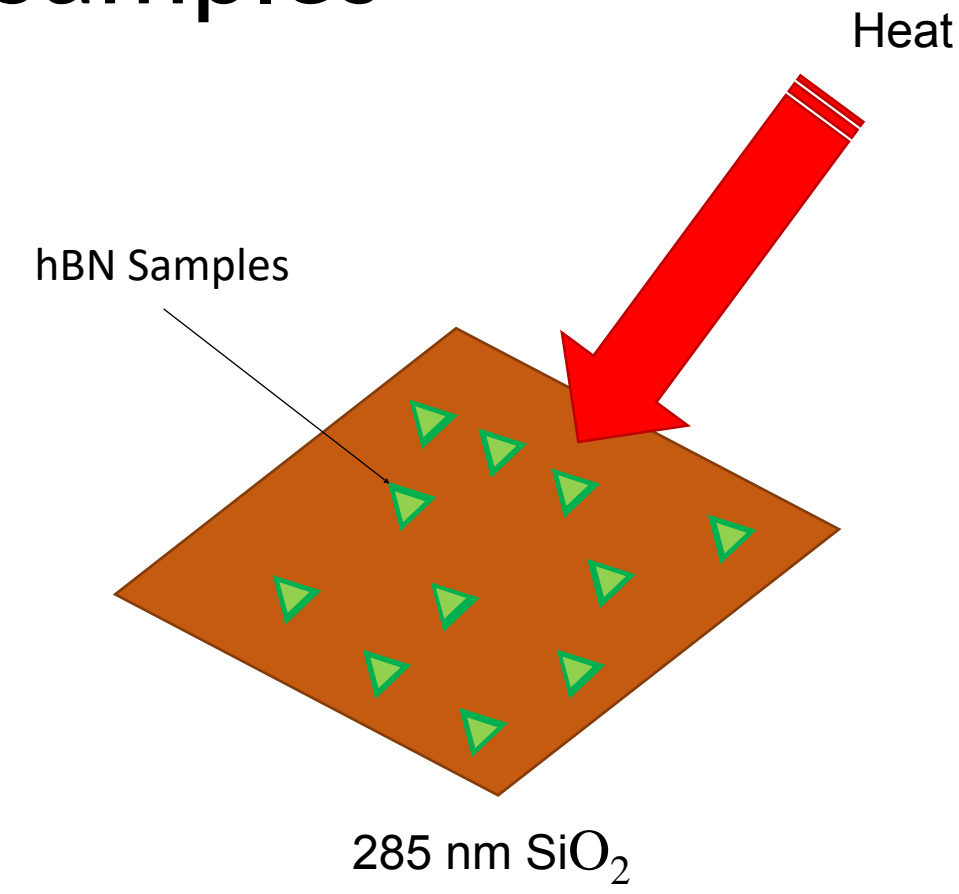
- Isolate nitrogen-based emitters in hBN by room-temperature photoluminescence spectroscopy
- Measure the ZPL and PSB energies of emitting defects
- Expect to measure a peak centered at 1.9-2.15 eV for the ZPL, and a peak centered at 1.77-2.02 eV for the PSB



Expected PL spectra of a hBN defect

Method for Preparing hBN Samples

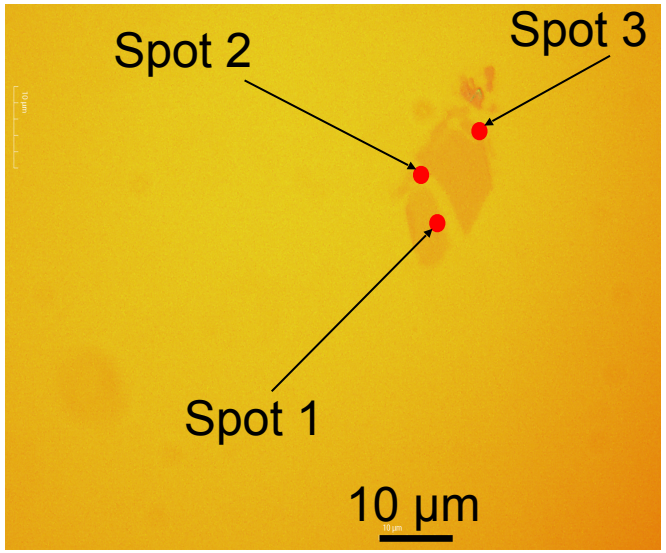
- hBN flakes were mechanically exfoliated using the scotch tape method and deposited onto 285 nm SiO_2 chips
- Chips were annealed under 1 Torr of Argon at 1000 °C for 30 minutes
- Suitable samples were identified through optical microscopy



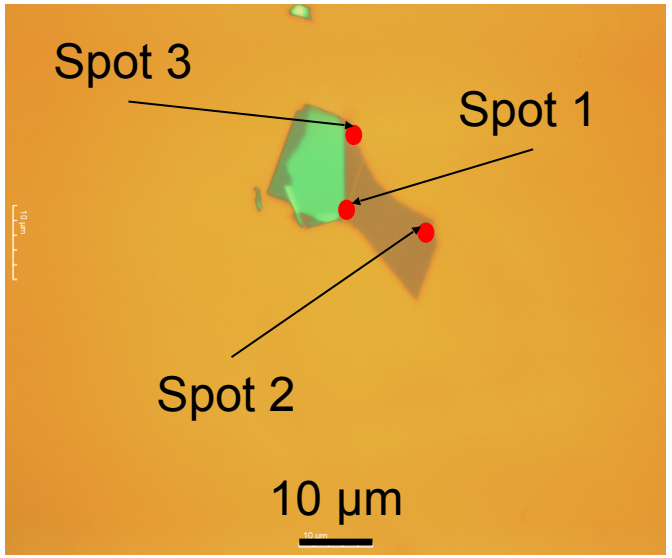
Possible Defect Locations

- From the annealed hBN, 4 suitable samples were selected
- Across these samples, 13 possible defect locations, or spots, were identified
- Defects were more likely to appear near edges or cracks, so those spots were selected

Sample 2

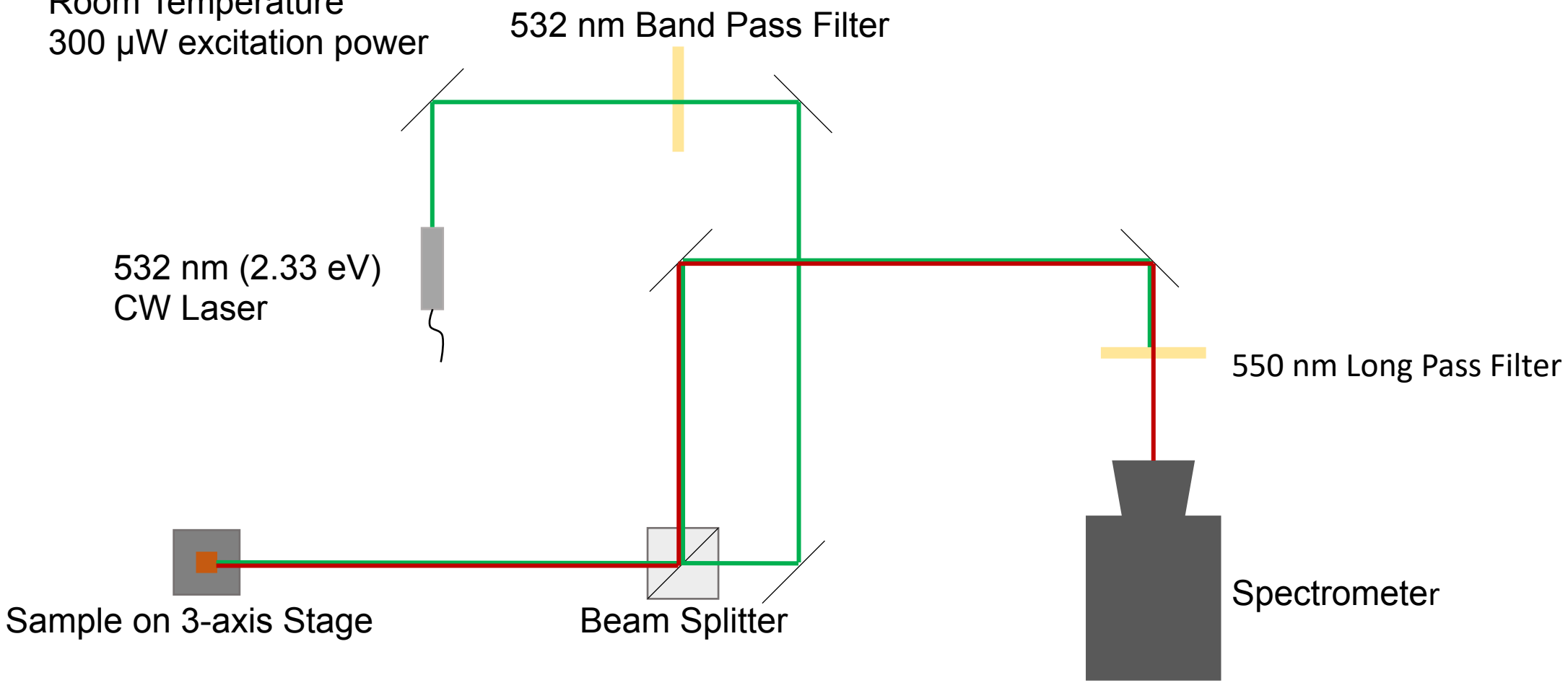


Sample 3

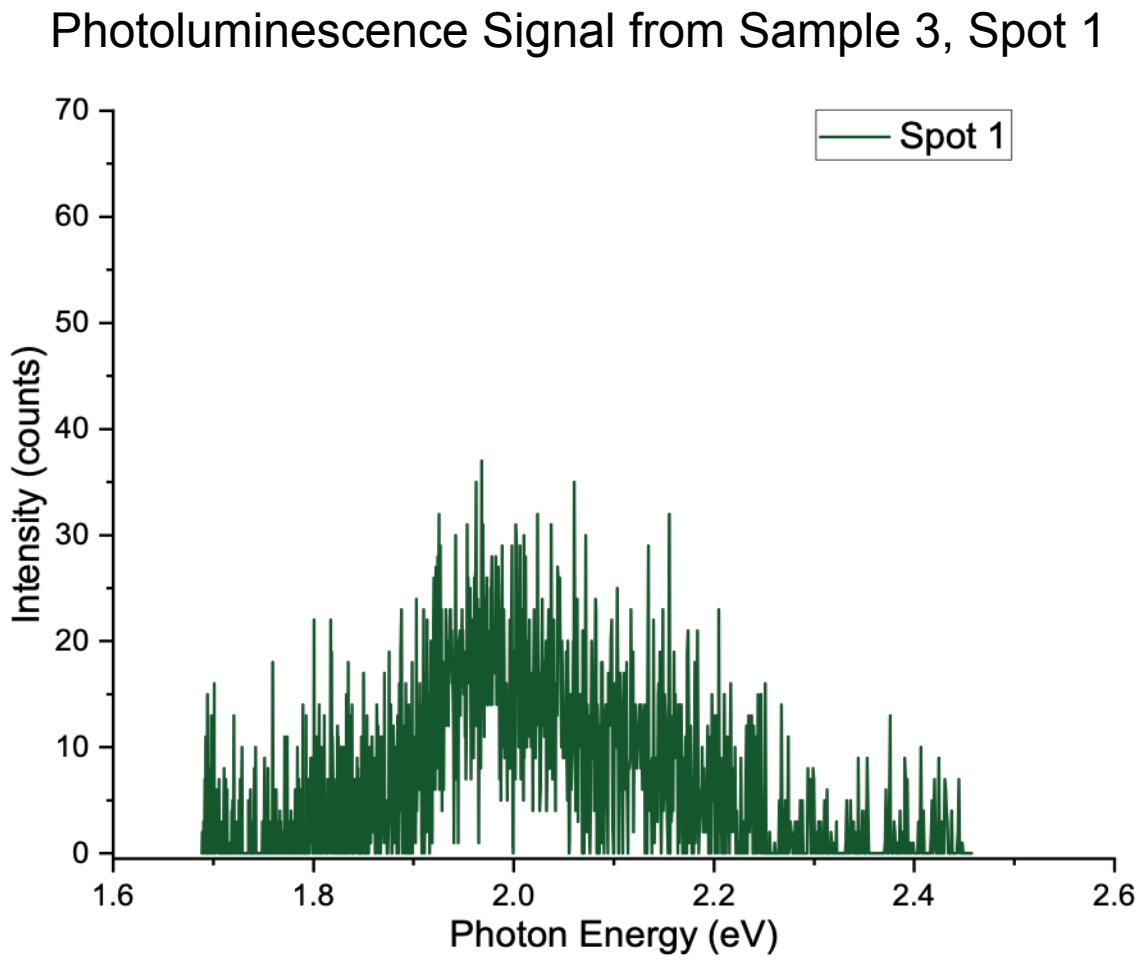


Method of Photoluminescence Measurement

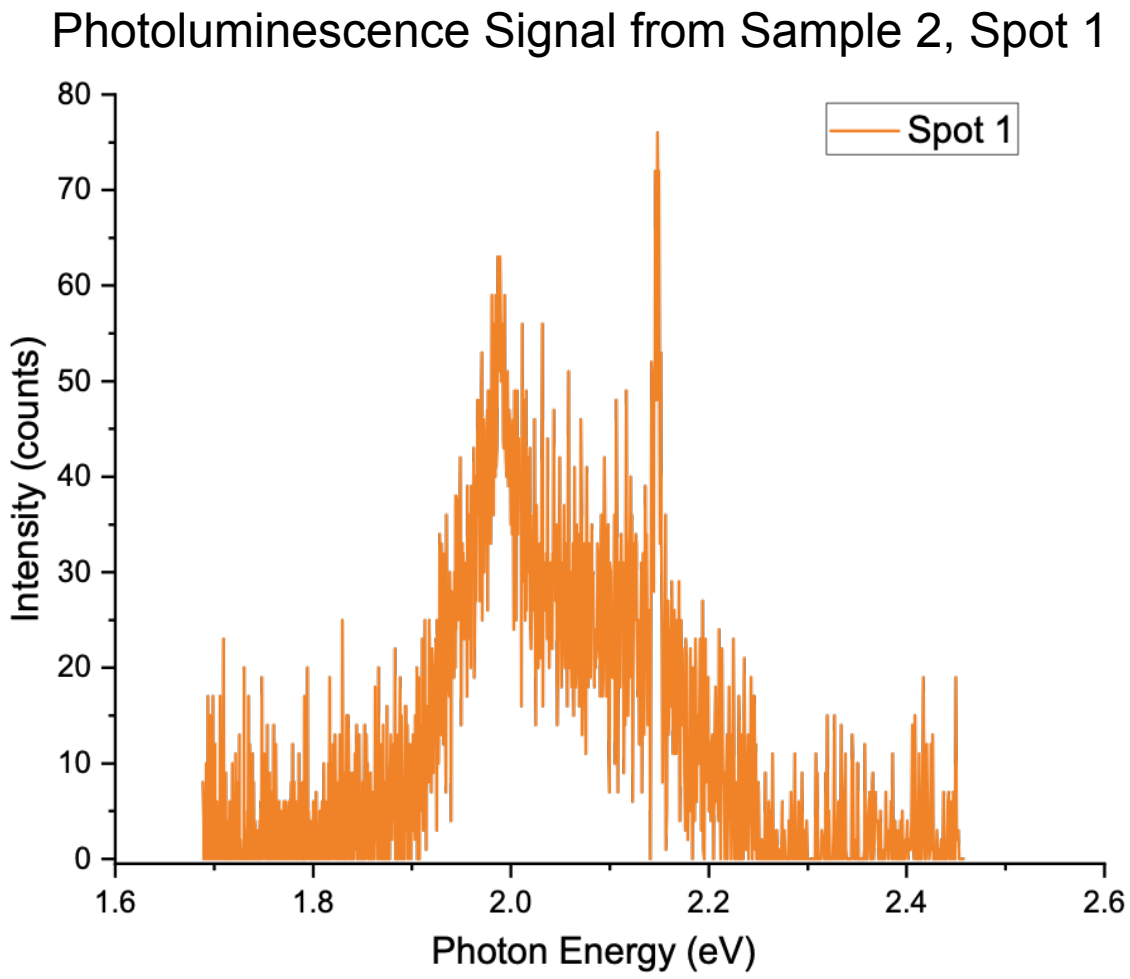
- Room Temperature
- 300 μW excitation power



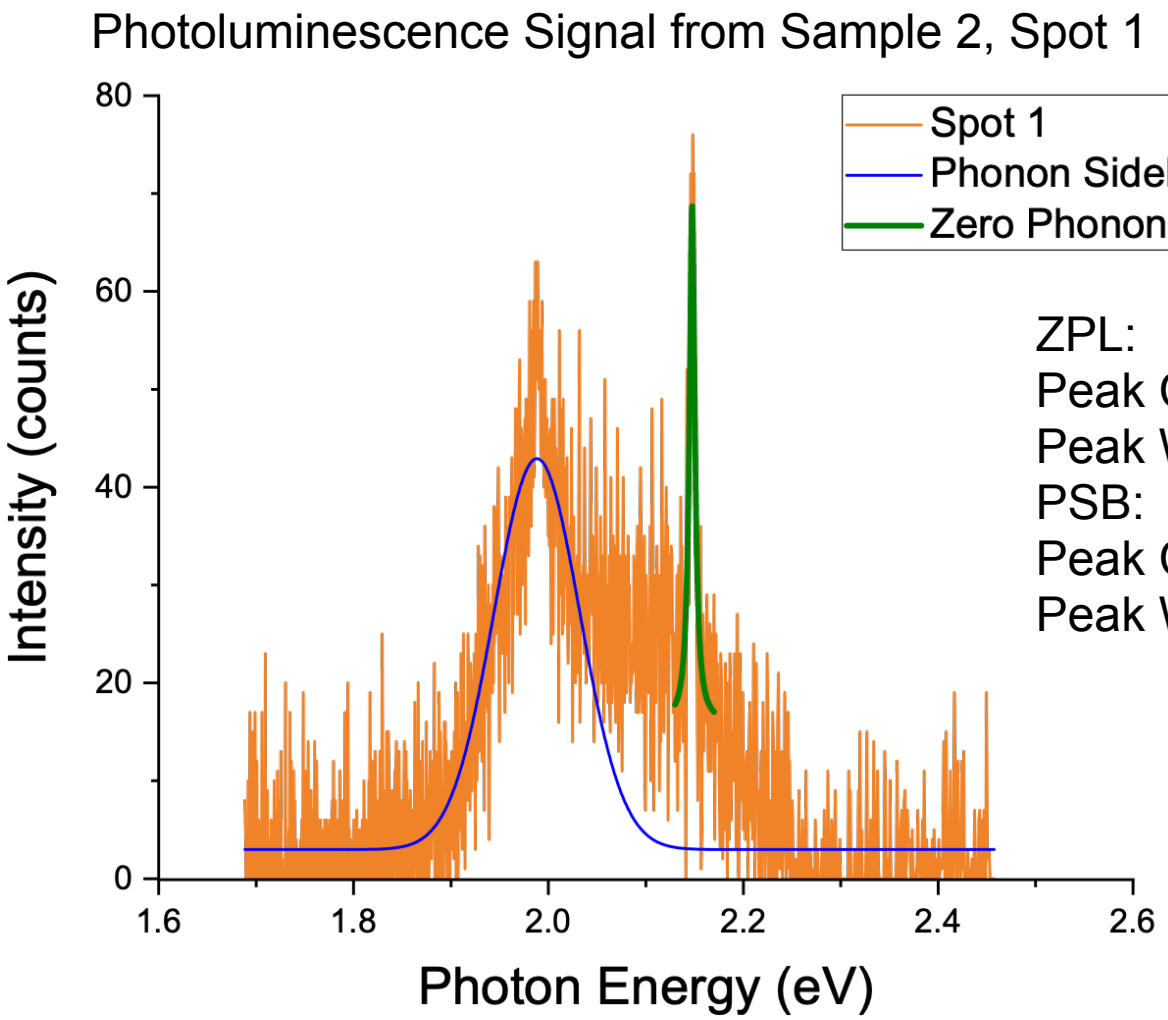
Spot with no Evidence of Defects



Spot with Evidence of Emitting Defect



Spot with Evidence of Emitting Defect



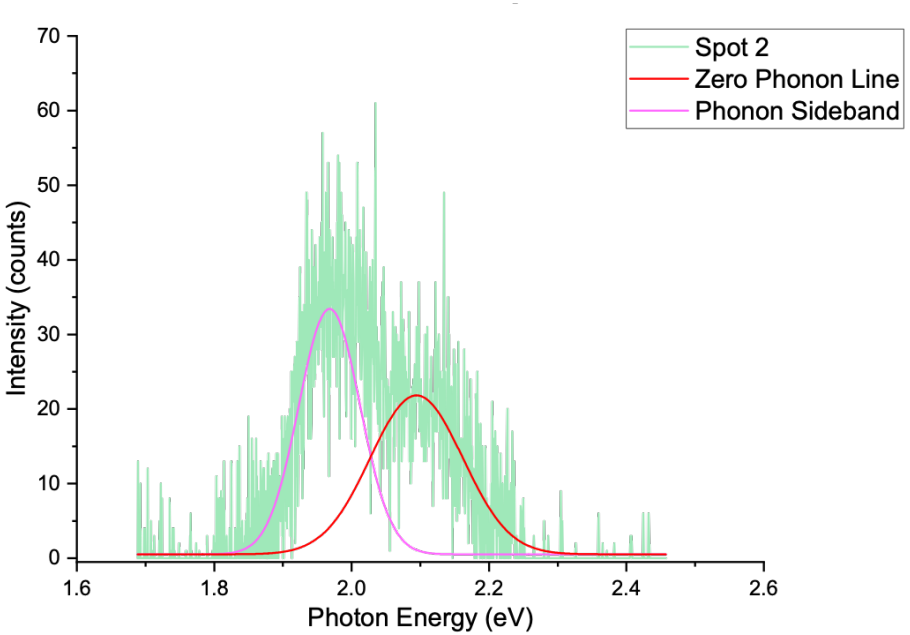
ZPL:
Peak Center = 2.147 ± 0.001 eV
Peak Width = 0.007 ± 0.001 eV
PSB:
Peak Center = 1.988 ± 0.002 eV
Peak Width = 0.088 ± 0.001 eV

PSB and ZPL Energies

- 3 spots yielded distinguishable ZPLs and PSBs
- Each ZPL was measured to be between 2.088 and 2.148 eV
- Each PSB was measured to be between 1.966 and 1.990 eV
- These energy ranges are within what was expected for nitrogen-based defects

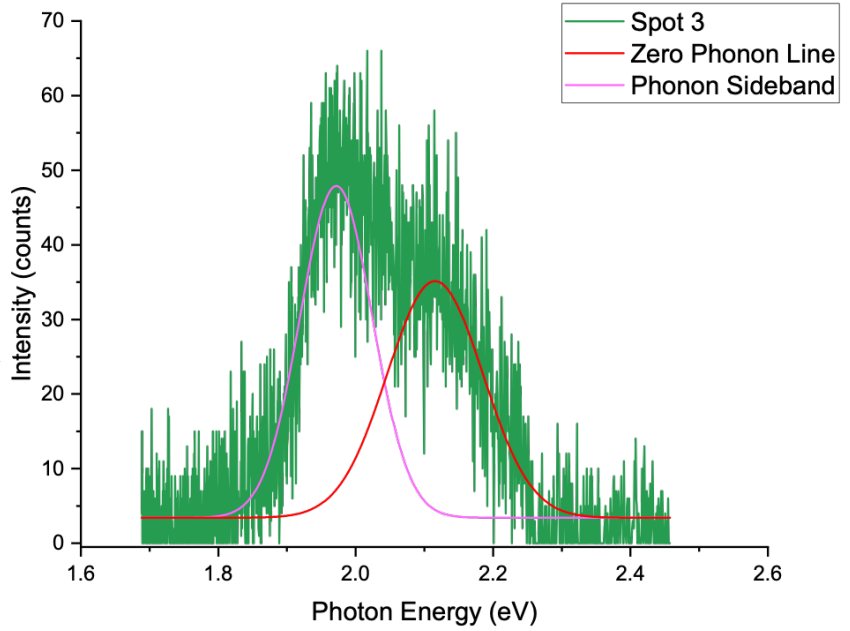
Sample 3, Spot 2

PSB:
Peak Center = 1.968 ± 0.002 eV
Peak Width = 0.089 ± 0.003 eV
ZPL:
Peak Center = 2.094 ± 0.006 eV
Peak Width = 0.135 ± 0.007 eV



Sample 3, Spot 3

PSB:
Peak Center = 1.972 ± 0.003 eV
Peak Width = 0.105 ± 0.003 eV
ZPL:
Peak Center = 2.116 ± 0.005 eV
Peak Width = 0.139 ± 0.008 eV



Measurement Implications

- These results confirm that nitrogen-based defects were successfully fabricated in hBN
- This shows that solid-state quantum emitters can be produced at relatively low cost
- These defects are often single photon emitter and may enable new advances in quantum technologies

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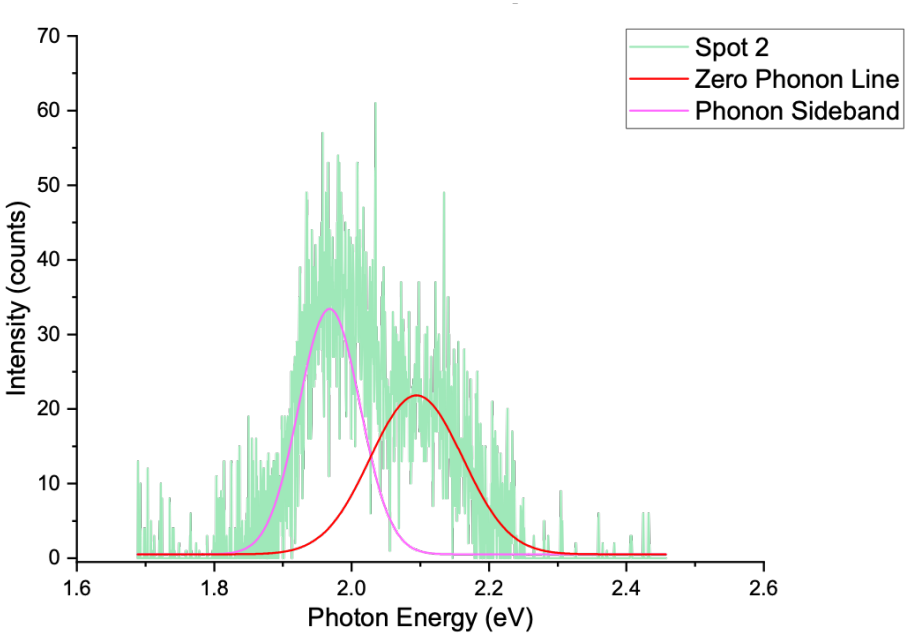

Sample 2, Spot 1

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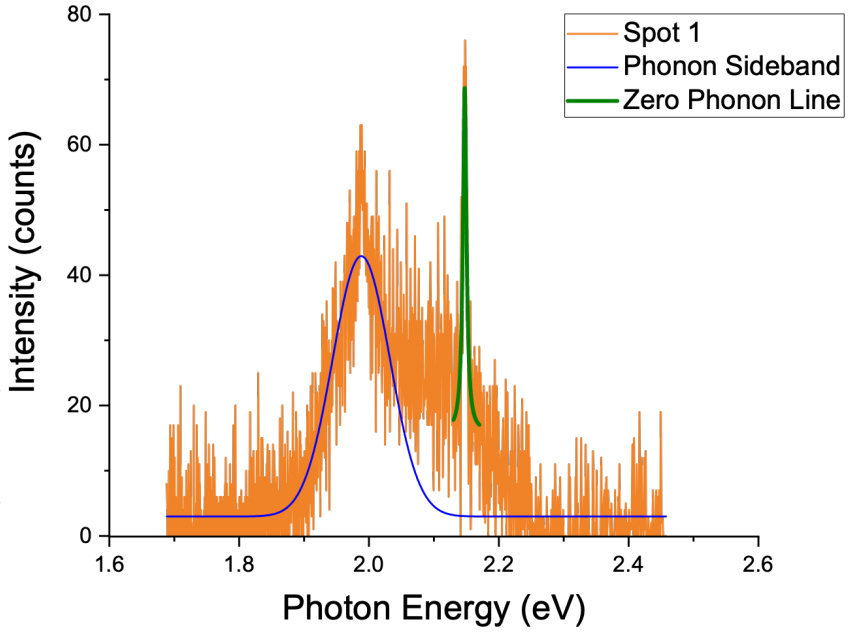

Future Directions

- Possible next steps include $g^{(2)}(0)$ measurements to determine if these defects are single photon emitters
- More photoluminescence measurements should be conducted using samples of different thickness

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Peak Center = 1.968 ± 0.002 eV
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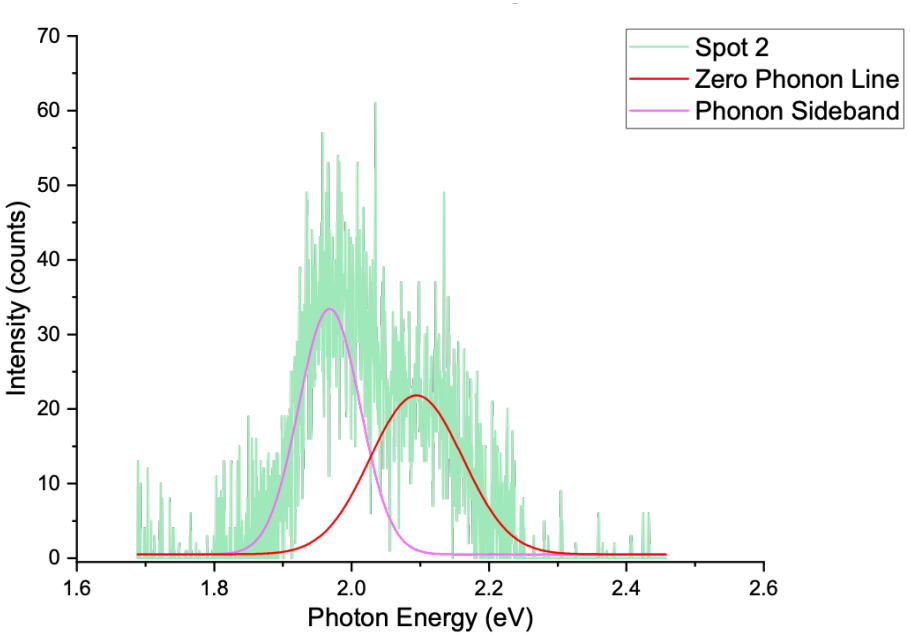
ZPL:
Peak Center = 2.094 ± 0.006 eV
Peak Width = 0.135 ± 0.0 eV



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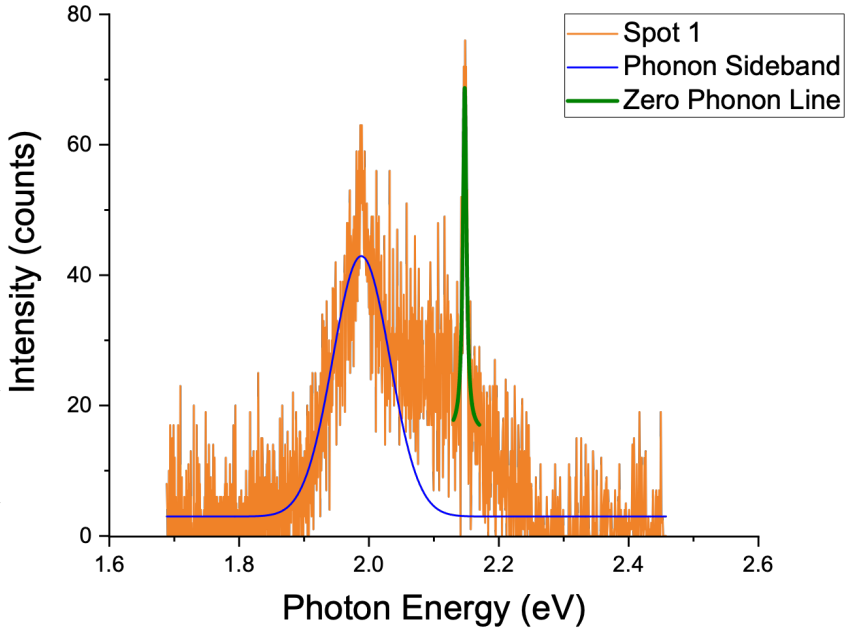

Acknowledgments

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