Room-Temperature Color Centers in Hexagonal Boron Nitride Engineered *via* Focused Ion Beams

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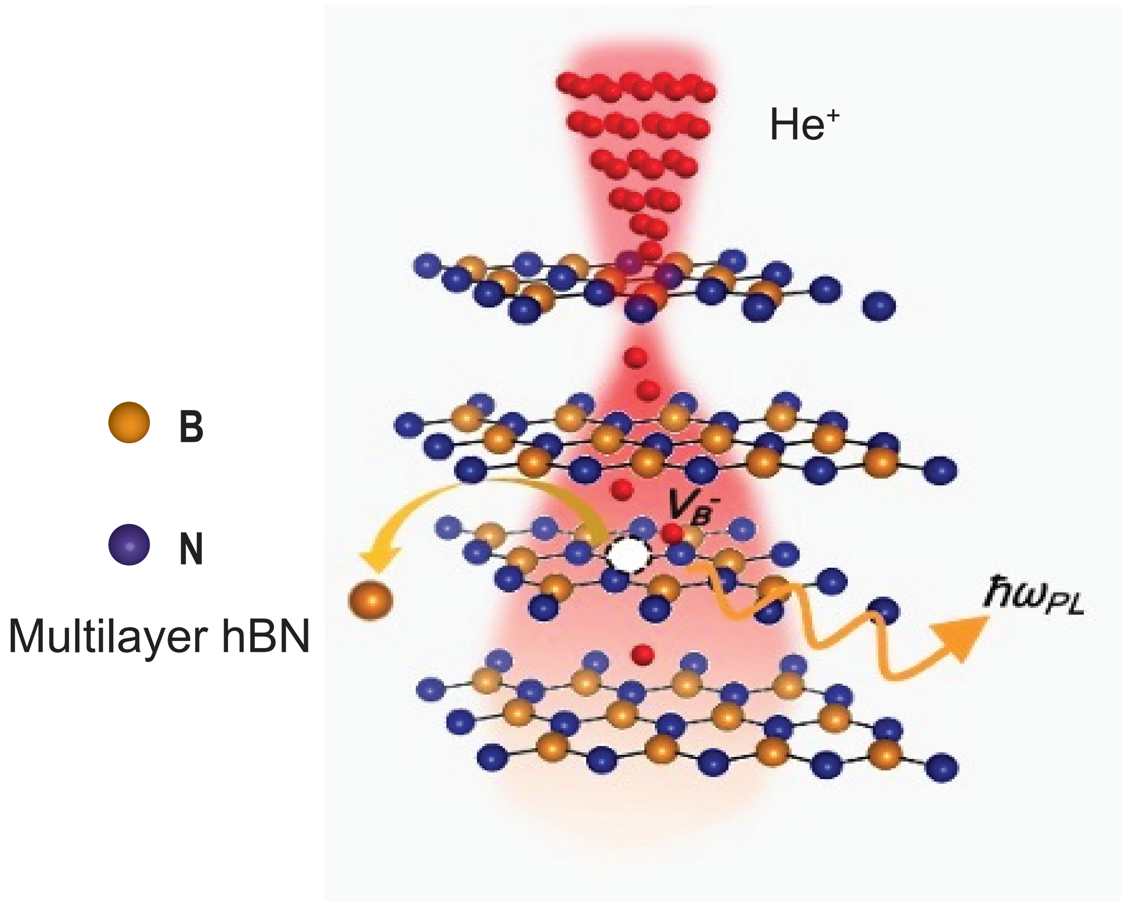
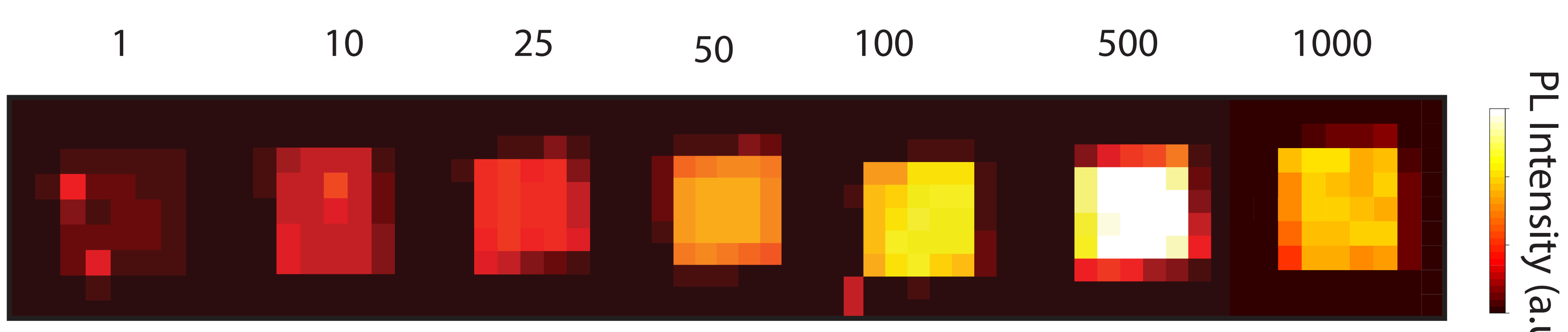
Introduction

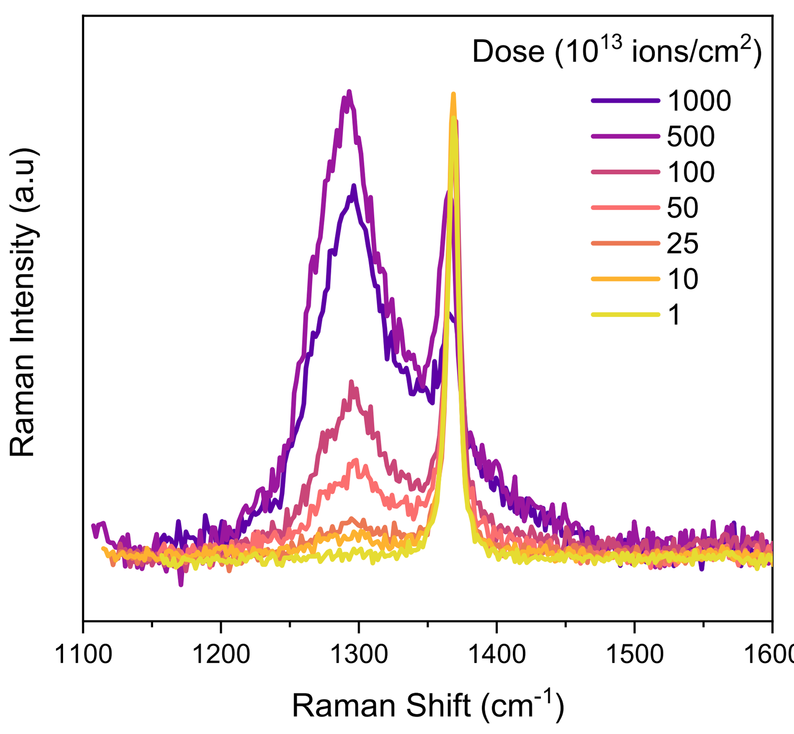
Hexagonal boron nitride (hBN), a van der Waals crystal with a honeycomb structure similar to graphene, has been widely investigated as a dielectric substrate for 2D materials-based devices. More recently, hBN has emerged as a prominent candidate for quantum nanophotonics after the observation of a series of single photon emitters[1] originated from intrinsic defects. However, to harness the emitters in hBN, we need **controllable means to generate optically active defects**. Here, we report the observation of **homogeneous near-infrared (~ 800 nm) photoluminescence (PL) emission at room temperature in hBN caused by defects formed *via* focused ion beam irradiation performed in Helium ion microscope (HIM).**

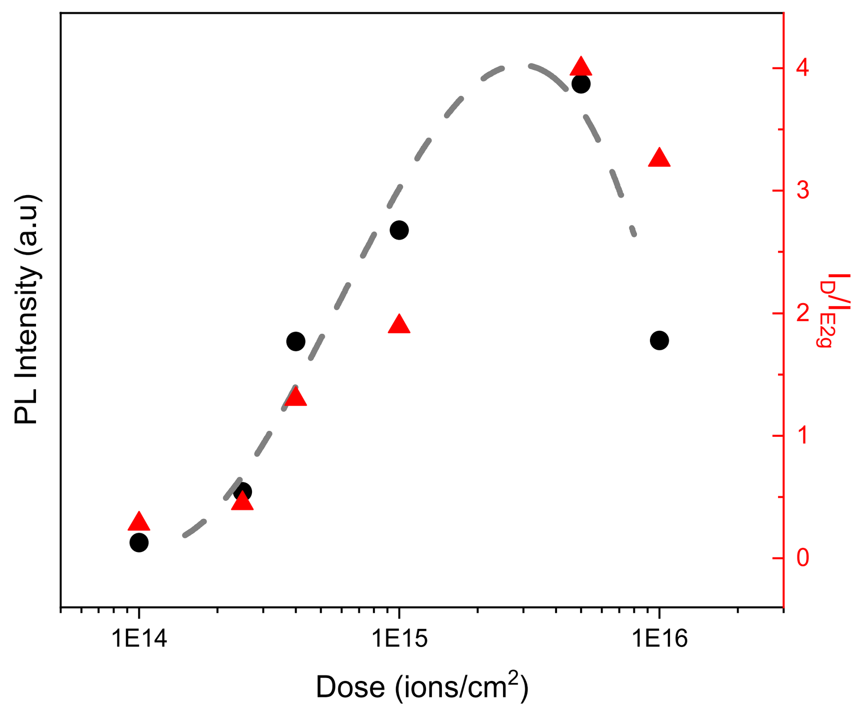


2. Controlled by Irradiation Parameters

He+ Dose (10^{13} ions/cm²)

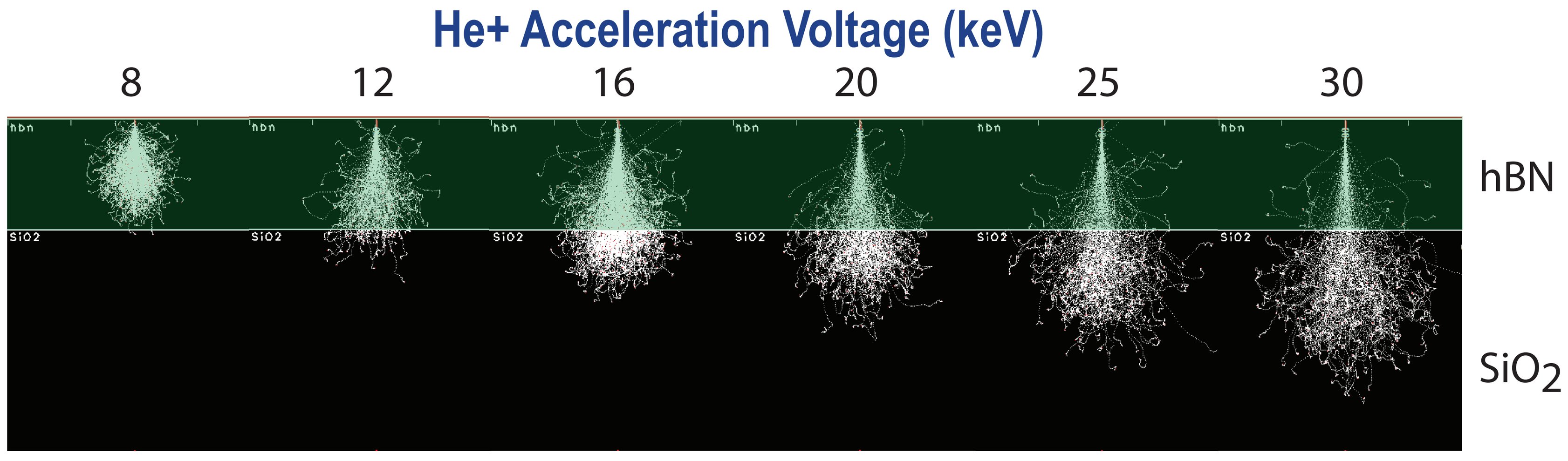


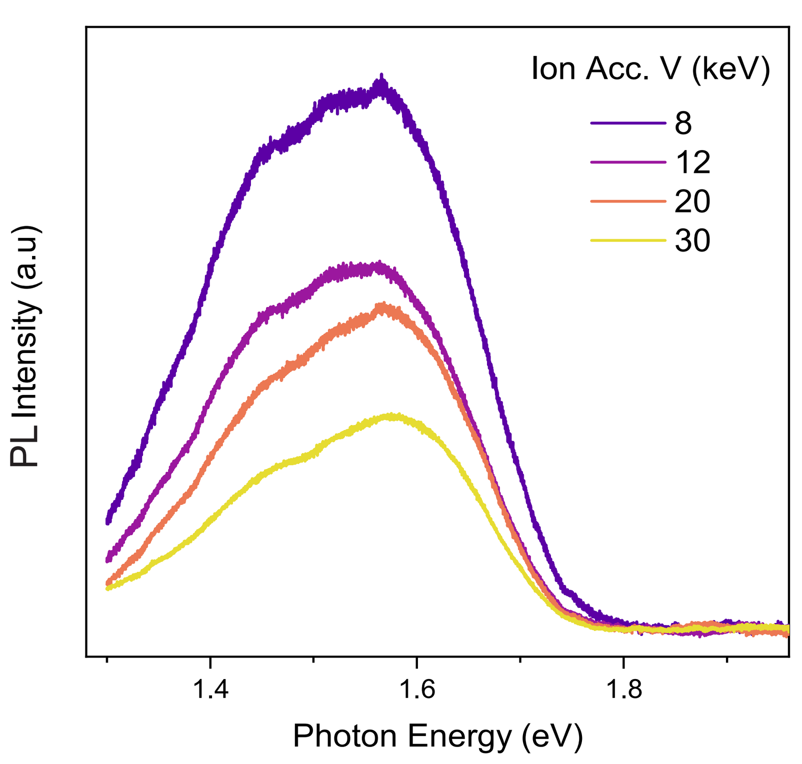


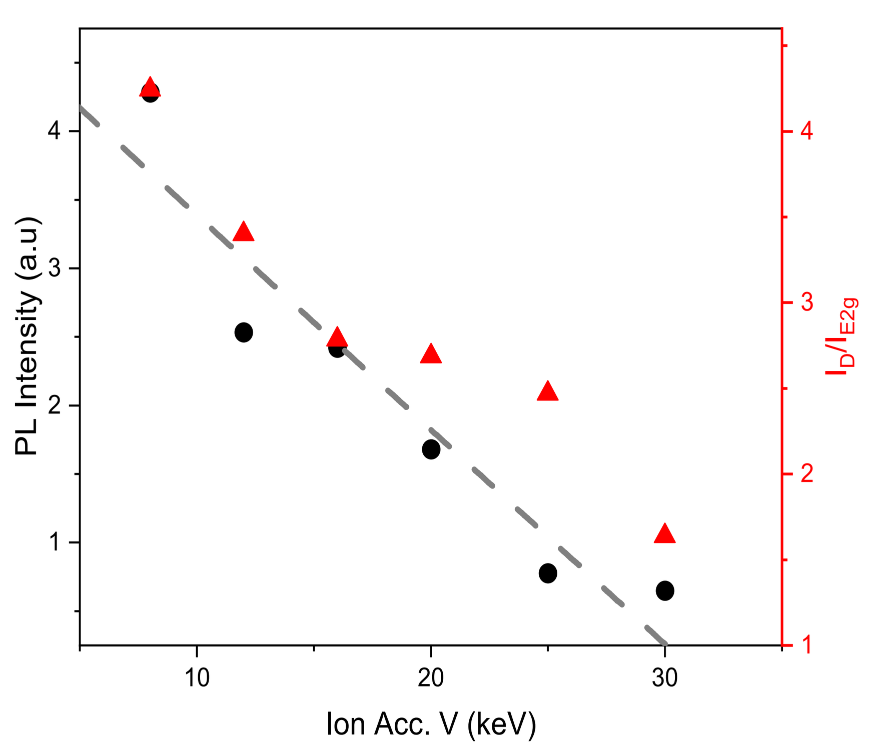


- Raman and PL intensities increase with incident ion dose.
- Emission intensity reaches maximal when dose is ~10^{15} ions/cm².

He+ Acceleration Voltage (keV)



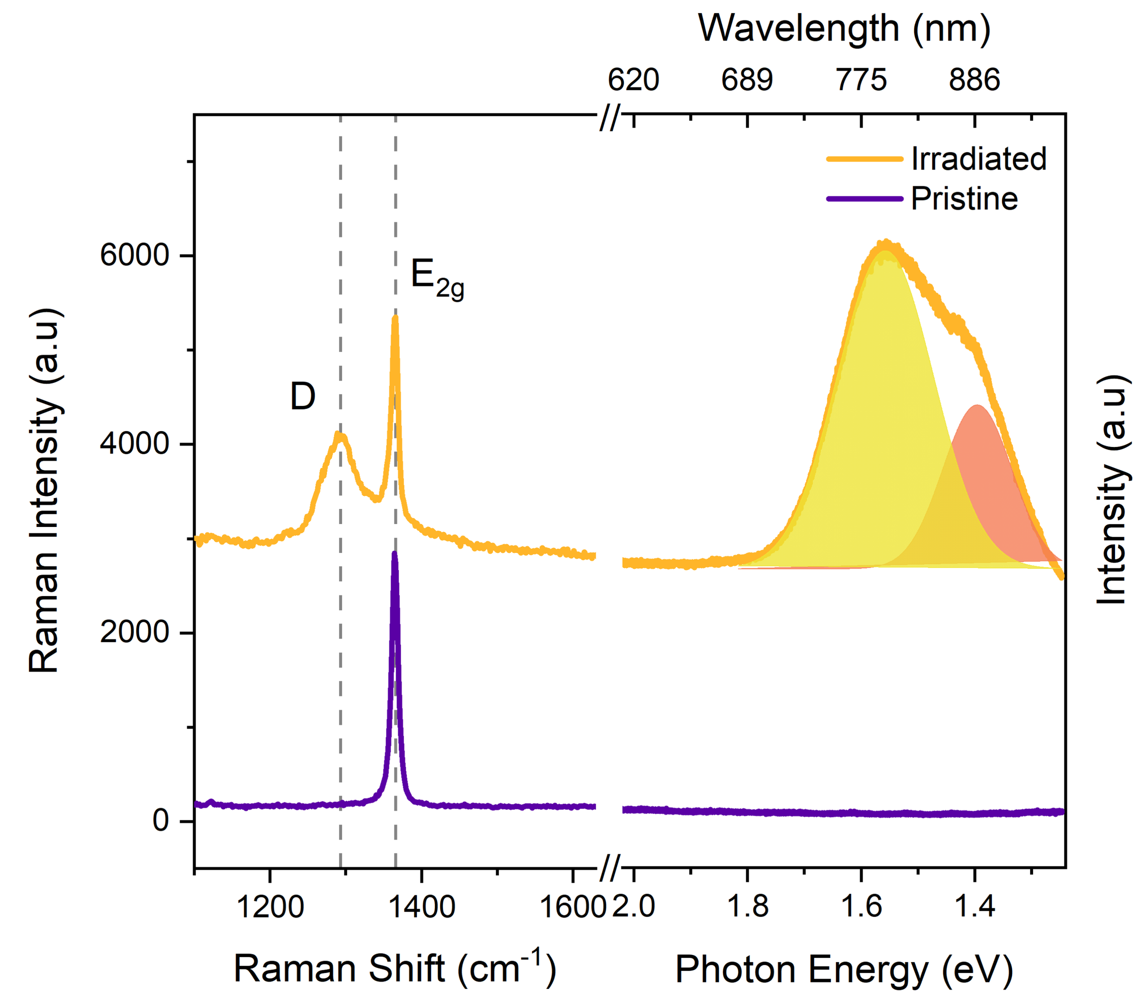




- End-of-range collisions in hBN enhance the Raman and PL response.
- Penetration range determined by ion acceleration voltage limits the thickness of hBN to host sufficient optical centers.

1. New Spectral Features

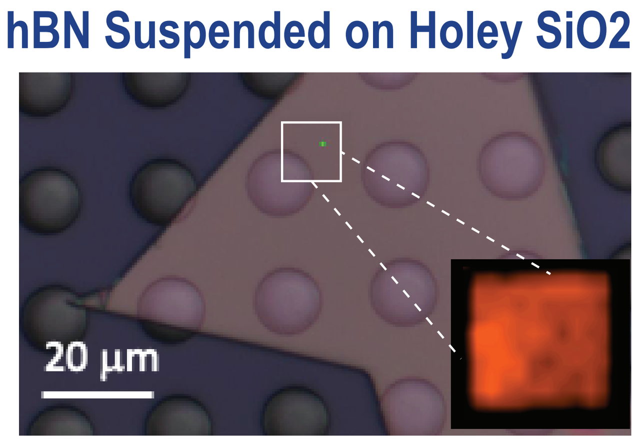
Raman/ PL Spectra of hBN



At **room temperature** we observed:

- **New Raman mode** at ~1300cm⁻¹ before the 1365cm⁻¹ E_{2g} mode.
- Bright **photoluminescence (PL)** emission in near infrared region resolved by 2 close peaks at 1.40eV and 1.55eV.
- Homogeneous emission from irradiated region.
- Programmable patterns designed and irradiated by HIM.

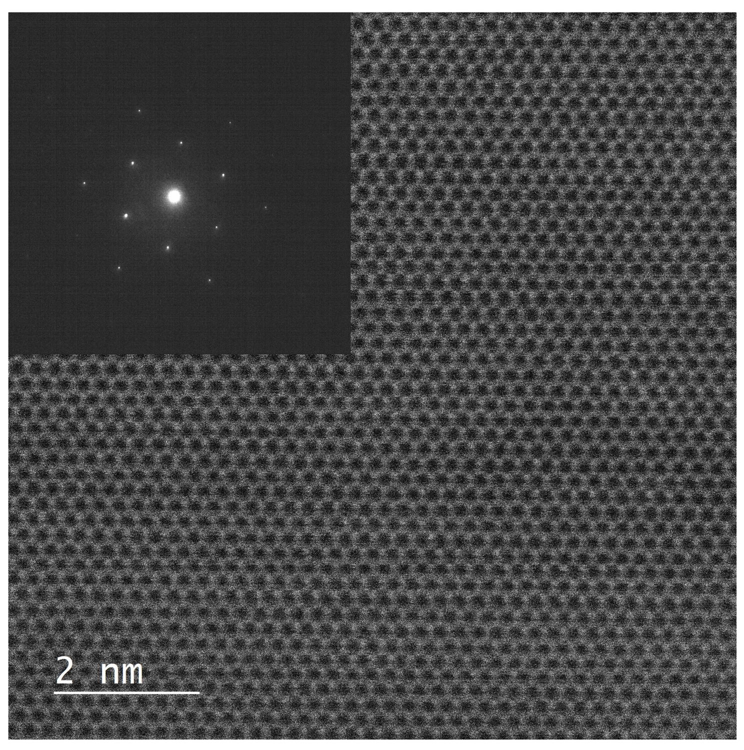
hBN Suspended on Holey SiO2



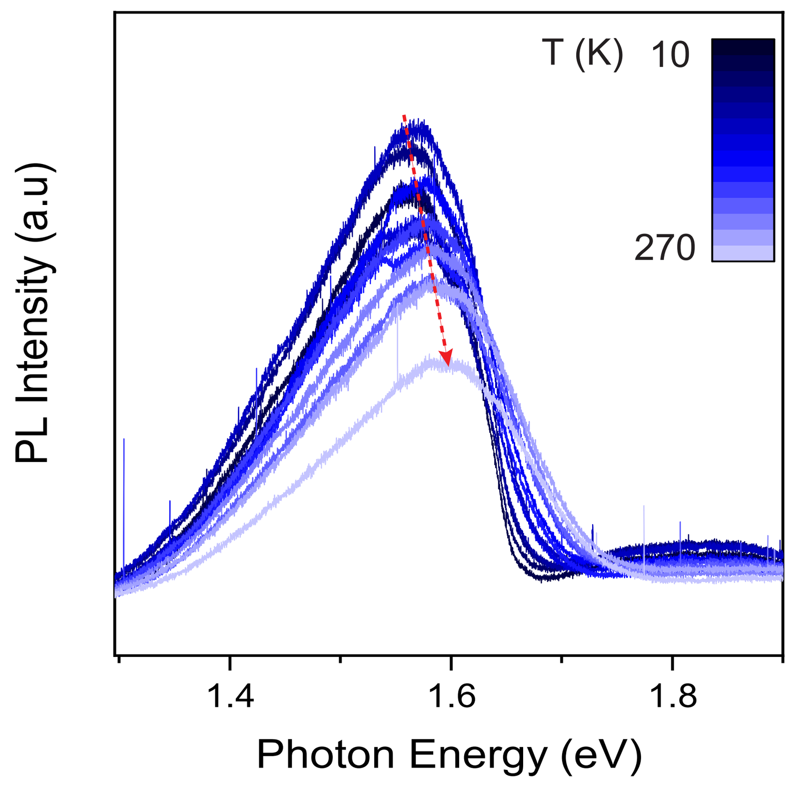
1.5eV PL Mapping at Room Temp

3. Possible Mechanisms

HAADF image & Diffraction Pattern



Low-Temp PL Spectra



- No phase transition nor ion implantation in irradiated hBN samples.
- PL peak shifting blue with temperature increase, typical in defect-related states.

Conclusions

In this work, we

- Presented the generation of room-temperature infrared **color centers in hBN *via* He ion irradiation**.
- Demonstrated **precise control of emission intensity** by tuning the irradiation parameters.
- Concluded intrinsic **atomic defect-related states** as the emitters. Especially, **B vacancies** are reported[2] to host 1.5eV in-band level, matching the observed PL peak.

B Vacancy in hBN Lattice

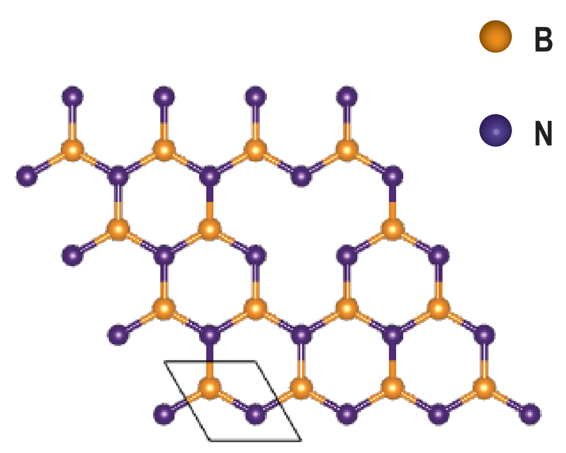
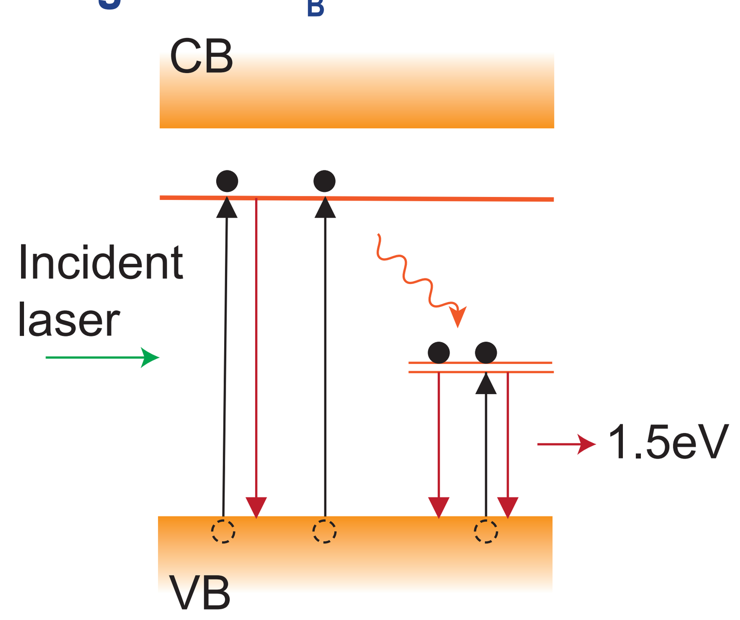


Diagram of V_B Recombination



- **Showcased a platform to serve as building blocks for next generation nanophotonic and potential quantum devices.**

[1] Tran, et al. "Quantum Emission From Hexagonal Boron Nitride Monolayers." Nature Nanotechnology 2015.
[2] Weston, L. et al., "Native Point Defects and Impurities in Hexagonal Boron Nitride." Physical Review B 2018.

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