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Laser-Induced Room-Temperature Single-Photon Emission from Defect Centers in Hexagonal Boron Nitride

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Single-photon emitters (SPEs) have attracted significant attention owing to their central role in quantum photonic technologies, including secure quantum communication, quantum information processing, and advanced sensing applications. Among solid-state platforms, hexagonal boron nitride (hBN) has emerged as a promising host material owing to its wide bandgap, two-dimensional layered structure, and ability to support bright quantum emitters operating at room temperature [1]. Nevertheless, the controlled generation of high-purity single-photon emitters at predefined locations remains a significant challenge for scalable quantum photonic applications.

Here, we investigate the formation of defect-based SPEs in mechanically exfoliated hBN through localized femtosecond laser processing followed by thermal annealing. The highly nonlinear interaction between ultrashort laser pulses and the hBN lattice enables spatially selective defect engineering with minimal impact on the surrounding material. Laser-modified regions exhibit bright and localized fluorescence, indicating the successful formation of optically active defect centers. Spectroscopic analysis reveals narrow emission peaks characteristic of defect-mediated optical transitions in hBN from UV to near IR region. Time-resolved measurements provide insight into the excited-state dynamics of the generated emitters, while Hanbury Brown and Twiss interferometry confirms their quantum nature through pronounced antibunching behavior with $g^2(0) < 0.5$. The influence of laser processing parameters and post-annealing conditions on emitter formation and optical performance was systematically investigated, demonstrating the importance of defect activation and local lattice modification in achieving stable single-photon emission.

The demonstrated approach provides a versatile route toward the deterministic fabrication of roomtemperature SPEs in hBN and offers a scalable pathway for integrating quantum light sources into photonic architectures. These findings advance the understanding of laser-induced defect engineering in two-dimensional materials and support the development of hBN-based platforms for future quantum communication systems and integrated quantum photonic devices.

REFERENCE

[1] Paulauskas, T., Janušonis, J., Markauskas, E., Nargelienė, V., Šilys, V., Bibi, I., ... & Talaikis, M. (2026). Laser direct writing and Raman Stokes contrast screening of quantum emitter sites in hBN. *Discover Nano*, *21*(1), 85.