Insight into the nature of blue emitters in hexagonal Boron Nitride via Stark effect

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Single photon sources in two-dimensional (2D) materials, such as hexagonal boron nitride (hBN) offer great prospects for integration in photonics, sensing and quantum communications devices. hBN hosts quantum emitters in the visible wavelength range, but it has only recently become possible to site-specifically generate blue quantum emitters within hBN lattice[1]. These blue emitters have a uniform wavelength of 436 nm and exhibit GHz-range linewidths, due to effects such as spectral diffusion. Here, we perform coherent photoluminescence excitation to measure the Stark shift under an in-plane or out-of-plane electric field, and map out the electric dipole interaction to determine the likely defect structure.

The Stark effect generated from an applied electric field on a quantum emitter is estimated from the Lorentz local field approximation given by $\Delta E = -\Delta\mu F - \frac{1}{2}\Delta\alpha F^2$ (1), where F is the electric field (MV/m), and $\Delta\mu$ and $\Delta\alpha$ are changes in permanent dipole moment and in polarizability, respectively, of the ground and excited states. Vertical and horizontal devices were fabricated to apply out-of-plane and in-plane electric fields, respectively. Both devices were cooled to 5 K, and considering the narrow inhomogeneous linewidth of blue emitters, measurements were conducted on resonance with high spectral resolution. From our results we observed an insignificant linear shift in the out-of-plane electric field orientation and a large quadratic response in the in-plane configuration. According to Equation (1), it was deduced that the observed wavelength shift of blue emitters has minimal contribution from permanent transition dipole moments, but is mainly governed by the second term, transition polarizability. In comparison to other studied quantum emitters in hBN, which emit at longer wavelengths[2,3], our findings reveal that blue emitters are less susceptible to local field variations in the lattice due to small permanent dipoles. The study concluded with a proposition of likely candidates for blue emitter defects via density functional theory (DFT) modelling.

[1] Gale, A.; Li, C.; Chen, Y.; Watanabe, K.; Taniguchi, T.; Aharonovich, I.; Toth, M. Site-Specific Fabrication of Blue Quantum Emitters in Hexagonal Boron Nitride. *ACS Photon*. **2022**, 8.

[2] Noh, G.; Choi, D.; Kim, J.-H.; Im, D.-G.; Kim, Y.-H.; Seo, H.; Lee, J. Stark Tuning of Single-Photon Emitters in Hexagonal Boron Nitride. *Nano Lett.* **2018**, *18* (8), 4710–4715.

[3] Nikolay, N.; Mendelson, N.; Sadzak, N.; Böhm, F.; Tran, T. T.; Sontheimer, B.; Aharonovich, I.; Benson, O. Very Large and Reversible Stark-Shift Tuning of Single Emitters in Layered Hexagonal Boron Nitride. *Phys. Rev. Appl.* **2019**, *11* (4), 041001.