OPEN Publisher Correction: Optical quantum technologies with hexagonal boron nitride single photon sources

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Correction to: *Scientific Reports* <https://doi.org/10.1038/s41598-021-90804-4>, published online 10 June 2021

The original version of this Article contained errors.

Affiliation 1 was incorrectly given as 'Center for Nanotechnology Research/Department of Micro and Nanoelectronics, School of Electronics Engineering, Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, 632014, India'. The correct affiliation is listed below:

Center for Nanotechnology Research & Department of Micro and Nanoelectronics, School of Electronics Engineering, Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, 632014, India.

Additionally, Figure 3 and Figure 4 contained incorrect reference numbers. The original Figure 3 and Figure 4 appear below with their accompanying legends.

Also, Table 13 was mistakenly duplicated in the place of Figure 13, causing Figure 13 to be omitted from the Article.

Furthermore, Table 13 and Table 16 contained errors in the merging of the columns, as well as in the references. The original Table 13 and Table 16 appear below with their accompanying legends.

Finally, Tables 2, 10, 17, 18 and 19 were updated to give layout uniformity.

The original Article has been corrected.

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Figure 3. Schematic representation of hBN stacking⁷⁴, electronic band structure of monolayer and Bulk hBN⁷⁵ and electrical/optical/crystal properties of hBN material. (a,b) Top view and side view of AA' stacking. (c,d) Top view and side view of AB stacking. (e,f) Electronic band structure of monolayer and bulk hBN with direct and indirect bandgaps respectively. (g) General properties of hBN material and similar Raman shifts (around values) can be observed for high quality crystals.

Figure 4. Schematic of HBT interferometer, important features of an ideal single photon source and experimentally observed quantum emitter characteristics, pictographic representation of atomic behaviour of defects within the host bandgap (a) Schematic representation of HBT interferometer working mechanism and resultant second order autocorrelation curve representing characteristics of a single photon emitter. (b) Important features of an ideal single photon source. (c) Experimentally observed some of the quantum emitter characteristics hosts in hBN, in which characteristic stability upto 800 K and single photon purity 0.01 makes a highest record among all the 2D materials (to date). (d) The energy band diagram of an hBN host with ~ 6 eV bandgap. A luminescent point defect in hBN (with energy range ~ 2.2 – 3 eV) exhibits an artificial atom kind of behaviour with ground and excited states.

Enhancement techniques		Excitation and Emission wavelength (ZPL width)	Fluorescence intensity and saturation power	Photon emission rate	Lifetime	$g^2(0)$	Ref.
Laser excitation technique	Two laser excitation	675 nm + 532 nm and 778 nm (ZPL width N/A)	$\sim 14 \times 10^3$ Hz and (1.5 – 3) mW	N/A	N/A	0.25	[114]
	Single laser excitation	675 nm and 778 nm (ZPL width N/A)	$\sim 5 \times 10^3$ Hz and ~ 14 mW				
Plasmonic coupling	Single nanosphere	532 nm and 578 nm (ZPL width N/A)	N/A	2.89×10^6 Hz	2.68 ns	0.26	[115]
	Two nanospheres			5.79×10^6 Hz	1.54 ns	0.31	
Resonant excitation	Off-resonant excitation	700 nm and 766.8 nm (ZPL width ~ 25 GHz)	1×10^6 Hz	N/A	~ 3 ns	0.16 ± 0.01	[117]
	On-resonant excitation	700 nm and 766.186 nm (ZPL width $\sim 6.3 \pm 0.3$ GHz)	N/A		~ 0.87 ns	0.11 ± 0.04	

Table 13. Intensified photophysical characteristics of emitters due to three different enhancement techniques. Enhancement in fluorescence intensity and reduction of excitation saturation power for two laser excitation technique has shown in first row; increase in photon emission rate and controlled fluorescence lifetime due to two nanospheres plasmonic coupling. Modulated ZPL (wavelength and width); enhanced single photon purity and controlled fluorescence lifetime due to on-resonant excitation is shown in third row.

Emission	Excitation	Materials	Supportive information	Ref.
Localized Excitonic emission associated to point defects and crystal imperfections	Optical	WSe ₂	Point defects and crystal imperfections (local strain) acts as efficient carrier trapping centers, where free excitons are trapped and localized.	[19-39]
		MoSe ₂	Intentionally induced strain traps exciton at maximum strain point as shown in Figure 14(a, d).	[41-49]
		MoS ₂	External electric and magnetic fields can control the excitonic emission.	
		GaSe		
	Electrical	Graphene/hBN/ MoX ₂ or WX ₂ /hBN/Graphene (X = S or Se)	TMDs monolayer as exciton recombination layer, hBN as tunnelling barriers and graphene as transparent electrodes as shown in Figure 14(e). Injection of both electrons and holes into recombination layer as explained in Figure 14(f) leads to formation of excitons.	[40] [59,60]
Localized Excitonic emission associated to moiré pattern	Optical	WSe ₂ /WS ₂ heterostructures	Moiré pattern creates an array of nanoscale electrostatic potential that can trap quasiparticles including excitons as shown in Figure 14(g, h).	[50-54]
		MoSe ₂ /WS ₂ heterobilayers	The energy states and the periodicity of the superlattice can be controlled by the twist angle as shown in Figure 14(g).	
		MoSe ₂ /WSe ₂ heterobilayers	External electric fields can control the excitonic emission.	
	Electrical	MoS ₂ /WSe ₂ heterobilayers		
Spontaneous emission due to intermediate energy state transition	Optical	Layered hBN	hBN as a wide bandgap material, host optically active luminescent point defects that have ground and excited states within the gap.	[57,58]
			Luminescent point defects are created using ion implantation, laser ablation, electron beam irradiation, Ar plasma etching and various subtler processes and activated with high temperature annealing.	[64-67]
			Emission from point defects can be controlled using electric and magnetic fields and enhanced using two laser excitations and plasmonic coupling.	[79]
			Tuning of emission can be performed by externally induced strain, electric and magnetic fields.	[97,99]
				[114] [115]

Table 16. Implementation of qubits using 2D materials. Qubits implementation using various 2D materials, bilayers and heterostructures, responsible excitation mechanisms and different emission phenomena and their corresponding detailed explanations.

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