Supporting Information

Violet Light Excitable $K_xNa_{5-x}B_2P_3O_{13}$: Eu (x = 0, 1, 2) Borophosphates as Novel Phosphors for Multifunctional Applications

Yaping You[1],Ya Zheng[1], Zesheng Pan[1], Yunluo Wang[1], Tianrui Zhou[1], Minghui Wang[2], Haijie Chen[1,*], Wan Jiang[1,*], and Lianjun Wang[1,*]

[1]*State Key Laboratory of Advanced Fiber Materials, Institute of Functional Materials, College of Materials Science and Engineering, Donghua University, Shanghai, 201620, China.*

[2]*Analysis and Testing Center, Donghua University, Shanghai, 201620, P. R. China*

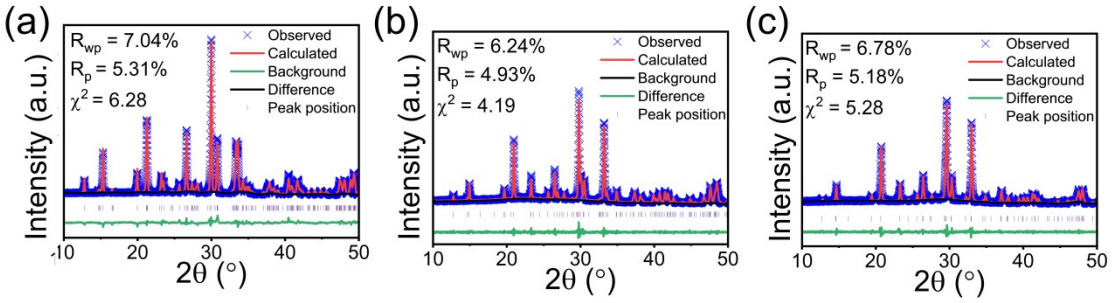

Fig. S1. Rietveld refinements of XRD patterns of (a) N_5BP, (b) KN_4BP, (c) K_2N_3BP.

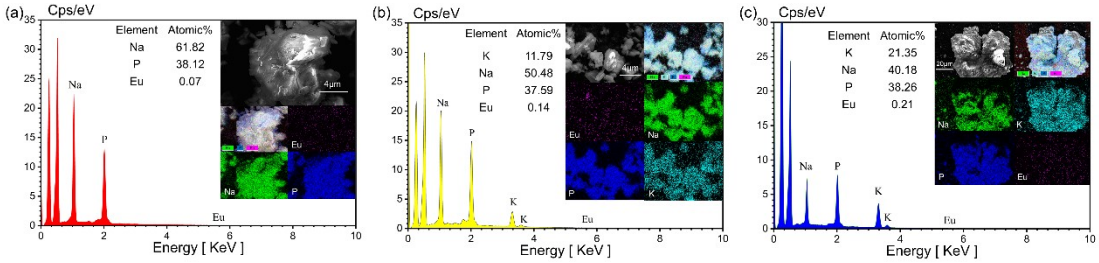

Fig. S2. SEM image, EDS spectrum and elemental mappings of the (a) $Na_5B_2P_3O_{13}$: $0.01Eu^{2+}$, (b)$KNa_4B_2P_3O_{13}$: $0.02Eu^{2+}$, (c) $K_2Na_3B_2P_3O_{13}$: $0.03Eu^{2+}$ powders.

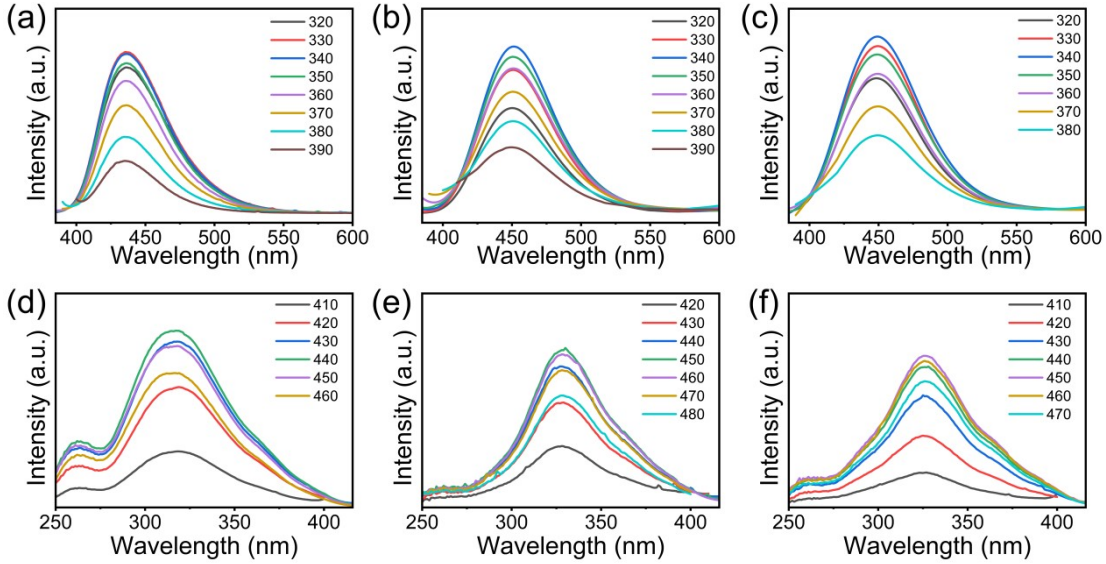

Fig. S3. PL spectra of (a) N_5BP: $0.01Eu^{2+}$, (b) KN_4BP: $0.02Eu^{2+}$, (c) K_2N_3BP: $0.03Eu^{2+}$ phosphors upon excitation by UV light. (a – c) PL and (d – f) PLE spectra of N_5BP: $0.01Eu^{2+}$/ KN_4BP: $0.02Eu^{2+}$/ K_2N_3BP: $0.03Eu^{2+}$ excited and monitored at different wavelengths.

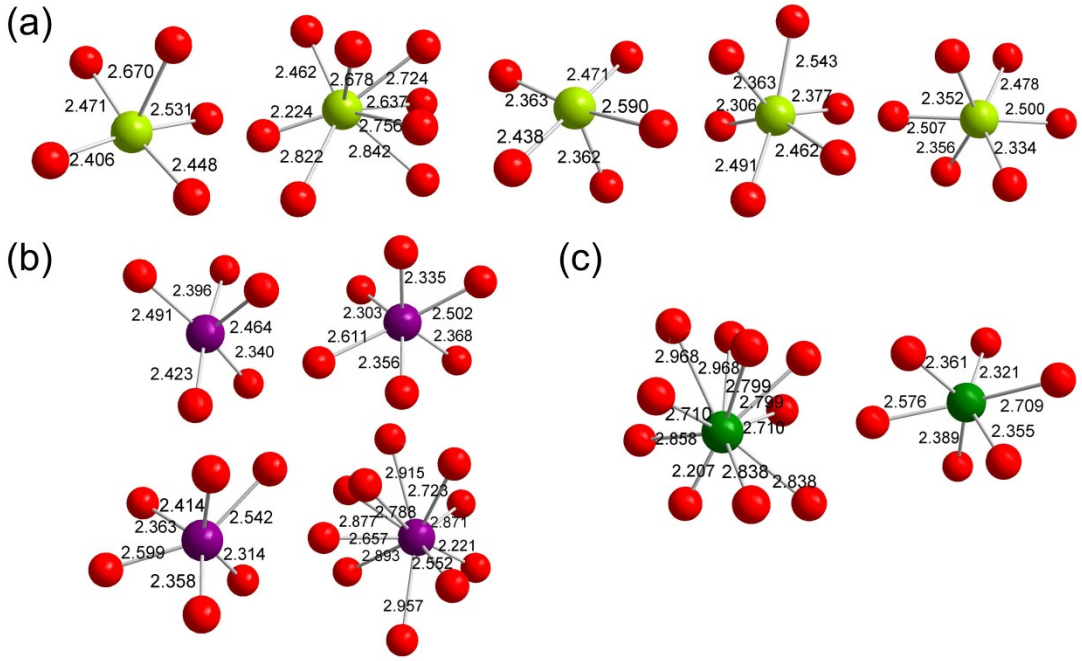

Fig. S4. coordination environments for Na atoms in (a) $Na_5B_2P_3O_{13}$, (b)$KNa_4B_2P_3O_{13}$, (c) $K_2Na_3B_2P_3O_{13}$

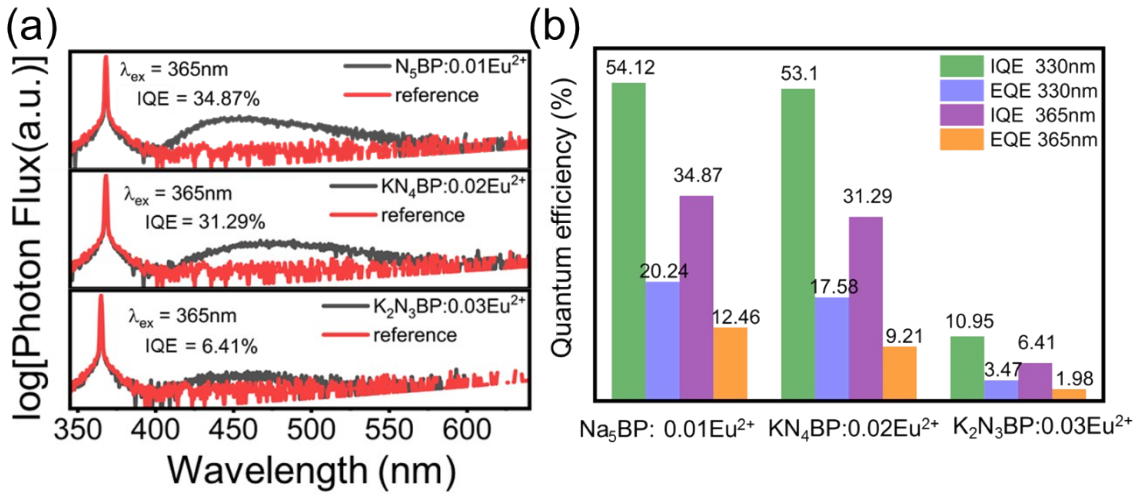

Fig. S5. (a) The IQE measured under 365 nm excitation. (b) The IQE and EQE measured under the excitation of 330 nm and 365 nm.

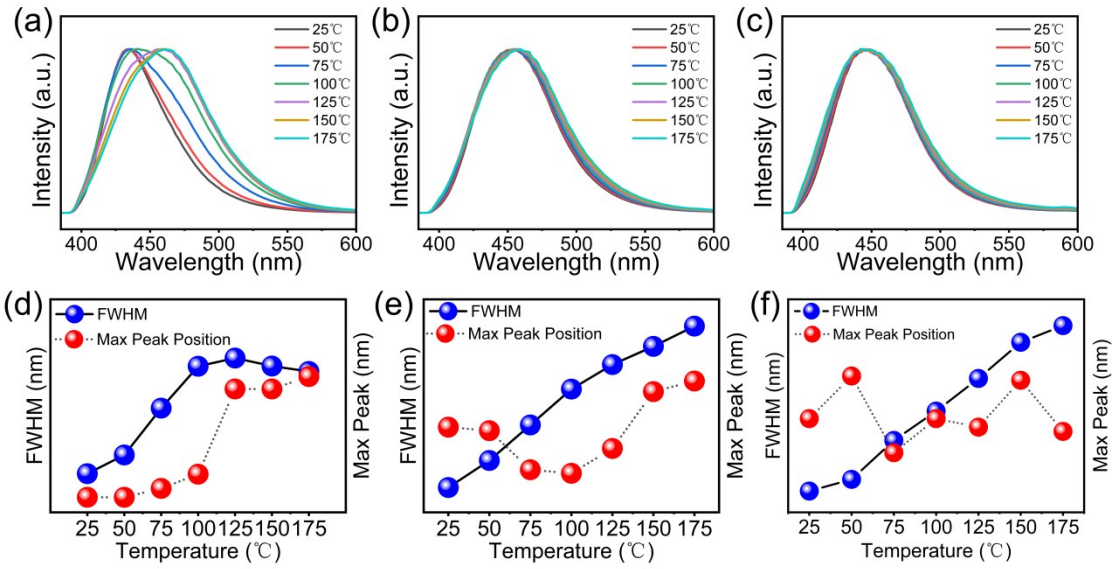

Fig. S6. Normalized temperature dependent emission spectra of (a) N_5BP: $0.01Eu^{2+}$, (b) KN_4BP: $0.02Eu^{2+}$ and (c) K_2N_3BP: $0.03Eu^{2+}$ from 25 °C to 175 °C under the excitation of 365nm. FWHM and Peak position of the emission spectra of (d) N_5BP: $0.01Eu^{2+}$, (e) KN_4BP: $0.02Eu^{2+}$ and (f) K_2N_3BP: $0.03Eu^{2+}$ as a function of temperature.

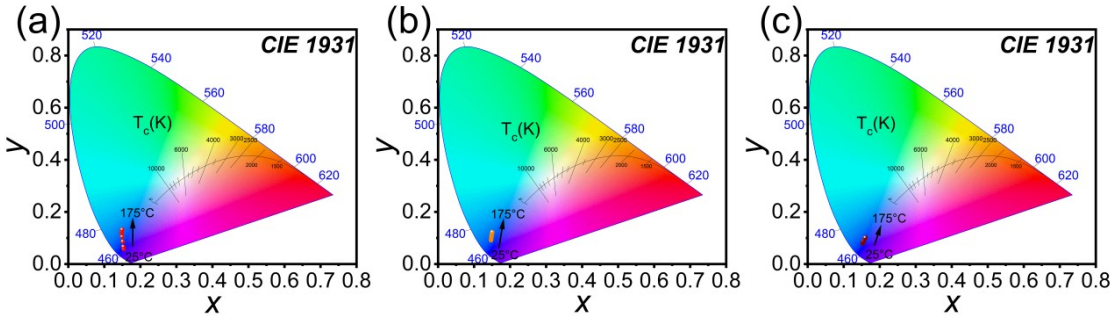

Fig. S7. CIE chromaticity diagram of (a) N_5BP: $0.01Eu^{2+}$, (b) KN_4BP: $0.02Eu^{2+}$, K_2N_3BP:$0.03Eu^{2+}$ phosphors at 25 °C – 175 °C.

Table S1. Crystal structure refinement data for samples.

Sample	Crystal system/Space group	Cell Volume ($Å^3$)	Lattice parameters
N_5BP	monoclinic $P2_1$	542.997	a = 6.7080 Å b = 7.6873 Å c = 11.6339 Å α=γ=90° β=115°
$N_5BP:0.01Eu^{2+}$	monoclinic $P2_1$	543.100	a = 6.7104 Å b = 7.6876 Å c = 11.6301 Å α=γ=90° β=115°
KN_4BP	orthorhombic $Pna2_1$	1116.047	a = 6.7374 Å b = 13.9221 Å c = 11.8982 Å α=β=γ=90°
$KN_4BP:0.02Eu^{2+}$	orthorhombic $Pna2_1$	1115.517	a = 6.7376 Å b = 13.9228 Å c = 11.8917 Å α=β=γ=90°
K_2N_3BP	orthorhombic $Cmc2_1$	1146.867	a = 13.9374 Å b = 6.7668 Å c = 12.1604 Å α=β=γ=90°
$K_2N_3BP:0.03Eu^{2+}$	orthorhombic $Cmc2_1$	1157.050	a = 14.0074 Å b = 6.7916 Å c = 12.1624 Å α=β=γ=90°

Table S2. The CIE coordinates of N_5BP: $0.01Eu^{2+}$, KN_4BP: $0.02Eu^{2+}$ and K_2N_3BP: $0.03Eu^{2+}$ phosphors under different ambient temperature.

Ambient-temperature (°C)	N_5BP: $0.01Eu^{2+}$ CIE coordinates	KN_4BP: $0.02Eu^{2+}$ CIE coordinates	K_2N_3BP: $0.03Eu^{2+}$ CIE coordinates
25	(0.154,0.058)	(0.147,0.092)	(0.152,0.079)
50	(0.153,0.067)	(0.147,0.094)	(0.153,0.080)
75	(0.151,0.087)	(0.147,0.099)	(0.153,0.082)
100	(0.149,0.105)	(0.148,0.104)	(0.154,0.086)
125	(0.148,0.119)	(0.148,0.110)	(0.156,0.091)
150	(0.148,0.126)	(0.149,0.116)	(0.157,0.097)
175	(0.149,0.132)	(0.150,0.123)	(0.160,0.102)