

Supporting Information

Title: Yolk-shell Structured $\text{Bi}_2\text{SiO}_5:\text{Yb}^{3+}, \text{Ln}^{3+}$ (Ln=Er, Ho, Tm) Upconversion Nanophosphors for Optical Thermometry and Solid-state Lighting

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Table S1. Calculated lattice parameters for the lanthanide-doped Bi₂SiO₅ nanophosphors and standard Bi₂SiO₅ host lattice.

Parameters	Compounds	
	Bi ₂ SiO ₅ (JCPDS No. 75-1483)	Bi ₂ SiO ₅ :8.8%Yb ³⁺
$a(\text{Å})$	15.1730	15.1812
$b(\text{Å})$	5.4729	5.3812
$c(\text{Å})$	5.3132	5.3731
$V(\text{Å}^3)$	441.21	438.94
$\alpha = \beta = \gamma$	90 °	90 °
Z	4	4
R_P	—	5.10 %
R_{WP}	—	6.60 %

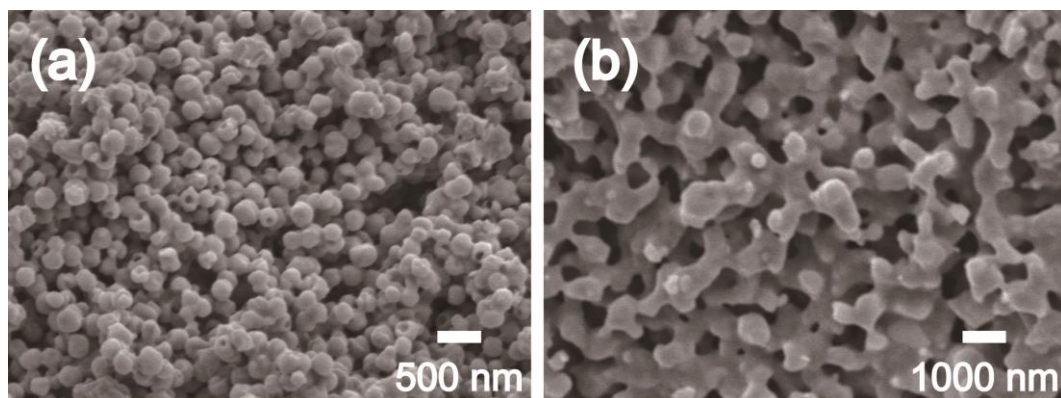


Fig. S1. SEM images of precursor@SiO₂ nanoparticles after calcination at (a) 900 °C and (b) 1000 °C for 2 h, respectively.

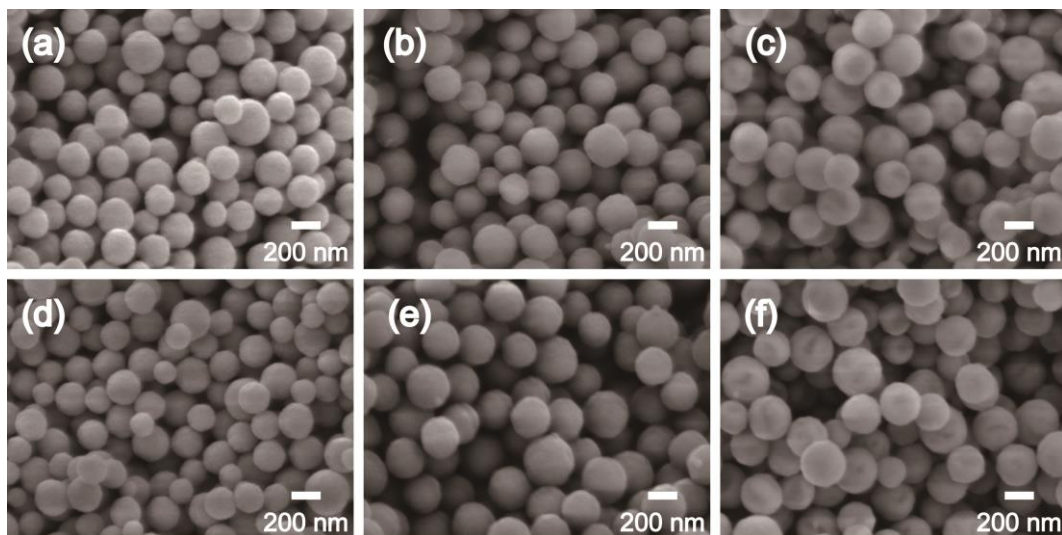


Fig. S2. (a-c) SEM images of 10%Yb³⁺/1%Ho³⁺ co-doped precursor, precursors@SiO₂ and precursors@SiO₂ calcinated at 750 °C for 2 h, respectively. (d-f) SEM images of 10%Yb³⁺/0.5%Tm³⁺ co-doped precursor, precursors@SiO₂ and precursors@SiO₂ after calcination at 750 °C for 2 h, respectively.

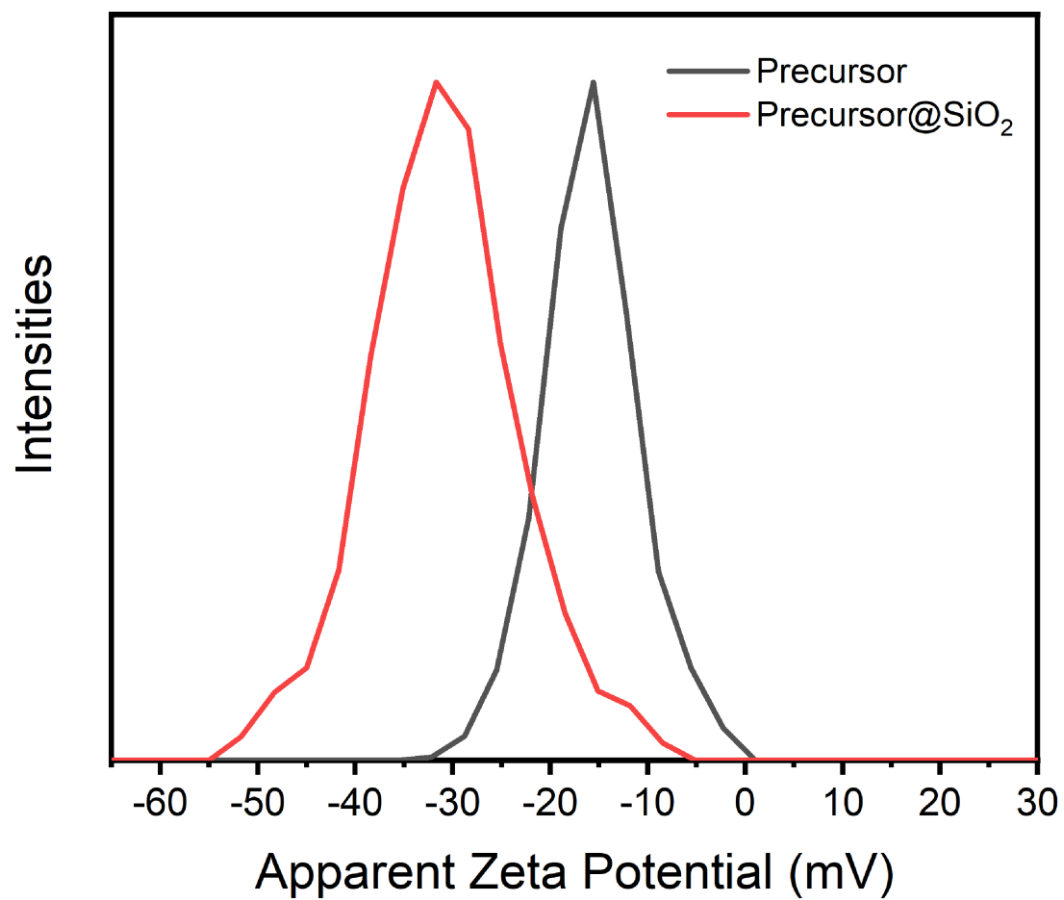


Fig. S3. Zeta potentials of 10%Yb³⁺/2%Er³⁺ co-doped precursor and precursor@SiO₂ nanoparticles.

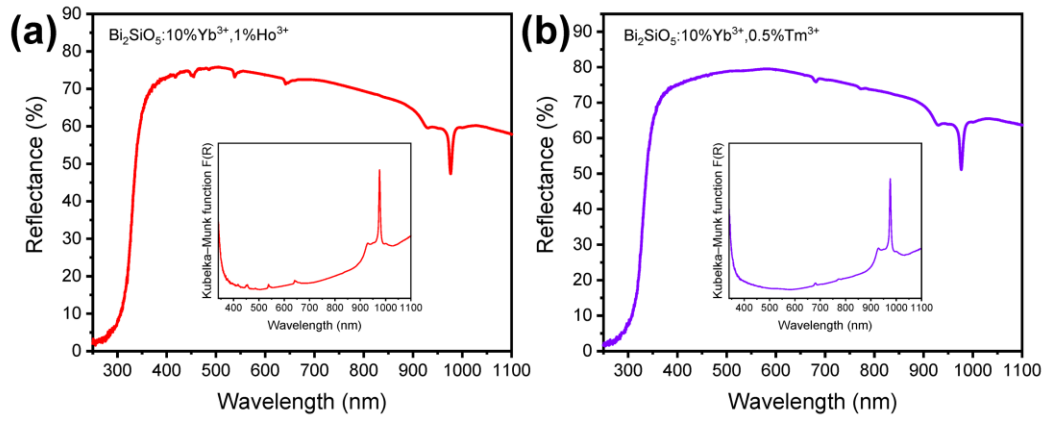


Fig. S4. Diffuse reflectance spectra of the Bi₂SiO₅:10%Yb³⁺,1%Ho³⁺ sample (a) with the Kubelka–Munk function and Bi₂SiO₅:10%Yb³⁺,0.5%Tm³⁺ sample (b) with the Kubelka–Munk function.

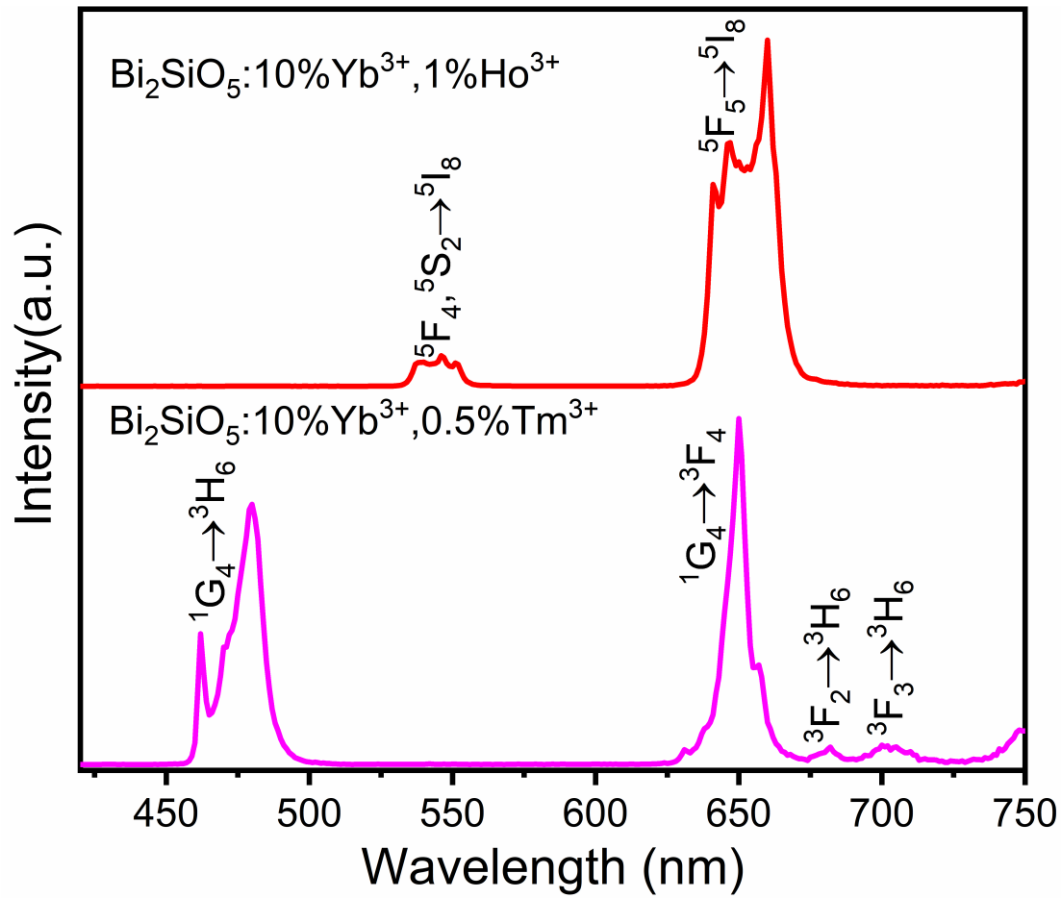


Fig. S5. Upconversion luminescence spectra of $\text{Bi}_2\text{SiO}_5:10\%\text{Yb}^{3+}, 1\%\text{Ho}^{3+}$ and $\text{Bi}_2\text{SiO}_5:10\%\text{Yb}^{3+}, 0.5\%\text{Tm}^{3+}$ under the excitation of 980 nm laser.

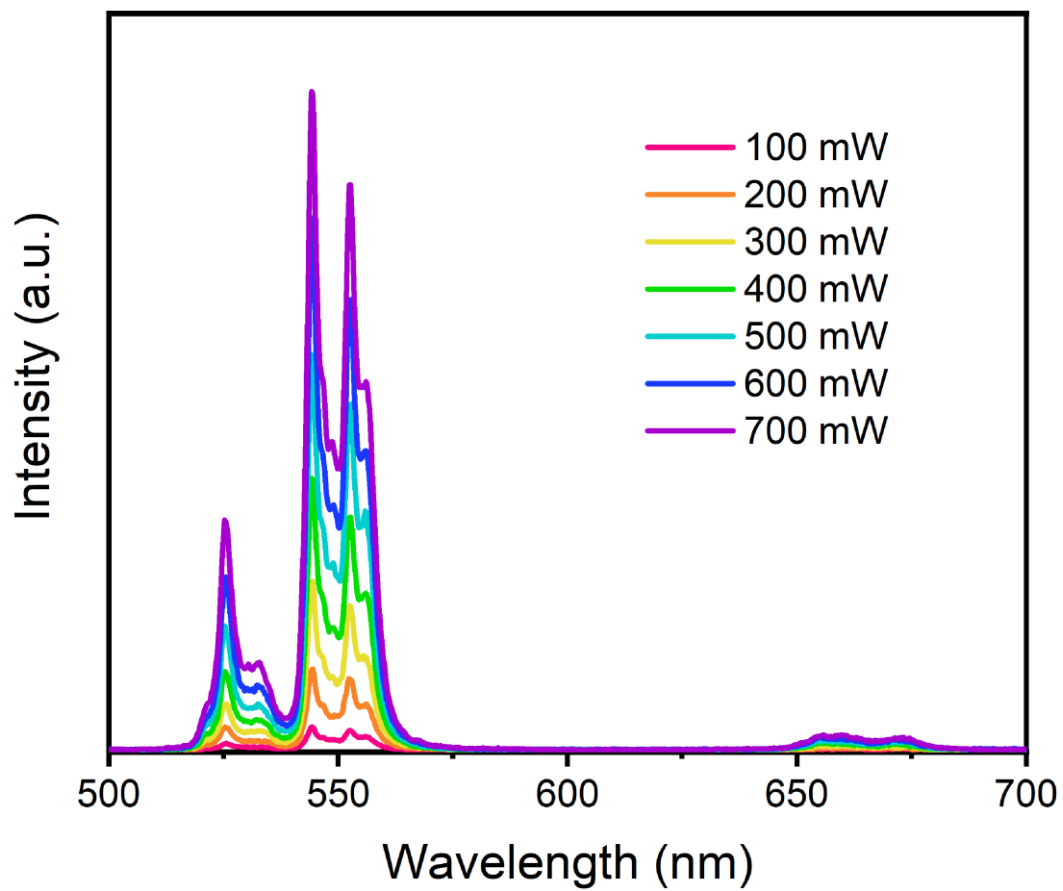


Fig. S6. (a) Upconversion luminescence spectra of Bi₂SiO₅:10%Yb³⁺,2%Er³⁺ when exciting by 980 nm laser with different output power between 100 mW and 700 mW.

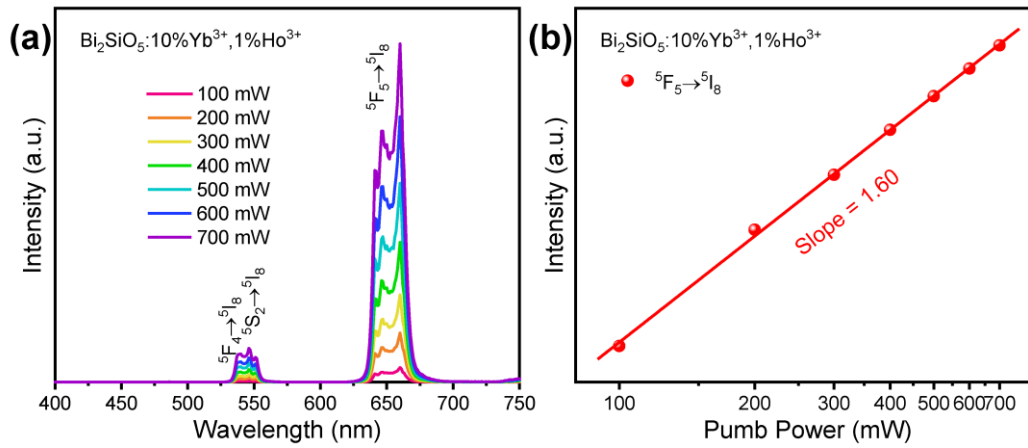


Fig. S7. (a) UCL spectra and (b) power dependence of red upconversion emission of the $\text{Bi}_2\text{SiO}_5:10\%\text{Yb}^{3+},1\%\text{Ho}^{3+}$ nanophosphors when exciting by 980 nm laser with different output power between 100 mW and 700 mW.

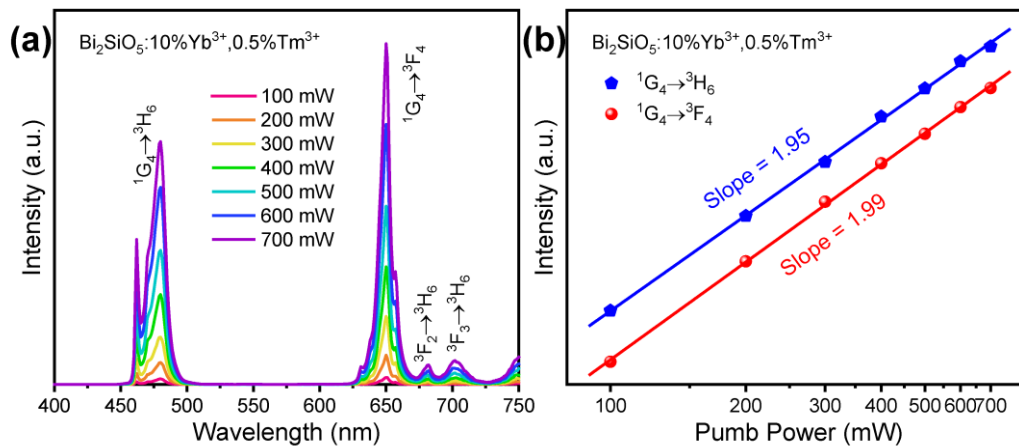


Fig. S8. (a) UCL spectra and (b) power dependence of blue and red upconversion emissions of the $\text{Bi}_2\text{SiO}_5:10\%\text{Yb}^{3+},0.5\%\text{Tm}^{3+}$ nanophosphors when exciting by 980 nm laser with different output power between 100 mW and 700 mW.

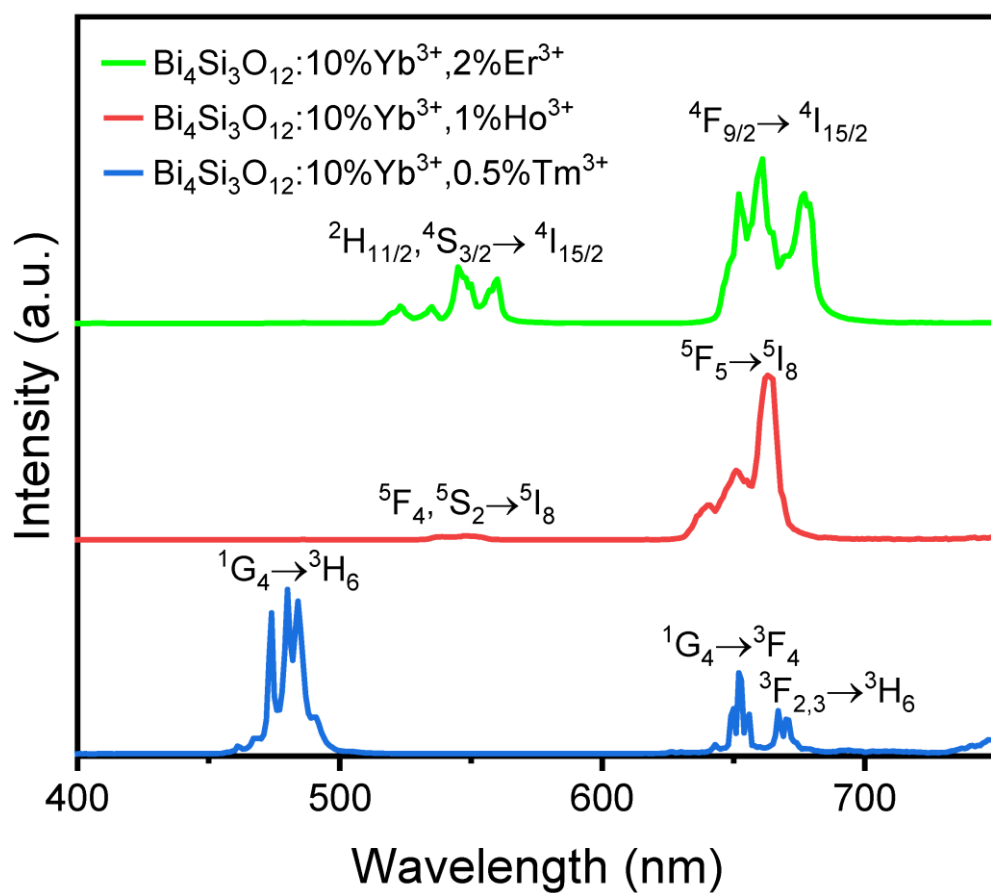


Fig. S9. UCL spectra of $\text{Bi}_4\text{Si}_3\text{O}_{12}:\text{10\%Yb}^{3+}, \text{2\%Er}^{3+}$, $\text{Bi}_4\text{Si}_3\text{O}_{12}:\text{10\%Yb}^{3+}, \text{1\%Ho}^{3+}$ and $\text{Bi}_4\text{Si}_3\text{O}_{12}:\text{10\%Yb}^{3+}, \text{0.5\%Tm}^{3+}$ under the excitation of 980 nm laser.

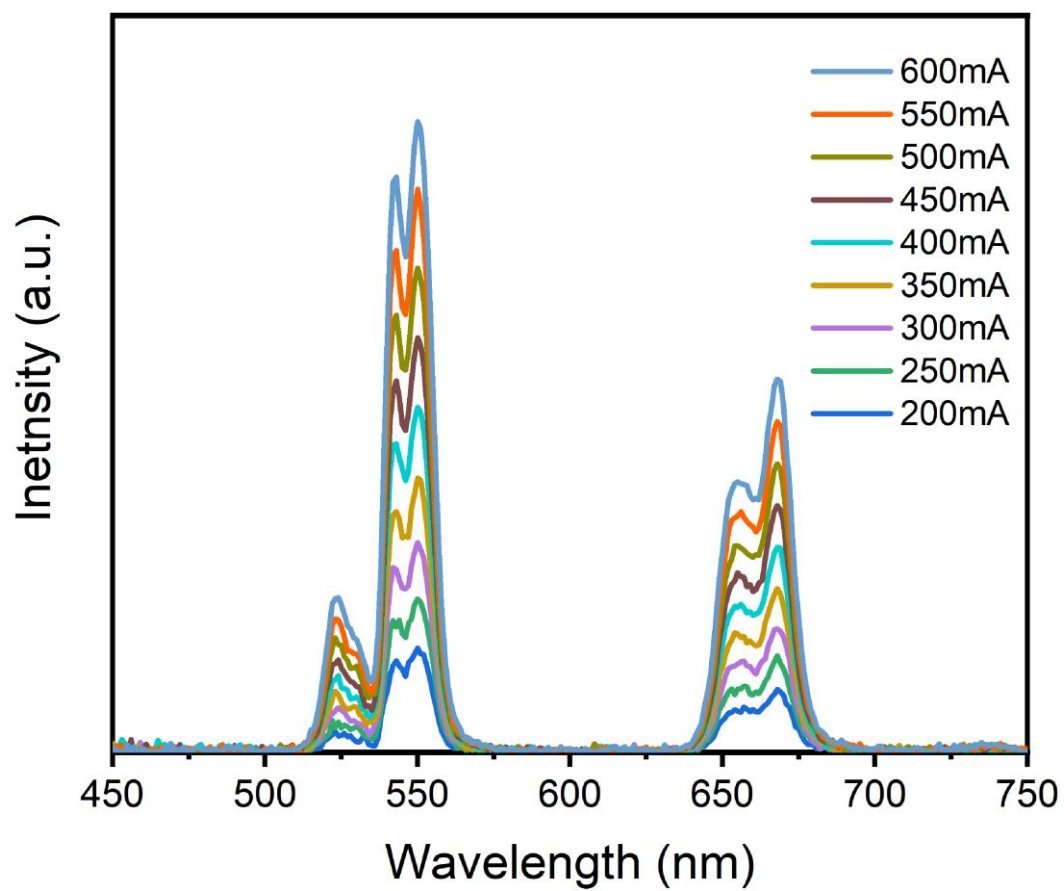


Fig. S10. EL spectra of the LED device fabricated by coating the $\text{Bi}_2\text{SiO}_5:\text{Yb}^{3+},\text{Er}^{3+}$ nanophosphors on the surface of the NIR chip under different drive current between 200 mA and 600 mA.

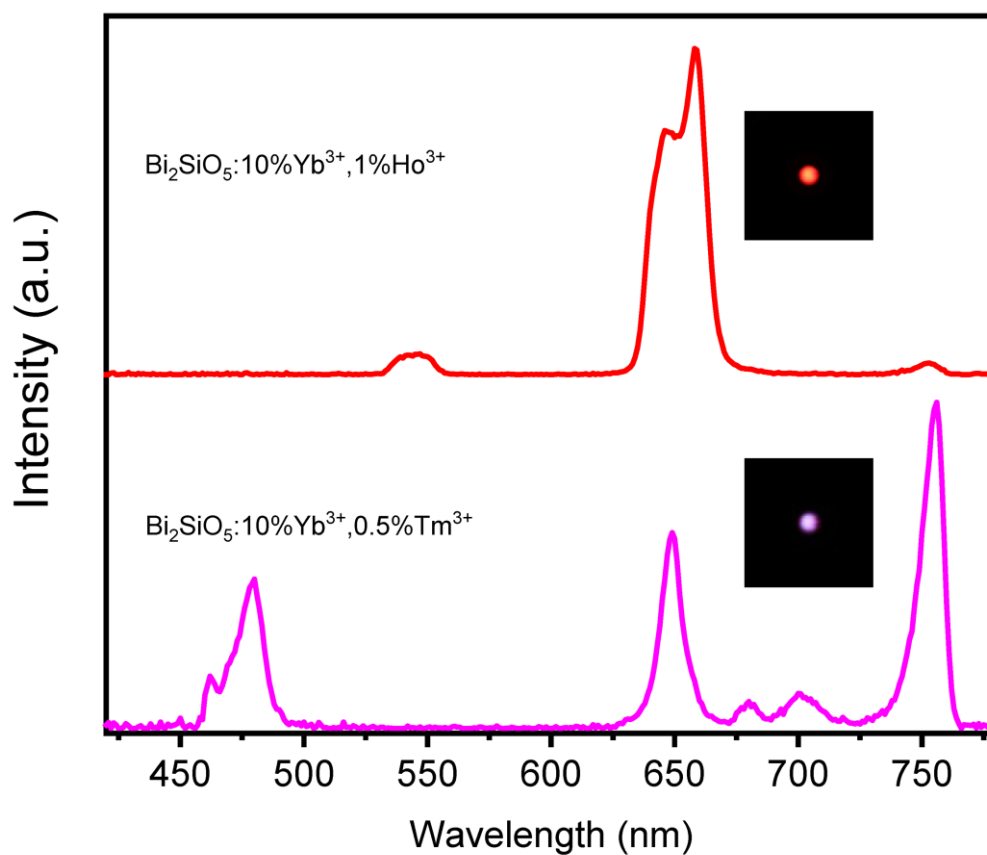


Fig. S11. EL spectra of the LED devices fabricated by coating $\text{Bi}_2\text{SiO}_5:10\%\text{Yb}^{3+},1\%\text{Ho}^{3+}$ and $\text{Bi}_2\text{SiO}_5:10\%\text{Yb}^{3+},0.5\%\text{Tm}^{3+}$ nanophosphors on the surface of NIR chips. The insets are digital luminescence images of the developed LED devices when they are lighted on under 300 mA drive current.