

Fig. S1 XRD diffraction pattern of the core, core-shell and the core-shell-shell nanoparticles and the standard reference pattern β -NaYF₄ (JCPDS-16-0334, bottom).

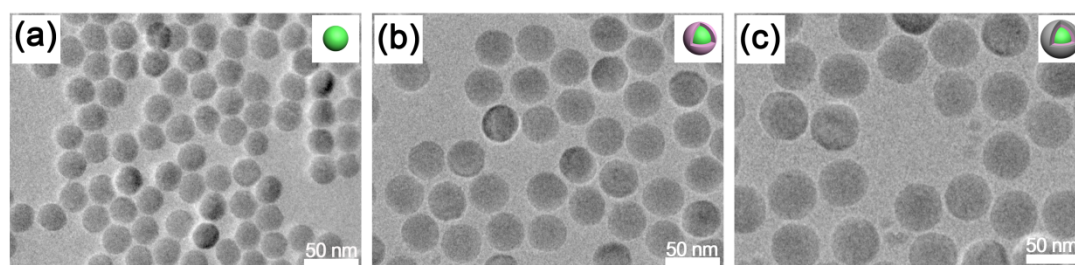


Fig. S2 TEM images of NaYF₄: Yb/Ho (8/1%) core (24.4 nm), NaYF₄: Yb/Ho (8/1%)@NaYF₄:Nd(20%) core-shell (34.5 nm) and NaYF₄: Yb/Ho (8/1%)@NaYF₄:Nd(20%)@NaYF₄ core-shell-shell (45.2 nm) nanoparticles.

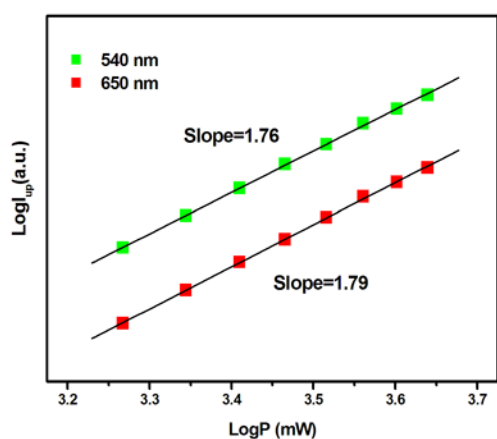


Fig. S3 Log-log plots of the $^5S_2 \rightarrow ^5I_8$ (540 nm) and $^5F_5 \rightarrow ^5I_8$ (650 nm) luminescence intensities for NaYF₄: Yb/Ho(8/1%)@NaYF₄: Nd (20%)@NaYF₄ nanoparticles excited by 808 nm laser.

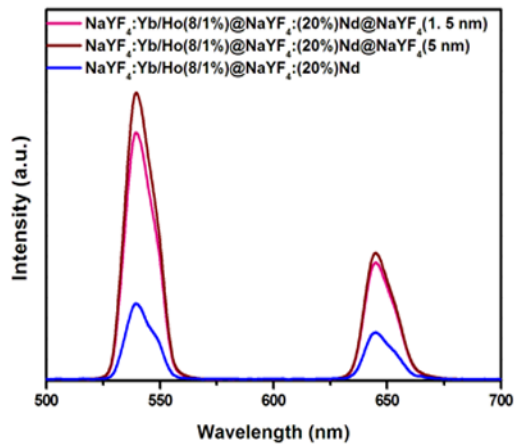


Fig. S4 Room-temperature NIR emission spectra of $\text{NaYF}_4: \text{Yb}/\text{Ho}(8/1\%)\text{@NaYF}_4: \text{Nd}(20\%)$ nanoparticles coated with 1.5 nm inert NaYF_4 shell (pink line), 5 nm inert NaYF_4 shell (dark red line), and $\text{NaYF}_4: \text{Yb}/\text{Ho}(8/1\%)\text{@NaYF}_4: \text{Nd}(20\%)$ (blue line) nanoparticles respectively. All active layers were kept about 5 nm. The spectra were recorded under excitation by 808 nm continuous-wave (CW) laser.

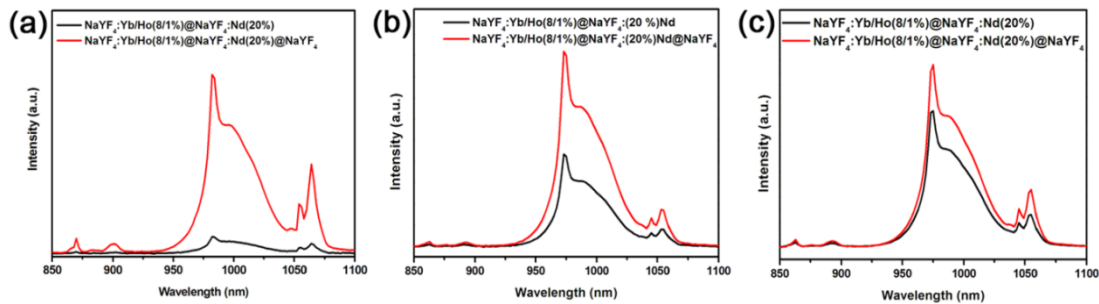


Fig. S5 Room-temperature NIR emission spectra of $\text{NaYF}_4: \text{Yb}/\text{Ho}(8/1\%)\text{@NaYF}_4: \text{Nd}(20\%)$ and $\text{NaYF}_4: \text{Yb}/\text{Ho}(8/1\%)\text{@NaYF}_4: \text{Nd}(20\%)\text{@NaYF}_4$ with different thickness of active layer ((a) for 0.4 nm, (b) for 1.5 nm and (c) for 4.2 nm). The spectra were recorded under excitation by a 808 nm continuous-wave (CW) laser.

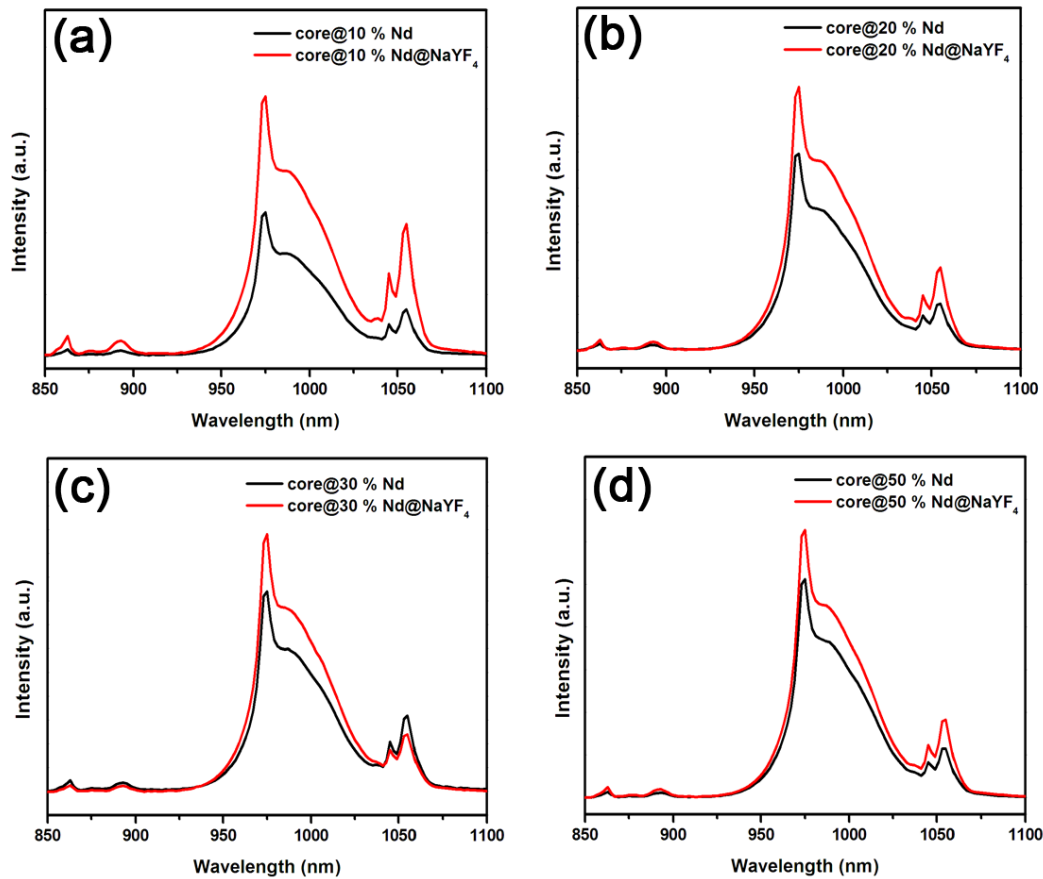


Fig. S6 Room-temperature NIR emission spectra of $\text{NaYF}_4:\text{Yb}/\text{Ho}(8/1\%)\text{@NaYF}_4:\text{Nd}(x\%)$ and $\text{NaYF}_4:\text{Yb}/\text{Ho}(8/1\%)\text{@NaYF}_4:\text{Nd}(x)\text{@NaYF}_4$ (a) $x=10\%$. (b) $x=20\%$. (c) $x=30\%$. (d) $x=50\%$. The spectra were recorded under excitation by a 808 nm continuous-wave (CW) laser.

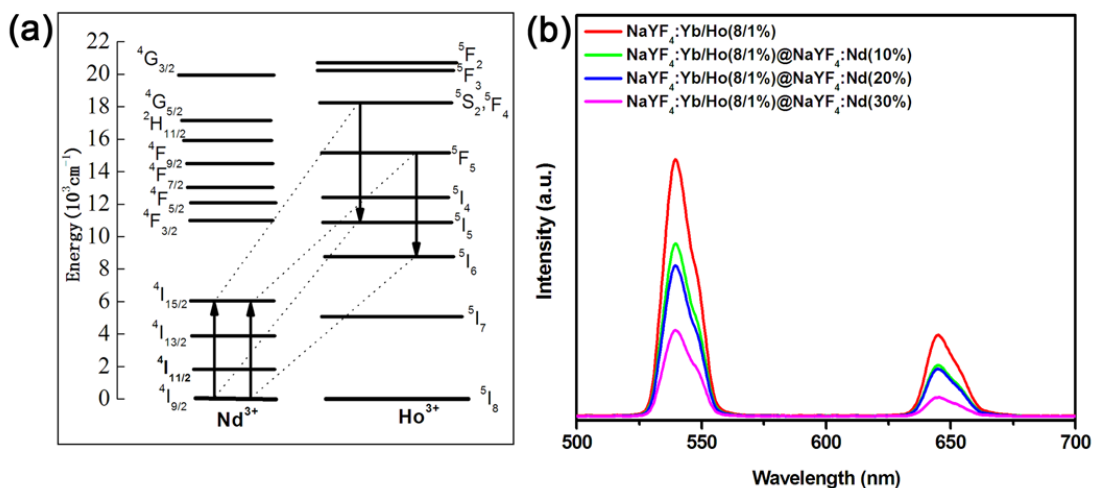


Fig. S7 (a) Energy diagram displaying the quenching mechanism of Ho^{3+} by Nd^{3+} . (b) Room-temperature upconversion emission spectra of $\text{NaYF}_4:\text{Yb}/\text{Ho}(8/1\%)$ nanoparticles and $\text{NaYF}_4:\text{Yb}/\text{Ho}(8/1\%)\text{@NaYF}_4:\text{Nd}(x\%)\text{@NaYF}_4$ ($x=10, 20,$

30)nanoparticles with 980 nm laser excitation.

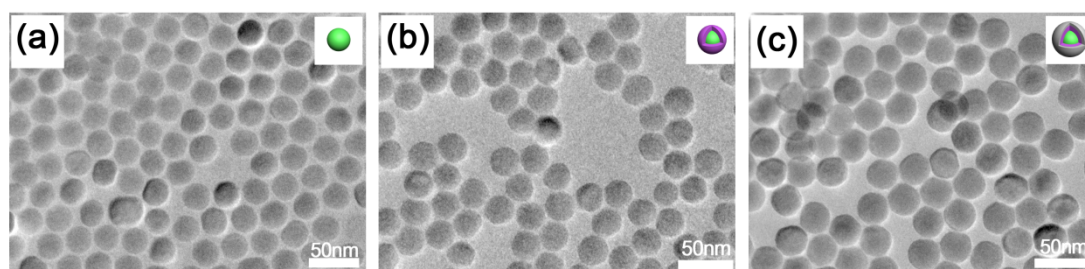


Fig. S8 TEM images of NaYF₄:Yb/Ho (8/1%) core, NaYF₄:Yb/Ho (8/1%)@NaYF₄:Nd(20%) core-shell, NaYF₄:Yb/Ho (8/1%) @ NaYF₄:Nd (20%) @ NaYF₄ core-shell-shell with 0.4 nm NaYF₄:Nd (20%) active-shell.

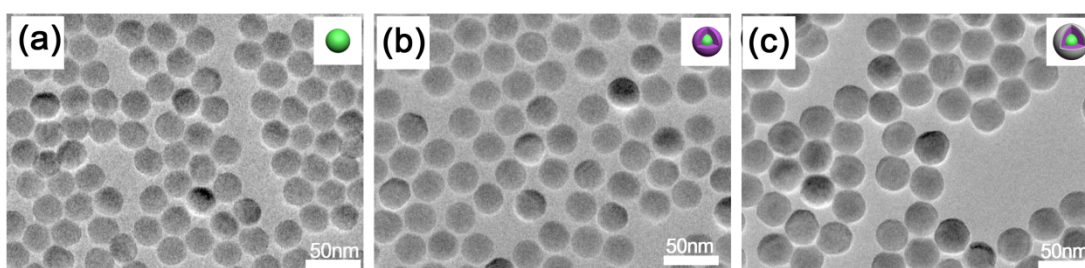


Fig. S9 TEM images of NaYF₄:Yb/Ho (8/1%) core, NaYF₄:Yb/Ho (8/1%)@NaYF₄:Nd(20%) core-shell, NaYF₄:Yb/Ho (8/1%) @ NaYF₄:Nd (20%) @ NaYF₄ core-shell-shell with 1.5 nm NaYF₄:Nd (20%) active-shell.

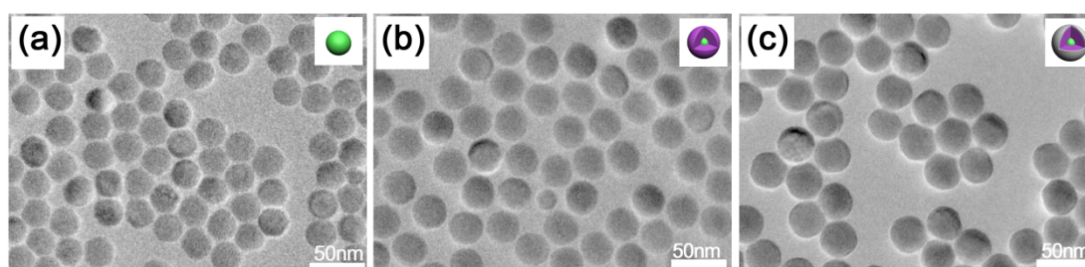


Fig. S10 TEM images of NaYF₄:Yb/Ho (8/1%) core, NaYF₄:Yb/Ho (8/1%)@NaYF₄:Nd(20%) core-shell, NaYF₄:Yb/Ho (8/1%) @ NaYF₄:Nd (20%) @ NaYF₄ core-shell-shell with 2.6 nm NaYF₄:Nd (20%) active-shell.

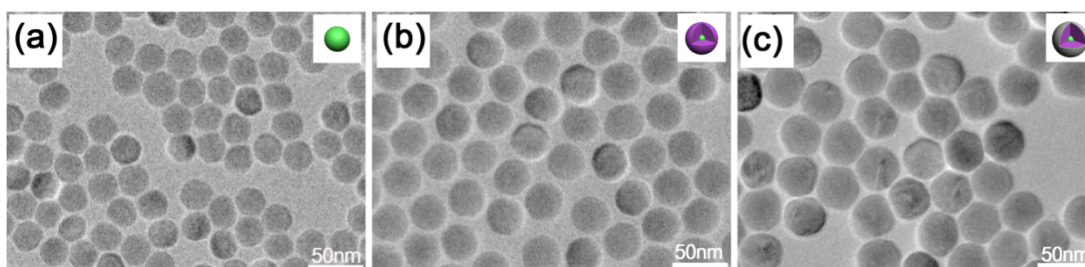


Fig. S11 TEM images of NaYF₄:Yb/Ho (8/1%) core, NaYF₄:Yb/Ho (8/1%)@NaYF₄:Nd(20%) core-shell, NaYF₄:Yb/Ho (8/1%) @ NaYF₄:Nd (20%) @ NaYF₄ core-shell-shell with 4.2 nm NaYF₄:Nd (20%) active-shell.

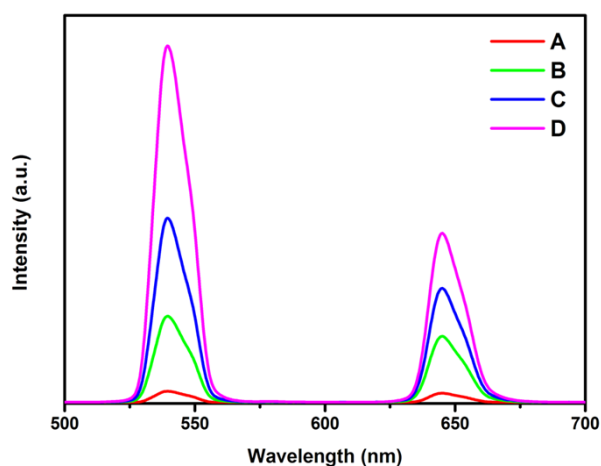


Fig. S12 Room-temperature upconversion emission spectra of NaYF₄:Yb/Ho (8/1%) @ NaYF₄:Nd (20%) @ NaYF₄ core-shell-shell samples A-D (A for 0.4 nm, B for 1.5 nm, C for 2.6 nm and D for 4.2 nm active layer in thickness, respectively).

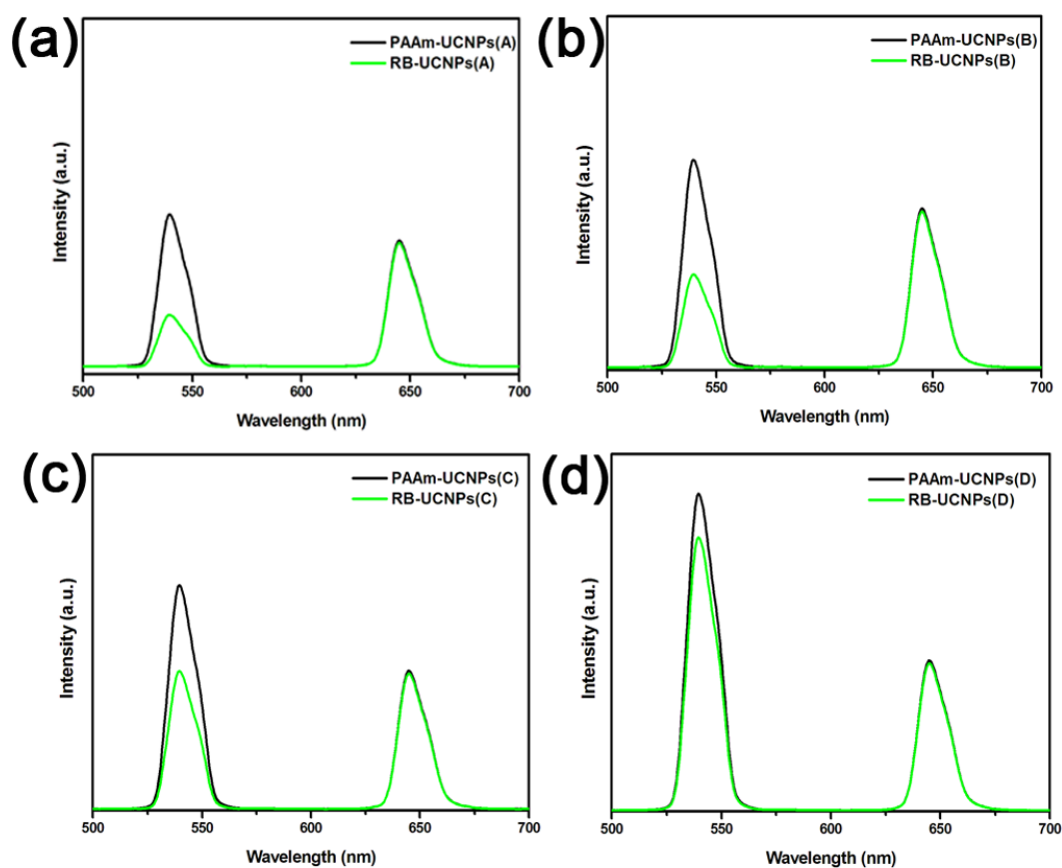


Fig. S13 Room-temperature upconversion emission spectra of NaYF₄:Yb/Ho(8/1%) @ NaYF₄:Nd(20%) @ NaYF₄ with different NaYF₄:Nd(20%) thickness active-shell (A,B,C,D) before and after conjugated RB.

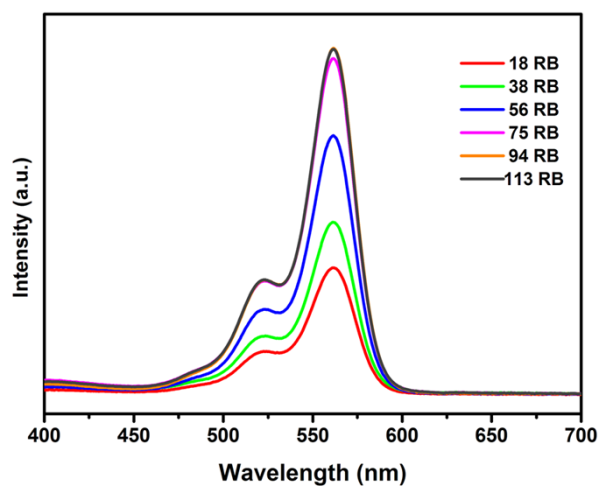


Fig. S14 UV-Vis absorption spectra of UCNPs-RB nanoconjugates incubated with RB of different concentrations. The numbers of RB per nanoparticle are also given.