

Supporting Information

Core-shell nanoarchitecture: a strategy to significantly enhance white-light upconversion of lanthanide-doped nanoparticles

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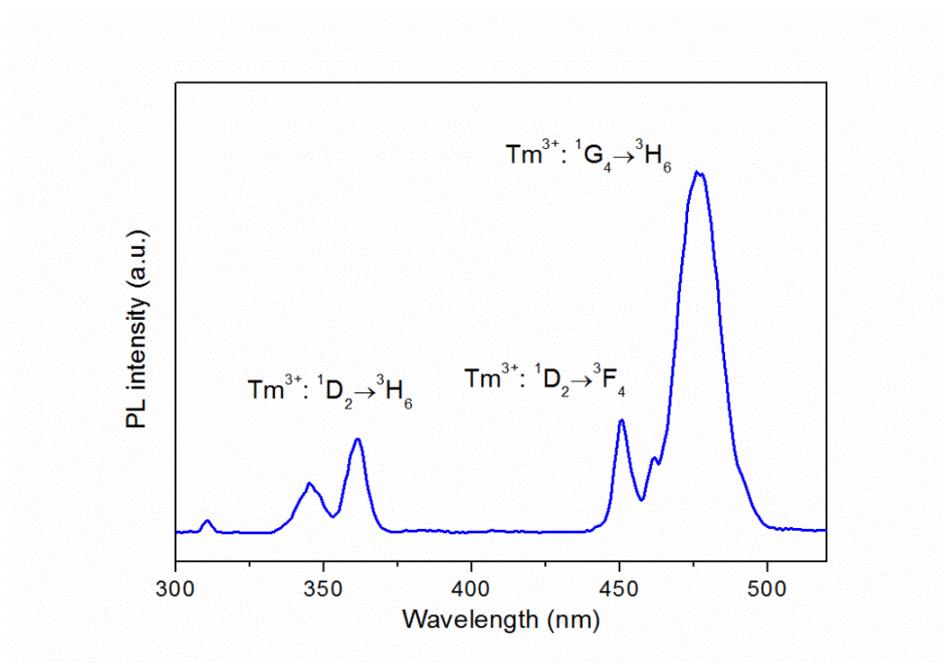


Figure S1. The UC emission spectrum of core $\text{CaF}_2:\text{Yb}/\text{Tm}$ (20/0.5 mol%) in 300-520 nm wavelength region upon a 980-nm LD excitation. The emission band at ~360 nm originates from the $\text{Tm}^{3+}: {}^1\text{D}_2 \rightarrow {}^3\text{H}_6$ transition. The energy in $\text{Tm}^{3+} {}^1\text{D}_2$ also leads to a blue emission at ~450 nm when it decays to the first excited state $\text{Tm}^{3+} {}^3\text{F}_4$.

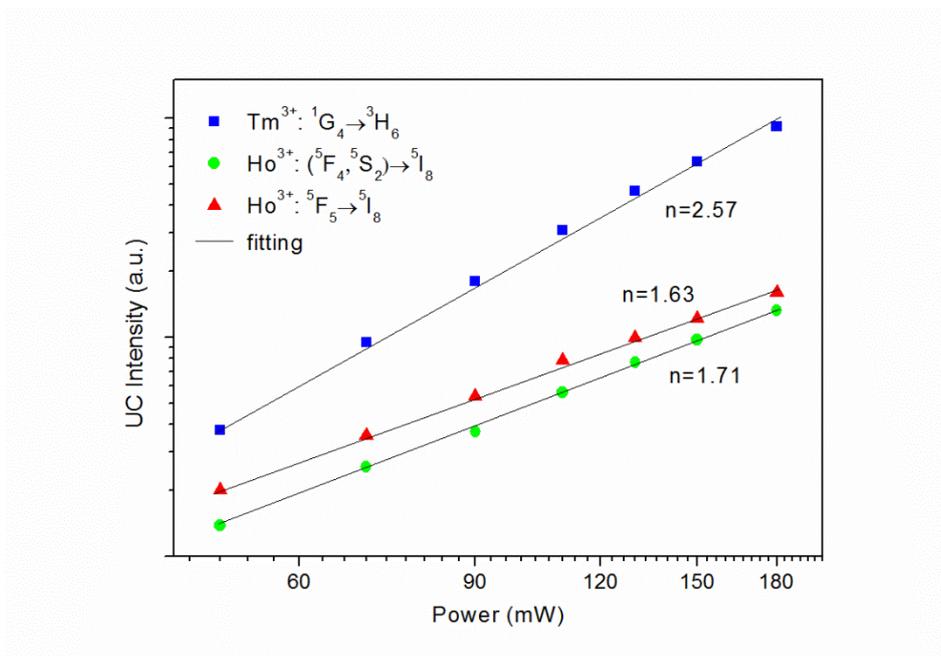


Figure S2. Power dependence of UC emission intensities in $\text{CaF}_2:\text{Yb}/\text{Ho}$ (20/0.5 mol%) and $\text{CaF}_2:\text{Yb}/\text{Tm}$ (20/0.5 mol%) under 980-nm excitation. The slope values are fitted to be 1.63, 1.71 and 2.57 for $\text{Ho}^{3+}: ^5\text{F}_5 \rightarrow ^5\text{I}_8$, $\text{Ho}^{3+}: (^5\text{F}_4, ^5\text{S}_2) \rightarrow ^5\text{I}_8$ and $\text{Tm}^{3+}: ^1\text{G}_4 \rightarrow ^3\text{H}_6$ transitions, respectively, confirming the red and green emissions of Ho^{3+} are two-step UC processes and blue of Tm^{3+} is a three-step UC process.

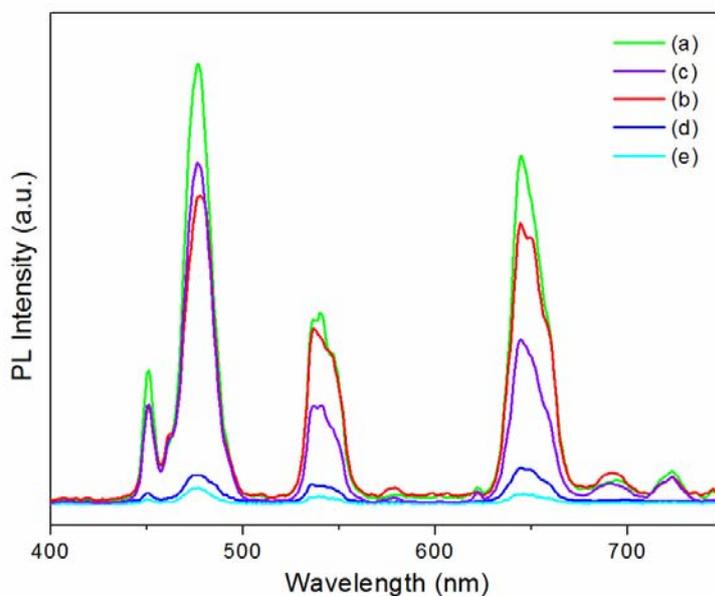


Figure S3. Comparison of UC emission spectra from core-shell samples of (a) $\text{CaF}_2\text{:Yb/Tm/Ho}$ (20/0.5/2.0 mol%)@ $\text{NaYF}_4\text{:Yb}$ (20 mol%), (b) $\text{CaF}_2\text{:Yb/Tm/Ho}$ (20/0.5/2.0 mol%)@ $\text{CaF}_2\text{:Yb}$ (20 mol%), (c) $\text{NaYF}_4\text{:Yb/Tm/Ho}$ (20/0.5/2.0 mol%)@ $\text{CaF}_2\text{:Yb}$ (20 mol%) and core only samples of (d) $\text{CaF}_2\text{:Yb/Tm/Ho}$ (20/0.5/2.0 mol%) and (e) $\text{NaYF}_4\text{:Yb/Tm/Ho}$ (20/0.5/2.0 mol%) recorded under 980-nm excitation.

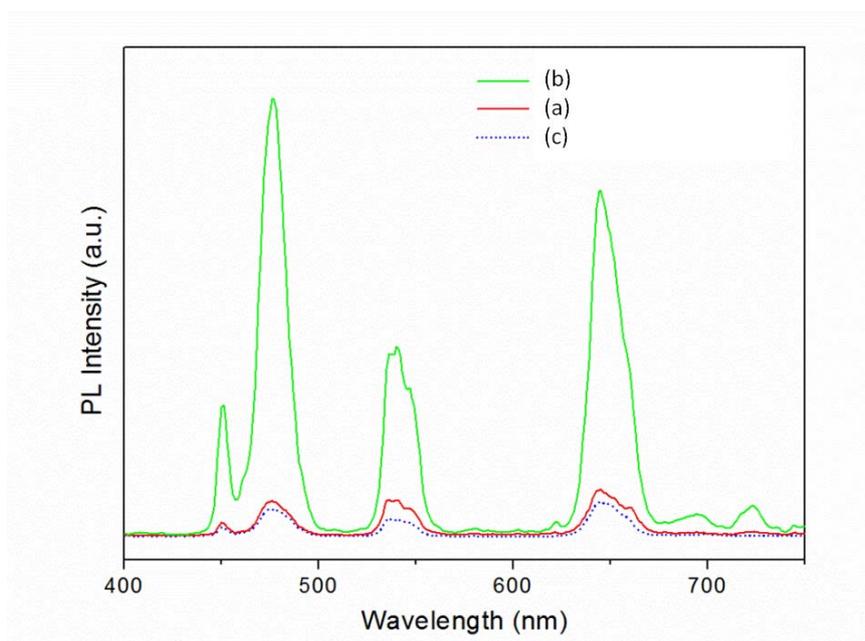


Figure S4. UC emission spectra from (a) core $\text{CaF}_2\text{:Yb/Tm/Ho}$ (40/0.5/2.0 mol%) and (b) core-shell $\text{CaF}_2\text{:Yb/Tm/Ho}$ (40/0.5/2.0 mol%)@ $\text{NaYF}_4\text{:Yb}$ (20 mol%) recorded under 980-nm excitation. The UC emission from (c) $\text{CaF}_2\text{:Yb/Tm/Ho}$ (20/0.5/2.0 mol%) is also plotted for comparison.