A novel strategy for markedly enhancing the red upconversion emission in Er$^{3+}$/Tm$^{3+}$ cooperated nanoparticles

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Fig. S1 FT-IR spectrum of the prepared NaErF$_4$:Tm@NaErF$_4$:Yb nanoparticles.
Fig. S2 Normalized upconversion emission intensity of NaErF$_4$:Tm core nanoparticles with different Tm$^{3+}$ doping content under 980 nm laser excitation.
**Fig. S3** Upconversion emission spectra (a) and the normalized emission intensity in red region (b) of NaErF$_4$:0.5%Tm, NaGdF$_4$:18%Yb,2%Er,0.5%Tm, NaErF$_4$:18%Yb,0.5%Tm and NaGdF$_4$:2%Er,0.5%Tm nanoparticles (a) under 980 nm laser excitation.
Fig. S4 Upconversion emission spectra of the NaErF$_4$:0.5%Tm core-only and NaErF$_4$:0.5%Tm@NaGdF$_4$ core-inert shell nanoparticles.
**Fig. S5** Upconversion emission spectra (a) and the R/G ratio (b) of the NaErF$_4$:0.5%Tm@NaGdF$_4$ and NaErF$_4$:0.5%Tm@NaGdF$_4$:40%Yb nanoparticles.
Fig. S6 CIE chromaticity diagram of NaErF₄ (a), NaErF₄:0.5%Tm core nanoparticles (b) and NaErF₄: 0.5%Tm@NaGdF₄:40%Yb (c) core-active shell nanoparticles.
Fig. S7 Photographs of NaErF\(_4\):0.5\%Tm core-only nanoparticles (left side) and NaErF\(_4\):0.5\%Tm@NaGdF\(_4\):40\%Yb core-active shell nanoparticles (right side) when dispersed in cyclohexane and radiated by 980 nm laser (note: the two solutions are at identical concentrations).
Fig. S8 Decay curve of Er$^{3+}$ at 654 nm in NaErF$_4$:0.5%Tm@NaGdF$_4$ core-inert shell nanoparticles under 980 nm laser excitation.
Fig. S9 Quantum yield measurement of NaErF$_4$:0.5%Tm@NaGdF$_4$:40%Yb core-active shell nanoparticles.