

Supplementary Information

The Effect of Hydrothermal Treatment on the Morphologies and Optical Properties of Upconversion $\text{NaYF}_4:\text{Ln}^{3+}$ Crystals

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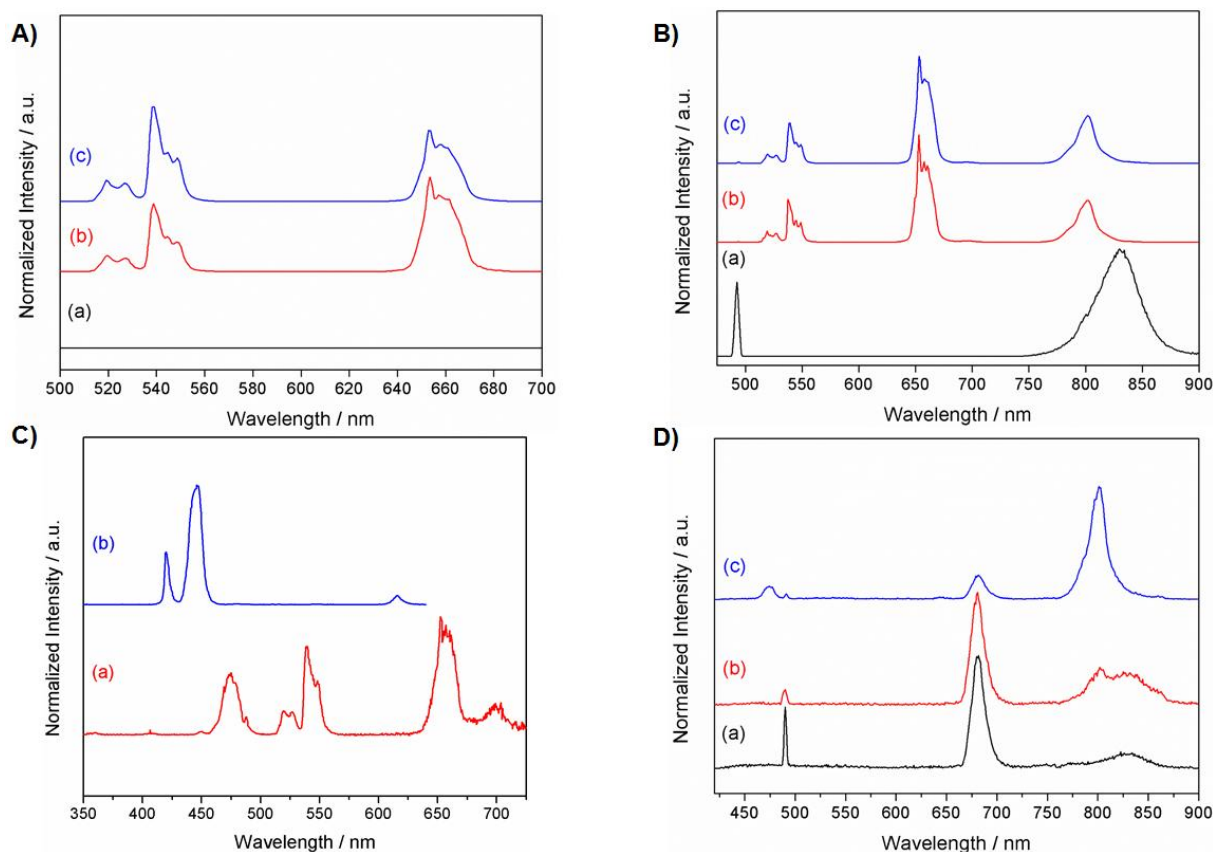


Figure S1. Upconversion spectra of (—) $\alpha\text{-NaYF}_4:\text{Yb}^{3+}:\text{Ln}^{3+}$, (—) $\alpha/\beta\text{-NaYF}_4:\text{Yb}^{3+}:\text{Ln}^{3+}$ and (—) $\beta\text{-NaYF}_4:\text{Yb}^{3+}:\text{Ln}^{3+}$ crystals under 980 nm laser excitation (30 mW). (A) $\text{Yb}^{3+}/\text{Er}^{3+}$ -doped crystals; (B) $\text{Yb}^{3+}/\text{Er}^{3+}/\text{Tm}^{3+}$ -doped crystals; (C) $\text{Yb}^{3+}/\text{Tm}^{3+}$ -doped crystals; (D) $\text{Yb}^{3+}/\text{Tm}^{3+}/\text{Nd}^{3+}$ -doped crystals.

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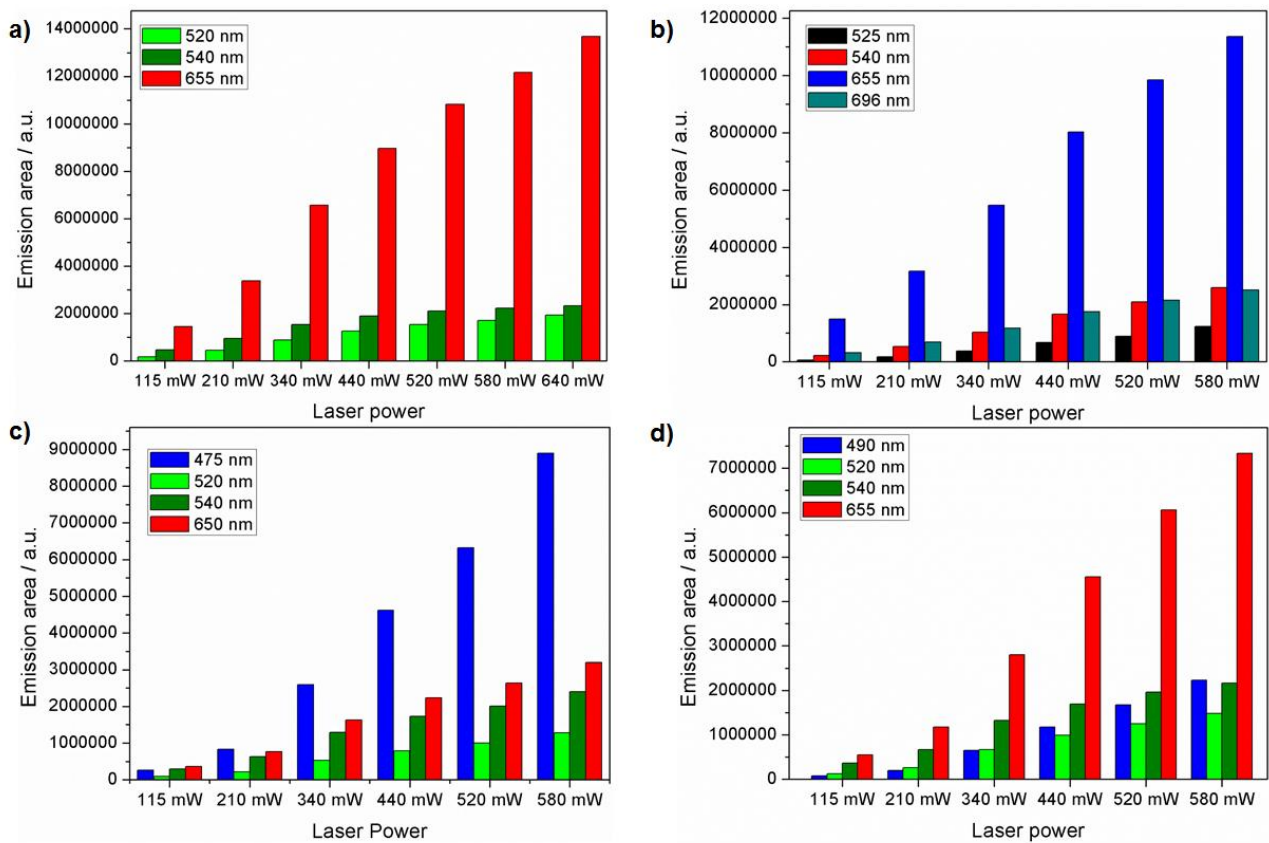


Figure S2. Peak areas of the upconverted emissions of (a) $\alpha/\beta\text{-NaYF}_4\text{:Yb}^{3+}/\text{Er}^{3+}$; (b) $\alpha/\beta\text{-NaYF}_4\text{:Yb}^{3+}/\text{Er}^{3+}/\text{Tm}^{3+}$; (c) $\alpha/\beta\text{-NaYF}_4\text{:Yb}^{3+}/\text{Tm}^{3+}$ and $\alpha/\beta\text{-NaYF}_4\text{:Yb}^{3+}/\text{Tm}^{3+}/\text{Nd}^{3+}$ crystals.

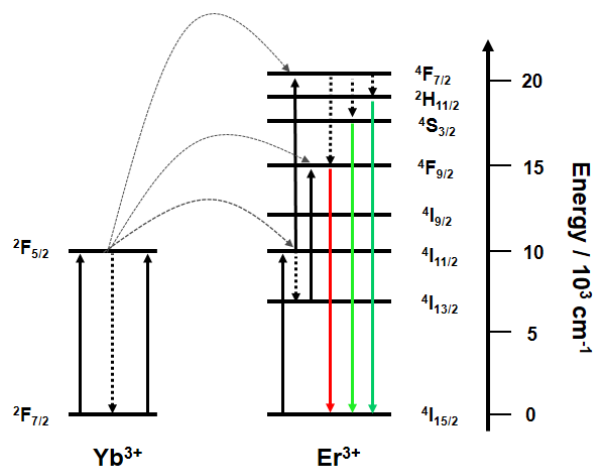


Figure S3. Energy level diagrams and proposed energy transfer mechanisms in the $\alpha/\beta\text{-NaYF}_4\text{:Yb}^{3+}/\text{Er}^{3+}$ crystals under 980 nm excitation (adapted from reference 1).

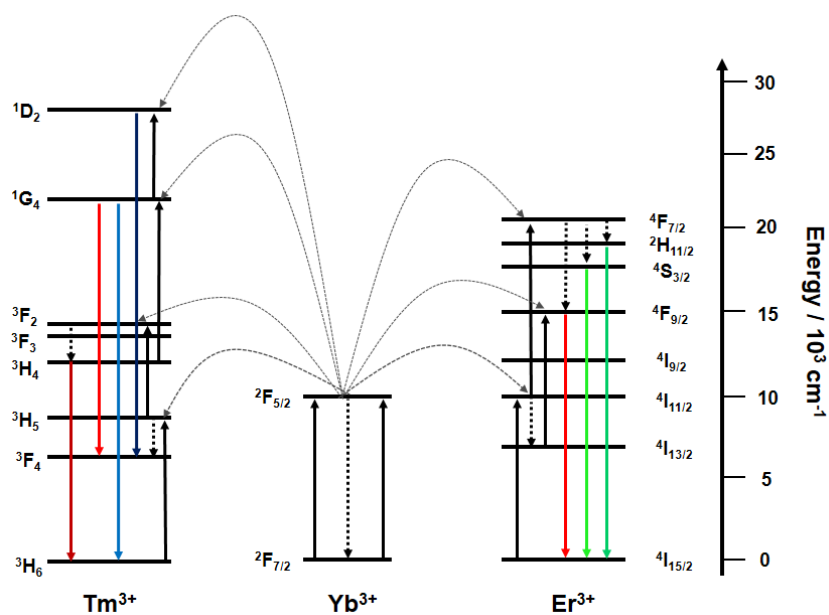


Figure S4. Energy level diagrams and proposed energy transfer mechanisms in the α/β -NaYF₄:Yb³⁺/Er³⁺/Tm³⁺ crystals under 980 nm excitation (adapted from reference 2).

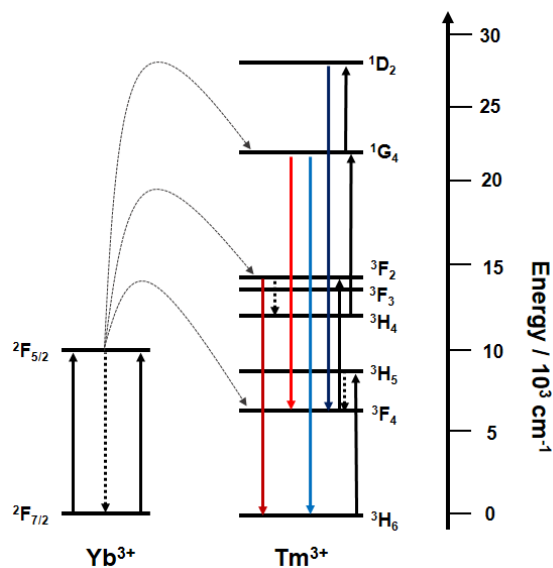


Figure S5. Energy level diagrams and proposed energy transfer mechanisms in the α/β -NaYF₄:Yb³⁺/Tm³⁺ crystals under 980 nm excitation (adapted from reference 3).

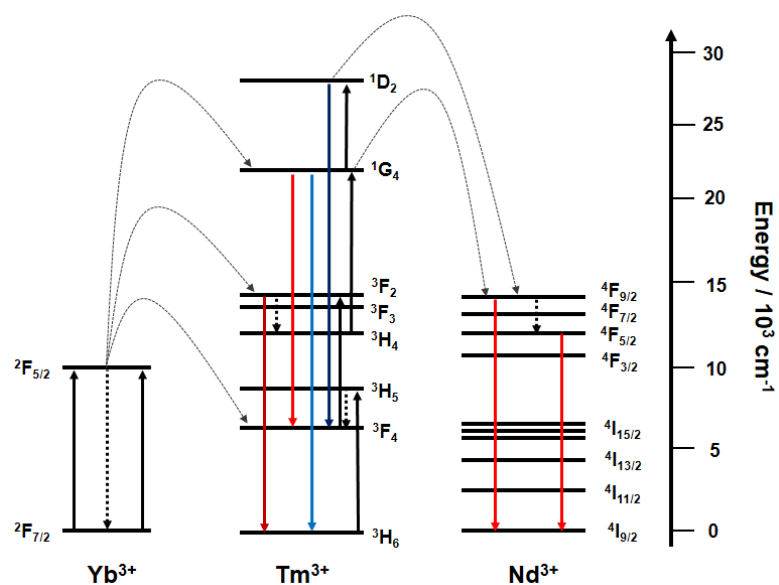


Figure S6. Energy level diagrams and proposed energy transfer mechanisms in the α/β -NaYF₄:Yb³⁺/Tm³⁺/Nd³⁺ crystals under 980 nm excitation (adapted from reference 4).

References

1. Park, Y. I.; Lee, K. T.; Suh, Y. D.; Hyeon, T.; *Chem. Soc. Rev.* **2015**, *44*, 1302.
2. Glaspell, G.; Anderson, J.; Wilkins, J. R.; El-Shall, M. S.; *J. Phys. Chem. C* **2008**, *112*, 11527.
3. Li, C.; Quan, Z.; Yang, J.; Yang, P.; Lin, J.; *Inorg. Chem.* **2007**, *46*, 6329.
4. Lv, R.; Yang, G.; He, F.; Dai, Y.; Gai, S.; Yang, P.; *Nanoscale* **2014**, *6*, 14799.