

## Supporting Information

### Engineering tri-channel orthogonal luminescence in a single nanoparticle for Information Encryption

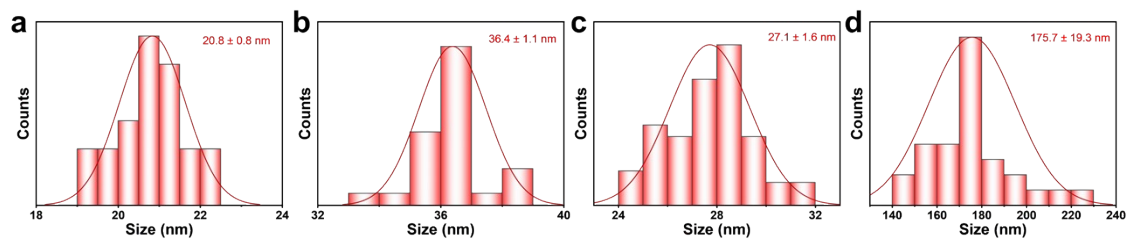
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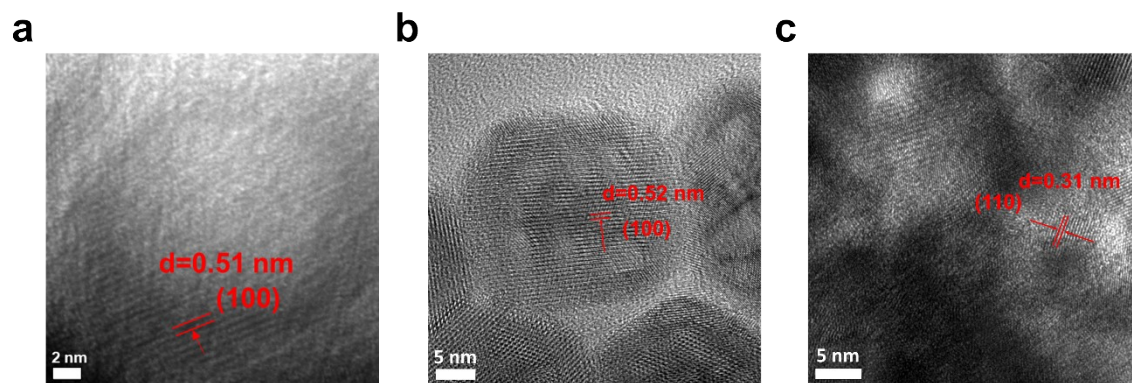
***E-mail:** anran@ciac.ac.cn; leipp@ciac.ac.cn; hongjie@ciac.ac.cn*

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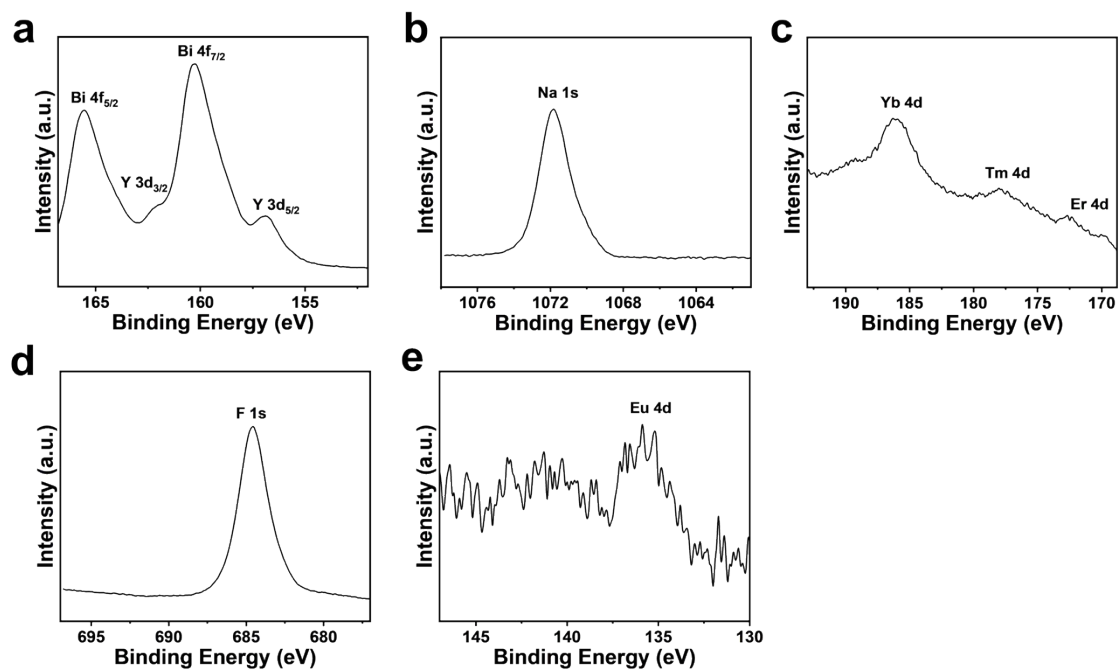
*<sup>c</sup>Department of Chemistry, Tsinghua University, Beijing 100084, China*



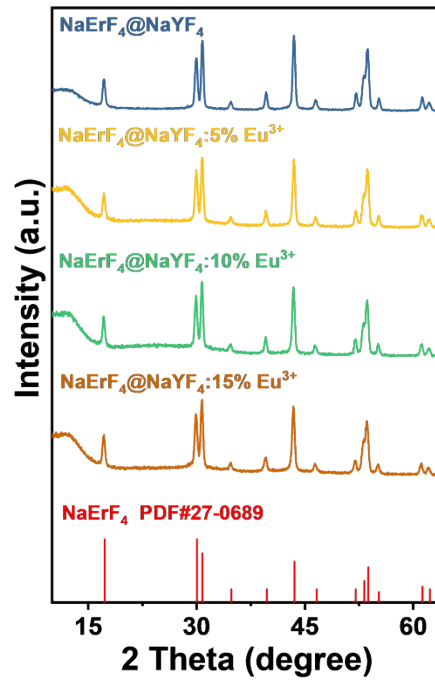
**Figure S1.** The corresponding size distributions of a) NaErF<sub>4</sub>, b and c) NaErF<sub>4</sub>@NaYF<sub>4</sub>:Eu<sup>3+</sup>, and d) NaErF<sub>4</sub>@NaYF<sub>4</sub>:Eu<sup>3+</sup>@NaBiF<sub>4</sub>:Yb<sup>3+</sup>,Tm<sup>3+</sup> nanoparticles.



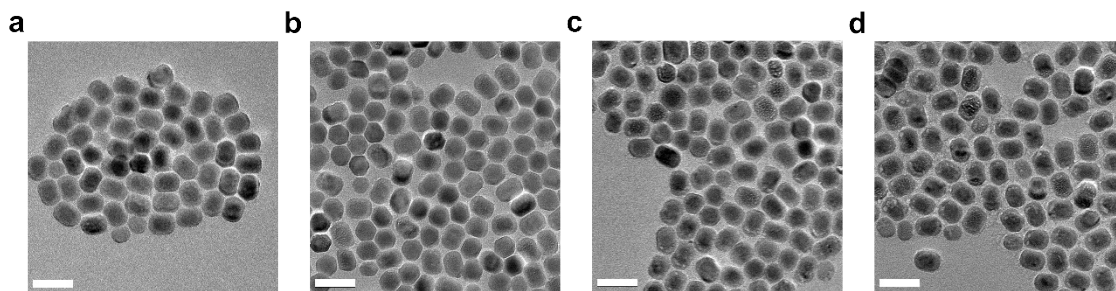
**Figure S2.** The high-resolution transmission electron microscopy images of the a)  $\text{NaErF}_4$ , b)  $\text{NaErF}_4@ \text{NaYF}_4:\text{Eu}^{3+}$ , and c)  $\text{NaErF}_4@ \text{NaYF}_4:\text{Eu}^{3+}@ \text{NaBiF}_4:\text{Yb}^{3+}, \text{Tm}^{3+}$  nanoparticles.



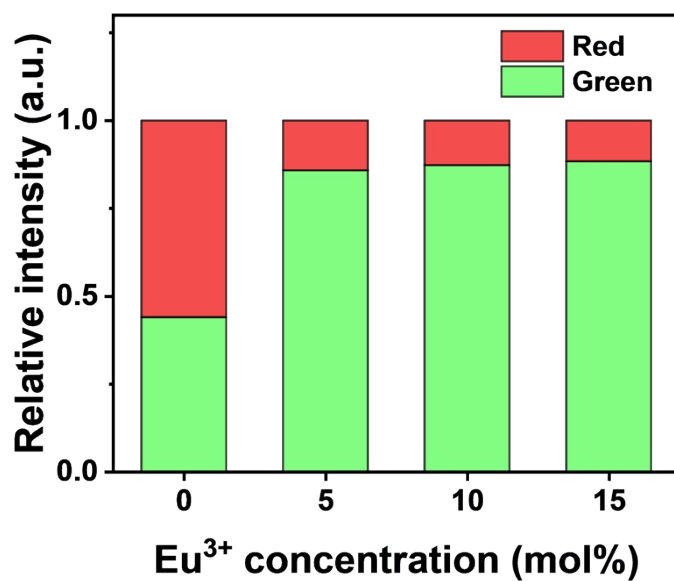
**Figure S3.** High-resolution X-ray photoelectron spectroscopy, a) Bi 4f and Y 3d, b) Na 1s, c) Yb 4d, Tm 4d, and Er 4d, d) F 1s, and e) Eu 4d.



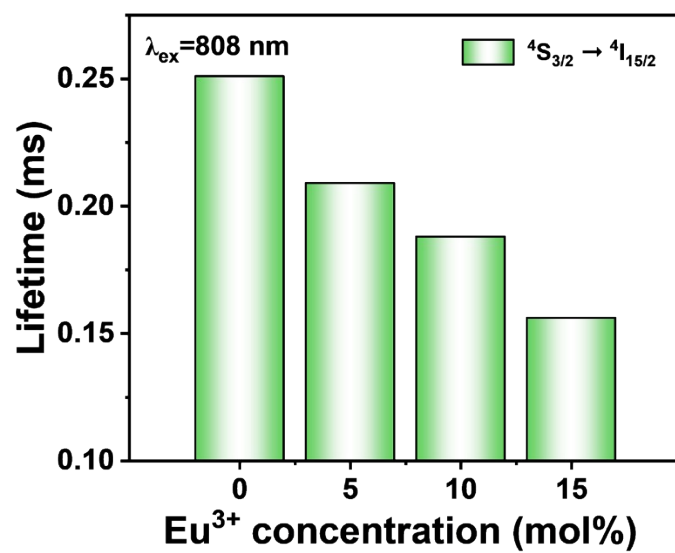
**Figure S4.** X-ray diffraction patterns of  $\text{NaErF}_4@NaYF_4:X\% \text{Eu}^{3+}$  nanoparticles. (X = 0, 5, 10, and 15).



**Figure S5.** TEM images of the a)  $\text{NaErF}_4@ \text{NaYF}_4:0\% \text{Eu}^{3+}$ , b)  $\text{NaErF}_4@ \text{NaYF}_4:5\% \text{Eu}^{3+}$ , c)  $\text{NaErF}_4@ \text{NaYF}_4:10\% \text{Eu}^{3+}$ , and d)  $\text{NaErF}_4@ \text{NaYF}_4:15\% \text{Eu}^{3+}$  nanoparticles. (scale bar is 50 nm).

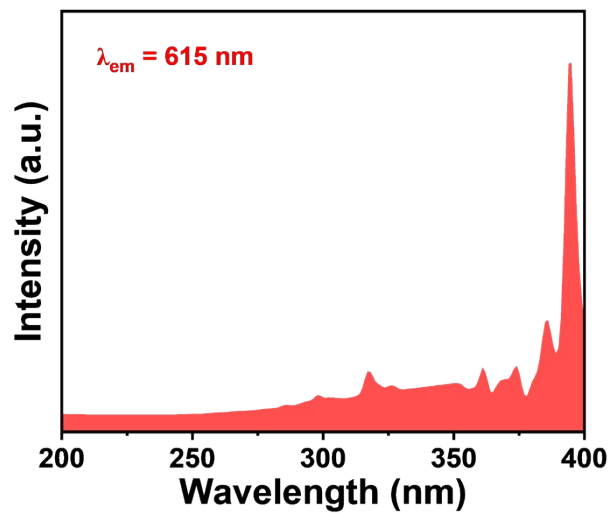


**Figure S6.** The relative intensity ratio of the green emission ( ${}^2\text{H}_{11/2}, {}^4\text{S}_{3/2} \rightarrow {}^4\text{I}_{15/2}$ ) and the red emission ( ${}^4\text{F}_{9/2} \rightarrow {}^4\text{I}_{15/2}$ ) of the  $\text{NaErF}_4@\text{NaYF}_4:\text{X}\% \text{Eu}^{3+}$  nanoparticles under 808 nm excitation. (X = 0, 5, 10, and 15).

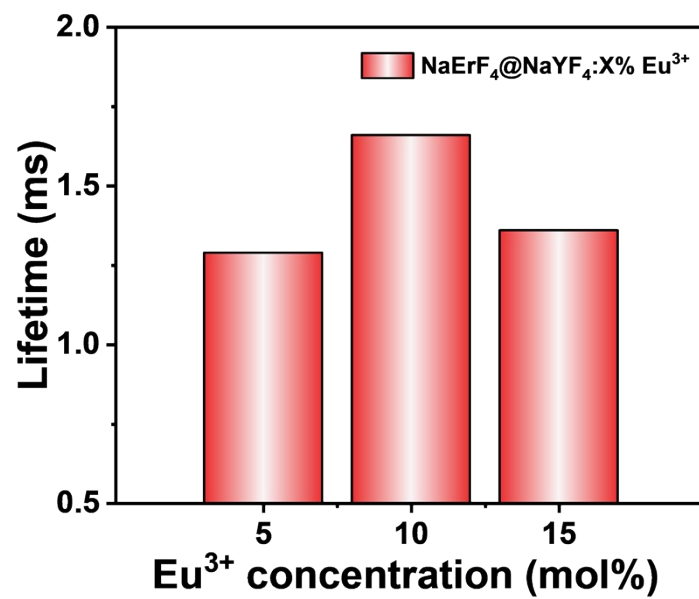


**Figure S7.** The lifetimes of the  $^4S_{3/2} \rightarrow ^4I_{15/2}$  transition of  $\text{NaErF}_4@\text{NaYF}_4:\text{X}\% \text{Eu}^{3+}$  nanoparticles under 808 nm excitation. (X = 0, 5, 10, and 15).

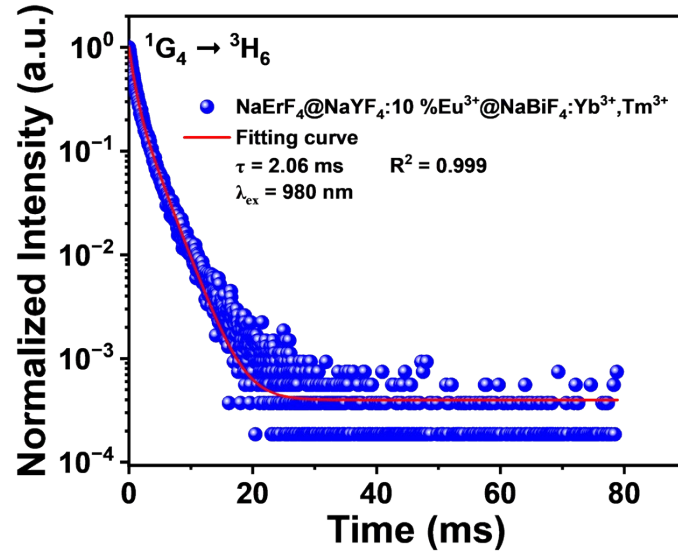




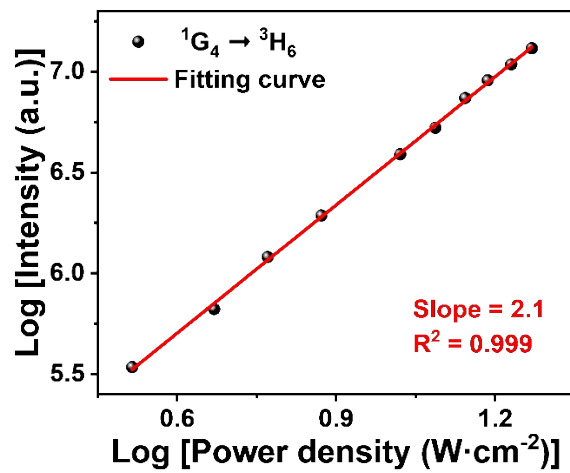
**Figure S8.** The excitation spectrum of the  $\text{NaErF}_4@\text{NaYF}_4:\text{Eu}^{3+}$  nanoparticles.



**Figure S9.** The lifetimes of the  ${}^5D_0 \rightarrow {}^7F_2$  transition of  $\text{NaErF}_4@ \text{NaYF}_4: X\% \text{Eu}^{3+}$  nanoparticles. ( $X = 5, 10,$  and  $15$ ).



**Figure S10.** The time-resolved photoluminescence (TRPL) decay curves and the corresponding fitting curve of the  $\text{NaErF}_4@ \text{NaYF}_4:10\% \text{Eu}^{3+}@ \text{NaBiF}_4:\text{Yb}^{3+}, \text{Tm}^{3+}$  samples under 980 nm excitation.



**Figure S11.** Pump power dependence of the  $^1G_4 \rightarrow ^3H_6$  transitions under 980 nm excitation.



**Figure S12.** Demonstration the double-color emissions of the construction of four 8-shaped pattern using  $\text{NaErF}_4@\text{NaYF}_4:\text{Eu}^{3+}$  nanoparticles and  $\text{NaErF}_4@\text{NaYF}_4:\text{Eu}^{3+}@\text{NaBiF}_4:\text{Yb}^{3+},\text{Tm}^{3+}$  nanoparticles. (i):  $\text{NaErF}_4@\text{NaYF}_4:10\% \text{Eu}^{3+}$  and  $\text{NaErF}_4@\text{NaYF}_4:10\% \text{Eu}^{3+}@\text{NaBiF}_4:\text{Yb}^{3+},\text{Tm}^{3+}$  nanoparticles. (ii):  $\text{NaErF}_4@\text{NaYF}_4:10\% \text{Eu}^{3+}$  nanoparticles.