

Supporting Information

Enhanced upconversion luminescence and controllable phase/shape in NaYF₄:Yb/Er crystals through Cu²⁺ ions doping

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Table S1 Nominal ratio and ICP-OES results of cation mole ratios in the products

NaYF ₄ :X%Cu/18%Yb/2%Er	Na: Y: Yb: Er: Cu	
	Nominal ratio	ICP-OES result
X=0	1.000: 0.800: 0.180: 0.020	0.876: 0.837: 0.146: 0.017
X=20	1.000: 0.600: 0.180: 0.020: 0.200	1.194: 0.766: 0.189: 0.025: 0.020
X=35	1.000: 0.450: 0.180: 0.020: 0.350	1.107: 0.638: 0.277: 0.035: 0.049
X=40	1.000: 0.400: 0.180: 0.020: 0.400	1.011: 0.711: 0.202: 0.025: 0.062
X=60	1.000: 0.200: 0.180: 0.020: 0.600	0.869: 0.671: 0.180: 0.022: 0.127

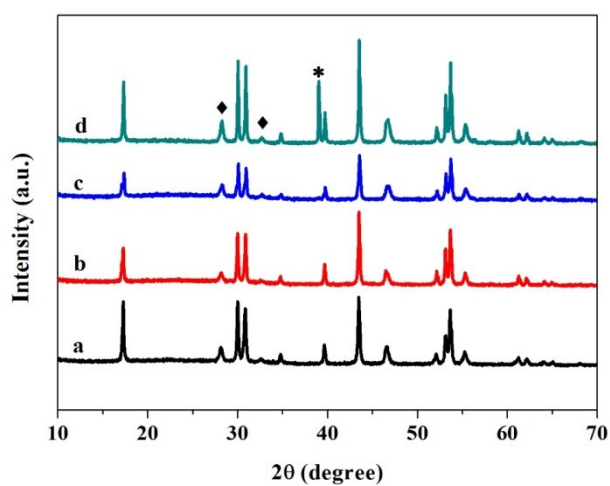


Fig. S1 XRD patterns of NaYF₄:Yb/Er crystals with various F⁻/RE³⁺ ratio of 4:1, 5:1, 6.67:1, 10:1 (curves a–d), some diffraction peaks of the cubic phase are marked with ◆; The peaks marked by an asterisk (*) arise from excessive cubic NaF.

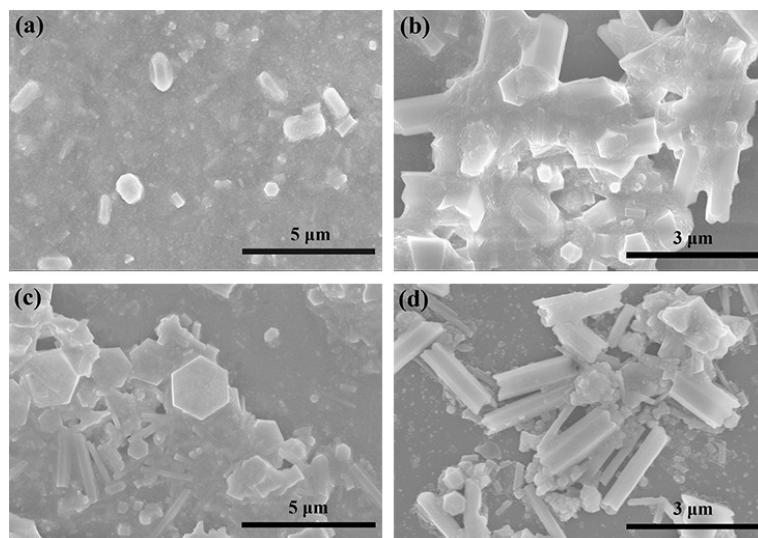


Fig. S2 The typical SEM images of NaYF₄:Yb/Er crystals with various F⁻/RE³⁺ ratio of (a) 4:1, (b) 5:1, (c) 6.67:1, (d) 10:1.

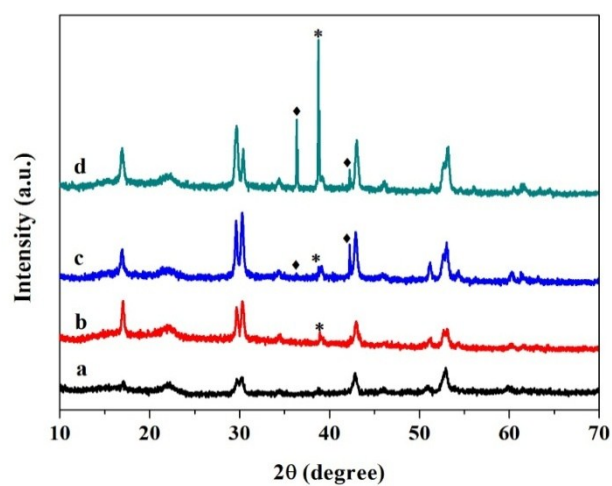


Fig. S3 XRD patterns of NaGdF₄:Yb/Er crystals co-doped with Cu²⁺ ions at various concentrations of 0, 20, 40 and 60 mol% (curves a–d). The peaks marked by an asterisk (*) arise from excessive cubic NaF.

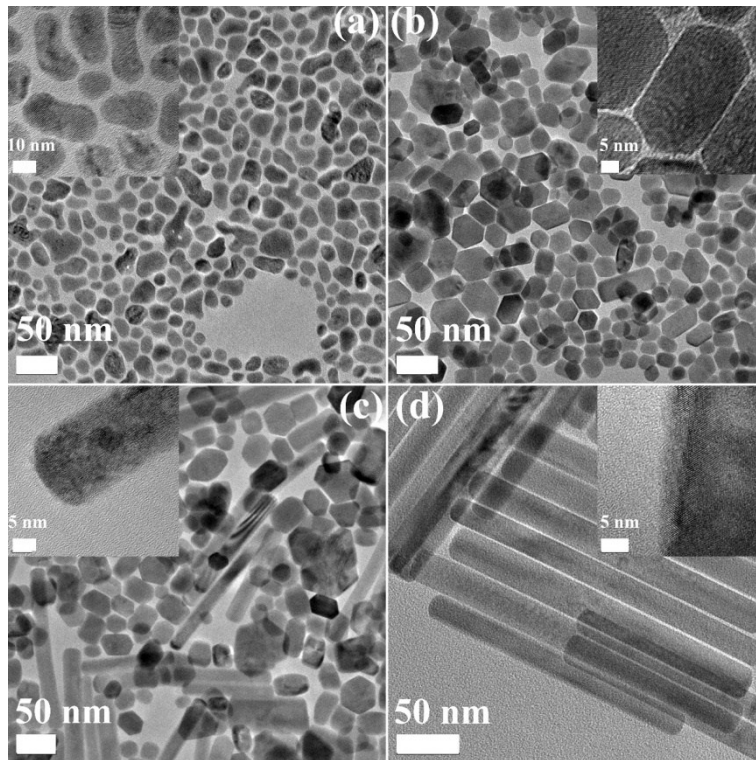


Fig. S4 Typical TEM images of NaGdF₄:Yb/Er/Cu crystals. (a) 0 mol% Cu²⁺ ion, (b) 20 mol% Cu²⁺ ions, (c) 40 mol% Cu²⁺ ions, (d) 60 mol% Cu²⁺ ions, insets show the corresponding HRTEM images.

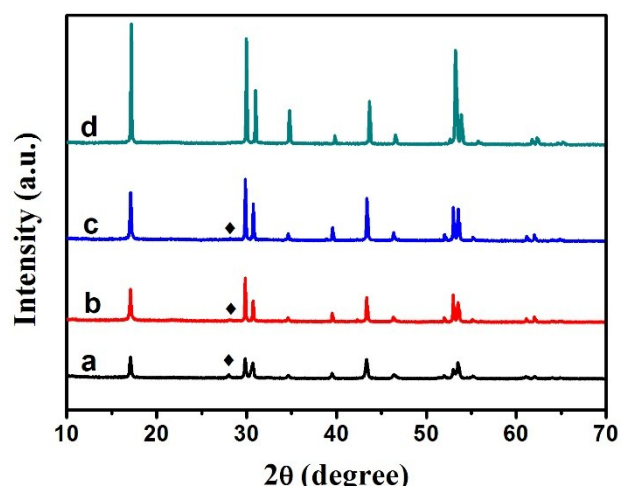


Fig. S5 XRD patterns of $\text{NaLuF}_4:\text{Yb/Er}$ crystals co-doped with Cu^{2+} ions at various concentrations of 0, 20, 40 and 60 mol% (curves a–d). Some diffraction peaks of the cubic phase are marked with \blacklozenge .

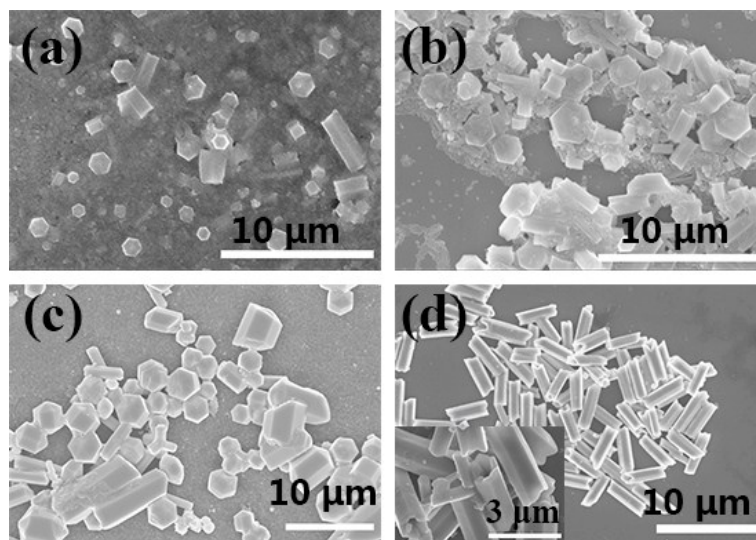


Fig. S6 Typical SEM images of NaLuF₄:Yb/Er/Cu crystals. (a) 0 mol% Cu²⁺ ion, (b) 20 mol% Cu²⁺ ions, (c) 40 mol% Cu²⁺ ions, (d) 60 mol% Cu²⁺ ions, insets show the corresponding enlarged morphology of the crystal.

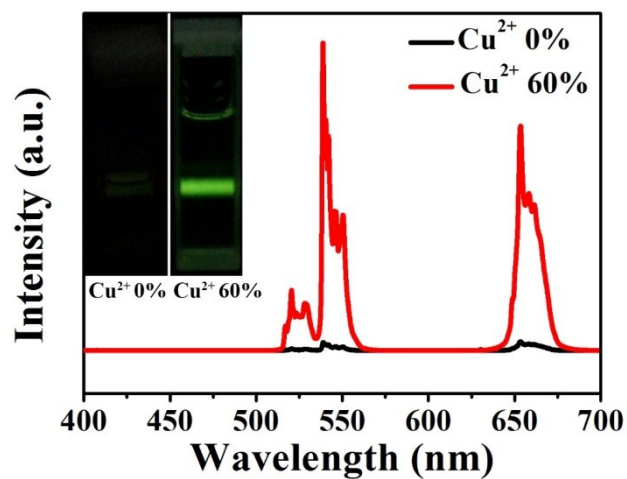


Fig. S7 Room temperature upconversion emission spectra of NaYF₄:Yb/Er crystals with 0 and 60 mol% Cu²⁺ dopant ions (0.14 W/mm²). Inset: luminescence photographs of the corresponding samples dispersed in cyclohexane (1 mg/mL, 0.71 W/mm²).

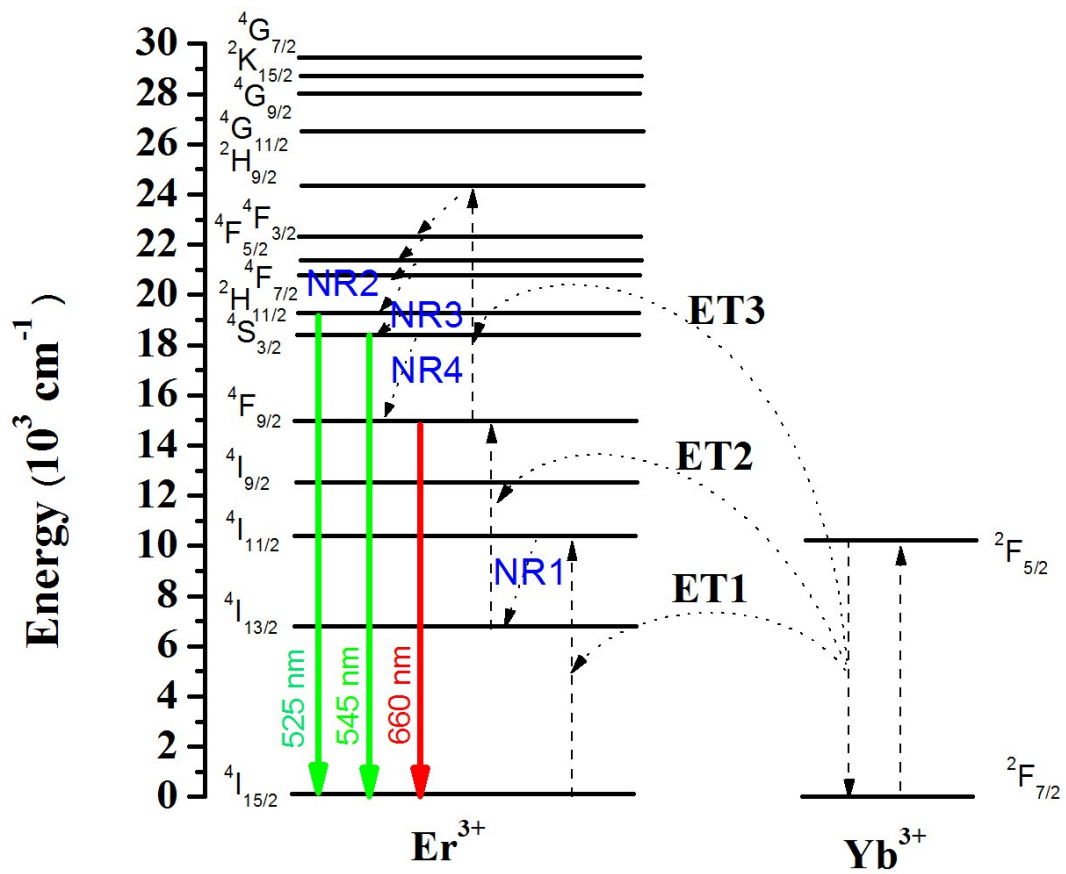


Fig. S8 Energy level diagrams of Er^{3+} and Yb^{3+} ions, showing possible energy transfer mechanisms for red and green UC emissions of Er^{3+} activators in the host.