Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

One-pot Synthesis of Ultrasmall β-$NaGdF_4$ Nanoparticles with Enhanced Upconversion Luminescence

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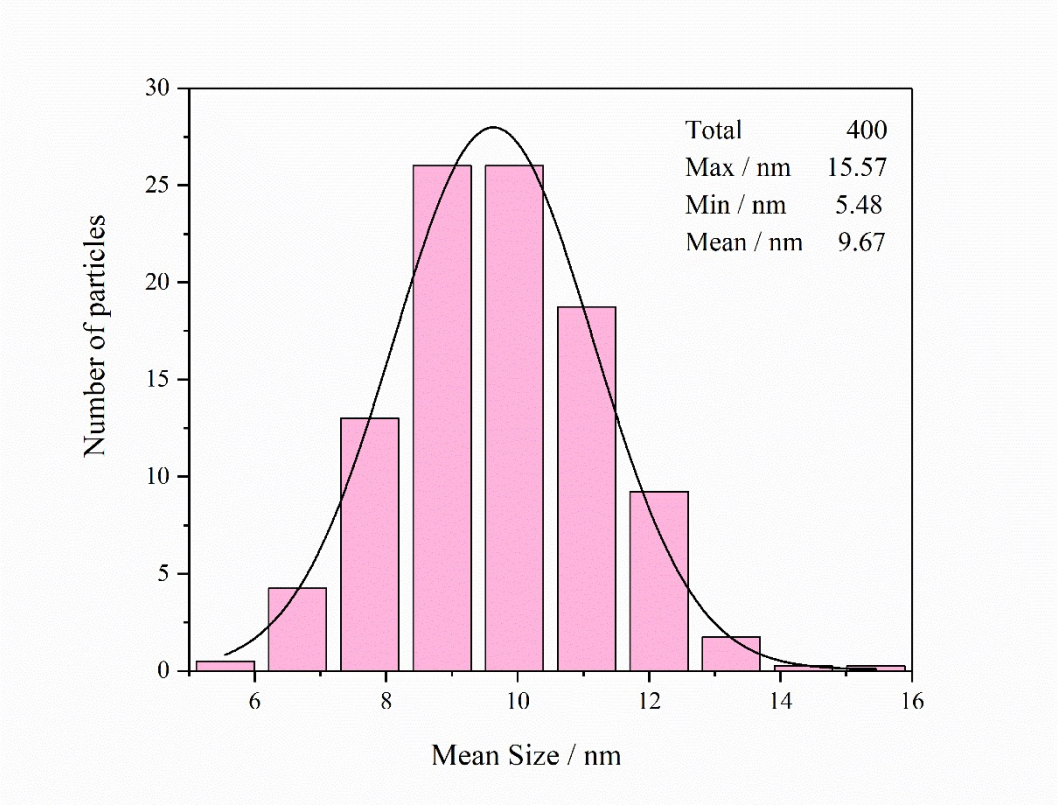

Figure S1. Histogram of the β-$NaGdF_4$: Yb/Er NPs size obtained under 12 mmol NaF, 15mL ODE, 15mL OA, at 290 °C for 1 h.

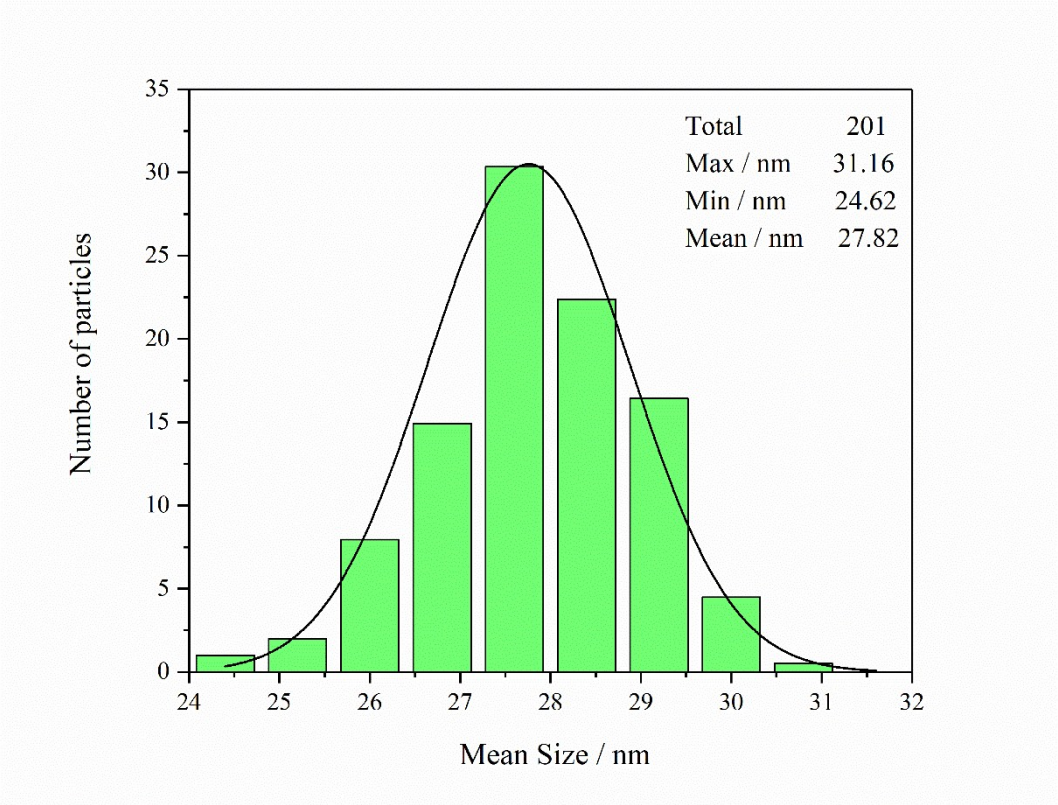

Figure S2. Histogram of the β-$NaYF_4$: Yb/Er NPs size obtained under 12 mmol NaF, 15mL ODE, 15mL OA, at 300 °C for 1.5 h.

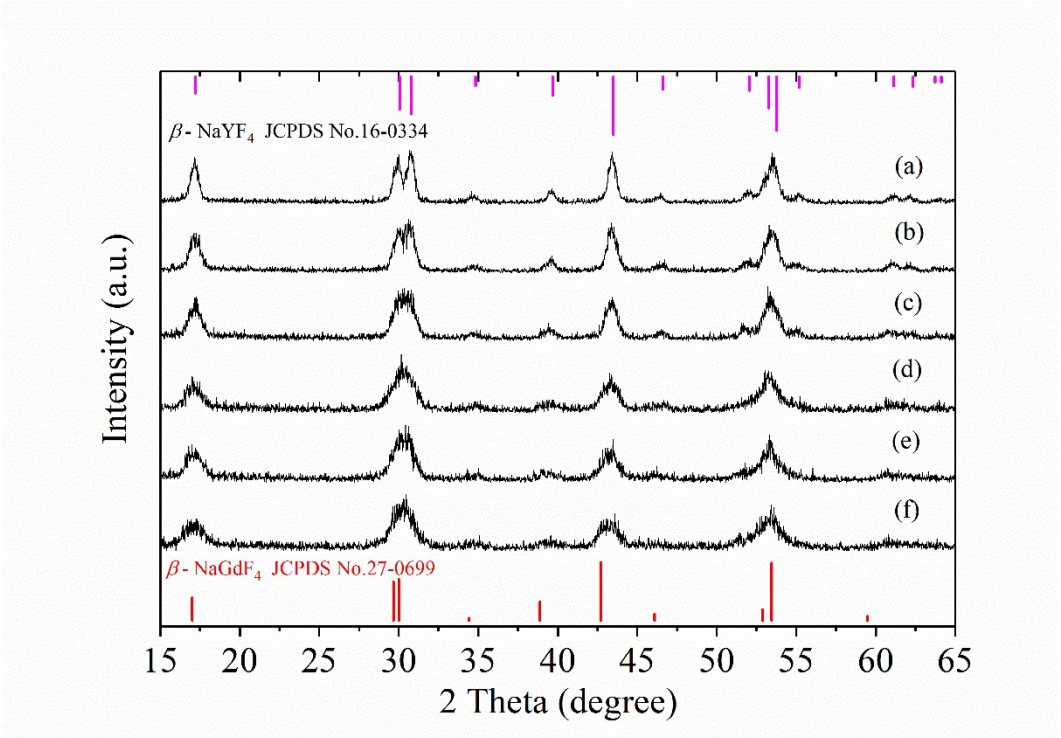

Figure S3. XRD patterns of β-$NaYF_4$: Yb/Er NPs synthesized under different Gd^{3+} doping concentration (a) 9 %, (b) 18 %, (c) 27 %, (d) 36 %, (e) 45 %, (f) 54 %.

Table S1. Effects of different Gd^{3+} doping concentration to size of β-$NaYF_4$: Yb/Er NPs.

Gd^{3+} doping concentrations	XRD Size / nm
9 %	14.44
18 %	10.74
27 %	9.13
36 %	7.03
45 %	6.25
54 %	4.61

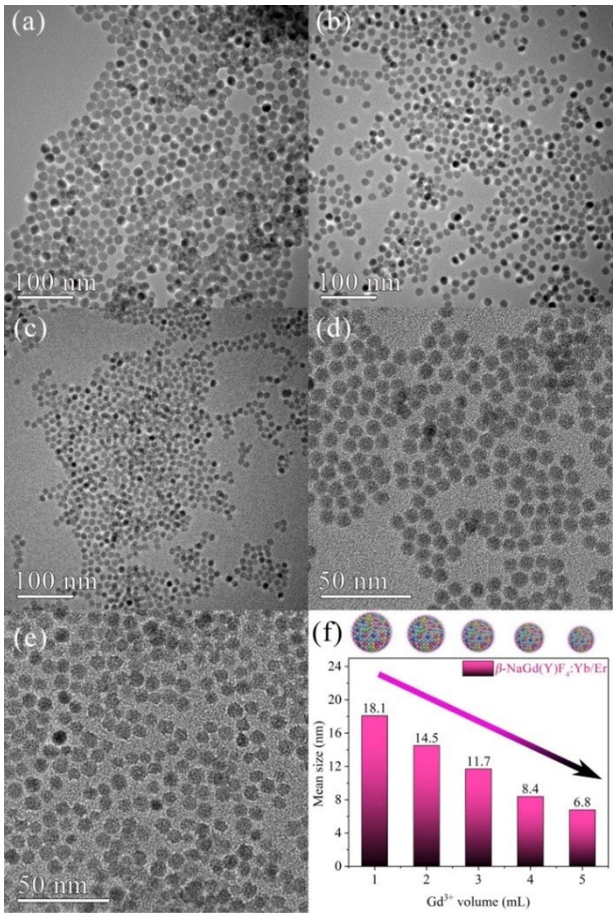

Figure S4. TEM images of $NaYF_4$: Yb/Er NPs synthesized under different Gd^{3+} doping concentration. (a) 9 %, (b) 18 %, (c) 27 %, (d) 36 %, (e) 45 %.

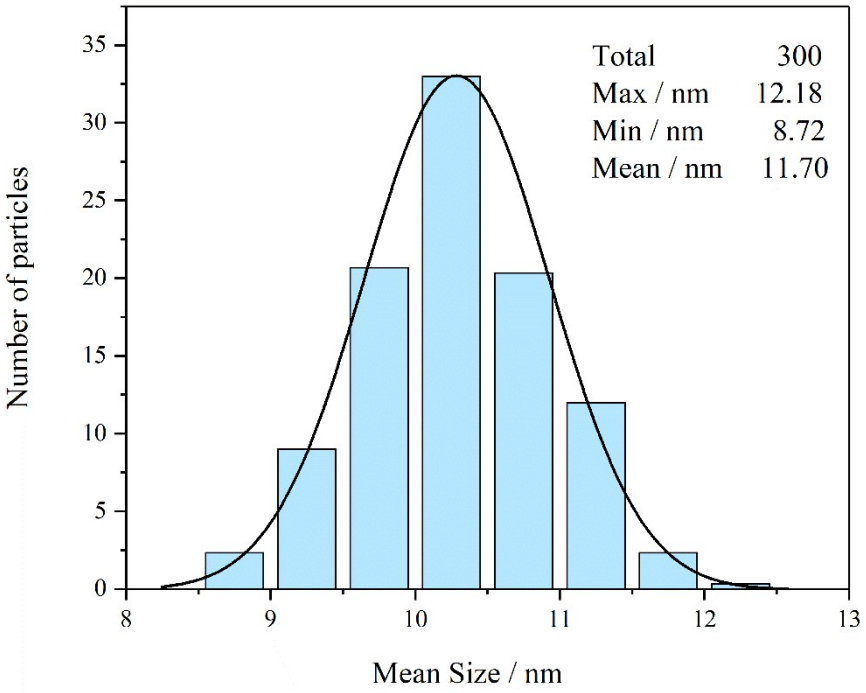

Figure S5. Histogram of the β-$NaYF_4$: 27 %Gd/Yb/Er NPs size obtained under 12 mmol NaF, 15mL ODE, 15mL OA, and 290 °C for 1 h.

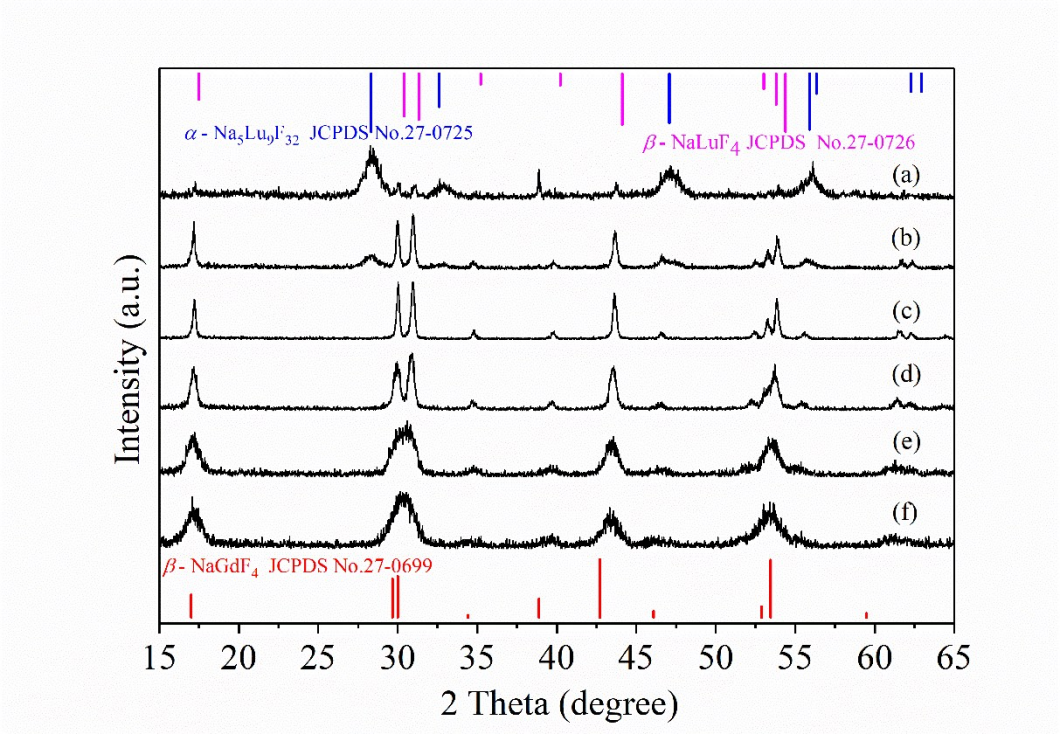

Figure S6. XRD patterns of $NaLuF_4$: Yb/Er NPs synthesized under different Gd^{3+} doping concentration (a) 9 %, (b) 18 %, (c) 27 %, (d) 36 %, (e) 45 %, (f) 54 %.

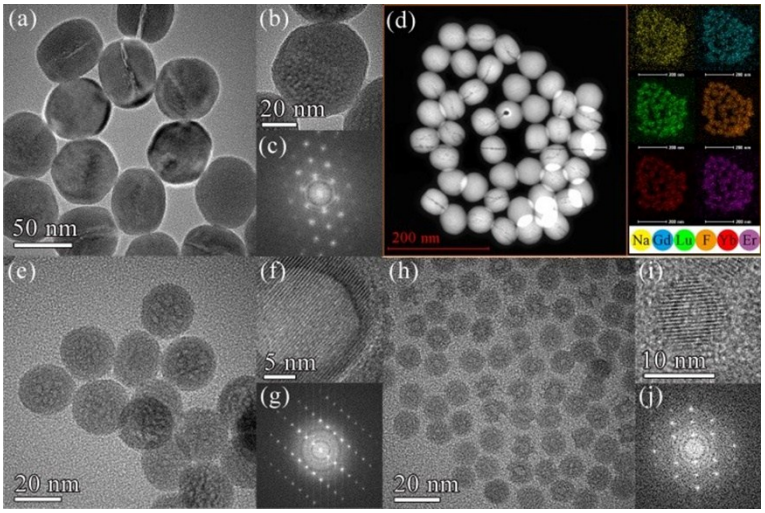

Figure S7. TEM, HRTEM, FFT, and elemental analysis images of $NaLuF_4$: Yb/Er NPs synthesized under different Gd^{3+} doping concentration (a), (b), (c), (d) 27 %; (e), (f), (g) 36 %; (h), (i), (j) 45 %.

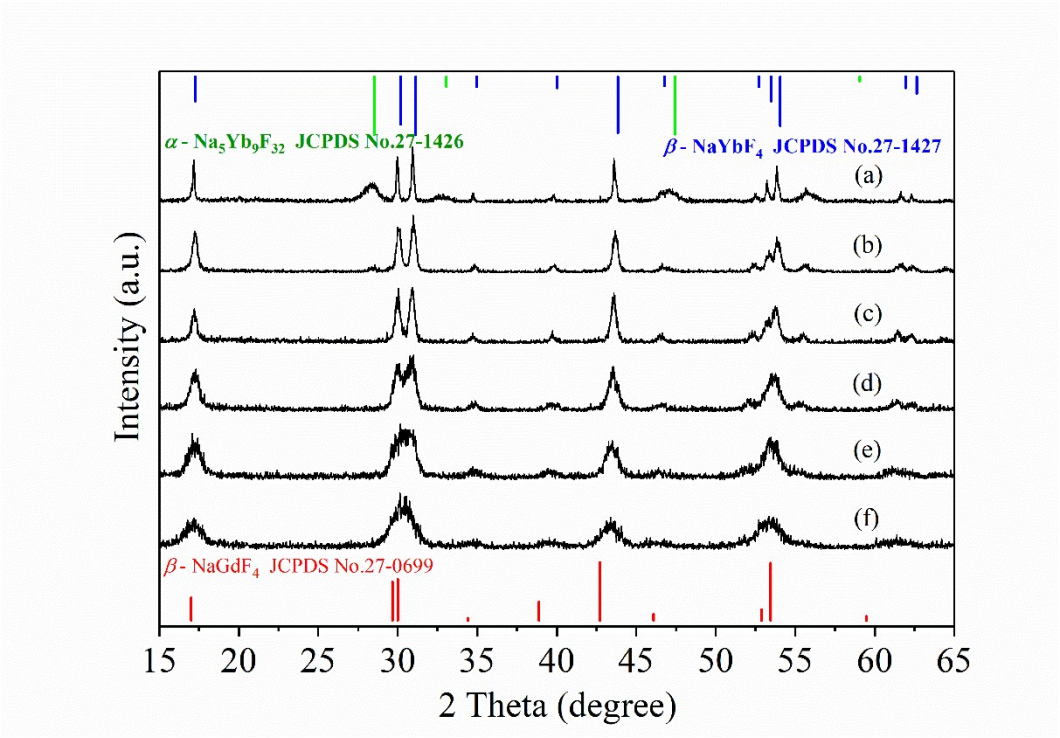

Figure S8. XRD patterns of $NaYbF_4$: Yb/Er NCs synthesized under different Gd^{3+} doping concentration (a) 9 %, (b) 18 %, (c) 27 %, (d) 36 %, (e) 45 %, (f) 54 %.

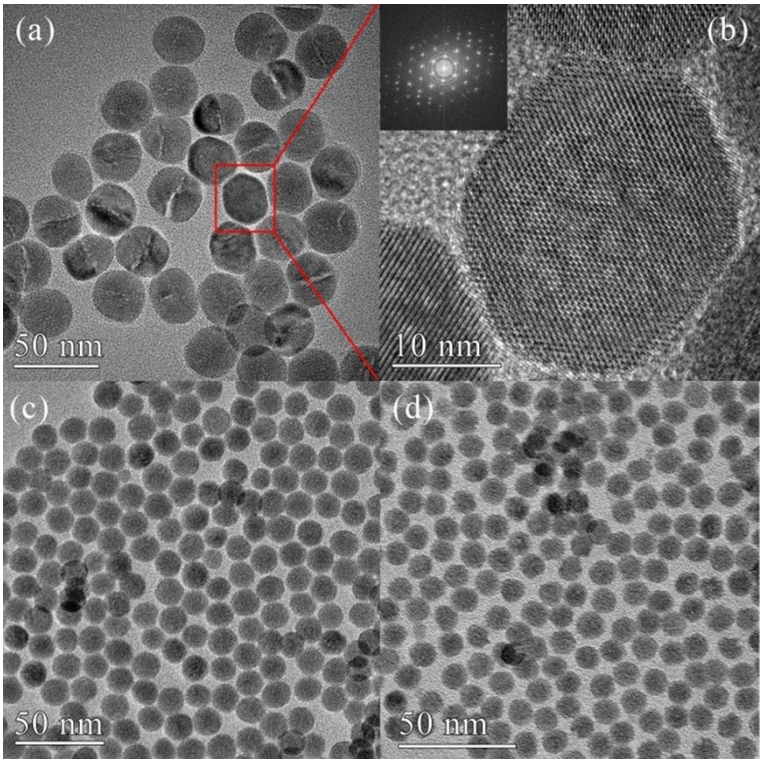

Figure S9. TEM, HRTEM and FFT image of $NaYbF_4$: Yb/Er NPs synthesized under different Gd^{3+} doping concentration (a) 27 %, (b) 27 %, (c) 36 %, (d) 45 %.

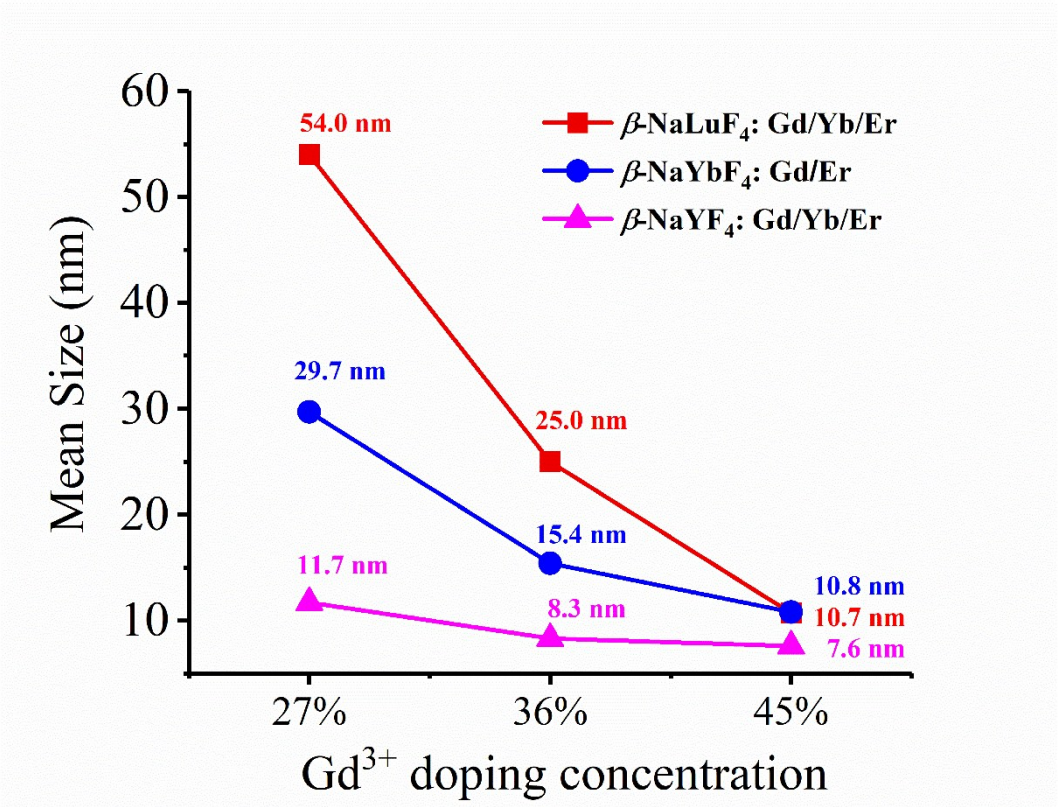

Figure S10. Size distribution of different Gd^{3+} doping concentration β-$NaLuF_4$: Gd/Yb/Er, β-$NaYbF_4$: Gd/Er and β-$NaYF_4$: Gd/Yb/Er.

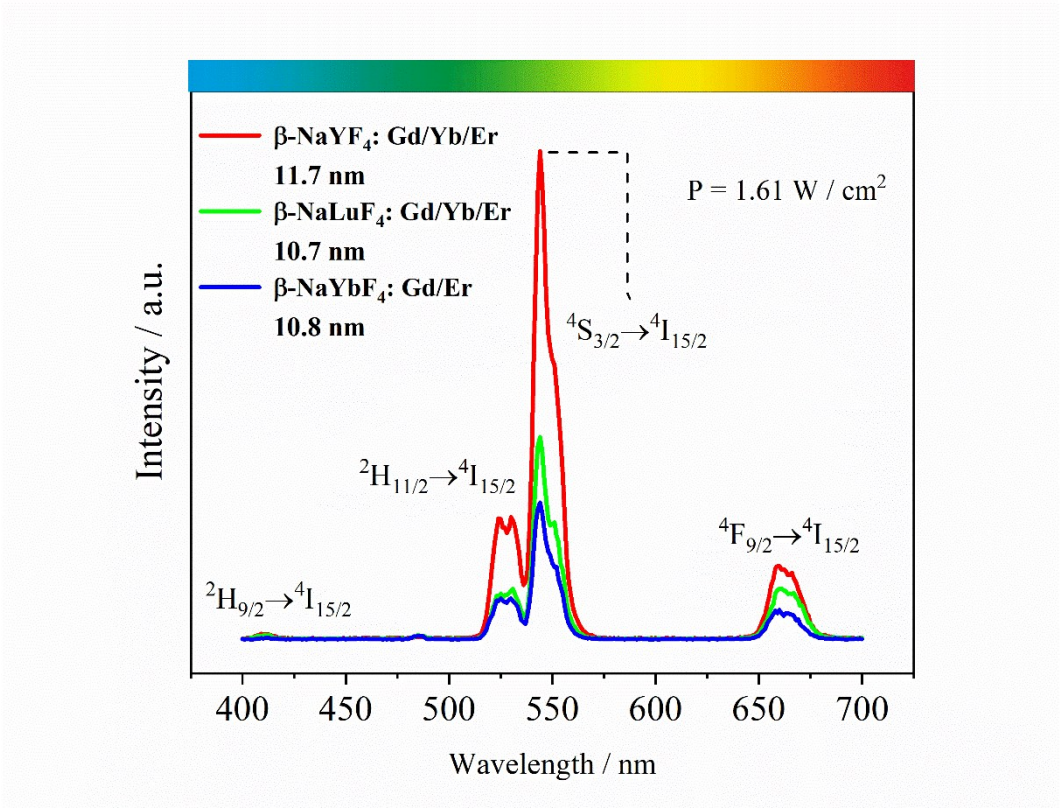

Figure S11. Room-temperature fluorescence emission spectra of similar size powder β-$NaYF_4$: Gd/Yb/Er, β-$NaLuF_4$: Gd/Yb/Er and β-$NaYbF_4$: Gd/Er NPs under the 980 nm laser diode excitation (1.61 W/cm^2).

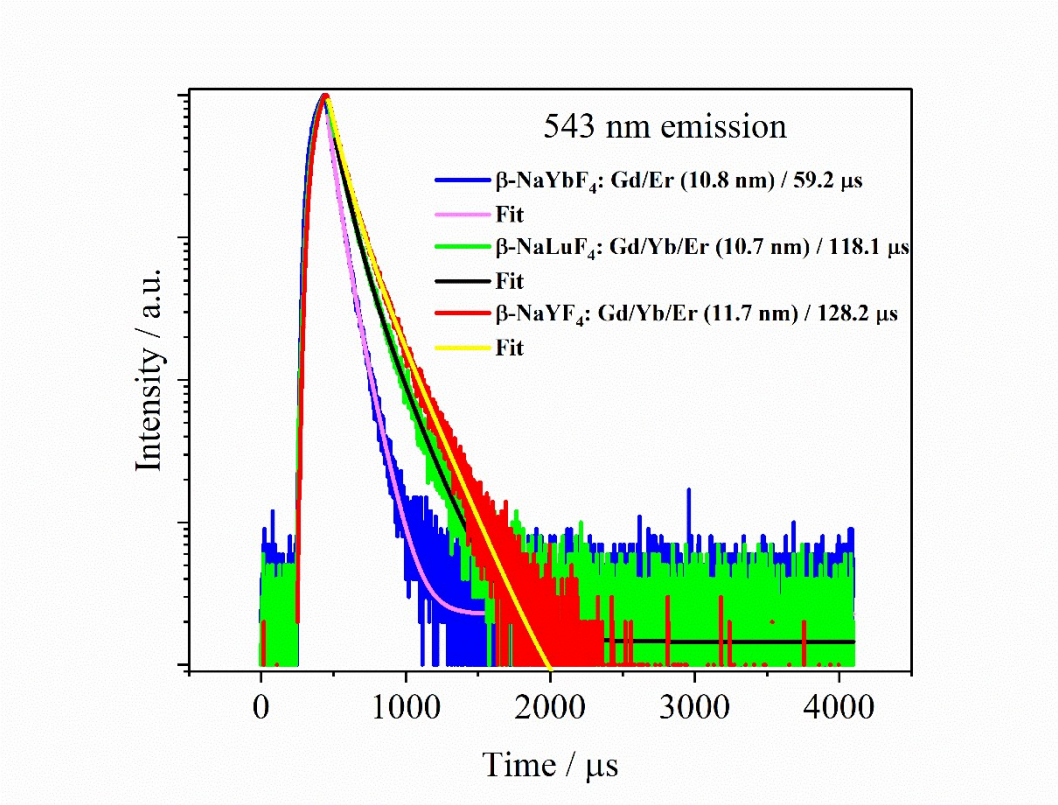

Figure S12. Decay curves of 543 nm ($^4S_{3/2}$ to $^4I_{15/2}$ transition of Er^{3+}) for similar size powder β-$NaYF_4$: Gd/Yb/Er, β-$NaLuF_4$: Gd/Yb/Er and β-$NaYbF_4$: Gd/Er NPs.

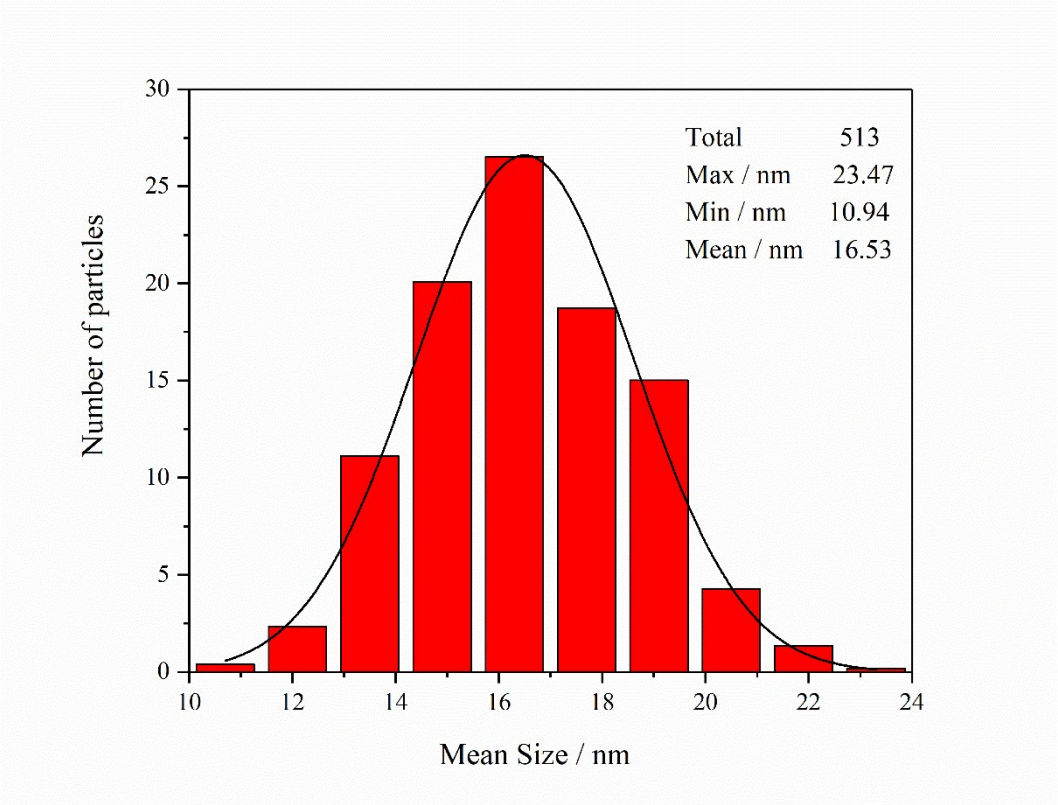

Figure S13. Histogram of the β-$NaGdF_4$: Yb/Er @ β-$NaYF_4$ core shell NPs size obtained under 12 mmol NaF, 15mL ODE, 15mL OA, and 290 °C for 1 h.

Table S2 Decay lifetime of typical upconveresion nanoparticles.

Sample	Phase	Average particle size(nm)	Power density (nm)	Lifetime (μs)	Ref.
$NaGdF_4$: Yb/Er@$NaYF_4$	Hexagonal	~16.5	980	448.6	This work
$NaGdF_4$: Yb/Er@$NaYF_4$	Hexagonal	14	980	253	[1]

Table S3 Absolute quantum yield of typical upconveresion nanoparticles.

Sample	Phase	Mean size (nm)	Power density (W/cm^2)	QY (%)	Ref.
$NaGdF_4$:Yb/Er@$NaYF_4$(powder)	Hexagonal	~16.5	0.3	0.22	This work
$NaGdF_4$:Yb/Er@$NaYF_4$(powder)	Hexagonal	11	2.5	0.051	[2]
$NaGdF_4$:Yb/Er@CaF_2(powder)	Hexagonal	16.6	25	3.7±0.4	[3]
$NaGdF_4$:Yb/Er@$NaGdF_4$(powder)	Hexagonal	16.0	25	2.6±1.4	[3]
$NaYF_4$:Yb/Er@$NaYF_4$(dispersion)	Hexagonal	30	150	0.3±0.1	[4]
$NaYF_4$:Yb/Tm@$NaYF_4$	Hexagonal	43	1.3	1.2	[5]

References

[1] Chen D, Huang P. *Dalton Transactions*, 2014, 43(29):11299.

[2] Lei L, Chen D, Huang P, et al. *Nanoscale*, 2013, 5(22):11298.

[3] H. Dong, L.D. Sun, L.D. Li, R. Si, R. Liu and C.H. Yan, *J. Am. Chem. Soc*, 2017, 139, 18492-18495

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[5] Xu C T, Svenmarker P, Liu H, et al. *ACS Nano*, 2012, 6(6):4788.