Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

Tailoring SWIR Emission in Tri-Lanthanide-Doped CaF_2 Nanoparticles

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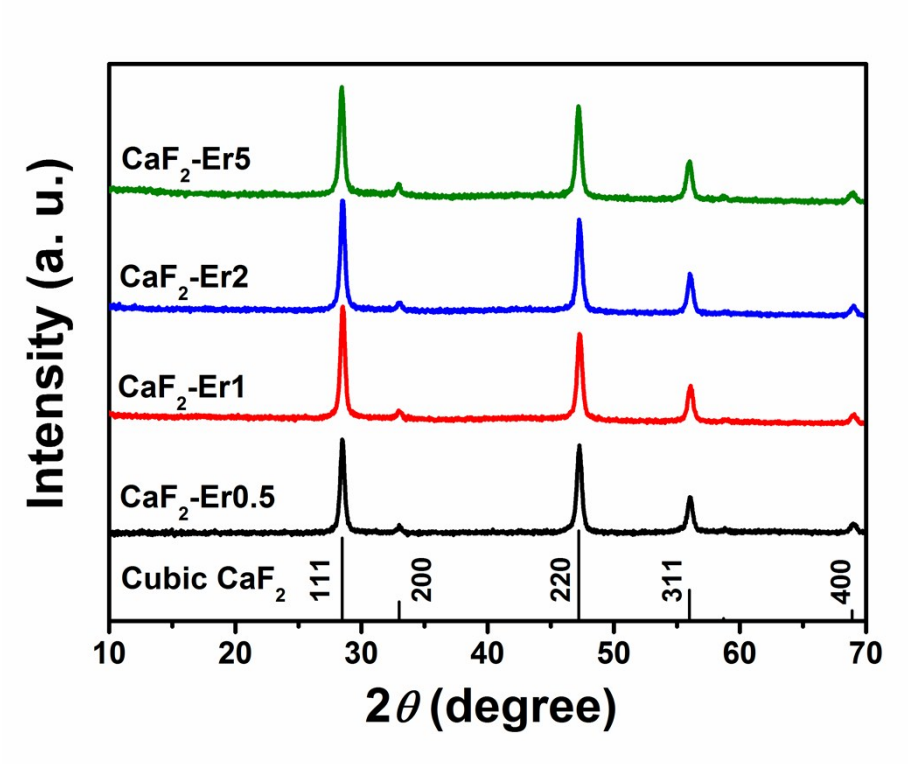

Figure S1. XRD patterns of CaF_2 nanoparticles with Yb dopant concentration 20 mol% synthesized using different Er concentrations ranging from 0.5 to 5 mol%. Reference powder diffraction files of cubic CaF_2 from JCPDS 35-0816 was used.

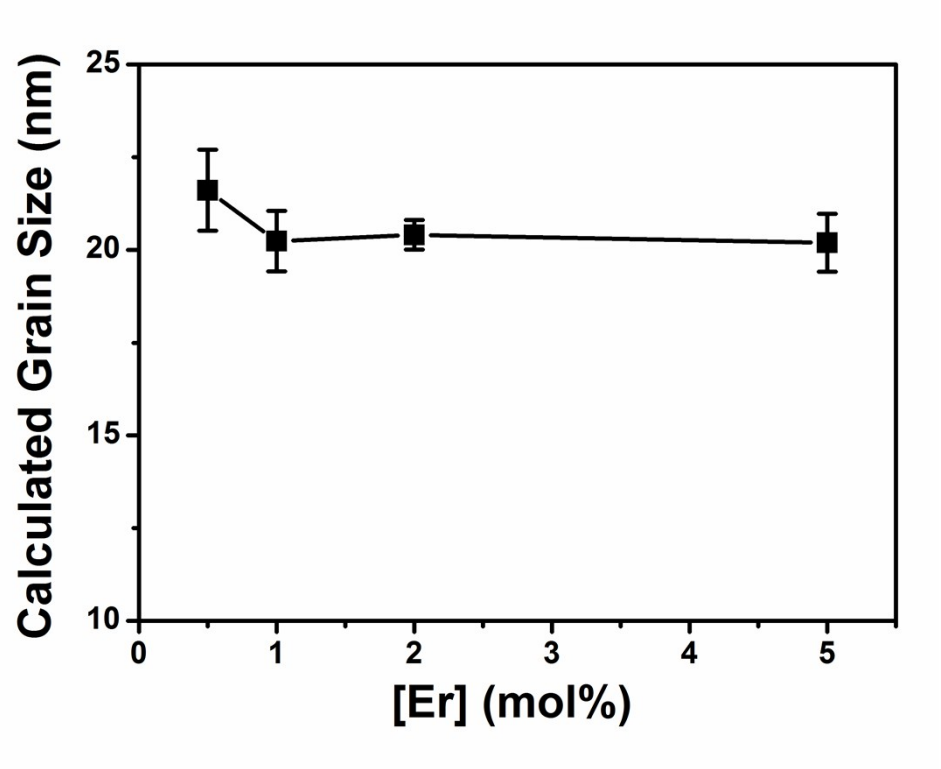

Figure S2. Estimated grain sizes using the Scherrer equation from XRD patterns of CaF_2:Yb,Er nanoparticles with Er doping concentration ranging from 0.5 to 5 mol%

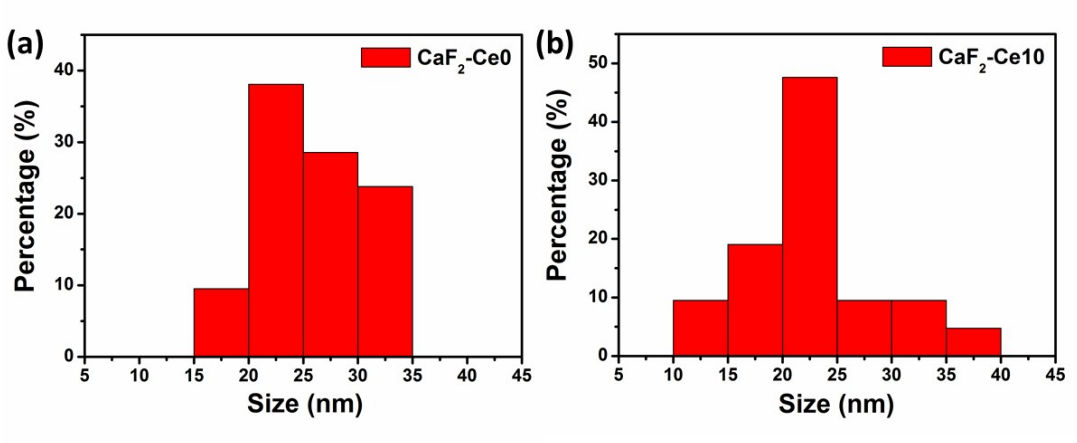

Figure S3. Size distributions of CaF_2-Ce0 (a) and CaF_2-Ce10 (b) samples measured by calculating 30 particles form TEM images. The average size of CaF_2-Ce0 and CaF_2-Ce10 samples are ~25.7±5.1 and ~23.0±5.5 nm.

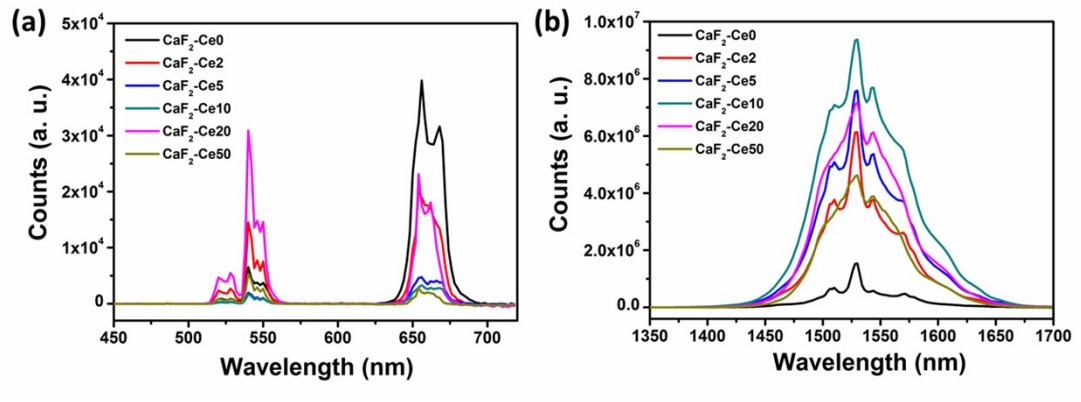

Figure S4. Up-converting visible (a) and down-shifting infrared emissions (b) of CaF_2:Yb,Er nanoparticles with Ce doping concentration ranging from 0 to 50 mol%.

Table S1. Atomic ratio of Ca, F and Ce element of CaF_2 nanoparticles calculated from EDX spectrum.

Sample	Ca	F	Ce
CaF_2:$Yb_{20}Er_2Ce_0$	1.00	2.94	0
CaF_2:$Yb_{20}Er_2Ce_{10}$	1.00	3.81	0.16

Table S2. Fitted decay constants of time resolved emission spectra at 1530 nm for CaF_2 nanoparticles using a double exponential equation.

Sample	A_1 (%)	τ_1 (μs)	Standard error	A_2 (%)	τ_2 (μs)	Standard error
$CaF_2:Yb_{20}Er_2Ce_0$	74.8	292.2	1.94	25.2	2300.3	11.35
$CaF_2:Yb_{20}Er_2Ce_2$	55.2	574.4	4.10	44.8	3014.9	10.67
$CaF_2:Yb_{20}Er_2Ce_5$	50.9	784.0	5.78	49.1	3826.5	14.60
$CaF_2:Yb_{20}Er_2Ce_{10}$	51.2	3883.0	14.66	48.8	810.2	6.41
$CaF_2:Yb_{20}Er_2Ce_{20}$	47.6	479.8	4.05	52.4	1916.2	5.90
$CaF_2:Yb_{20}Er_2Ce_{50}$	48.2	1461.9	5.36	51.8	400.9	3.40
$CaF_2:Er_2Ce_{10}Yb_{10}$	45	3953.0	15.50	55	771.8	5.17
$CaF_2:Er_2Ce_{10}Yb_{20}$	51.2	3883.0	14.66	48.8	810.2	6.41
$CaF_2:Er_2Ce_{10}Yb_{30}$	42.6	616.6	5.39	57.4	2606.0	7.60