Electronic Supporting Information for:

# Tuning the Upconversion Luminescence of Cubic $KMnF_3:Yb^{3+}/Er^{3+}$ Nanocrystals through Inert Lanthanide Ions Doping

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# Experimental section

## Materials

$YbCl_3 \cdot 6H_2O$ (99.99%), $ErCl_3 \cdot 6H_2O$ (99.99%), $GdCl_3 \cdot 6H_2O$ (99.99%), $YCl_3 \cdot 6H_2O$ (99.99%) were supplied by Beijing Founde Star Science and Technology Co., Ltd China. $MnCl_2$, KF, KOH, oleic acid (OA) at AR grade were obtained from Aladdin. All other chemicals were used without further purification.

## Typical preparation of $KMnF_3$ nanoparticles

$KMnF_3$:$Yb^{3+}$/$Er^{3+}$ nanoparticles were synthesized via a facile hydrothermal method by using oleic acid as capping agent. In a typical procedure, 1.5g KOH was dissolved in 3mL $H_2O$, then 6 mL $C_2H_5OH$ and 9 mL OA were mixed together to form a homogeneous viscous solution. A mixed aqueous solution contains 0.88 mmol $MnCl_2$, 0.10 mmol $YbCl_3$, 0.02 mmol $ErCl_3$ was subsequently added under intense stirring. 30 mins later, 5 mmol KF aqueous solution was added to the above solution. After another 1h strong stirring, the mixed solution was transferred to a 50 mL Teflon-lined autoclave, and then kept at 180 $^oC$ for 24h. When the reaction is over, the autoclave was cooling down to room temperature, and the products were obtained through centrifugation and washed with ethanol for several times.

## Characterizations

The morphology and size of the resulting nanoparticles were investigated by means of field emission scanning electron microscope (FESEM, MX2600FE, AIKE Sepp, Oxford, UK). The powder X-Ray diffraction (XRD) pattern was carried out on a Rigaku D/max-γB diffractometer equipped with a rotating anode and a Cu Kα source (λ=0.15418 nm). The 2θ angle of the XRD

spectra was recorded at a scanning rate of 5 °/min from 10° to 80°. The upconversion luminescence spectra were recorded using a lens-coupled monochromator (Zolix Instruments Co. Ltd, Beijing, China) of 1 nm spectral resolution with an attached photomultiplier tube (Hamamatsu CR131, Hamamatsu Photonics, Hamamatsu, Japan). An 842 nm short pass filter was placed before the spectrometer to cut off the excitation light.

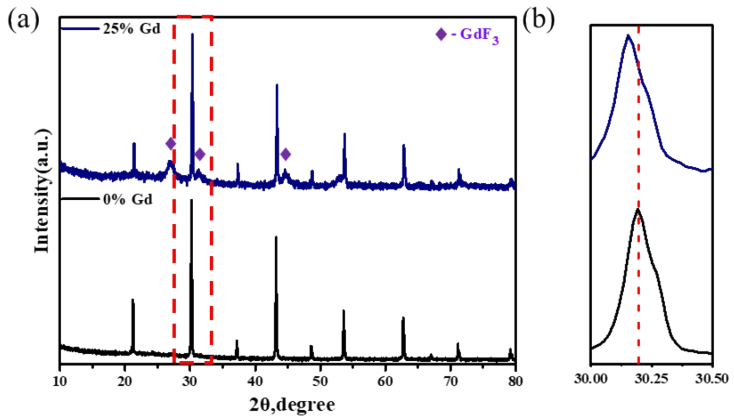


**Figure S1**. (a) and (b) the enlarged XRD patterns comparation of $KMnF_3$:10$Yb^{3+}$/2$Er^{3+}$ nanocrystals doped with 0% and 25% $Gd^{3+}$ ions.

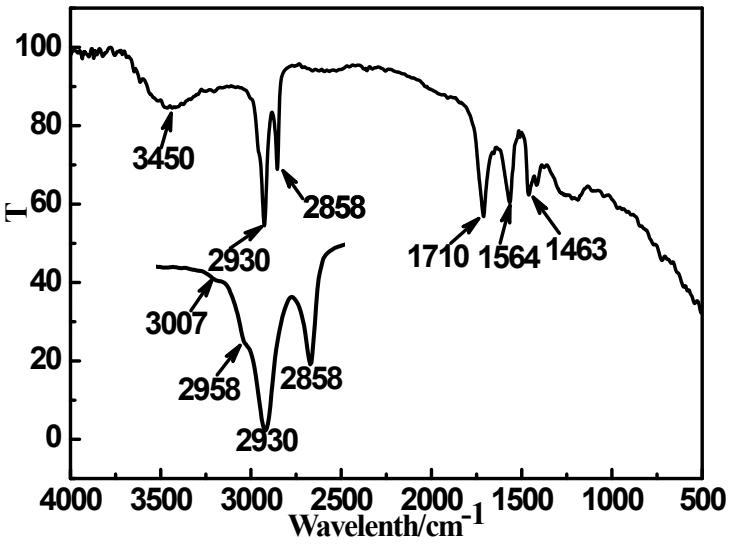


**Figure S2**. Fourier transform infrared (FTIR) patterns of $KMnF_3$:10$Yb^{3+}$/2$Er^{3+}$ nanoparticles. The surfactant layer around the nanoparticles is identified with Fourier transform infrared (FTIR) analysis.The band at 3450 $cm^{-1}$ arises from the O-H (COO-H) stretching vibration. The transmission bands at 2930 and 2858 $cm^{-1}$ are appreciable for the asymmetric (vas) and symmetric (vs) stretching vibration of methylene ($CH_2$). The peaks at 3007 $cm^{-1}$ and 1705 $cm^{-1}$ are assigned to the dC-H stretching vibration and CdO stretching vibration frequency, respectively. The bands at 1564 and 1463 $cm^{-1}$ can correspond to the asymmetric (vas) and symmetric (vs) stretching vibration of the carboxylic group (-COOH). This result suggests the

presence of a certain amount of oleic acid on the surface of cubic nanoparticles.

**Table S1**. Calculated CIE Chromaticity Coordinate (x, y) of $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$ nanoparticles with different $Gd^{3+}$ dopant

| Point | samples | CIE chromaticity coordinate | |
|---|---|---|---|
| | | *x* | *y* |
| a | $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$ | 0.6621 | 0.2847 |
| b | $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$/$5Gd^{3+}$ | 0.6126 | 0.3256 |
| c | $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$/$10Gd^{3+}$ | 0.4943 | 0.4402 |
| d | $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$/$15Gd^{3+}$ | 0.4756 | 0.4790 |
| e | $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$/$20Gd^{3+}$ | 0.4203 | 0.4996 |
| f | $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$/$25Gd^{3+}$ | 0.3332 | 0.6211 |

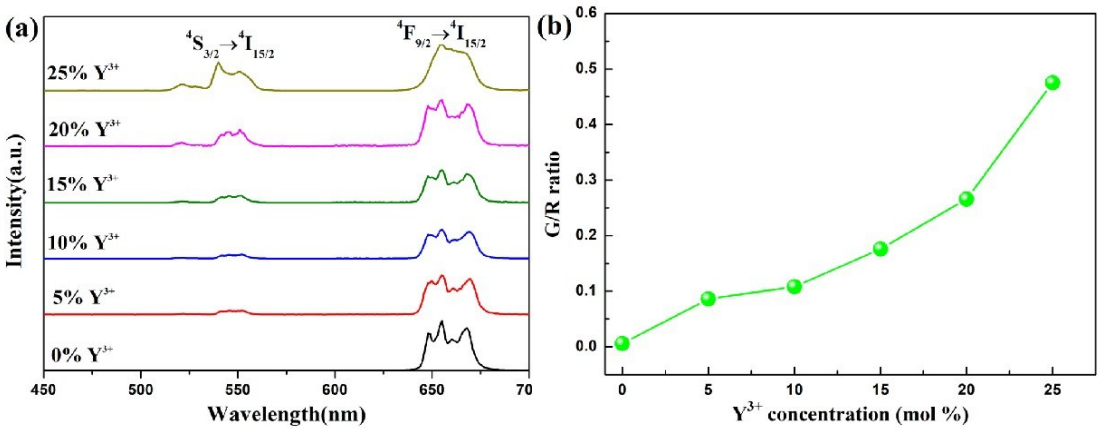


**Figure S3.** UC emission spectra (a) and G/R ratio (b) of $KMnF_3$:$10Yb^{3+}$/$2Er^{3+}$ with different $Y^{3+}$ doping concentrations.

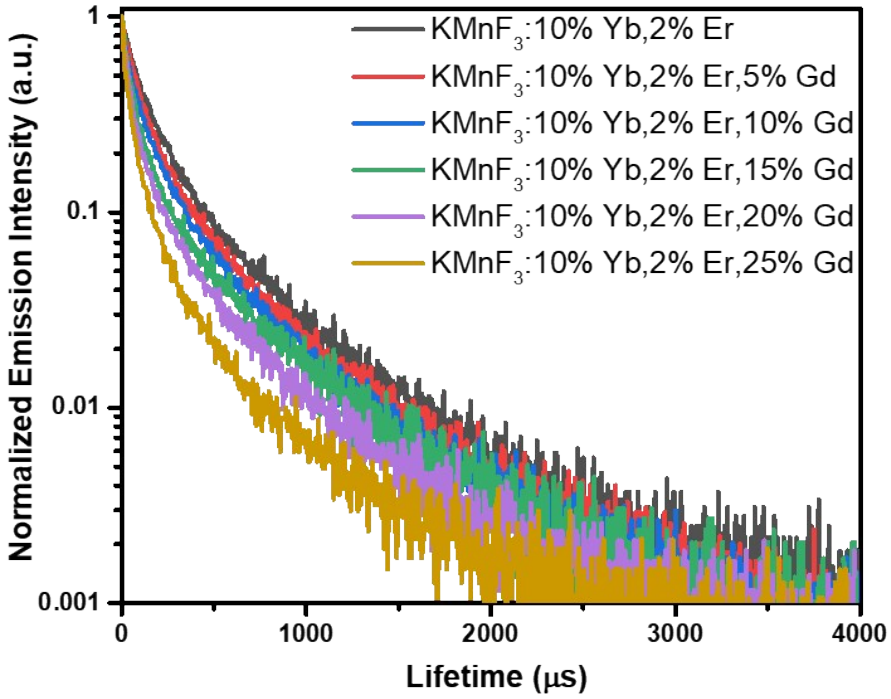


**Figure S4.** Decays of red upconversion emission at 660nm in $KMnF_3$:10$Yb^{3+}$/2$Er^{3+}$ nanocrystals with different concentration of $Gd^{3+}$ ions: 0% to 25% under the excitation of 980 nm laser.

**Table S2**. Cell edges and agreement factors of $KMnF_3$:10$Yb^{3+}$/2$Er^{3+}$ with different $Gd^{3+}$ doping concentrations by XRD define.

| Sample | a/b/c (Å) | Cell Volume (Å$^3$) | RF-factor |
|---|---|---|---|
| 0% Gd | 4.18781 | 73.44478 | 4.298 |
| 5% Gd | 4.18826 | 73.46845 | 2.683 |
| 10% Gd | 4.18838 | 73.47477 | 3.530 |
| 15% Gd | 4.18891 | 73.50267 | 3.359 |
| 20% Gd | 4.18937 | 73.52688 | 3.337 |
| 25% Gd | 4.19033 | 73.57744 | 5.932 |