Supporting Information

Polarization modulated upconversion luminescence: single particle
vs few-particle aggregate

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1. Experimental Section

Y(NO$_3$)$_3$·6H$_2$O (99.99%), Er(NO$_3$)$_3$·6H$_2$O (99.99%) were purchased from Ansheng Inorganic Materials Center (Ganzhou) in China. NaOH, NH$_4$F, NaF, HNO$_3$, sodium citrate, EDTA, ethanol, 1-octadecene (90%), and oleic acid (90%) were purchased from Sigma-Aldrich. All of the chemicals were used as starting materials without further purification.

1.1 Synthesis of NaYF$_4$: 5% Er nanodisks

NaYF$_4$: 5% Er nanodisks were prepared with a facile and mild hydrothermal process, in which pH value in the reaction system is critical external parameters for determining the architectural features of the β-NaYF$_4$ nanodisks.$^{1}$ In a typical synthesis, an aqueous solution (2.5 mL, 0.2 M) of Y(NO$_3$)$_3$·6H$_2$O and Er(NO$_3$)$_3$·6H$_2$O (lanthanide ions molar ratio, Y/Er = 95:5) was mixed with an aqueous solution of sodium citrate (22.5 mL, 2.08 M) under stirring for 30 min to form a white solution. Subsequently, aqueous solution (10 mL) of NaF (10 mL, 0.625 M) was added and stirred for 1 h, resulting in a complex with the lanthanide/ sodium citrate/ NaF molar ratio being 1/90/12. Then, HNO$_3$ was added to adjust the pH of the solution to 3. The obtained solution was then transferred into a 50 mL autoclave and hydrothermally treated at 180 °C for 2 h. After cooling to room temperature, products were separated by centrifugation and washed with ethanol for three times and then dried at 60 °C in vacuum.

1.2 Structural characterizations

X-ray diffraction (XRD) pattern of the dry powder was obtained on a RIGAKU D/Max 2550/PC diffractometer (Japan) with a slit of 0.02° at a scanning rate of 5° min$^{-1}$ using Cu K$_\alpha$ radiation ($\lambda$ = 1.5406 Å). Scanning Electron Microscopy (SEM) analysis was performed on a Field Emission Scanning Electron Microscopy (FESEM) (ZEISS SU-8010). High-resolution
Transmission Electron Microscopy (HRTEM) analysis was performed on a FEG-TEM (Tecnai G2 F30 S-Twin, Philips-FEI, Netherlands) operated at 300 kV.
2. Supplementary data

Fig. S1 Schematic diagram of luminescence spectrum test system.
**Fig. S2** A) AFM images of single nanodisk recorded for a single nanodisk in which the $a$ axis is parallel to the horizontal plane (HP). B) Polar plots of integrated UC luminescence intensity of single nanodisk as a function of excitation polarization angle for the transitions from $^2H_{11/2} \rightarrow ^4I_{15/2}, ^4S_{3/2} \rightarrow ^4I_{15/2}, ^4F_{9/2} \rightarrow ^4I_{15/2}$ of Er$^{3+}$, recorded at $a$ // HP and $E_{ex} // a$ axis @ $\theta = 0^\circ$. C) AFM images of single nanodisk recorded for a single nanodisk in which the $c$ axis is parallel to HP. D) Polar plots of integrated UC luminescence intensity of single nanodisk as a function of excitation polarization angle for the transitions from $^2H_{11/2} \rightarrow ^4I_{15/2}, ^4S_{3/2} \rightarrow ^4I_{15/2}, ^4F_{9/2} \rightarrow ^4I_{15/2}$ of Er$^{3+}$, recorded at $c$ // HP and $E_{ex} // c$ axis @ $\theta = 0^\circ$. 


**Fig. S3** A) UC luminescence spectra recorded at emission polarization angles of 0° - 360° for single nanodisk under conditions of $a$ // HP and $E_{ex}$ // $a$. B) Polar plots of integrated UC luminescence intensity as a function of emission polarization angle for the transitions from $^2H_{11/2}$ $\rightarrow$ $^4I_{15/2}$, $^4S_{3/2}$ $\rightarrow$ $^4I_{15/2}$, $^4F_{9/2}$ $\rightarrow$ $^4I_{15/2}$ of Er$^{3+}$ for single nanodisk under configurations of $a$ // HP and $E_{ex}$ // $a$. C) UC luminescence spectra recorded at emission polarization angles of 0° - 360° for single nanodisk under conditions of $a$ // HP and $E_{ex}$ // [100]. D) Polar plots of integrated UC luminescence intensity as a function of emission polarization angle for the transitions from $^2H_{11/2}$ $\rightarrow$ $^4I_{15/2}$, $^4S_{3/2}$ $\rightarrow$ $^4I_{15/2}$, $^4F_{9/2}$ $\rightarrow$ $^4I_{15/2}$ of Er$^{3+}$ for single nanodisk under configurations of $a$ // HP and $E_{ex}$ // [100].
**Fig. S4** A) UC luminescence spectra recorded at emission polarization angles of 0° - 360° for single nanodisk under conditions of $c \parallel$ HP and $E_{ex} \parallel c$. B) Polar plots of integrated UC luminescence intensity as a function of emission polarization angle for the transitions from $^2H_{11/2} \rightarrow ^4I_{15/2}$, $^4S_{3/2} \rightarrow ^4I_{15/2}$, $^4F_{9/2} \rightarrow ^4I_{15/2}$ of Er$^{3+}$ for single nanodisk under configurations of $c \parallel$ HP and $E_{ex} \parallel c$. 
Fig. S5 A) UC luminescence spectra of the aggregated nanodisks recorded under emission polarization angle varied from 0° to 360°. C) The dependence of UC luminescence intensity of the aggregated nanodisks with different transitions of Er³⁺ on the emission polarization angle.
Reference