Supporting Information

Upconversion NaLuF$_4$ fluorescent nanoprobes for jellyfish cell imaging and irritation assessment of organic dyes

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Scheme S1. Detailed schematic illustration of jellyfish imaging after incubated with basic organic dyes using UCNPs as probes.
**Figure S1.** XRD results from the synthesized NaLuF$_4$:Yb/Er doped with 0%Zn$^{2+}$, 5%Zn$^{2+}$, respectively. The diffraction peaks of the hexagonal phase are marked by snowflake symbol.
**Figure S2** EDX spectrum of NaLuF$_4$:18%Yb/2%Er/4%Zn nanoparticles.
Figure S3. TEM images of NaLuF$_4$:18%Yb$^{3+}$/2%Er$^{3+}$/xZn$^{2+}$ nanocrystals doped with (a) 0%; (b) 1%; (c) 5%; (d) 8% Zn$^{2+}$, and (i) 4% Zn$^{2+}$; the corresponding high-resolution TEM images of (a-d, i) was shown in (e-h, j), respectively.
Figure S4. Upconversion fluorescence spectra (a and b) of the NaLuF₄:Yb³⁺,Er³⁺ (Tm³⁺), and PEG coated NaLuF₄:Yb³⁺,Er³⁺ (Tm³⁺) nanoparticles. The excitation was a 800 mW 980 nm NIR laser. Insets: pictures of cyclohexane colloidal dispersions for Yb³⁺/Er³⁺ (upper picture) and Yb³⁺/Tm³⁺ (lower picture) codoped NaLuF₄, in sunlight and upon laser excitation at 980 nm.
Figure S5. FT-IR spectra of unmodified UCNPs and PEG-UCNPs, respectively.
Figure S6. Schematic energy level diagram of upconversion excitation and emission processes.
Figure S7. Fluorescence cell imaging of jellyfish after incubated with NaLuF₄:Yb³⁺/Er³⁺ UCNPs in bright field (a), and excited by a 980 nm NIR laser with different excitation powers: (b) 0.34; (c) 0.55; (d) 0.75; (e) 1.01 and (f) 1.23 W.
Figure S8. *In vivo* conventional optical images of jellyfish after subcutaneously injected with 20 ul Rhodamine B for various time. Concentration of Rhodamine B equals to (a) 2.5 mg/ml; (b) 0.25 mg/ml; (c) 0.05 mg/ml; (d) 0.01 mg/ml.
Figure S9. *In vivo* conventional optical images of jellyfish after subcutaneously injected with 20 ul sodium fluorescein for various time. Concentration of sodium fluorescein equals to (a) 2.5 mg/ml; (b) 0.25 mg/ml; (c) 0.05 mg/ml; (d) 0.01mg/ml.
Supplementary discussion

Part I: jellyfish cell imaging

**Figure S10.** *In vivo* cell imaging of jellyfish in bright field (a), in vitro cell images of jellyfish by enlarging 500×(b), 1000×(c).

In this work, the jellyfish cells before incubation with dyes was observed first by using Olympus BX43 fluorescence microscopy in bright field, as shown in Figure S10a-c. Figure S10a showed that clear jellyfish cell cytoskeleton and some ambiguous cells were simultaneously imaged *in vivo*, it can be ascribed for the different focal length from cells to lens in the transparent living jellyfish body. When the jellyfish body was cut into ultra-thin slices, almost all cells can be imaged clearly in vitro (Figure S10b and Figure S10c).

The irritation of UCNPs for jellyfish cell was also investigated when incubated for different time and shown in **Figure S11**. It can be observed that the size and morphology of cells almost remain unchangeable when incubation time was increased to 5 hours, which indicated that the prepared NaLuF₄ nanoparticles showed low irritation on the living cells.
**Figure S11.** Right column: *In vitro* fluorescence microscope cell imaging of jellyfish slices after incubated with UCNPs for (a) 1 h; (b) 2 h; (c) 5 h. **Left column:** conventional slice transmission imaging of jellyfish.

**References**


