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Supplementary information of

Nanosecond kinetics of multiphoton upconversion in an optically trapped single microcrystal

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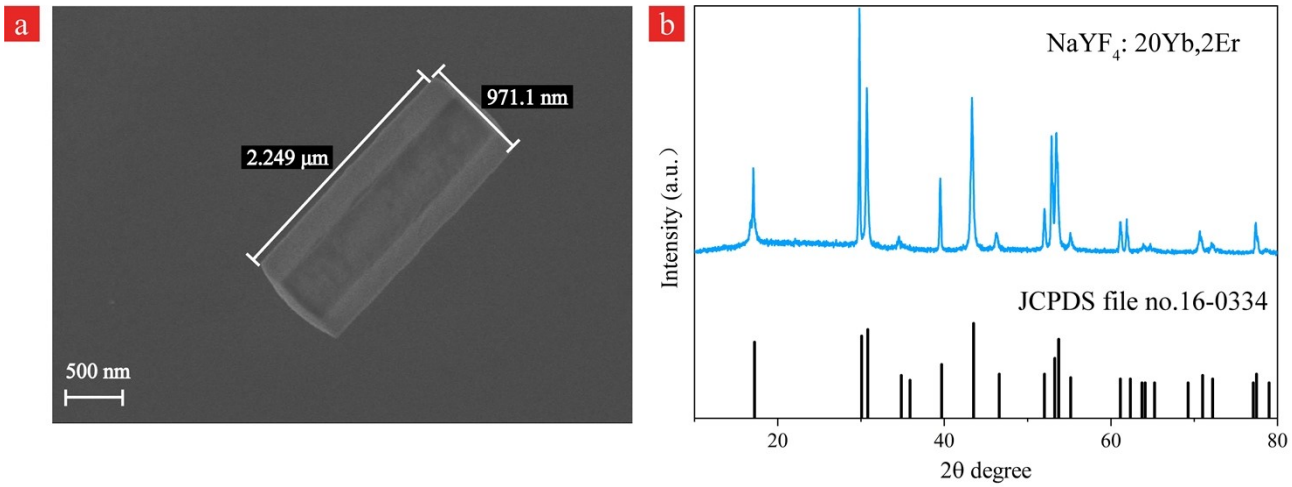

Fig. S1 (a) SEM micrographs of β-$NaYF_4$: Yb/Er (20/2%) microcrystals. (b) XRD patterns of the β-$NaYF_4$:Yb/Er (20/2%) microcrystals compared to the known peaks of the hexagonal phase of $NaYF_4$.

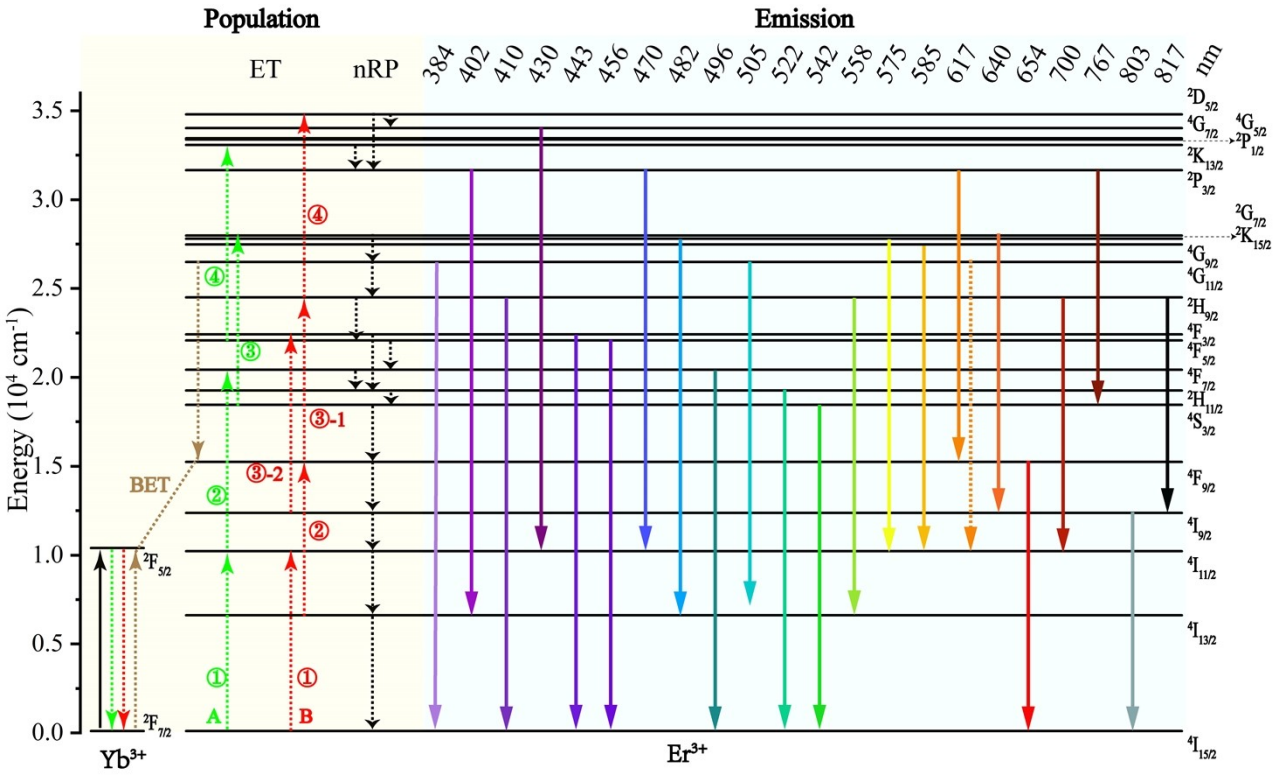

Fig. S2 Energy level scheme of the Yb^{3+}– Er^{3+} ions under 976 nm excitation. The population processes, non-radiative transitions, radiative transitions of the Er^{3+} ions are also provided.

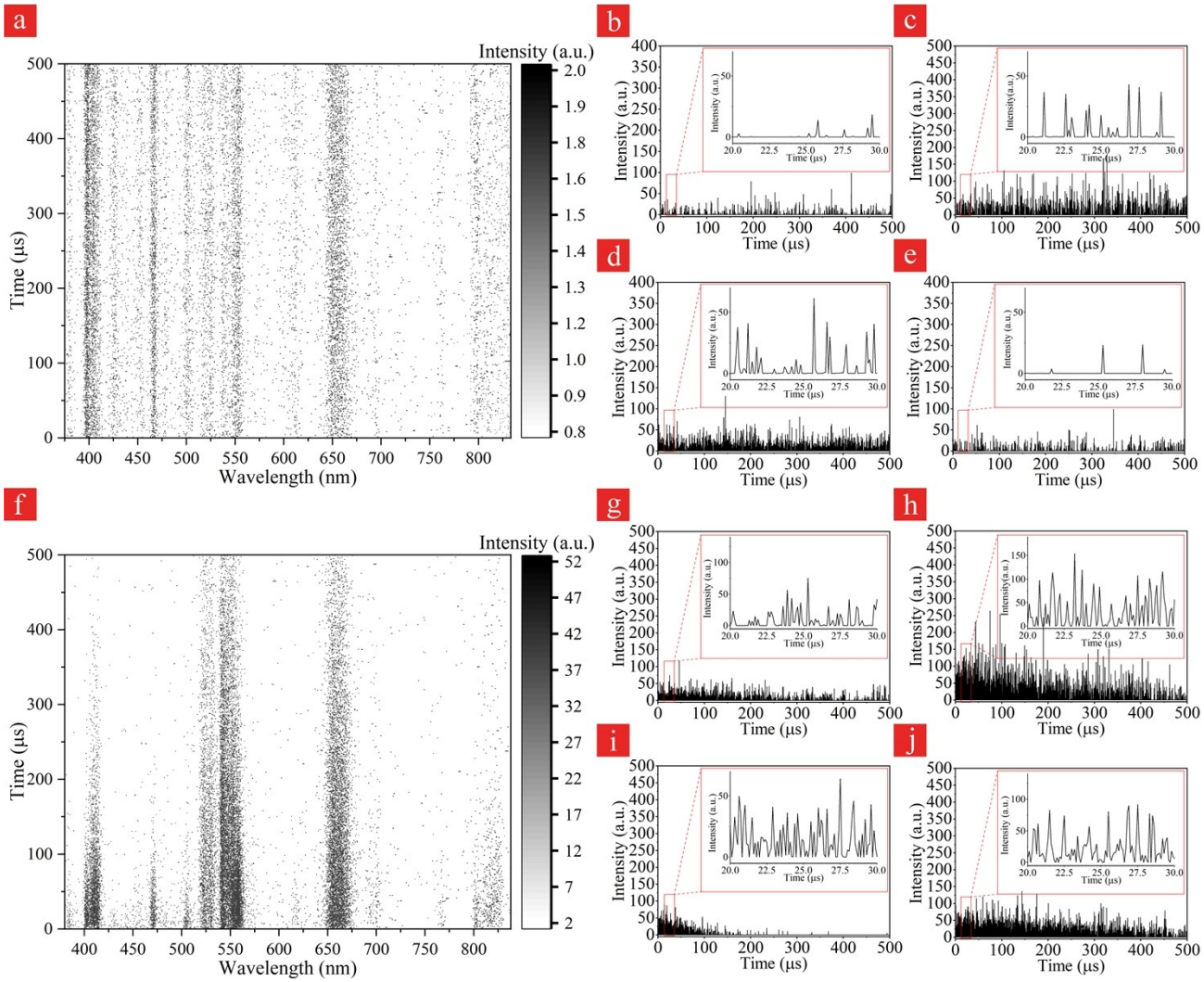

Fig. S3 Temporal spectra within 500 μs of different excitation. The spectra are acquired by a gate width with an integration time of 100 ns. The wavelength resolution of the spectra is 0.21 nm. (a) Temporal spectra under continuous excitation. (b-e) Time trace of UCL under continuous excitation with a different central wavelength and the bandwidth is 6 nm. (f) Temporal spectra under pulsed excitation. For nanosecond pulse excitation, the 0 moment is the time of the pulse excitation. (g-j) Time trace of UCL under pulsed excitation with a different central wavelength and the bandwidth is 6 nm.

Table S1 Comparison of the luminescence lifetimes for Er^{3+} doped in different host.

Transitions	λ_{em} (nm)	Lifetime (ms)			
		Er/Yb-codoped phosphate glass[1]	Er^{3+}-doped fluoride glass[2]	Er/Yb-codoped $NaY(WO_4)_2$ crystal[3]	Our work
$^4F_{9/2}\rightarrow{}^4I_{15/2}$	654	0.88	0.938	0.26	0.175
$^4S_{3/2}\rightarrow{}^4I_{15/2}$	542	0.56	0.949	0.329	0.269
$^2H_{11/2}\rightarrow{}^4I_{15/2}$	522	0.12	0.265	0.0241	0.172
$^4G_{11/2}\rightarrow{}^4I_{15/2}$	384		0.072	0.0067	0.026
$^4G_{11/2}\rightarrow{}^4I_{13/2}$	505				0.023
$^2H_{9/2}\rightarrow{}^4I_{13/2}$	410		0.4	0.108	0.084
$^2H_{9/2}\rightarrow{}^4I_{13/2}$	558				0.081
$^2P_{3/2}\rightarrow{}^4I_{13/2}$	402				0.043
$^2P_{3/2}\rightarrow{}^4I_{11/2}$	470				0.041

Notes and references

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