Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Crystallization and Concentration Modulated Tunable Upconversion Luminescence of Er^{3+} Doped PZT Nanofibers

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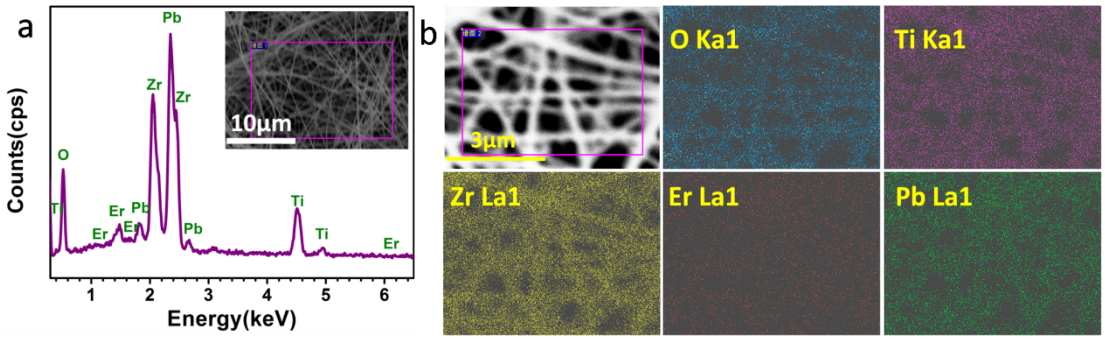

Figure S1 (a) Energy dispersive spectroscopy (EDS) spectrum and (b) elemental mapping of PZT:4Er nanofibers calcined at 800 °C.

Element	wt%	atom%
O K	20.99	67.38
Ti K	7.55	8.10
Zr L	21.19	11.93
Er L	2.30	0.71
Pb M	47.96	11.89
Total	100.00	

Table S1 The EDS elemental quantification of PZT:4Er nanofibers calcined at 800 °C.

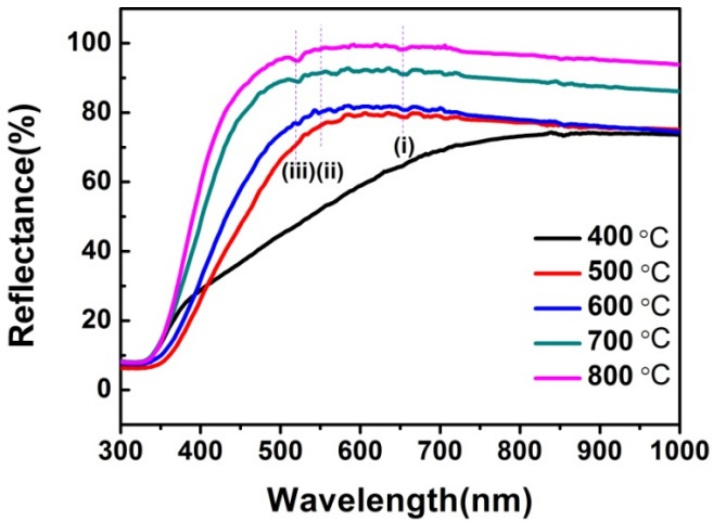

Figure S2 Diffuse reflectance spectra of PZT:4Er nanofibers calcined at 400-800 °C: (i) $^4I_{15/2}\rightarrow{}^4F_{9/2}$; (ii) $^4I_{15/2}\rightarrow{}^4S_{3/2}$; (iii) $^4I_{15/2}\rightarrow{}^2H_{11/2}$.

The dependence of emission intensity (I) depends on the excitation power (P), can be described by the power law $I=AP^n$ (A is a constant). [*W. B. Niu, et al., Dalton. T, 2011, 40, 3305.*]The number of pumping photons (n) required to give the UC emissions can be obtained from the slope of the fitted line of the plot of log(I) *versus* log(P). The experimental data for the 524, 550, and 660 nm emission of PZT:2Er nanofibers were fitted with a straight line with a slope of ~2 (Fig. S3b), indicating that two-photon processes are involved in the upconversion luminescence [*L. H. Luo, et al., J. Appl. Phys., 2013, 114.*].

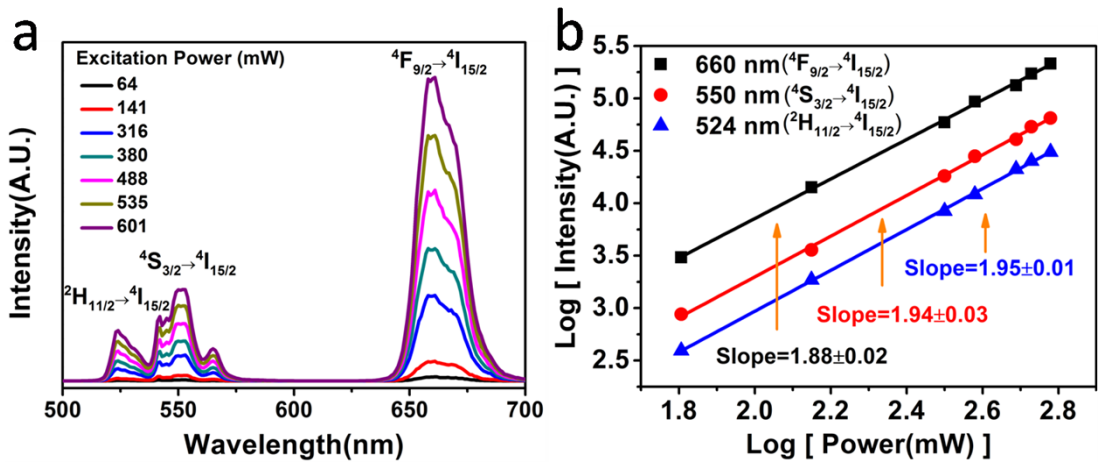

Figure S3 (a) The upconversion spectra under different pump power by excitation at 980 nm at room temperature; and (b) log-log diagrams of green and red upconversion emission intensity vs. pump power of PZT:2Er nanofibers calcined at 800 °C.

The decay curves are fitted using double exponential function (eq.1), and the lifetimes given in Table. S2 are determined by eq. 2 using the lifetimes derived from the fitting (Fig. S4c, d and e).

$$I(t) = \alpha_1 * \exp(-\frac{t}{\tau_1}) + \alpha_2 * \exp(-\frac{t}{\tau_2}) + I_0 \quad (1)$$

Where α_1 and α_2 are pre-exponential factors representing the fractional contribution to the time-resolved decay of the component with a lifetime τ_1 and τ_2, I is the luminescence intensity.

$$\tau = \frac{\alpha_1\tau_1^2 + \alpha_2\tau_2^2}{\alpha_1\tau_1 + \alpha_2\tau_2} \quad (2)$$

Where α_1, α_2 are the amplitude and τ_1, τ_2 are the lifetimes corresponding to the level depopulation channels, respectively. The τ is the average lifetime.

The decay times of the green ($^2H_{11/2}$, $^4S_{3/2}$) and red ($^4F_{9/2}$) excited states under excitation at 980 nm is much longer than that obtained by excitation of 488 nm. Evidence of ETU is provided by lengthened emission lifetimes by 980 nm excitation compared to those obtained by direct excitation of the $^4F_{7/2}$ excited state with 488 nm. These results suggest that the energy transfer mechanism might be account for the UC emission in the examined materials, and the same mechanism has also been documented in different Er doped materials [*e.g., F. Vetrone, et al., Chem. Mater., 2003, 15, 2737; J. A. Capobianco, et al., Phys. Chem. Chem. Phys., 2000, 2, 3203.*].

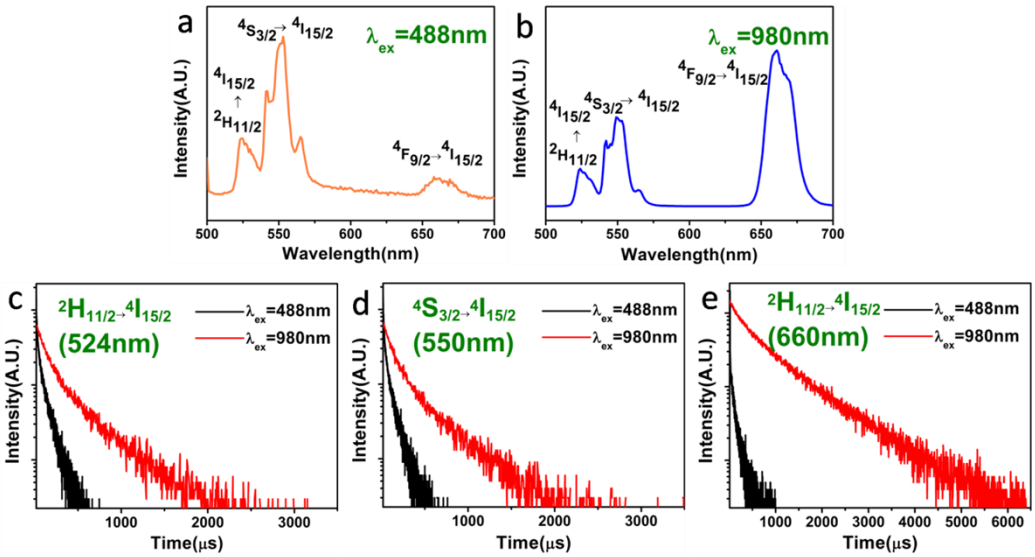

Figure S4 The emission spectrum upon (a) 488nm and (b) 980nm excitation of PZT:2Er nanofibers calcined at 800 °C; Decay curves of (c) $^2H_{11/2}\rightarrow{}^4I_{15/2}$, (d) $^4S_{3/2}\rightarrow{}^4I_{15/2}$ and (e) $^4F_{9/2}\rightarrow{}^4I_{15/2}$ transitions upon 488 and 980 nm excitation.

Transition	λ_{ex}=488 nm	λ_{ex} =980 nm
$^2H_{11/2}\rightarrow{}^4I_{15/2}$	90.5	282.1
$^4S_{3/2}\rightarrow{}^4I_{15/2}$	85.3	286.7
$^4F_{9/2}\rightarrow{}^4I_{15/2}$	86.5	752.5

Table S2 Decay times (μs) obtained from a double exponential fit function of the room temperature decay curves for different transitions upon 488 nm and 980 nm excitation.