Supplementary Information

Ultrahigh-sensitive optical temperature sensing based on quasi-thermalized green emissions from Er:ZnO

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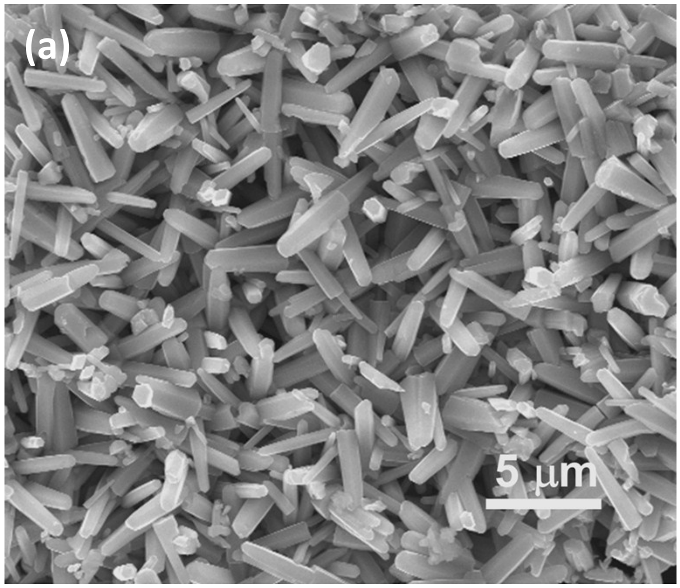

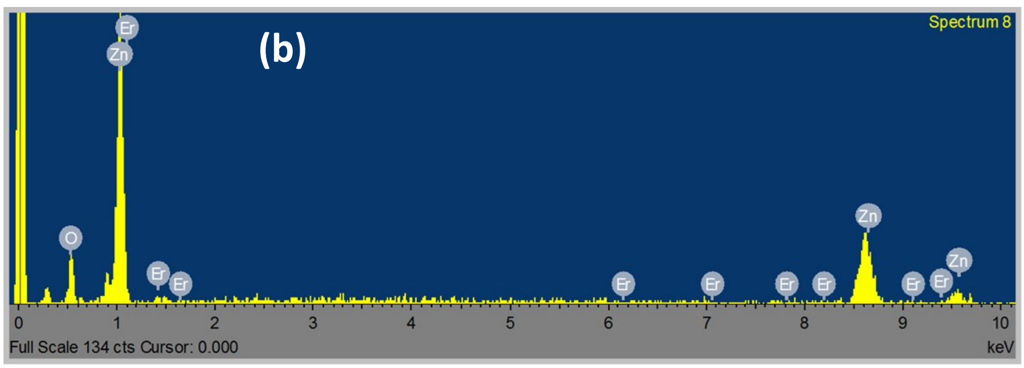

Figure S1. (a) FESEM image of Er:ZnO micro rods for Er-0.005 and (b) corresponding EDX spectrum representing presence of Zn, O and Er in the sample.

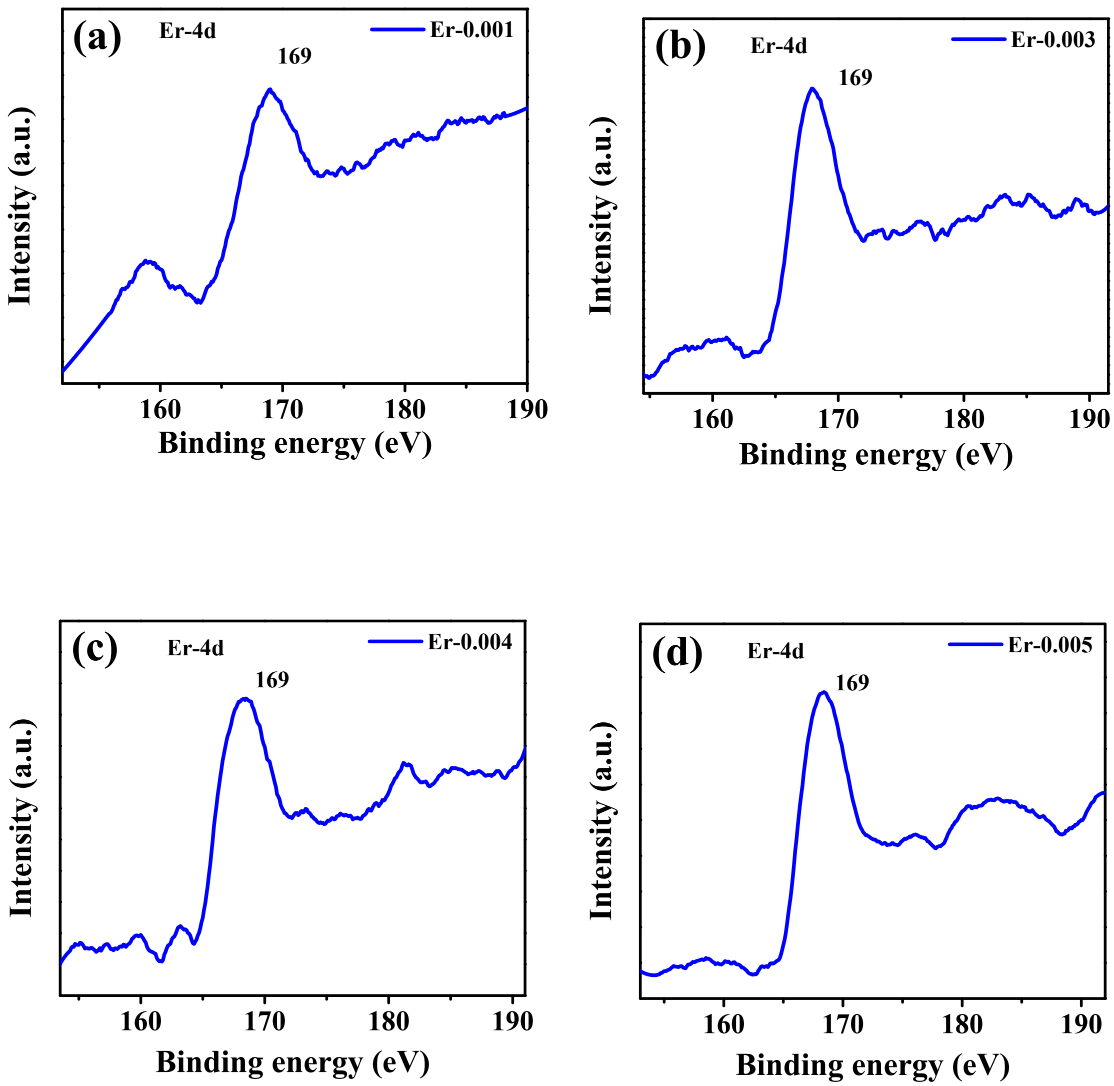

Figure S2. (a–d) High resolution XPS spectra of Er–4d of Er:ZnO sample for different Er doping content (0.001, 0.003, 0.004, 0.005) respectively.

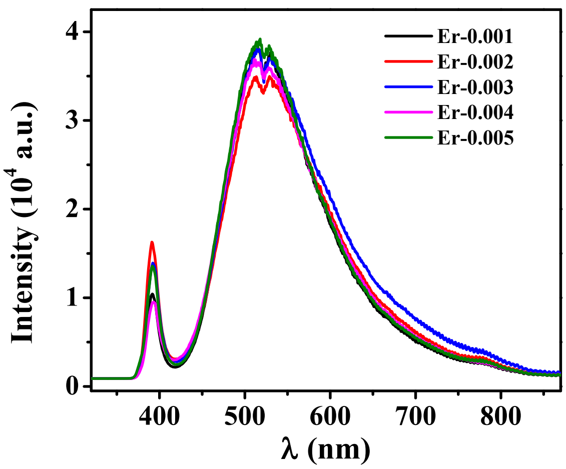

Figure S3. Room temperature PL spectra of Eu:ZnO with 355 nm excitation for different Er doping content.

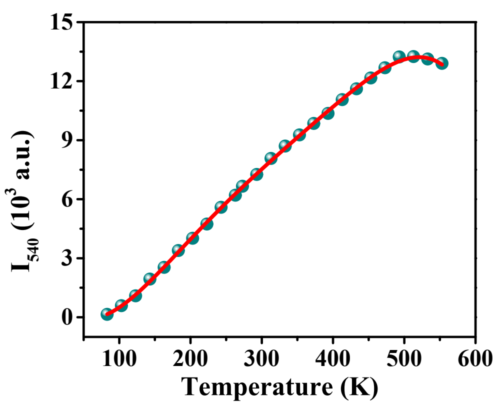

Figure S4. Variation of 540 nm peak intensity with temperature in the 83-553 K range for the Er-0.002 sample.

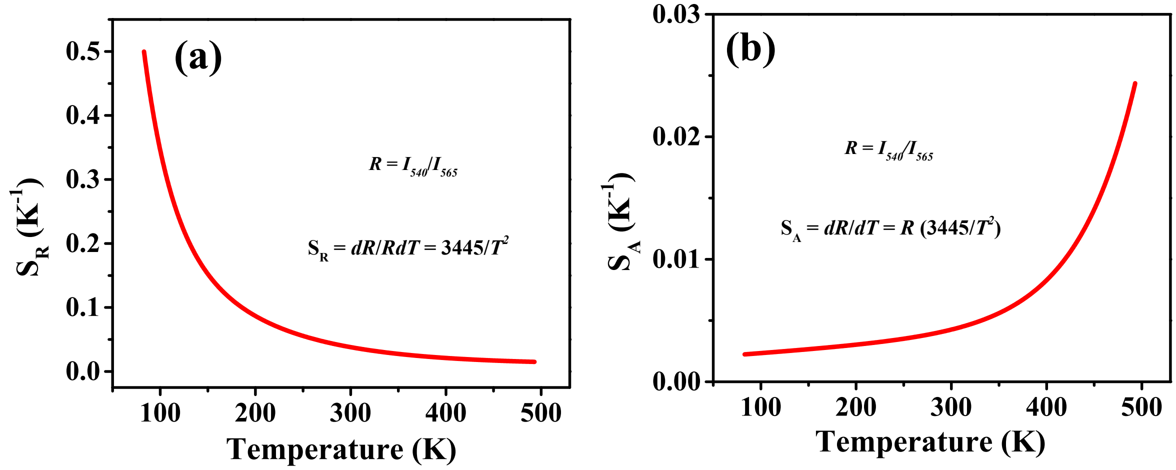

Figure S5. Variation of sensitivity (relative (a) and absolute (b)) for green intensity ratio with applied temperature.

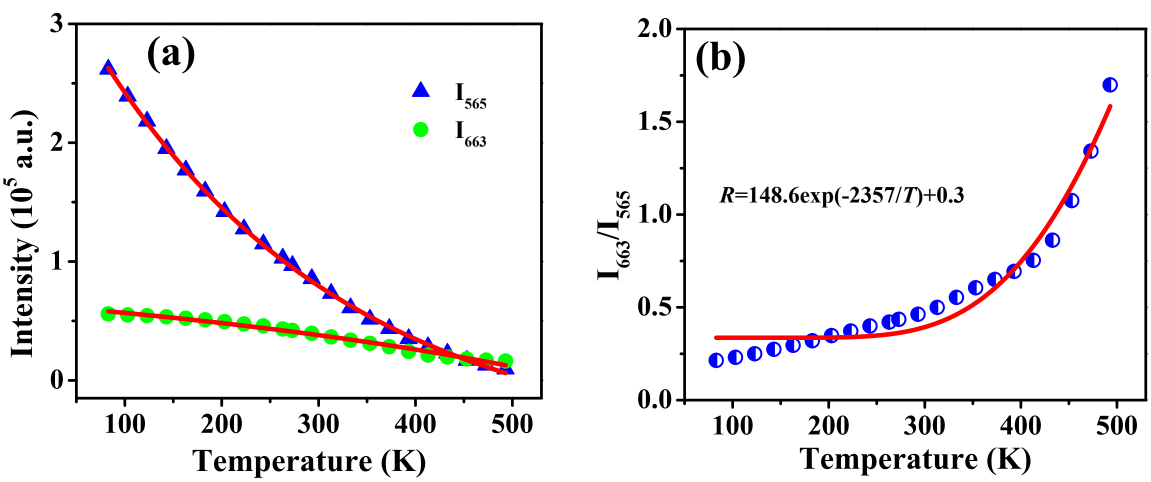

Figure S6. (a) Variation of 565 and 663 nm integral peak intensity with temperature and (b) corresponding intensity ratio variation with temperature.

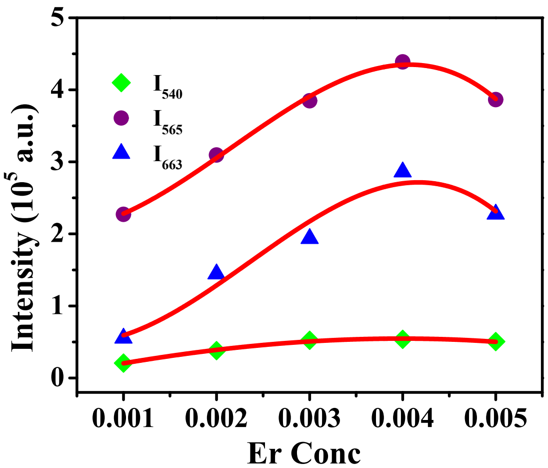

Figure S7. Plot for variation of different integral peak intensities with Er doping amount at room temperature.

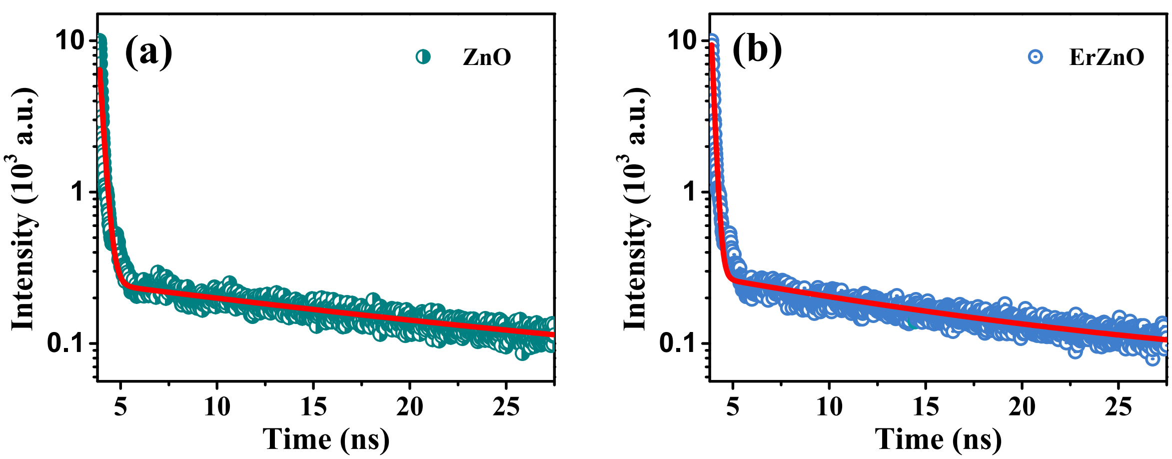

Figure S8. Time resolved PL for (a) ZnO and (b) ErZnO (for Er-4%) with excitation and detection wavelength respectively at 469 nm 520 nm for both the cases. The curves are fitted to double exponential functions and the average life time is obtained as 0.232 ns and 0.143 ns respectively for ZnO and ErZnO.

The population transfer efficiency can be obtained by following equation

$$\eta = 1 - \tau / \tau_0$$

where τ and τ_0 represents average life time of ErZnO and ZnO respectively. The value of η is found to be 38.4% for the 4% Er doped ZnO sample (as it the maximum intense one).

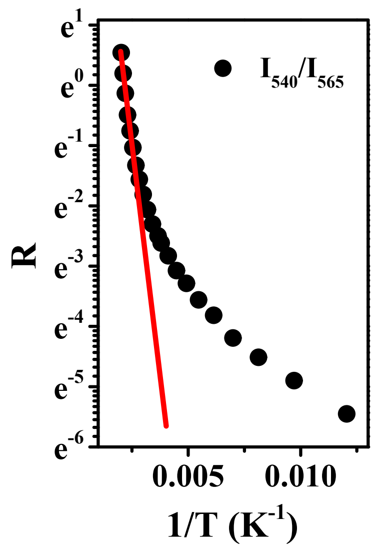

Figure S9. Variation of green intensity ratio with temperature in logarithmic scale. The linear part is fitted to $\ln I_{540}/I_{565}$=6.65-3053/T and the deviation increases at lower temperature. This suggests that the degree of population (η) is equal to 1 at higher temperature, which is only due to the thermal population process,[1] and $\eta < 1$ at lower temperature.[1]

Table S1. Comparison of maximum S_A values for 540 and 565 nm intensity ratio.

Er	Temp range (K)	Maximum S_A (K^{-1})	Temperature for maximum S_A (K)
0.001	83 – 493	2.127x10-2	493
0.002	83 – 493	2.435×10-2	493
0.003	83 – 493	1.774x10-2	493
0.004	83 – 493	1.756x10-2	493
0.005	83 – 493	1.413x10-2	493

Table S2. Comparison of ΔE and S_R of different Er:ZnO microrods for I_{663}/I_{565}. Theoretical ΔE is 2616.2 cm^{-1}. T_{max} is the temperature corresponds to maximum S_A value.

Er	Temp range (K)	Maximum S_A (K^{-1}) (T_{max}, K)	ΔE (cm^{-1})	Sensitivity (S_R) (K^{-1})
0.001	83 – 493	2.976x10-2 (83)	1414	$2034/T^2$
0.002	83 – 493	7.314x10-2 (83)	1638	$2357/T^2$
0.003	83 – 493	6.555x10-2 (83)	1170	$1683/T^2$
0.004	83 – 493	5.561x10-2 (83)	1384	$1991/T^2$
0.005	83 – 493	7.539x10-2 (83)	997	$1434/T^2$

Table S3. Comparison table for theoretical and experimental ΔE ratio for various materials.

Host Materials	Excitations (nm)	Temperature range (K)	ΔE (cm^{-1}) (Theoretical)	ΔE (cm^{-1}) (Experimental)	$\Delta E_e/\Delta E_t$	ΔE/k (K) (experimental)	References
Er3+ Si–B–Ba–Na glass	978	297-673	512	233	0.4550	335	2
Er3+ PLZT ceramics	980	310-883	1027	773	0.7526	1112	3
Er3+, Mo6+ :YbAG	976	295-973	842	901	1.0701	1296	4
Er3+, Yb3+:β-NaLuF4	980	303-523	2830.6	266.8	0.0943	384	5
Er3+, Yb3+, Eu3+ :Y2O3	980	301-403	972	474	0.4877	682	6
Er3+, Yb3+ :YVO4	980	300-485	1033	538	0.5208	774	7
Er3+, Yb3+ :NaBiTiO3 ceramics	980	93-613	866	575	0.6639	827	8
Er3+, Yb3+ :LiNbO3	980	285-453	686	860	1.2536	1250	9
Pr^{3+}-doped $(K_{0.5}Na_{0.5})NbO_3$	325	293-456	3866	5557	1.4374	7997	10
Er3+: ZnO	532	83-493	819	2394	2.9230	3445	This work

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