

Supplementary information

Simultaneous negative thermal quenching luminescence of upconversion and downshifting processes in $\text{Al}_2(\text{WO}_4)_3:\text{Yb}/\text{Er}$ Phosphors with low thermal expansion

Haokun Yan^a, Renfu Li^a, Liuzhen Feng^a, Yiqi Yu^a, Guoliang Gong^a, Haiping Huang^a, He-Rui Wen^a and
Jinsheng Liao^{*ab}

^aSchool of Chemistry and Chemical Engineering/Jiangxi Provincial Key Laboratory of Functional Molecular
Materials Chemistry, Jiangxi University of Science and Technology, Ganzhou, Jiangxi, 341000, P.R. China.

E-mail address: jsliao1209@126.com (J. S. Liao)

^bNational Rare Earth Functional Material Innovation Center, Ganzhou 341000, P.R. China

Table S1 AWO:20%Yb³⁺/2%Er³⁺ phosphor cell parameters and refinement parameters at different temperatures and AWO host cell parameters at 293 K.

T (K)	298	323	348	373	398	423
Crystal system	Orthorhombic					
Space group	<i>Pnca</i> (No.60)					
Lattice parameters (Å)	<i>a</i> =9.1555	9.1554	9.1551	9.1550	9.1550	9.1547
	<i>b</i> =12.6384	12.6398	12.6421	12.6443	12.6464	12.6479
	<i>c</i> =9.0718	9.0719	9.0719	9.0724	9.0726	9.0726
V (Å ³)	1049.725	1049.815	1049.980	1050.207	1050.403	1050.491
<i>R</i> _{wp} (%)	4.25	4.28	4.18	4.25	4.54	4.61
<i>R</i> _p (%)	3.30	3.34	3.25	3.30	3.55	3.57
χ^2	2.20	2.15	2.09	2.45	2.53	2.62
T (K)	448	473	498	523	548	573
Crystal system	Orthorhombic					
Space group	<i>Pnca</i> (No.60)					
Lattice parameters (Å)	9.1548	9.1546	9.1545	9.1542	9.1540	9.1364
	12.6497	12.6516	12.6534	12.6549	12.6570	12.5913
	9.0728	9.0729	9.0731	9.0732	9.0732	9.0560
V (Å ³)	1050.682	1050.831	1050.990	1051.087	1051.245	1051.589
<i>R</i> _{wp} (%)	4.42	4.45	4.14	4.44	4.47	4.48
<i>R</i> _p (%)	3.43	3.47	3.44	3.45	3.45	3.39
χ^2	2.48	2.58	2.58	2.70	2.73	3.09
Al ₂ (WO ₄) ₃ at 293K						
Crystal system	Orthorhombic					
Space group	<i>Pnca</i> (No.60)					
Lattice parameters (Å)	<i>a</i> =9.1364					
	<i>b</i> =12.5913					
	<i>c</i> =9.0560					
V (Å ³)	1041.795					

Table S2 Temperature-dependent lifetime of Yb^{3+} (τ_{Yb}) in AWO: 20% Yb^{3+} and temperature-dependent lifetime of Yb^{3+} and Er^{3+} (τ_{Er}) in AWO:20% Yb^{3+} /2% Er^{3+}

T (K)	298	323	348	373	398	423
τ_{Yb} of AWO: 20% Yb^{3+} (μs)	423.7	422.7	330.7	261.2	262.0	472.3
τ_{Yb} of AWO:20% Yb^{3+} /2% Er^{3+} (μs)	503.6	492.7	483.9	470.2	462.1	480.1
τ_{Er} of $^4\text{H}_{11/2}$ of AWO:20% Yb^{3+} /2% Er^{3+} (μs)	107.6	111.3	113.6	113.6	101.6	111.8
τ_{Er} of $^4\text{I}_{13/2}$ of AWO:20% Yb^{3+} /2% Er^{3+} (ms)	10.55	10.39	10.39	10.14	9.640	9.661
T (K)	448	473	498	523	548	573
τ_{Yb} of AWO: 20% Yb^{3+} (μs)	614.7	804.2	896.7	887.3	842.2	820.5
τ_{Yb} of AWO:20% Yb^{3+} /2% Er^{3+} (μs)	486.8	471.8	467.5	471.3	462.1	456.6
τ_{Er} of $^4\text{H}_{11/2}$ of AWO:20% Yb^{3+} /2% Er^{3+} (μs)	133.0	139.2	157.5	166.4	168.4	184.6
τ_{Er} of $^4\text{I}_{13/2}$ of AWO:20% Yb^{3+} /2% Er^{3+} (ms)	10.29	10.24	9.950	9.494	8.900	8.244

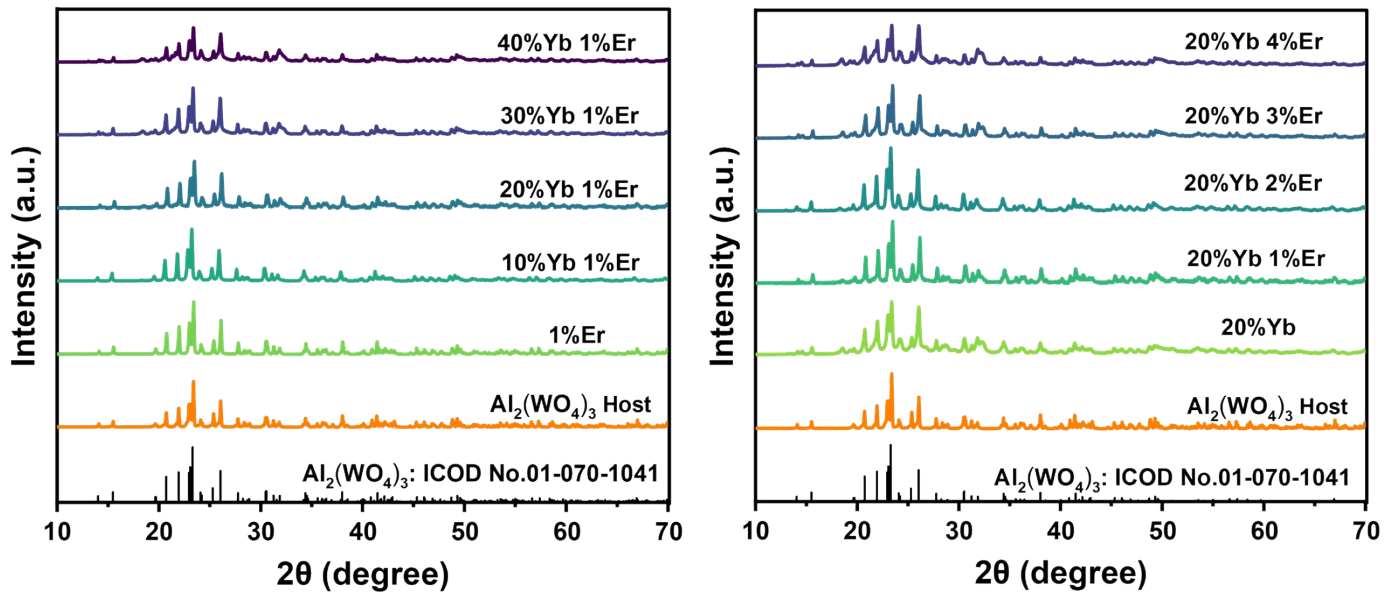


Fig. S1 XRD patterns of AWO:xYb/yEr phosphors with different Yb³⁺/Er³⁺ concentrations at room temperature.

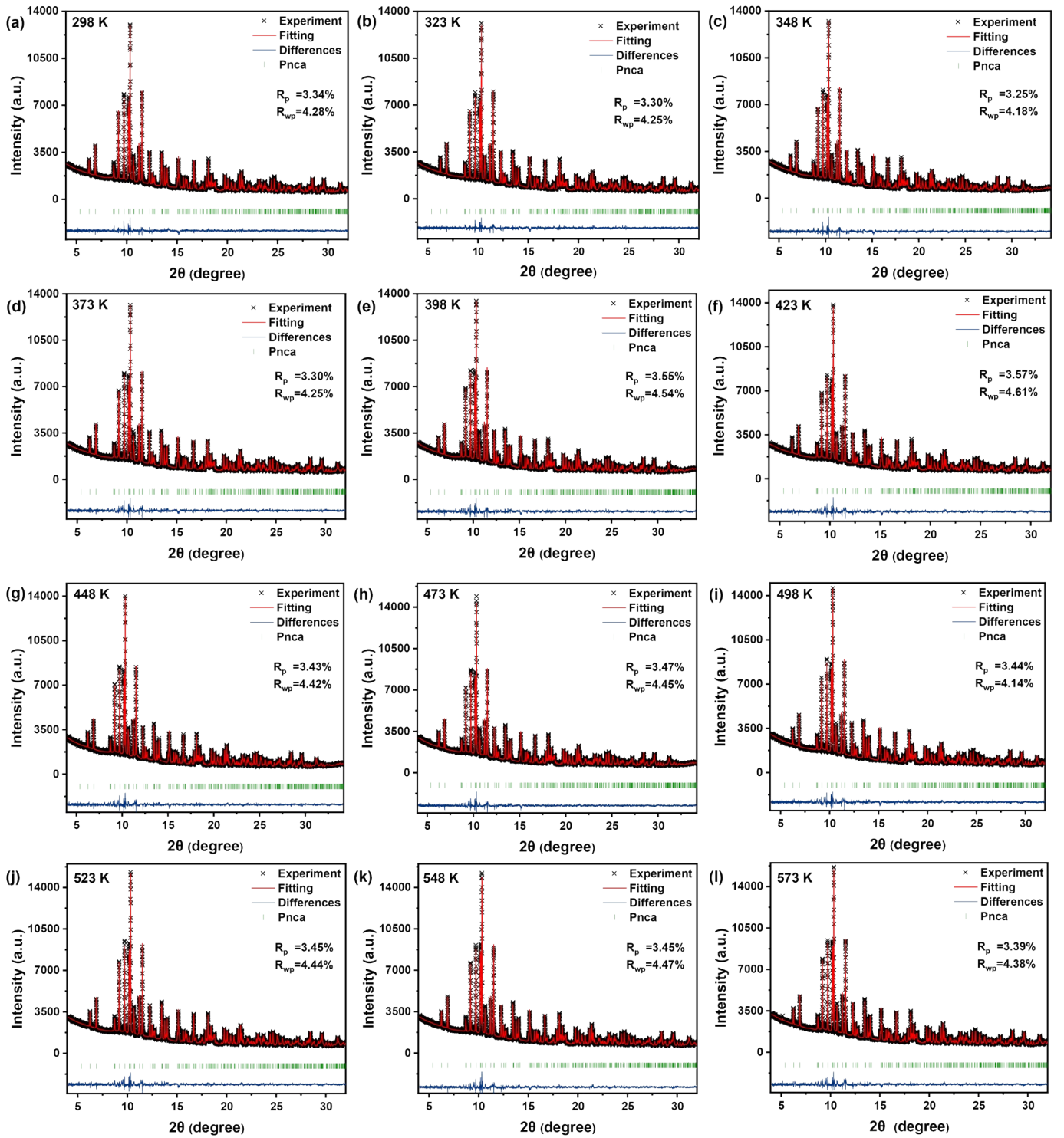


Fig. S2 The Rietveld refinement of the SXR D patterns of the AWO:20%Yb/2%Er phosphor at different temperatures.

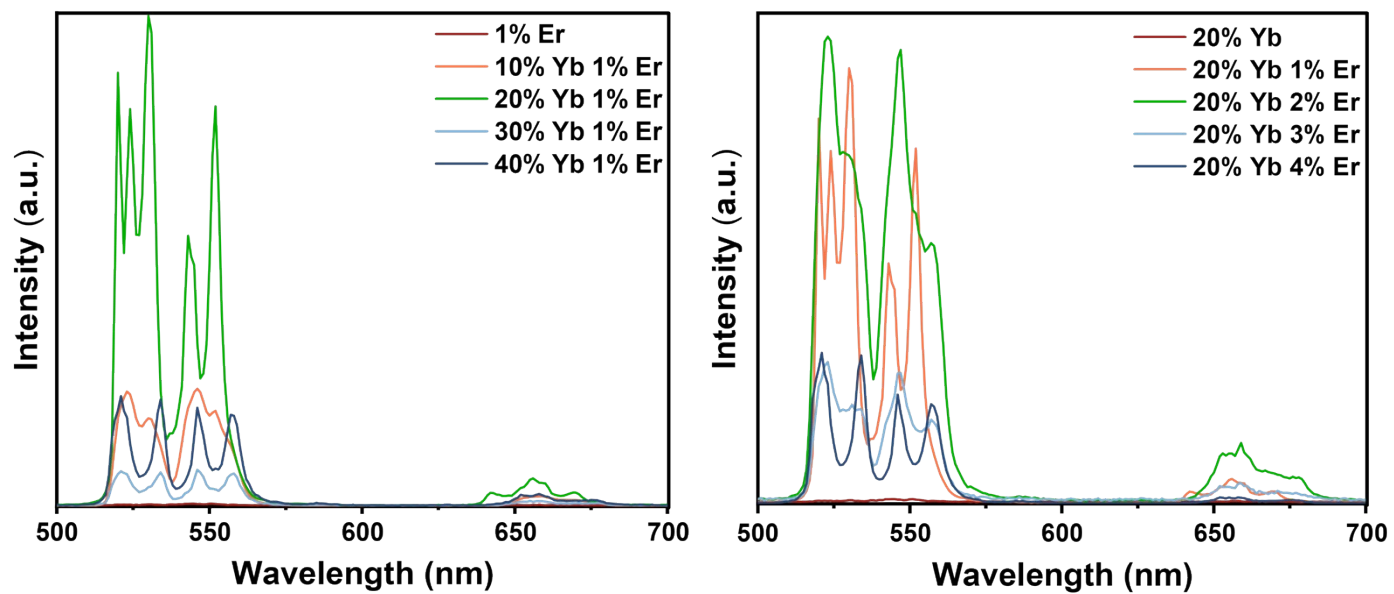


Fig. S3 Room temperature UC spectra of varying AWO: xYb/yEr phosphors under 980 nm laser excitation.

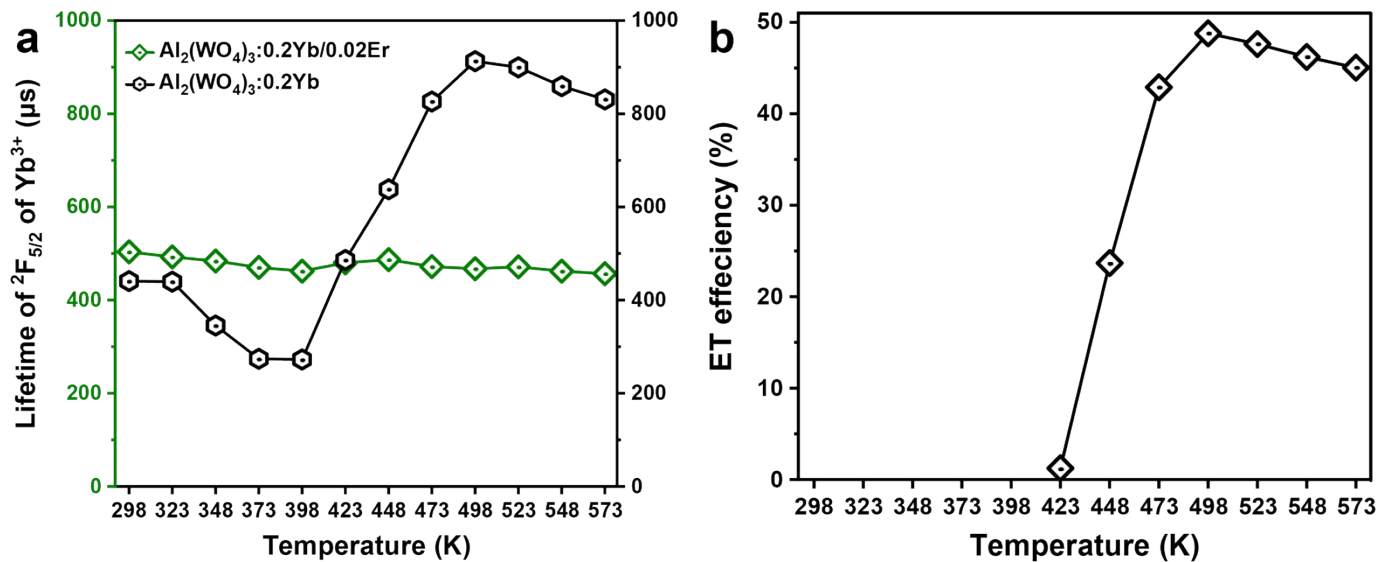


Fig. S4 (a) Temperature-related average luminescence lifetime of ²F_{5/2} excited state of Yb³⁺ in Yb³⁺-doped and Yb³⁺/Er³⁺-codoped Al₂(WO₄)₃ phosphors. (b) Temperature-dependent energy transfer efficiency of Yb³⁺ to Er³⁺.

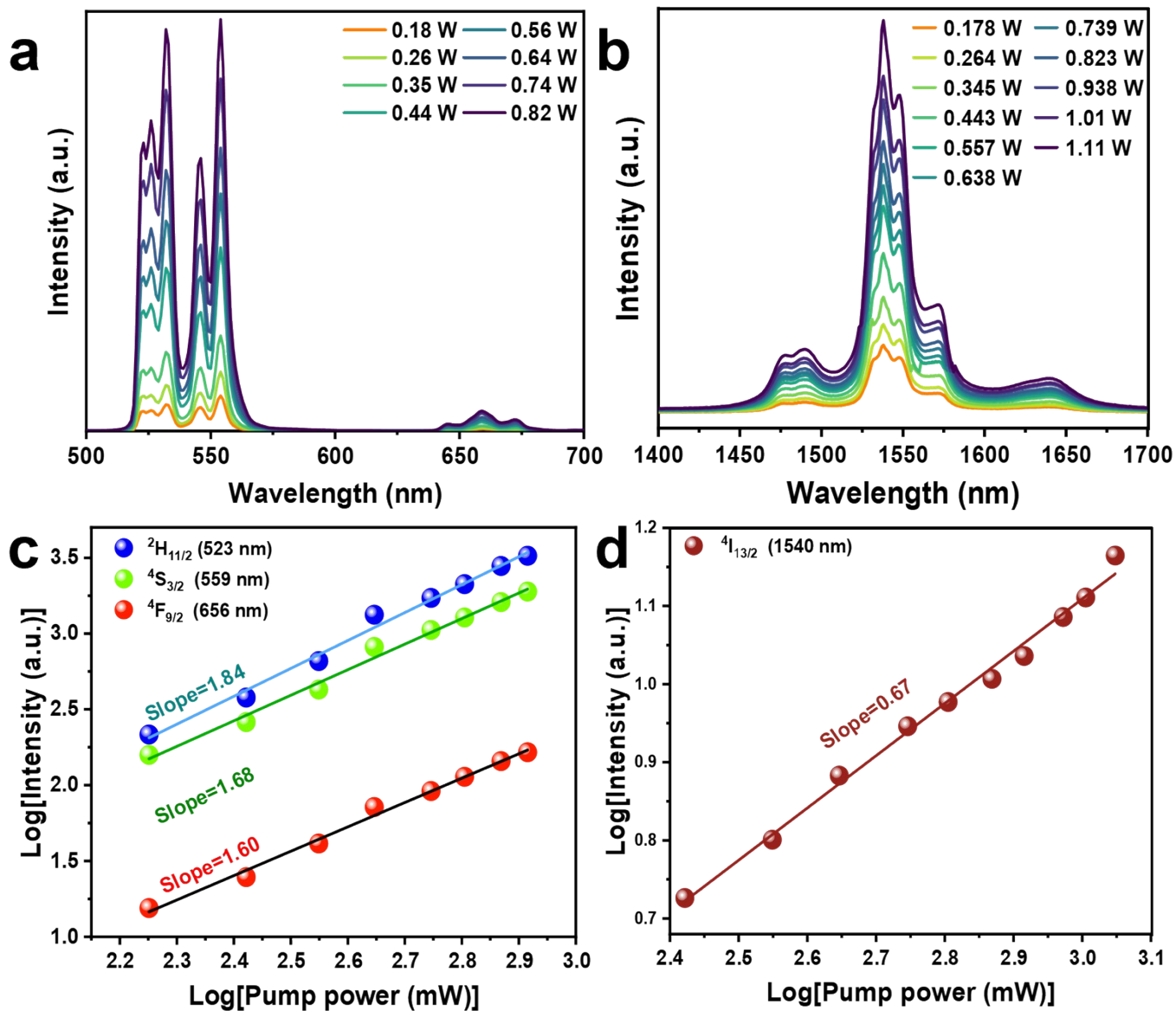


Fig. S5 The power-dependent UC (a) and DS (b) spectra and Log-Log plots of the luminescence intensity against the excitation power of UC (c) and DS (d) emission in the AWO:20%Yb/2%Er phosphors product under 980 nm laser excitation.