Supporting Information

Figure Captions

Fig. S1. Digital photographs of CSO:xMn (x = 0.01-0.05) phosphor samples irradiated with 254 nm and 365 nm UV lamps, respectively, as well as afterglow photographs after stopping irradiation with the 254 nm UV lamp.

Fig. S2. Emission spectra of the CaSb2O6:xMn samples under 310 nm excitation.

Fig. S3. XRD patterns of phosphor samples CSO:0.01Mn (different Mn sources), CSO:0.04Mn and CSO:0.04Mn,0.06La^{3+}.

Fig. S4. XPS spectrum of CSO:0.04Mn,0.06La^{3+} phosphor sample.

Fig. S5. EDS spectrum of CSO:0.01Mn,0.01La^{3+} samples.

Fig. S6. Sa values of CSO:0.01Mn,0.02La^{3+} samples excited at different wavelengths.

Fig. S7. Sr values of CSO:0.01Mn,0.02La^{3+} samples excited at different wavelengths.

Fig. S8. Photographs of CSO under daylight, 254 nm and 365 nm UV irradiation, and at different times after stopping 254 nm UV irradiation.

Fig. S9. Afterglow decay curves of CSO matrix.

Fig. S10. Fitted TL spectra for CSO:0.01Mn,xLa^{3+} (x = 0.02-0.06). The red, green, blue and cyan lines correspond to peak 1 (trap 1), peak (trap 2), peak (trap 3) and peak (trap 4), respectively.

Fig. S11. Fitted TL spectra of the CSO. The red and blue lines correspond to peak 1 (trap 1) and peak 2 (trap 2), respectively.

Fig. S12. Pictures of CSO:0.01Mn phosphor under continuous irradiation with a 365 nm UV lamp (5 W) for different times. The phosphor was first irradiated with a 254 nm UV lamp for 3 minutes and then placed in a dark environment for different periods of time (1 day, 10 days, 30 days).

Fig S13. Thermogravimetric curves of CSO:0.01Mn,0.02La^{3+} samples.

Table. S1. J and d_0 values of Ca^{2+}-O^{2-}, Sb^{5+}-O^{2-}, La^{3+}-O^{2-}, Mn^{4+}-O^{2-}, Mn^{2+}-O^{2-}.

Ion pair	J(Kcal/mol)	d_0 (Å)
Ca^{2+}-O^{2-}	126.6	1.967
Sb^{5+}-O^{2-}	65.64	1.912
La^{3+}-O^{2-}	135.56	2.172
Mn^{4+}-O^{2-}	77.6	1.753
Mn^{2+}-O^{2-}	109.3	1.790

Table. S2. Ca^{2+}-O^{2-}, Sb^{5+}-O^{2-}, Mn^{4+}-O^{2-}, Mn^{2+}-O^{2-} Key parameters and bond energy values (E_{m-o}, $E_{Mn^{4+}\text{-}O^{2-}}$, $E_{Mn^{2+}\text{-}O^{2-}}$), Bond energy deviation ($\Delta E_{Mn^{4+}-O^{2-}}^{m}$, $\Delta E_{Mn^{2+}-O^{2-}}^{m}$), m represents the Ca, Sb bond energy is the unit of kcal/mol.

Central atom	Coordination atom	Count	$d_{m\text{-}o}$(Å)	E_{m-o}	$E_{Mn^{4+}\text{-}O^{2-}}$	$E_{Mn^{2+}\text{-}O^{2-}}$	$\Delta E_{Mn^{4+}-O^{2-}}^{m}$	$\Delta E_{Mn^{2+}-O^{2-}}^{m}$
Ca1	O1	3x	2.437	35.524	6.106	19.009		
	O1	3x	2.437	35.515	6.104	19.004		
Average				35.520	6.105	19.006	29.415	16.513
Central atom	Coordination atom	Count	$d_{m\text{-}o}$(Å)	E_{m-o}	$E_{Mn^{4+}\text{-}O^{2-}}$	$E_{Mn^{2+}\text{-}O^{2-}}$	$\Delta E_{Mn^{4+}-O^{2-}}^{m}$	$\Delta E_{Mn^{2+}-O^{2-}}^{m}$
Sb1	O1	2x	1.961	57.576	55.362	172.358		
	O1	1x	1.961	57.545	55.332	172.265		
	O1	1x	1.961	57.529	55.318	172.219		
	O1	2x	1.961	57.467	55.258	172.033		
Averag				57.529	55.318	172.219	2.212	114.690

e

Table. S3. Ca^{2+}-O^{2-}, Sb^{5+}-O^{2-}, La^{3+}-O^{2-} Key parameters and bond energy values (E_{m-o}, $E_{La^{3+}\text{-}O^{2-}}$), Bond energy deviation ($\Delta E_{La^{3+}-O^{2-}}^{m}$), m represents the Ca, Sb bond energy is the unit of kcal/mol.

Central atom	Coordination atom	Count	$d_{m\text{-}o}$(Å)	E_{m-o}	$E_{La^{3+}\text{-}O^{2-}}$	$\Delta E_{La^{3+}-O^{2-}}^{m}$
Ca1	O1	3x	2.437	35.524	44.132	
	O1	3x	2.437	35.515	44.120	
Average				35.520	44.126	8.607
Central atom	Coordination atom	Count	$d_{m\text{-}o}$(Å)	E_{m-o}	$E_{La^{3+}\text{-}O^{2-}}$	$\Delta E_{La^{3+}-O^{2-}}^{m}$
Sb1	O1	2x	1.961	57.576	400.159	
	O1	1x	1.961	57.545	399.943	
	O1	1x	1.961	57.529	399.835	
	O1	2x	1.961	57.467	399.403	
Average				57.529	399.835	342.305

Table. S4. Rietveld refinement lattice parameters of CSO:0.01Mn,0.01La^{3+} phosphor as well as the standard CSO (PDF#46-1496).

Parameters	CSO	CSO:0.01Mn,0.01La^{3+}
Crystal system	trigonal	trigonal
Space-group	P-31m	P-31m

a (Å)	5.2405	5.2399
b (Å)	5.2405	5.2399
c (Å)	5.0221	5.0309
V(Å^3)	119.44	119.62
Z	1	6
Rwp		10.10%
Rp		7.64%
χ^2		1.32

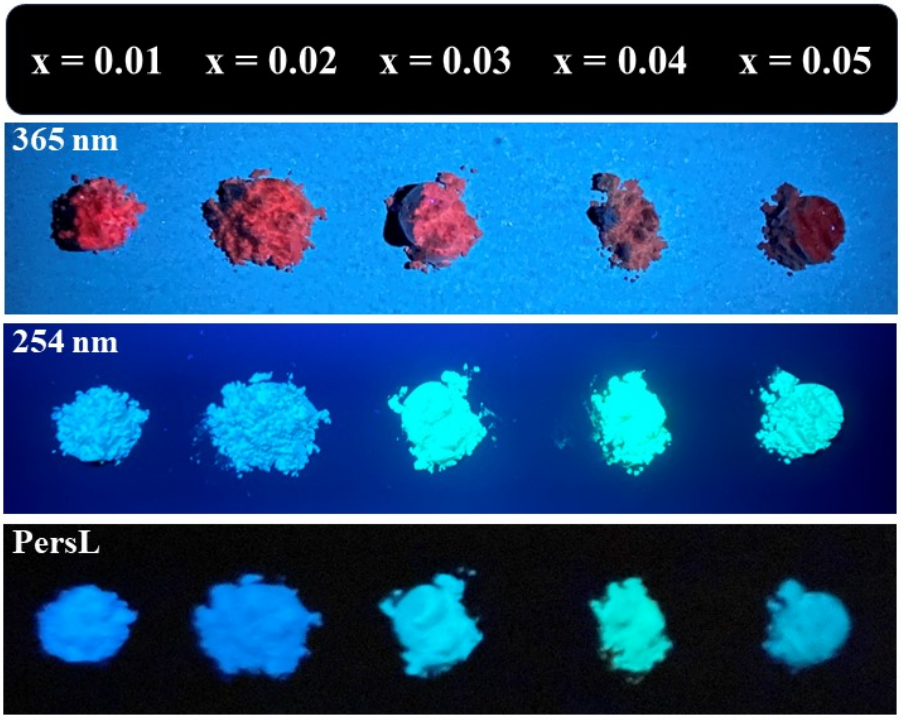
Table. S5. The refined positions of all atoms for CSO:0.01Mn,0.01La^{3+}.

Atomic parameters					
Atom	Wyck.	x/a	y/b	z/c	U [Å^2]
Ca1	1a	0	0	0	0.0232(19)
Sb1	2d	1/3	2/3	1/2	0.0156(15)
O1	6k	0.3644(10)	0	0.2692(9)	0.01

Table. S6. Relative parameters for temperature measurements of partial phosphors based on double light emission.

Hosts	Doped ions	Temperature range(K)	Sr(%K^{-1})	Sa(K^{-1})	Ref.
Ca_2LaSbO_6	Eu^{3+},Mn^{4+}	273-473	2.60	0.098	[1]
La_2LiSbO_6	Eu^{3+},Mn^{4+}	303-523	0.89	0.000264	[2]

$La_2Mg_{1.33}Ta_{0.67}O_6$	Eu^{3+},Mn^{4+}	298-443	2.72	0.057	[3]
$NaLaMgWO_6$	Eu^{3+},Mn^{4+}	303-523	0.86	0.0302	[4]
Ca_2LuSbO_6	Eu^{3+},Mn^{4+}	303-523	0.79	0.0028	[5]
$ZnTiO_3$	Eu^{3+},Mn^{4+}	80-310	2.70	0.028	[6]
$Mg_3Eu_2Ge_3O_{12}$	Eu^{3+},Mn^{4+}	7-300	0.019	0.015	[7]
$Ba_3MgSb_2O_9$	Mn^{2+},Mn^{4+}	10-300	1.51	1.32	[8]
$ZnGa_{2-y}Al_yO_4$	Mn^{2+},Mn^{4+}	100-475	4.34	-	[9]
$Ba_{0.75}Al_{11}O_{17.25}$	Mn^{2+},Mn^{4+}	303-453	1.63	-	[10]
$LaM_{1-x}Al1_{1-y}O_{19}$	Mn^{2+},Mn^{4+}	225-475	3.22	-	[11]
$Ca_2Sb_2O_7$	Eu^{3+},host	303-523	3.36	0.3031	[12]
$CaSb_2O_6$	Mn^{2+},Mn^{4+}	300-440	3.06	0.092	This work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x = 0.03
x = 0.04
x = 0.05
365 nm
254 nm
PersL

Fig. S1

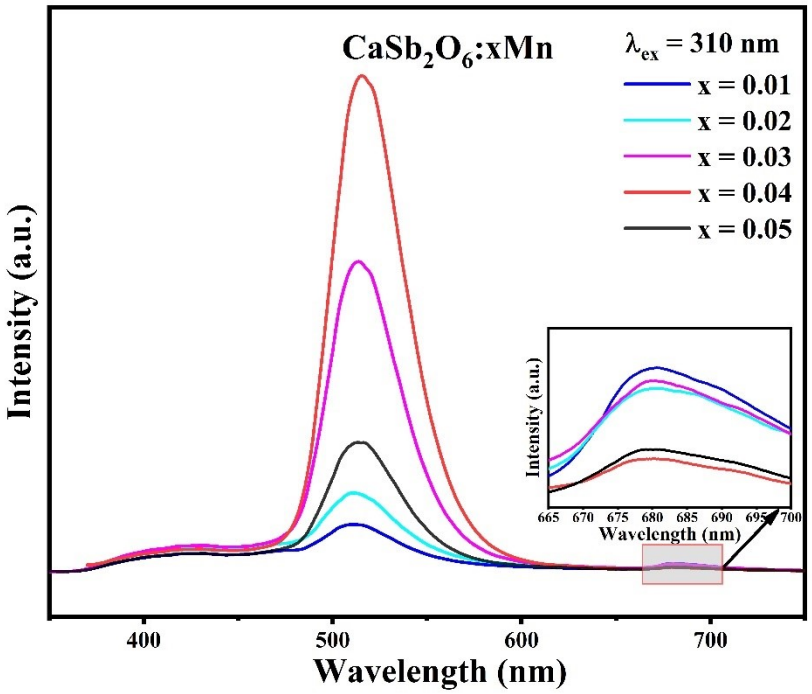

CaSb2O6:xMn
λex = 310 nm
x = 0.01
x = 0.02
x = 0.03
x = 0.04
x = 0.05
Intensity (a.u.)
400
500
600
700
Wavelength (nm)
Intensity (a.u.)
665 670 675 680 685 690 695 700
Wavelength (nm)

Fig. S2

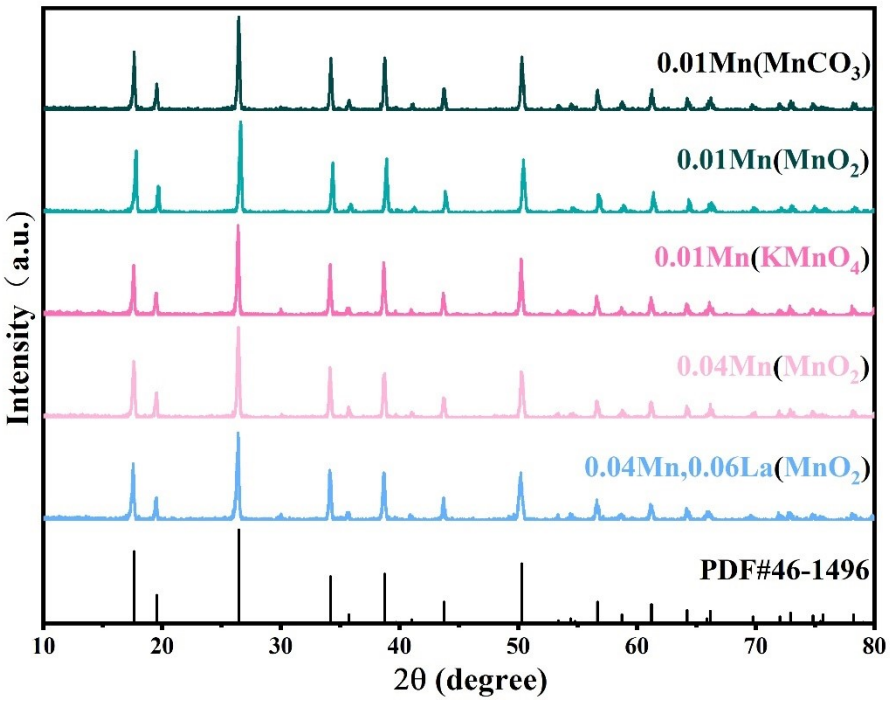

0.01Mn(MnCO3)
0.01Mn(MnO2)
0.01Mn(KMnO4)
0.04Mn(MnO2)
0.04Mn,0.06La(MnO2)
PDF#46-1496
Intensity（a.u.）
10
20
30
40
50
60
70
80
2θ (degree)

Fig. S3

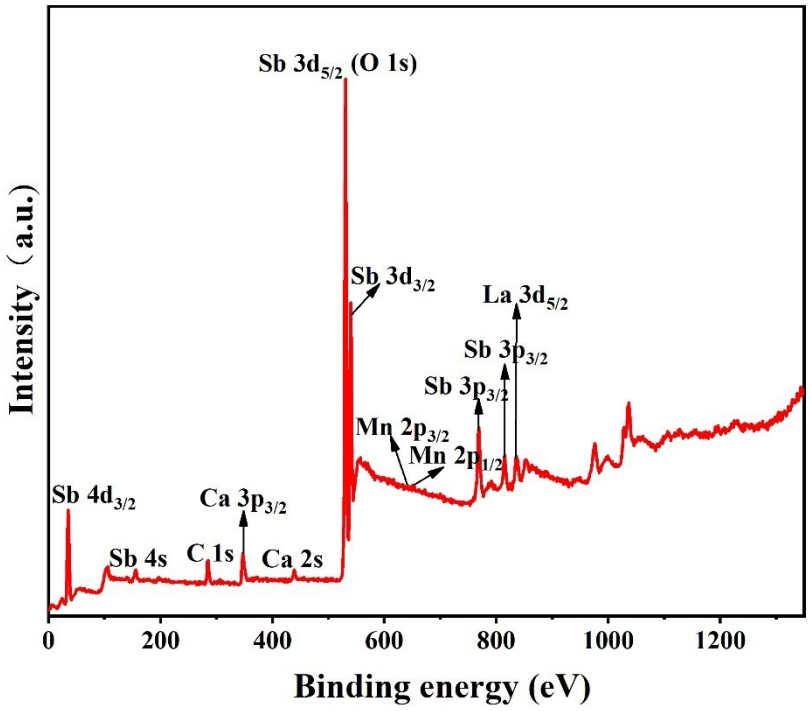

Sb 3d5/2 (O 1s)
Sb 3d3/2
La 3d5/2
Sb 3p3/2
Sb 3p3/2
Mn 2p3/2
Mn 2p1/2
Sb 4d3/2
Ca 3p3/2
Sb 4s
C 1s
Ca 2s
Intensity（a.u.）
0
200
400
600
800
1000
1200
Binding energy (eV)

Fig. S4

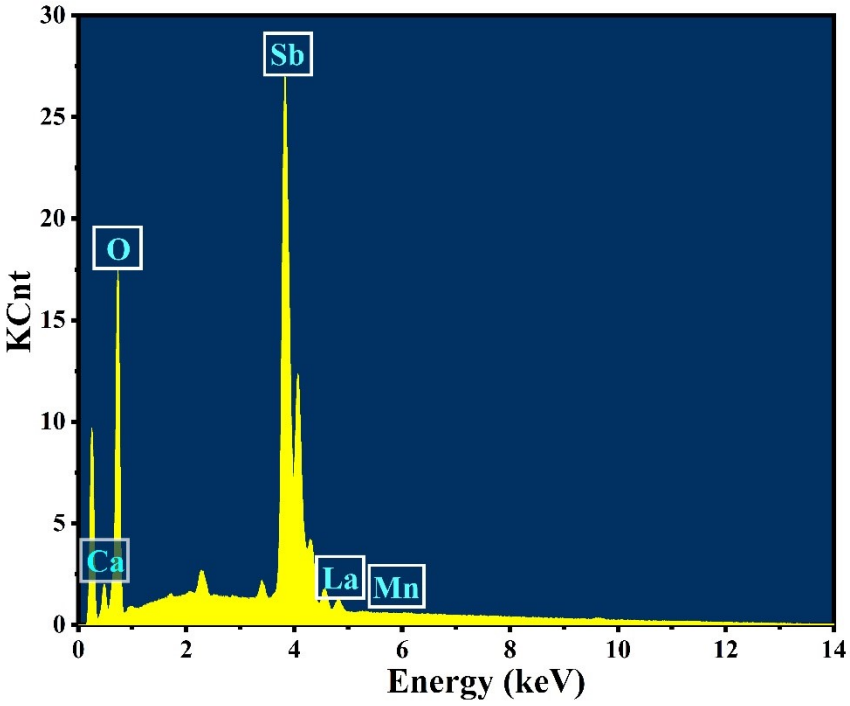
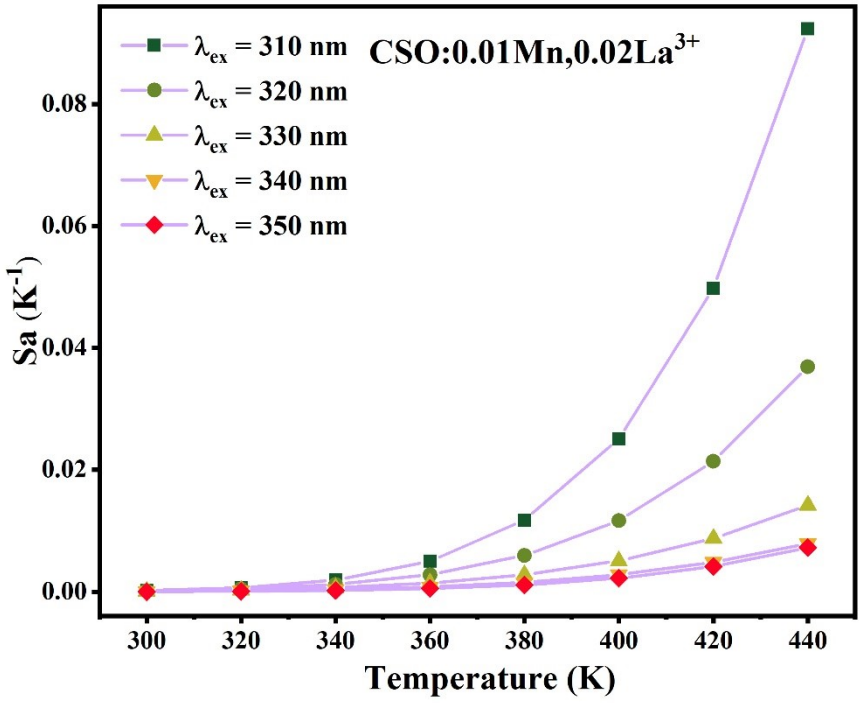

Sb
O
Ca
La
Mn
KCnt
Energy (keV)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
14

Fig. S5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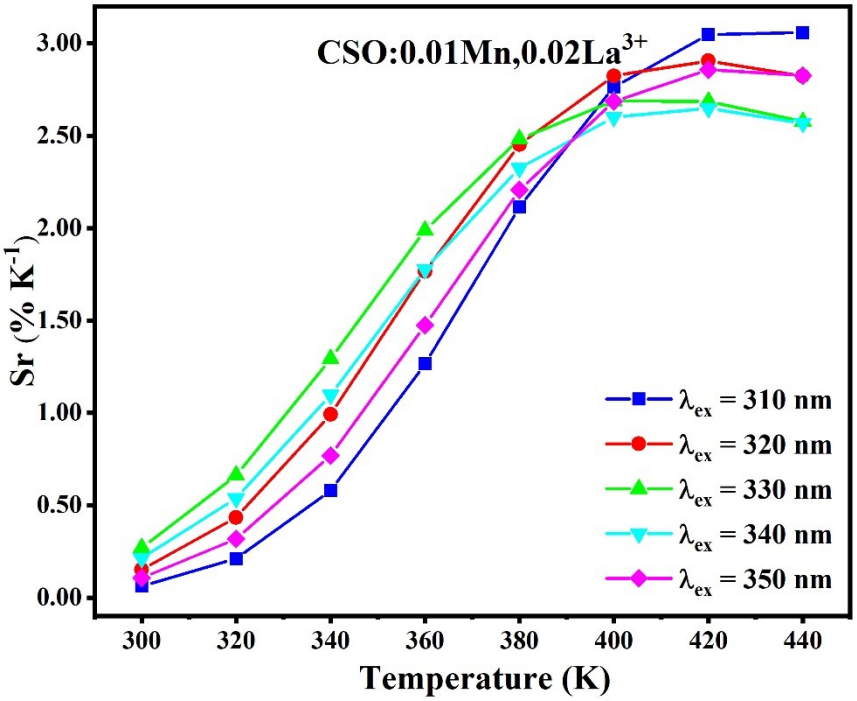
λex = 320 nm
λex = 330 nm
λex = 340 nm
λex = 350 nm
CSO:0.01Mn,0.02La3+
Sa (K-1)
Temperature (K)
0.00
0.02
0.04
0.06
0.08
300
320
340
360
380
400
420
440

Fig. S6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Sr (% K-1)
Temperature (K)
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λex = 320 nm
λex = 330 nm
λex = 340 nm
λex = 350 nm

Fig. S7

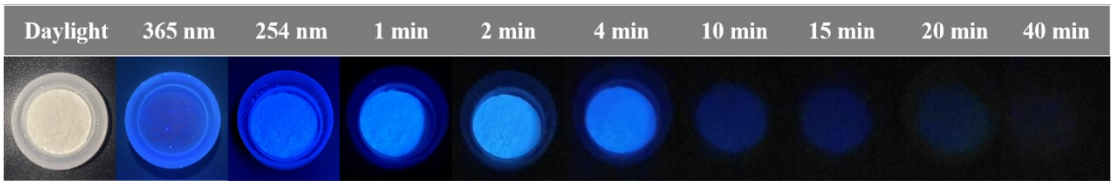
Daylight
365 nm
254 nm
1 min
2 min
4 min
10 min
15 min
20 min
40 min

Fig. S8

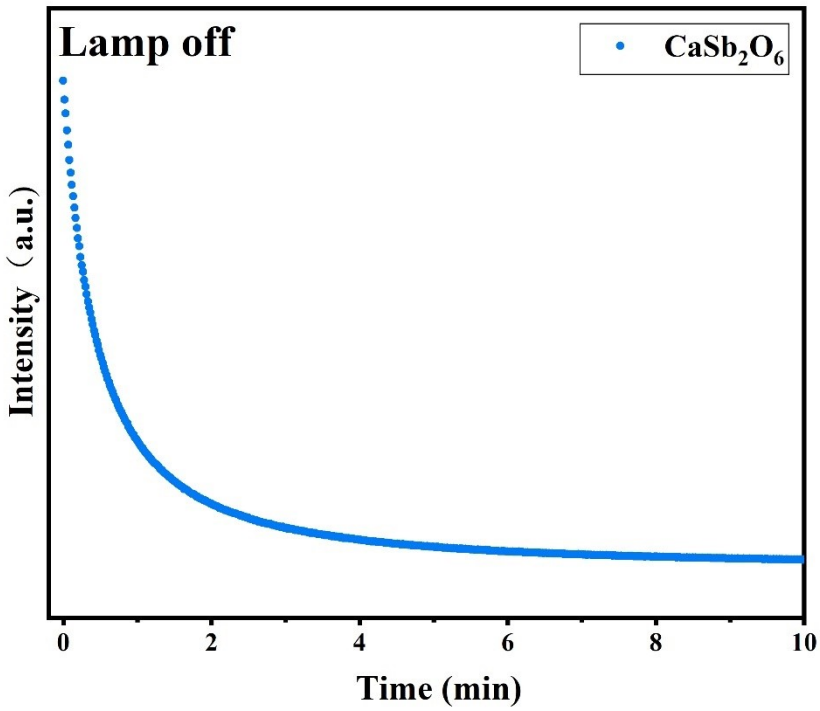

Fig. S9

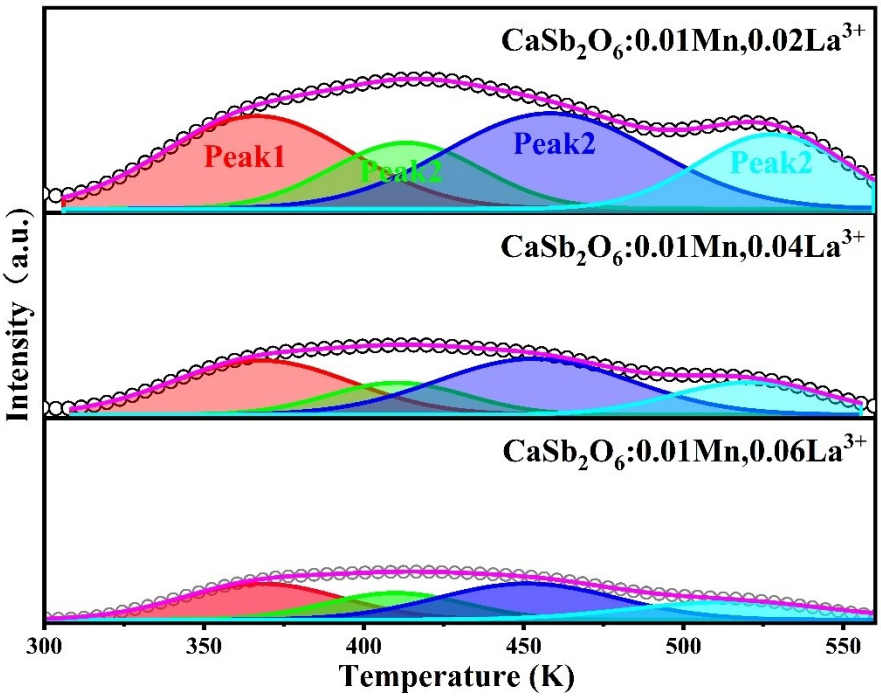

Fig. S10

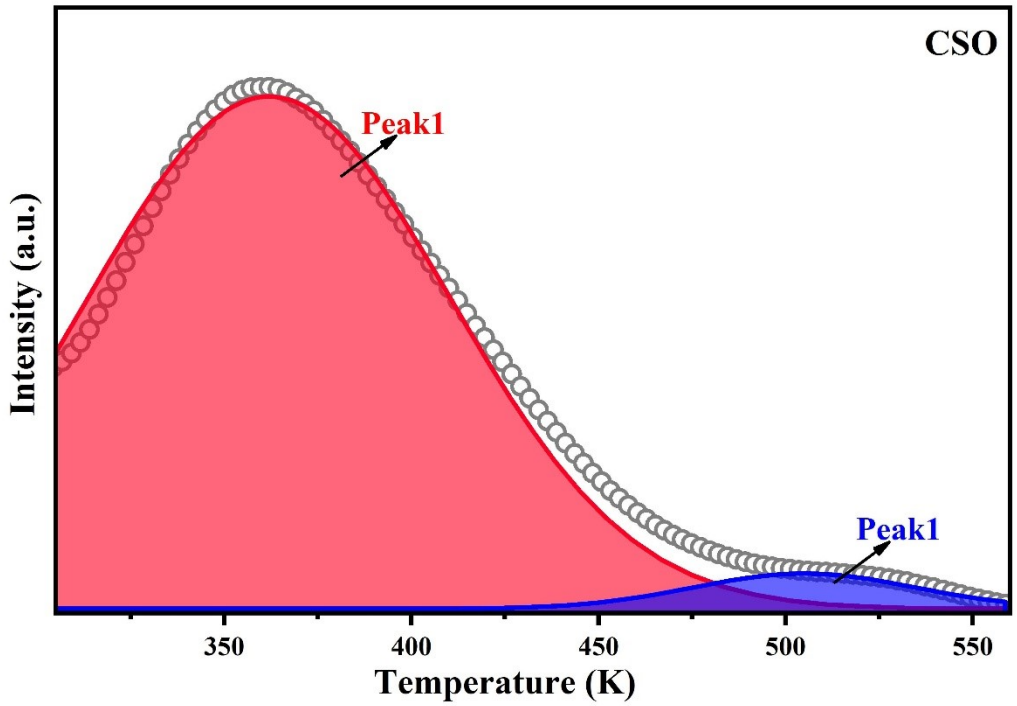

Fig. S11

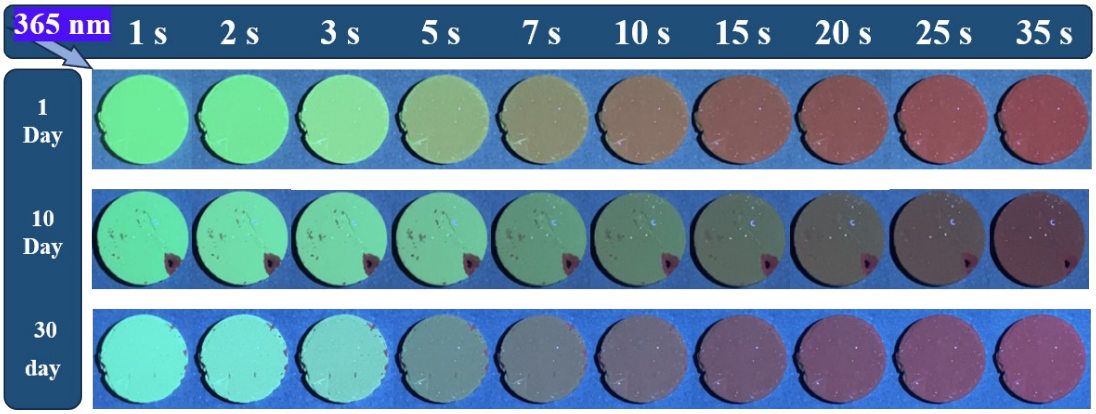

Fig. S12

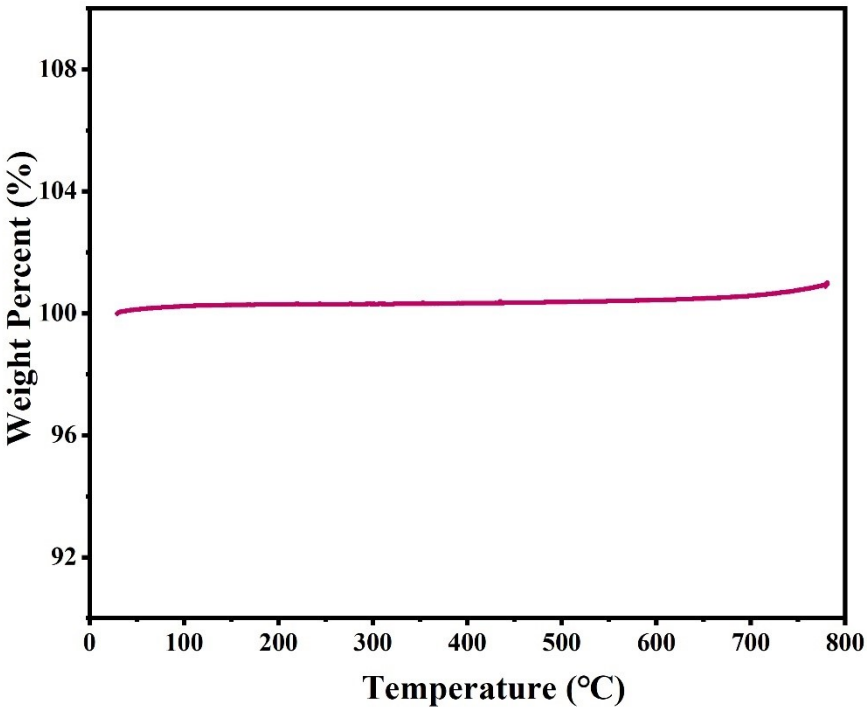
Weight Percent (%)
108
104
100
96
92
0
100
200
300
400
500
600
700
800
Temperature (°C)

Fig. S13

Reference

1. H. Fan, Z. Lu, Y. Meng, P. Chen, L. Zhou, J. Zhao and X. He, Optical temperature sensor with superior sensitivity based on Ca_2LaSbO_6: Mn^{4+}, Eu^{3+} phosphor, *Opt. Laser. Technol*, 2022, **148**, 107804.

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