

Supporting Information

Highly efficient tunable white emission with ultralong afterglow in Sb³⁺/Mn²⁺-codoped CsCdCl₃ crystals for multifunctional applications

Ruonan Zhi, Linghang Kong,^{†*} Hui Peng,^{†*} Qilin Wei,[‡] Guang Dai,^{&*} Bingsuo Zou[†]

[†]State Key Laboratory of Featured Metal Materials and Life-cycle Safety for Composite Structures, MOE Key Laboratory of New Processing Technology for Nonferrous Metals and Materials, and School of Resources, Environment and Materials, Guangxi University, Nanning 530004, China.

[‡]School of Chemistry and Chemical Engineering, Shandong University, Jinan 250100, China.

[&]Tianjin Key Laboratory of Quantum Optics and Intelligent Photonics, School of Science, Tianjin University of Technology, Tianjin 300384, China.

Table S1. Comparison of element concentrations obtained from EDS of $y\%Mn^{2+}$ -doped $CsCdCl_3:0.1\%Sb^{3+}$.

Samples	Nominal/mol % (Sb)	Actual/mol % (Sb)	Nominal/mo l% (Mn)	Actual/mol % (Mn)
$CsCdCl_3:0.1\%Sb^{3+}$	0.1	0.035	/	/
0.1%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.1	0.036	0.1	0.06
0.5%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.1	0.035	0.5	0.32
1%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.1	0.037	1	0.71
3%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.1	0.034	3	2.18
5%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.1	0.033	5	3.46
10% Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.1	0.036	10	7.63

Table S2. PL decay lifetime of $y\%Mn^{2+}$ -doped $CsCdCl_3:0.1\%Sb^{3+}$ monitored at 510 nm and the corresponding energy transfer efficiency.

Samples	Decay lifetime (μs)	Energy transfer efficiency (%)
$CsCdCl_3:0.1\%Sb^{3+}$	1.30	/
0.1%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	1.21	6.9
0.5%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.998	23.2
1%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.852	34.5
3%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.617	52.5
5%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.453	65.2
10% Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	0.313	75.9

Table S3. PLQY of $0.1\%Sb^{3+}/y\%Mn^{2+}$ codoped $CsCdCl_3$.

Samples	PLQY (%)
$CsCdCl_3:0.1\%Sb^{3+}$	60
0.1%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	64
0.5%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	69
1%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	74
3%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	67
5%Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	57
10% Mn ²⁺ -doped $CsCdCl_3:0.1\%Sb^{3+}$	50

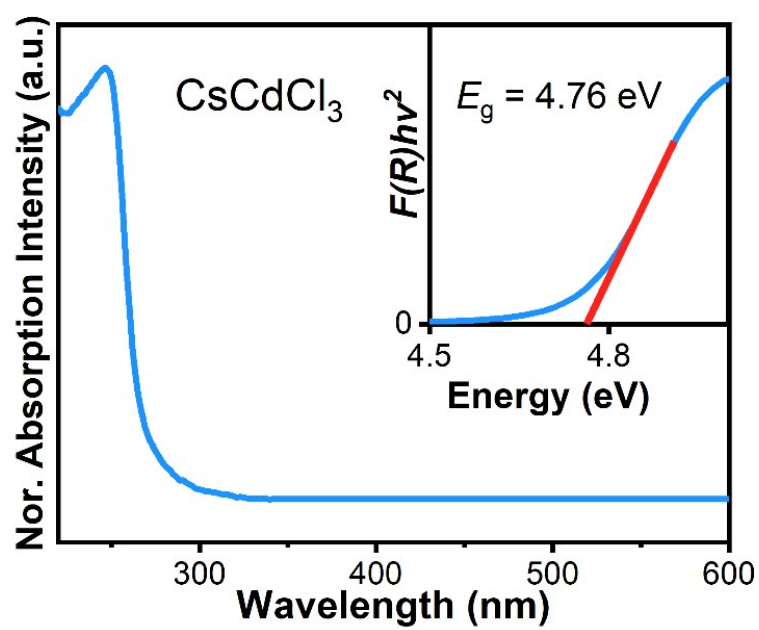


Figure S1. Absorption spectrum of CsCdCl₃.

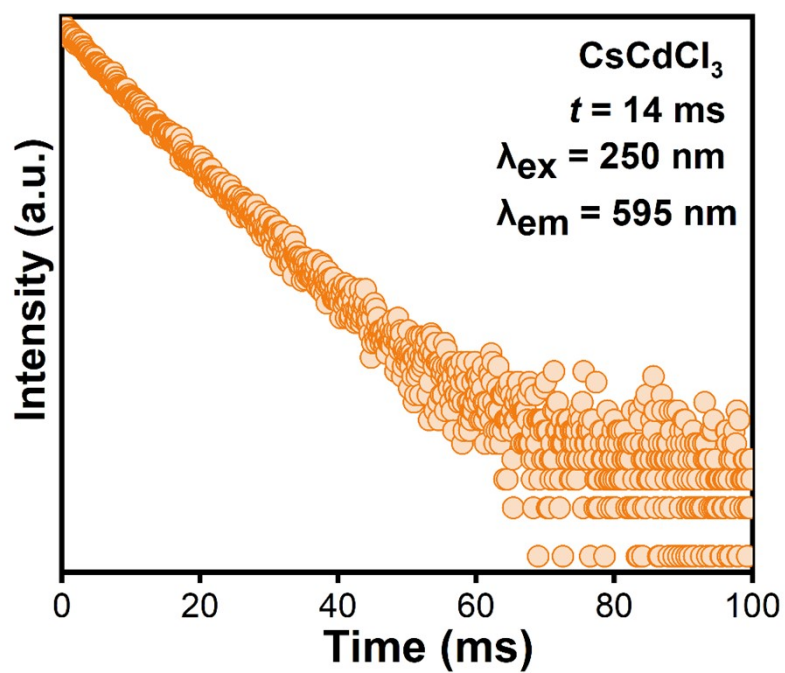


Figure S2. PL decay lifetime of CsCdCl₃.

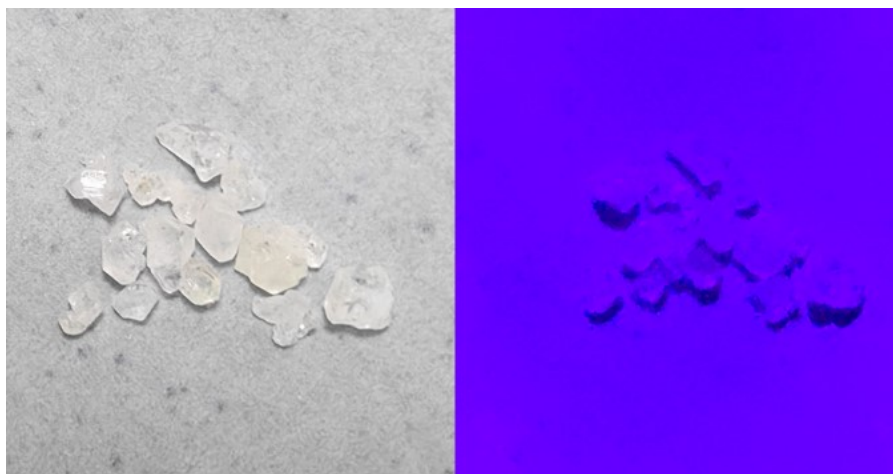


Figure S3. Optical images of CsCdCl_3 under 350 nm UV lamp.

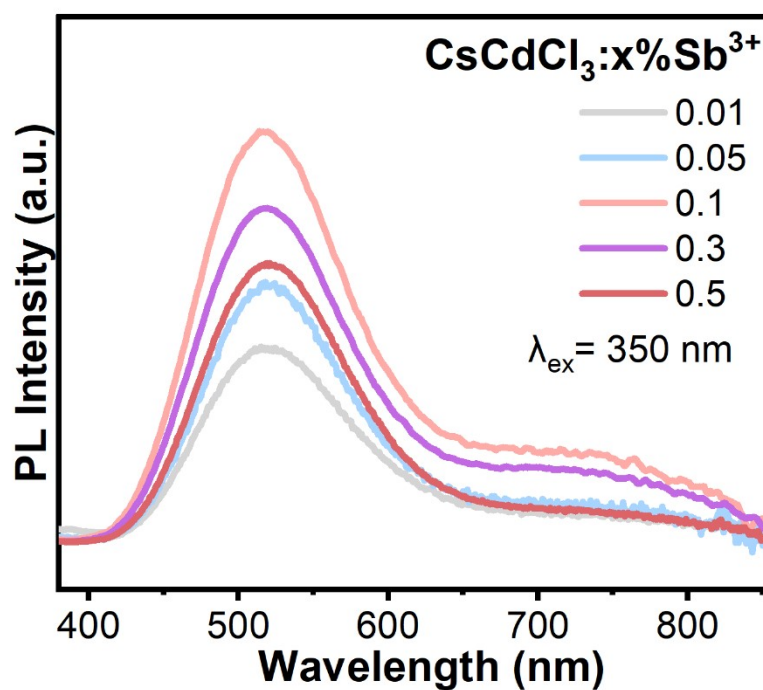


Figure S4. PL spectra of $x\%\text{Sb}^{3+}$ -doped CsCdCl_3 under 350 nm excitation.

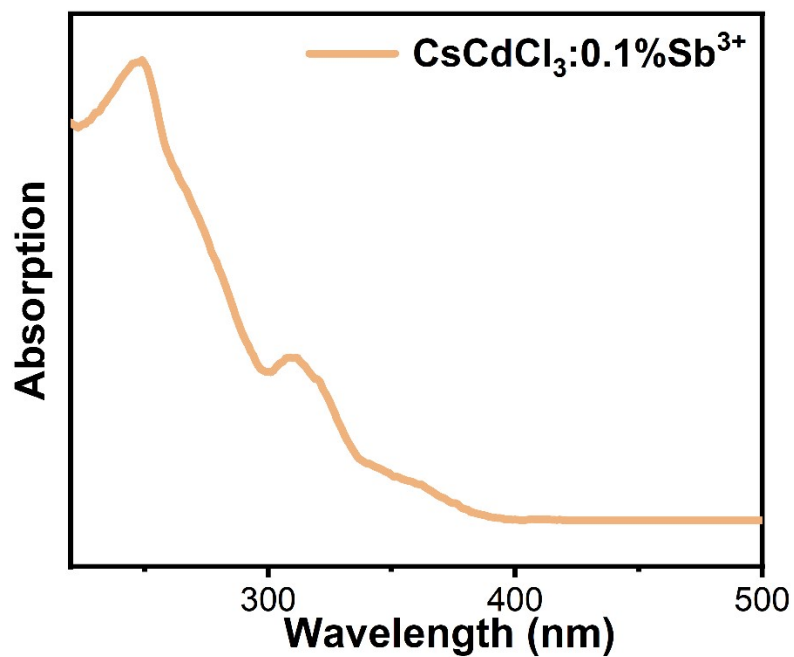


Figure S5. Absorption spectrum of 0.1%Sb³⁺-doped CsCdCl₃.

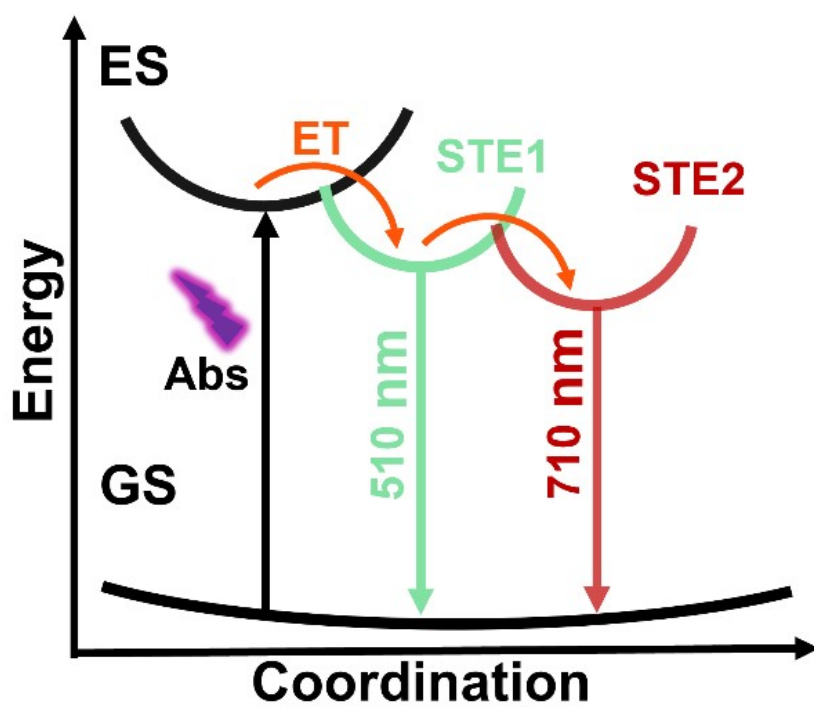


Figure S6. Schematic of the photophysical processes of Sb³⁺-doped CsCdCl₃.

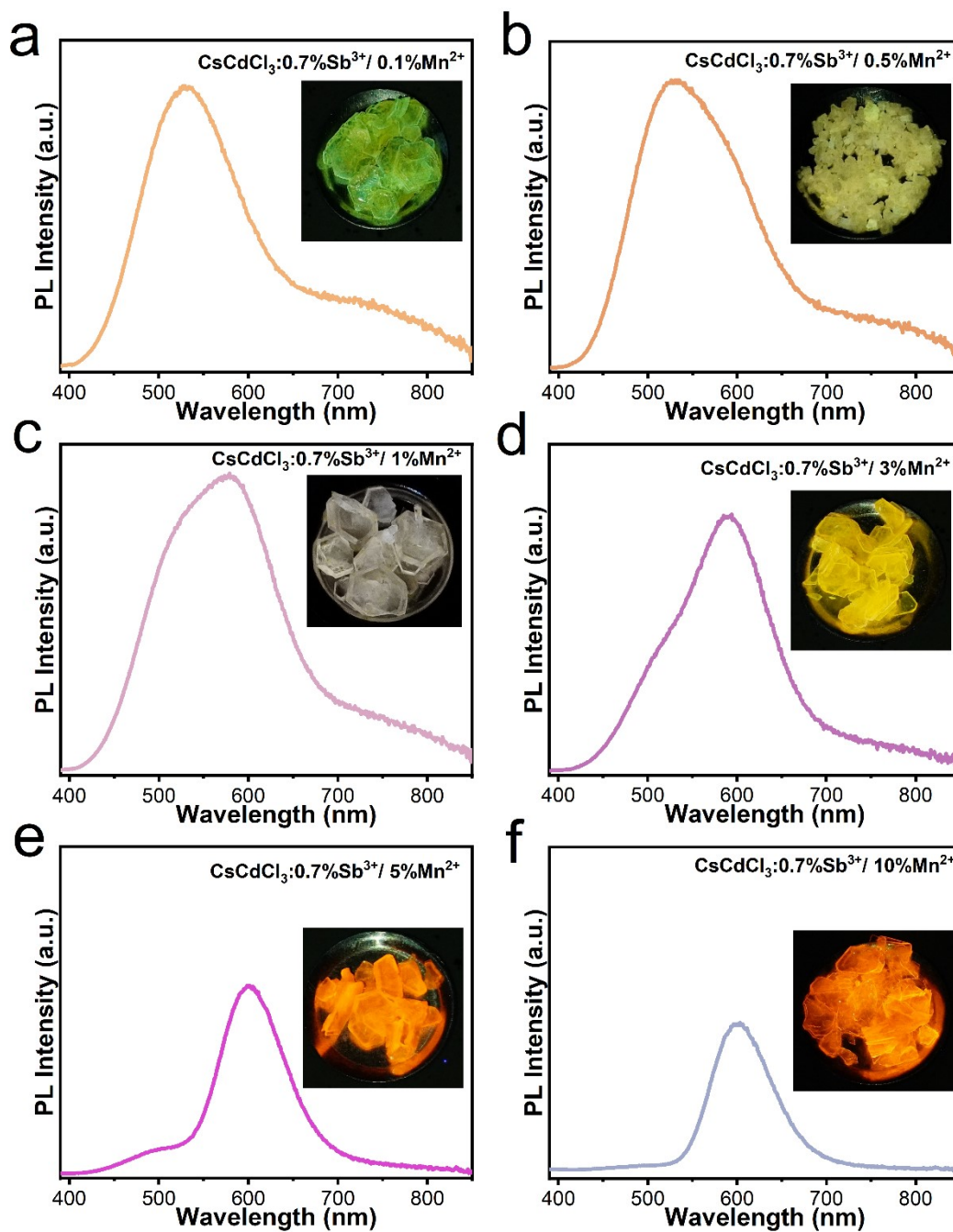


Figure S7. PL spectra of $0.1\% \text{Sb}^{3+}/\gamma\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals, and the inset shows the photographs of $0.1\% \text{Sb}^{3+}/\gamma\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals under 365 nm irradiation. (a) $0.1\% \text{Sb}^{3+}/0.1\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals; (b) $0.1\% \text{Sb}^{3+}/0.5\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals; (c) $0.1\% \text{Sb}^{3+}/1\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals; (d) $0.1\% \text{Sb}^{3+}/3\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals; (e) $0.1\% \text{Sb}^{3+}/5\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals; (f) $0.1\% \text{Sb}^{3+}/10\% \text{Mn}^{2+}$ -codoped CsCdCl_3 crystals.

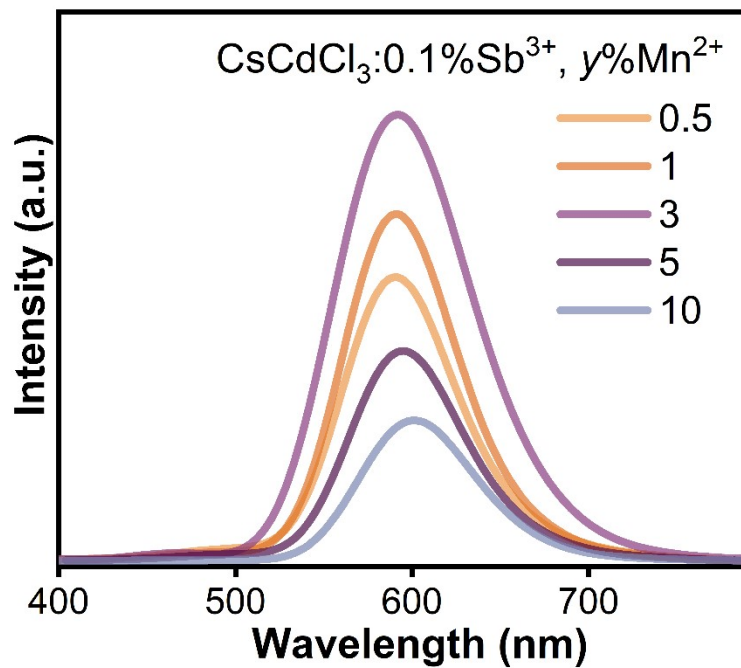


Figure S8. PL spectra of 0.1%Sb³⁺/Mn²⁺-codoped CsCdCl₃ under 254 nm excitation.

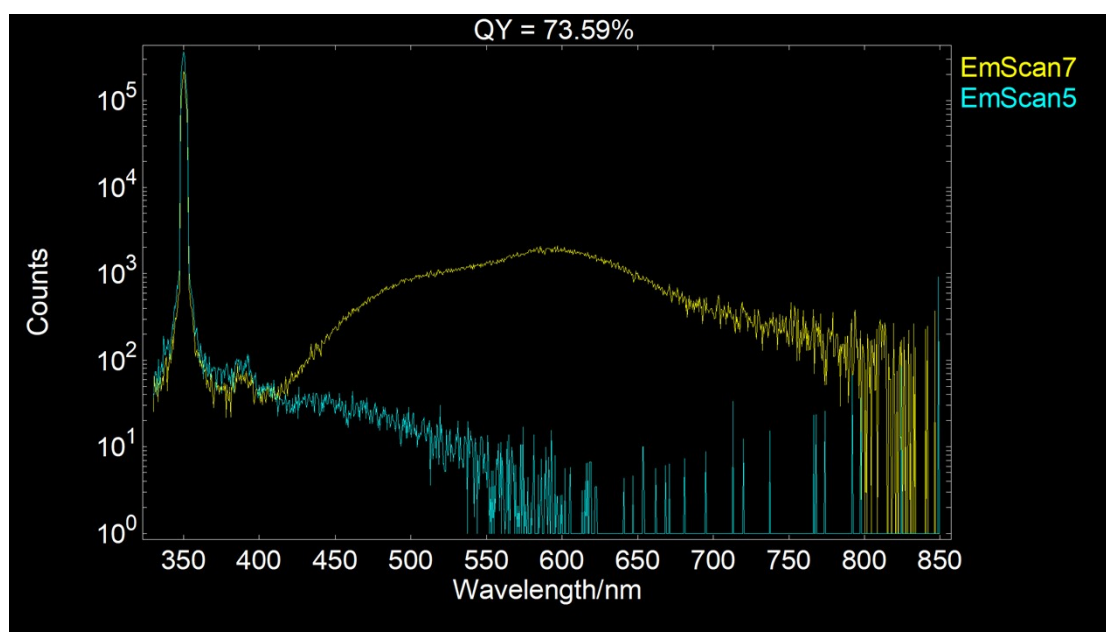


Figure S9. The PLQY of 0.1%Sb³⁺/1%Mn²⁺-codoped CsCdCl₃.

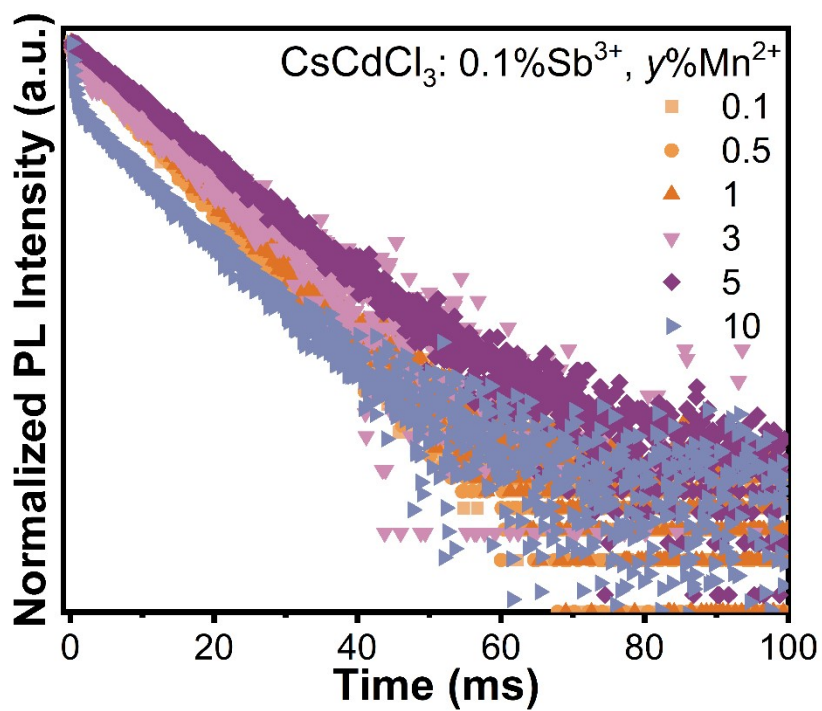


Figure S10. PL decay lifetime of 0.1% Sb^{3+} / Mn^{2+} -codoped CsCdCl_3 monitored at 600 nm.

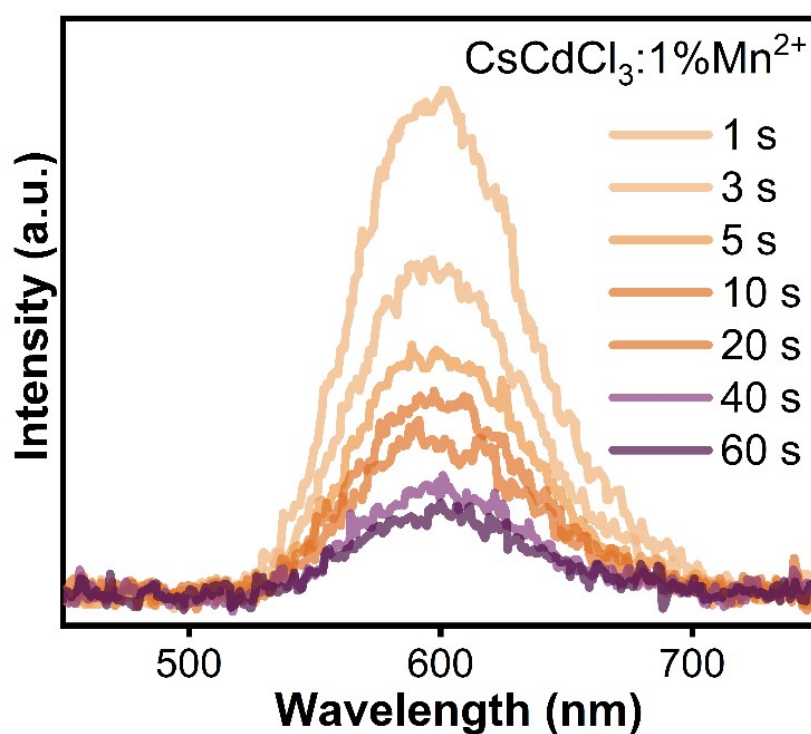


Figure S11. Afterglow emission spectra of 1% Mn^{2+} -doped CsCdCl_3 at various delay times after stopping 254 nm excitation.

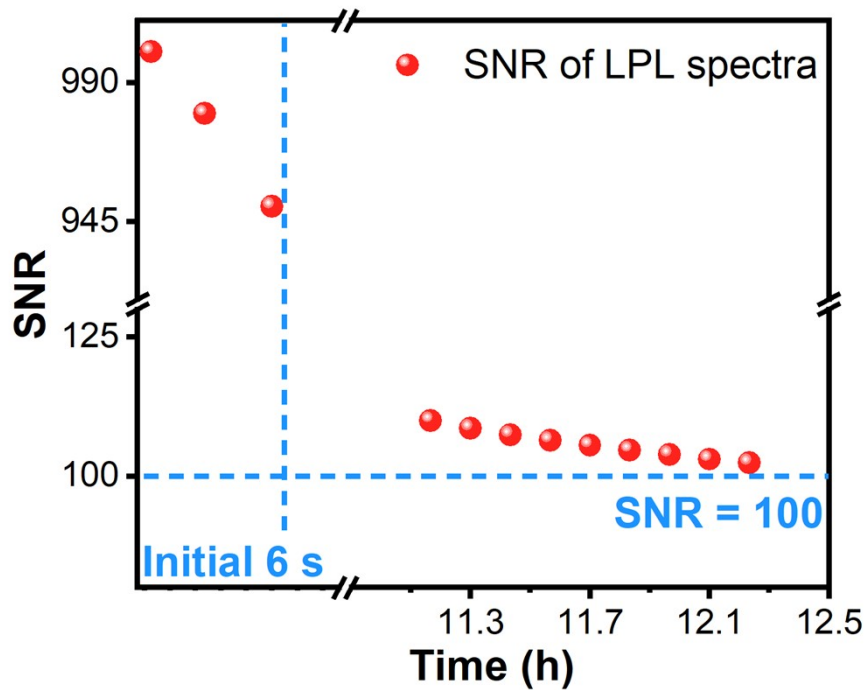


Figure S12. The signal-to-noise of afterglow spectra of 0.1% Sb^{3+} /1% Mn^{2+} -codoped CsCdCl_3 .

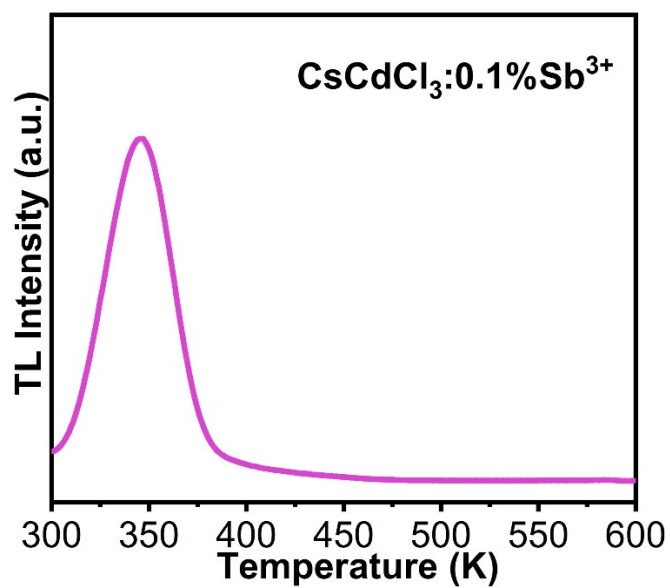


Figure S13. TL spectra of 0.1% Sb^{3+} -doped CsCdCl_3 .

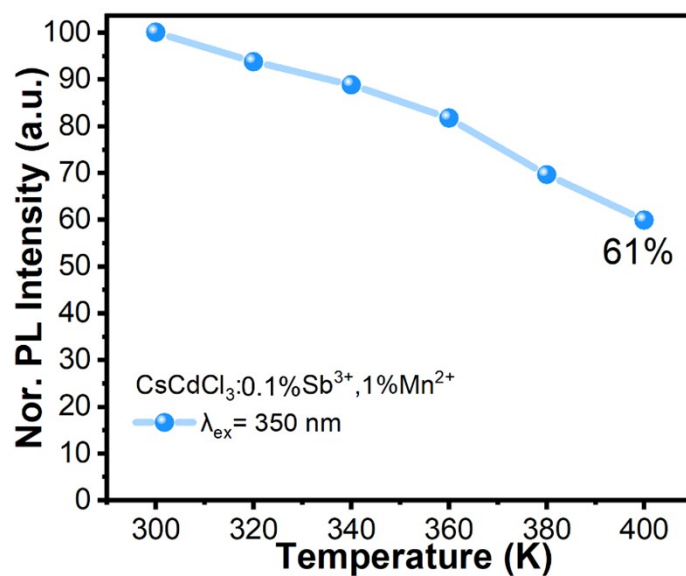


Figure S14. PL intensity of high temperature-dependent PL spectra excited by 350 nm.

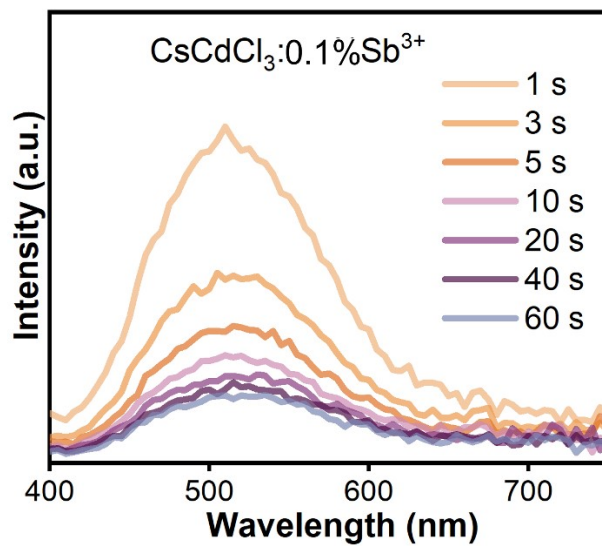


Figure S15. Afterglow emission spectra of 0.1%Sb³⁺-doped CsCdCl₃ at various delay times after stopping 350 nm excitation.

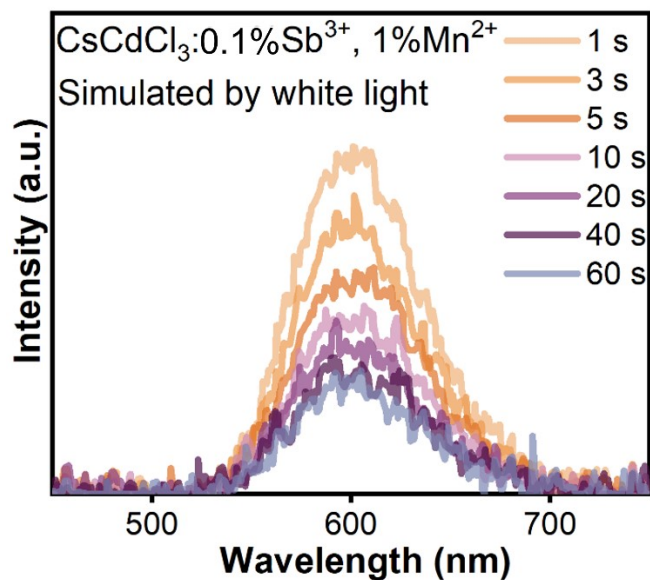


Figure S16. Afterglow emission spectra of 0.1%Sb³⁺/1%Mn²⁺-codoped CsCdCl₃ simulated by white light after 12 hours pre-delay.

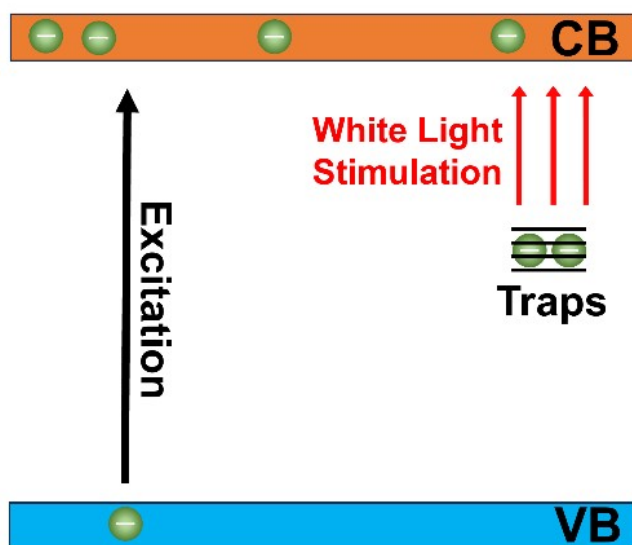


Figure S17. The difference between “excitation” and “white-stimulation” behaviors.

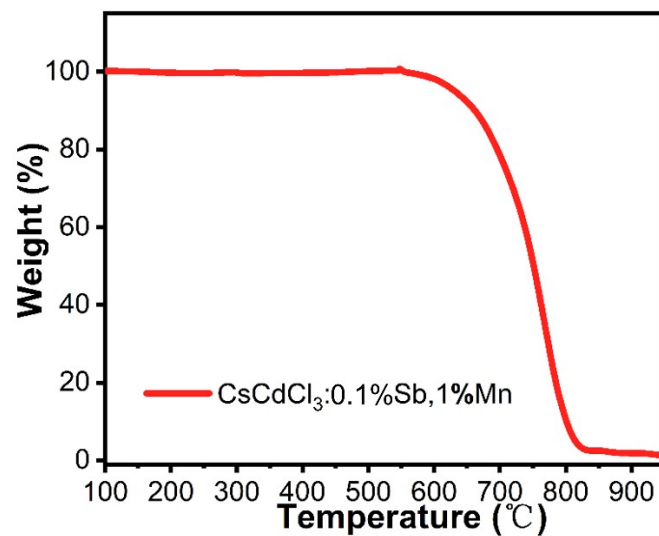


Figure S18. TGA curve of 0.1%Sb³⁺/1%Mn²⁺-codoped CsCdCl₃-codoped CsCdCl₃.

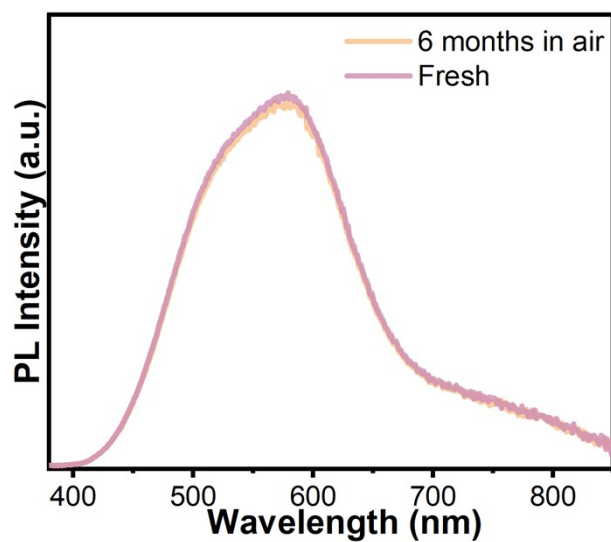


Figure S19. PL spectra of 0.1%Sb³⁺/1%Mn²⁺-codoped CsCdCl₃ before and after storing in air for 6 months.

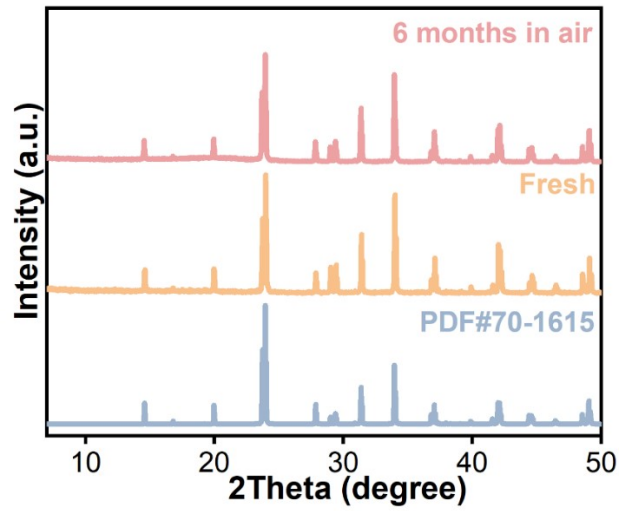


Figure S20. PXRD patterns of 0.1% Sb^{3+} /1% Mn^{2+} -codoped CsCdCl_3 before and after storing in air for 6 months.

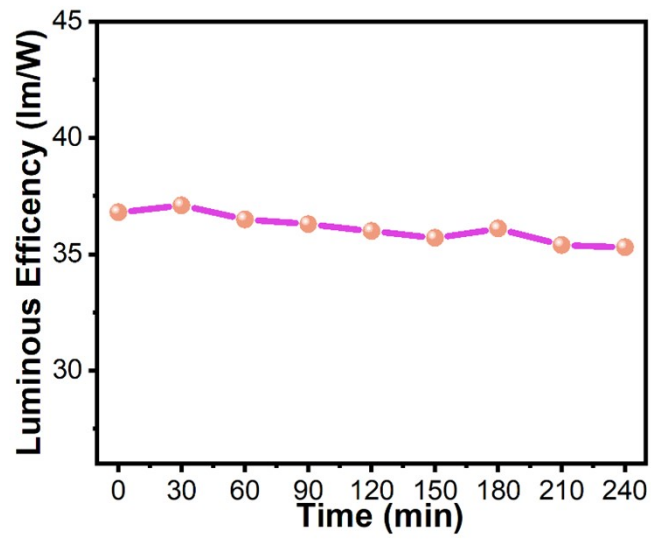


Figure S21. The operational stability of 0.1% Sb^{3+} /1% Mn^{2+} -codoped CsCdCl_3 -based WLED.