

Supporting Information

Multicolor Luminescence and Anti-Counterfeiting Applications in Cs₂KGdCl₆ Double Perovskite

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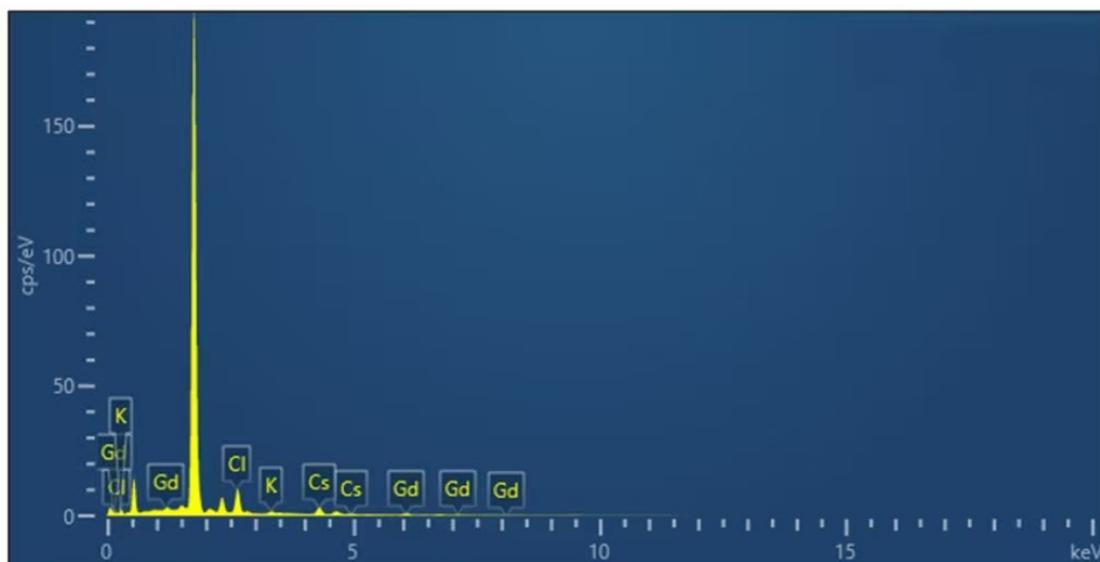


Fig. S1 Energy dispersive spectrum of Cs₂KGdCl₆.

Table. S1(a) The percentage of element content obtained from EDS.

Atomic% Element	Cs ₂ KGdCl ₆ : 1%Sb ³⁺	Cs ₂ KGdCl ₆ : 1%Sb ³⁺ /50%Ho ³⁺	Cs ₂ KGdCl ₆ : 1%Sb ³⁺ /13%Ho ³⁺ /35%Yb ³⁺
Cs	20.25	20.51	21.73
K	9.89	10.52	10.32
Gd	10.39	5.35	5.26
Cl	59.36	58.25	58.04
Sb	0.11	0.09	0.09
Ho		5.28	1.29
Yb			3.27

Table. S1(b) The percentage of element content obtained from EDS.

Atomic% Element	Cs ₂ KGdCl ₆ : 9%Er ³⁺ /35%Yb ³⁺	Cs ₂ KGdCl ₆ : 13%Ho ³⁺ /35%Yb ³⁺	Cs ₂ KGdCl ₆ : 2%Tm ³⁺ /40%Yb ³⁺
Cs	21.36	20.35	20.46
K	11.39	11.02	10.78
Gd	6.05	5.70	5.78
Cl	57.17	58.34	58.84
Er	0.91		
Ho		1.19	
Tm			0.18
Yb	3.12	3.40	3.96

Table. S2(a) A comparison of nominal versus actual doping level in ion-doped Cs₂KGdCl₆. The values in parentheses represent the nominal doping level.

Content Element	Cs ₂ KGdCl ₆ : 1%Sb ³⁺	Cs ₂ KGdCl ₆ : 1%Sb ³⁺ /50%Ho ³⁺	Cs ₂ KGdCl ₆ : 1%Sb ³⁺ /13%Ho ³⁺ /35%Yb ³⁺
Sb	1.05% (1%)	0.84% (1%)	0.91% (1%)
Ho		49.25% (50%)	13.02% (13%)
Yb			33.0% (35%)

Table. S2(b) A comparison of nominal versus actual doping level in ion-doped Cs₂KGdCl₆. The values in parentheses represent the nominal doping level.

Content Element	Cs ₂ KGdCl ₆ : 9%Er ³⁺ /35%Yb ³⁺	Cs ₂ KGdCl ₆ : 13%Ho ³⁺ /35%Yb ³⁺	Cs ₂ KGdCl ₆ : 2%Tm ³⁺ /40%Yb ³⁺
Er	9.03% (9%)		
Ho		11.56% (13%)	
Tm			1.81% (2%)
Yb	30.95% (35%)	33.04% (35%)	39.92% (40%)

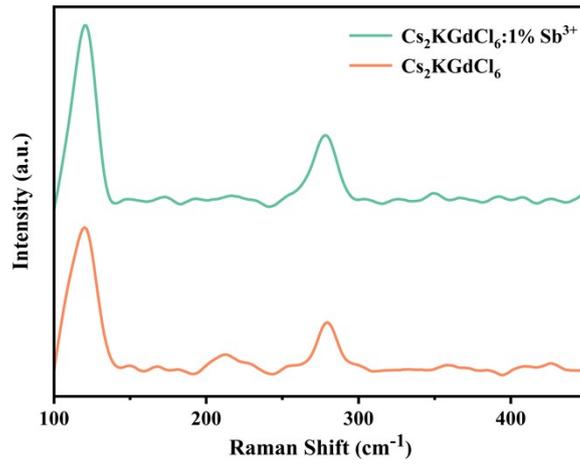


Fig. S2 The Raman spectra of Cs₂KGdCl₆ and Cs₂KGdCl₆:1%Sb³⁺.

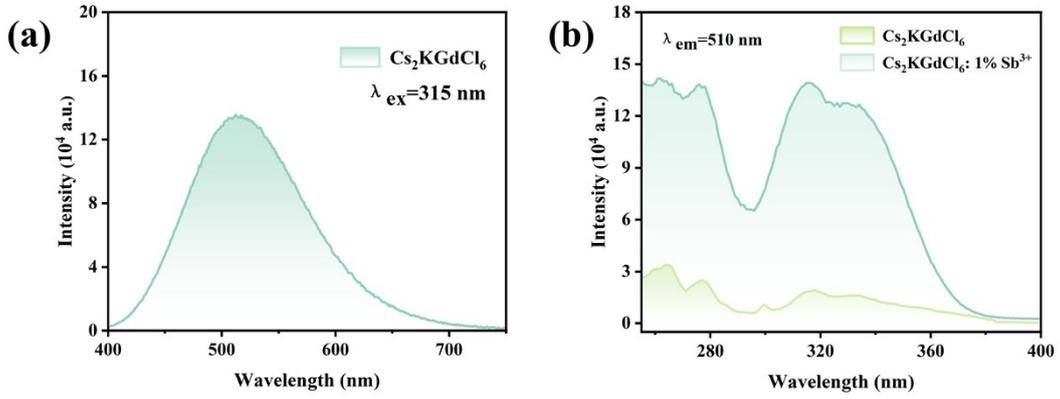


Fig. S3 (a) PL spectrum of Cs₂KGdCl₆ under 315 nm excitation. (b) PLE spectrum of Cs₂KGdCl₆ and Cs₂KGdCl₆:1%Sb³⁺.

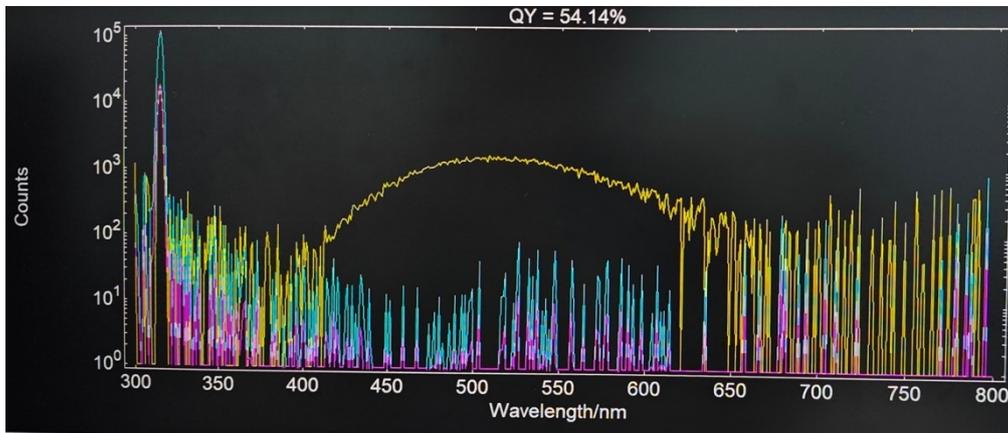


Fig. S4 PLQY of the 1%Sb³⁺ doped Cs₂KGdCl₆ under 315nm excitation.

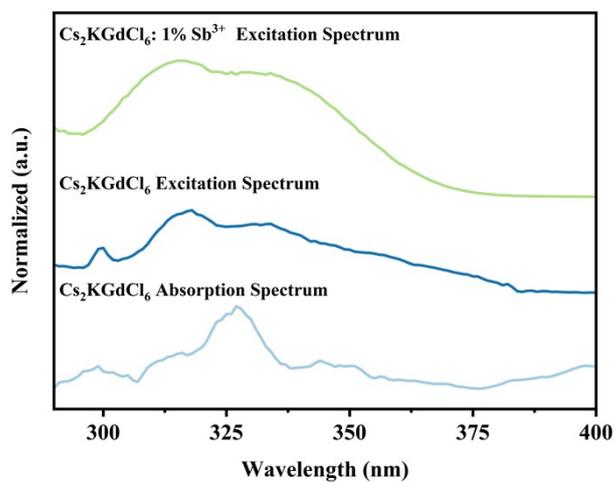


Fig. S5 The UV-Vis absorption spectrum of $\text{Cs}_2\text{KGdCl}_6$ and the excitation spectra of $\text{Cs}_2\text{KGdCl}_6$ as well as $\text{Cs}_2\text{KGdCl}_6:1\% \text{Sb}^{3+}$.

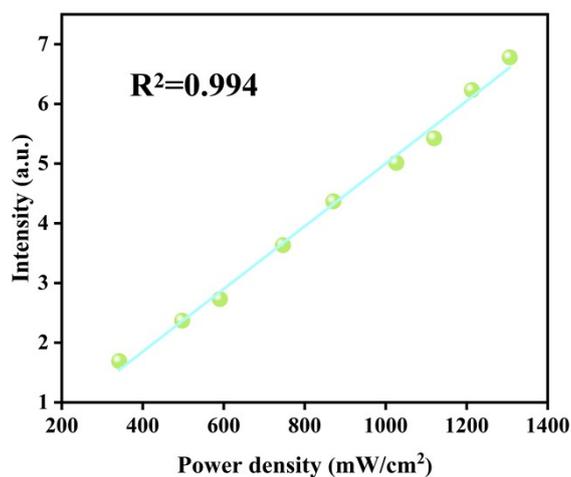


Fig. S6 PL intensity versus excitation power density at room temperature for $\text{Cs}_2\text{KGdCl}_6:1\% \text{Sb}^{3+}$.

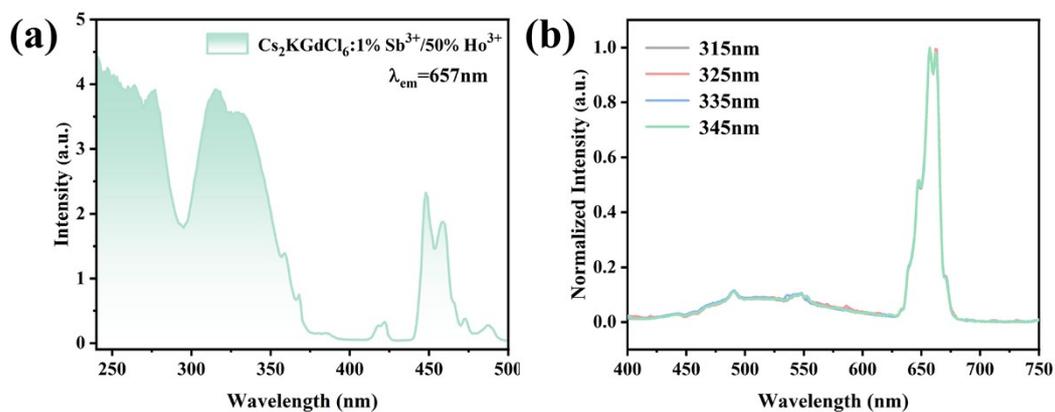


Fig. S7 (a) PLE spectrum of $\text{Cs}_2\text{KGdCl}_6:1\%\text{Sb}^{3+}/50\%\text{Ho}^{3+}$ monitored at 657 nm. (b) Normalized PL spectra of $\text{Cs}_2\text{KGdCl}_6:1\%\text{Sb}^{3+}/50\%\text{Ho}^{3+}$ under 315–345 nm excitation.

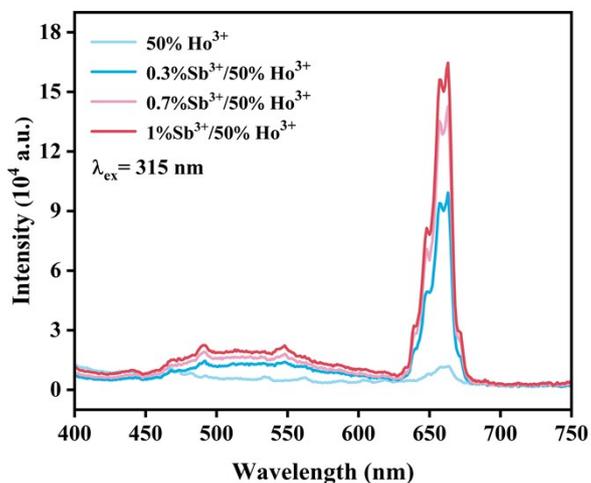


Fig. S8 Emission spectra of $\text{Cs}_2\text{KGdCl}_6:x\text{Sb}^{3+}/50\%\text{Ho}^{3+}$ ($x = 0\text{--}1\%$) under 315 nm excitation.

Table. S3 Fluorescence lifetimes and energy transfer efficiency of $1\%\text{Sb}^{3+}/y\text{Ho}^{3+}$ at 510 nm and 657 nm under 315 nm excitation.

Samples	510 nm	657 nm	$\eta_{ET}(\%)$
$y = 0\%$	2.64 μs	-	-
$y = 10\%$	1.91 μs	0.149 ms	27.7
$y = 20\%$	1.28 μs	0.162 ms	51.5
$y = 30\%$	0.95 μs	0.185 ms	64.0
$y = 40\%$	0.58 μs	0.188 ms	78.0
$y = 50\%$	0.35 μs	0.194 ms	86.7
$y = 60\%$	0.26 μs	0.186 ms	90.2

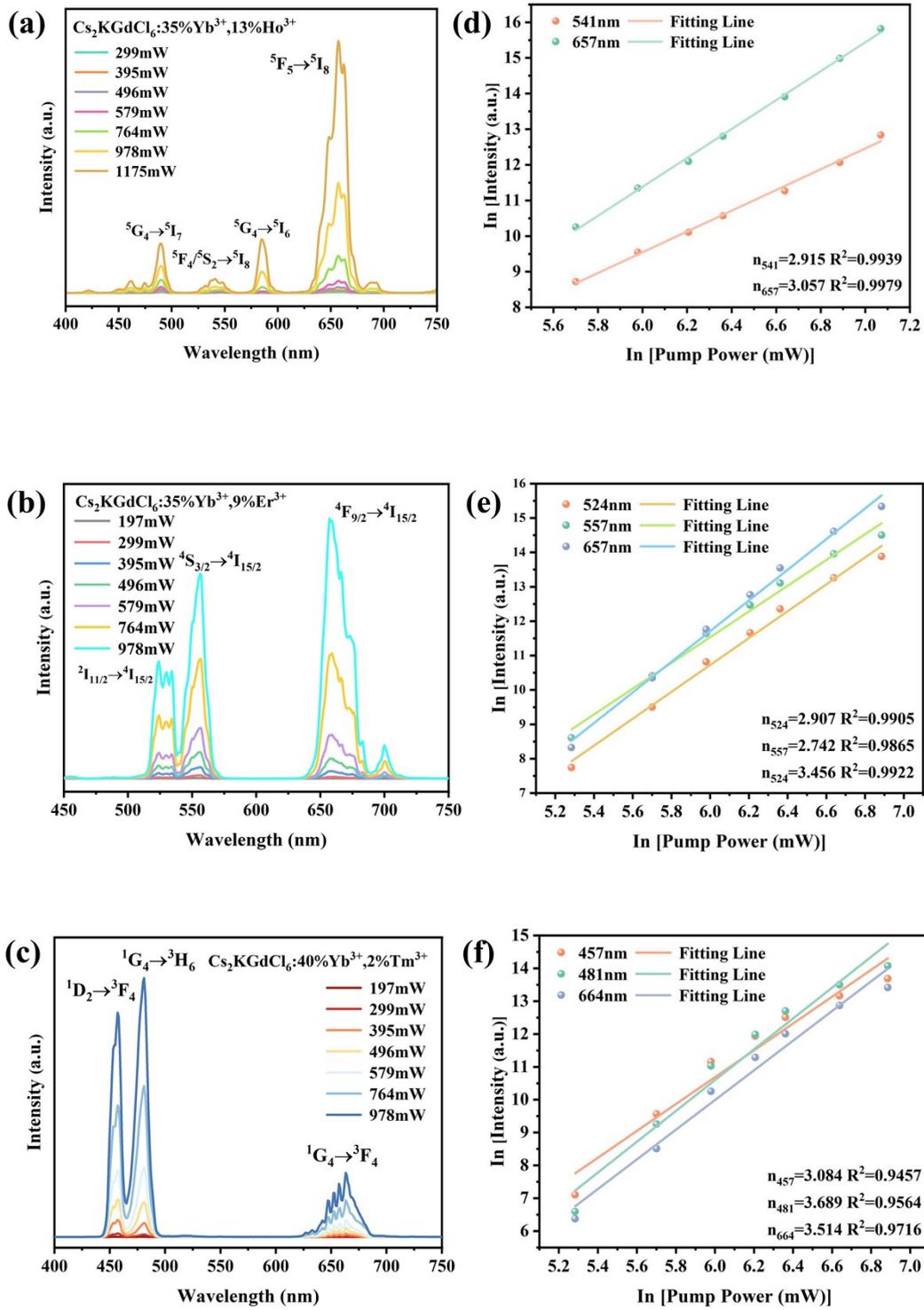


Fig. S9 Up-conversion emission spectra of (a) $\text{Cs}_2\text{KGdCl}_6:35\%\text{Yb}^{3+}, 13\%\text{Ho}^{3+}$ (b) $\text{Cs}_2\text{KGdCl}_6:35\%\text{Yb}^{3+}, 9\%\text{Er}^{3+}$ and (c) $\text{Cs}_2\text{KGdCl}_6:40\%\text{Yb}^{3+}, 2\%\text{Tm}^{3+}$ under different pump powers. Dependence of up-conversion emission intensity on pump power for (d) $\text{Cs}_2\text{KGdCl}_6:35\%\text{Yb}^{3+}, 13\%\text{Ho}^{3+}$ (e) $\text{Cs}_2\text{KGdCl}_6:35\%\text{Yb}^{3+}, 9\%\text{Er}^{3+}$ and (f) $\text{Cs}_2\text{KGdCl}_6:40\%\text{Yb}^{3+}, 2\%\text{Tm}^{3+}$.

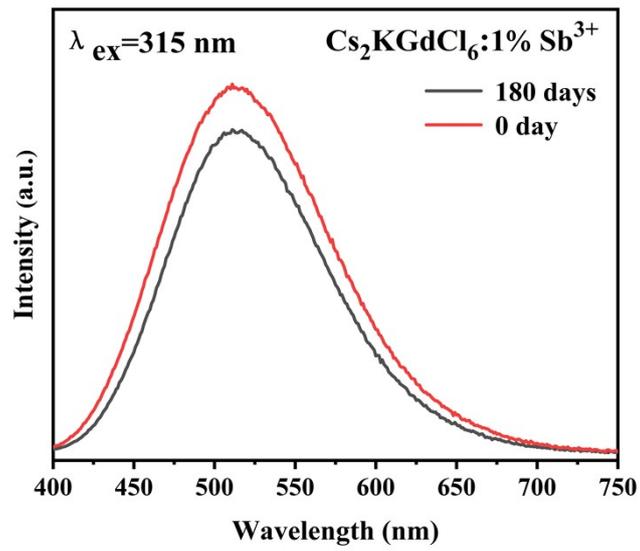


Fig. S10 The PL spectra of $\text{Cs}_2\text{KGdCl}_6:1\% \text{Sb}^{3+}$ measured on day 0 and after 180 days.

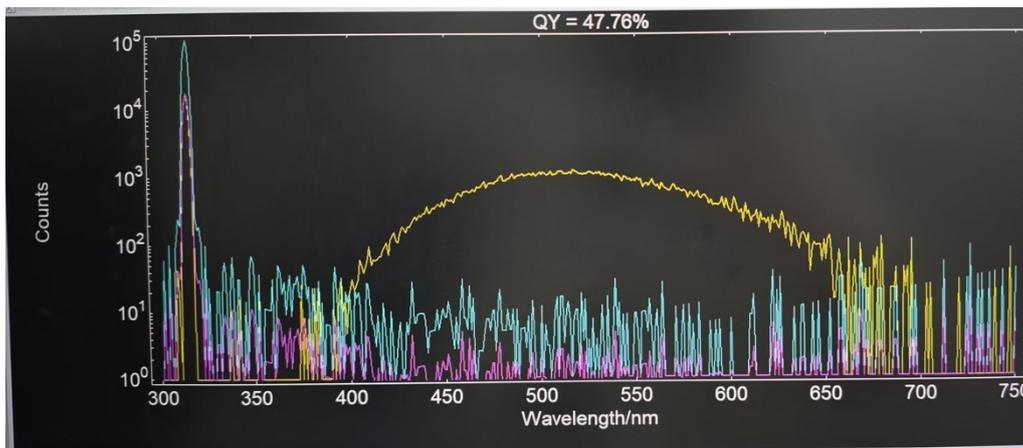


Fig. S11 The PLQY of $\text{Cs}_2\text{KGdCl}_6:1\% \text{Sb}^{3+}$ measured after 180 days.