

## Highly efficient near-infrared emission from Cr<sup>3+</sup>-sensitized double perovskite Cs<sub>2</sub>Ag<sub>0.6</sub>Na<sub>0.4</sub>InCl<sub>6</sub>:Tm<sup>3+</sup> under visible light excitation

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Table S1 Actual doping concentrations of Cr<sup>3+</sup> and Tm<sup>3+</sup> in Cs<sub>2</sub>Ag<sub>0.6</sub>Na<sub>0.4</sub>InCl<sub>6</sub>:Cr<sup>3+</sup>/Tm<sup>3+</sup> determined by ICP-OES. The atomic percentages are calculated as [Cr]/([In]+[Cr]+[Tm])×100% for Cr<sup>3+</sup> and [Tm]/([In]+[Cr]+[Tm])×100% for Tm<sup>3+</sup>.

Feeding atomic ratio (%)		Actual atomic ratio (%)	
Cr <sup>3+</sup>	Tm <sup>3+</sup>	Cr <sup>3+</sup>	Tm <sup>3+</sup>
30	10	0.10	0.24
30	20	0.13	0.62
30	30	0.14	1.57
30	40	0.28	2.80
30	50	0.40	5.07

Table S2 A summary of the NIR emission performance of NIR-emitting double perovskites.

Compositions	$\lambda_{ex}$ (nm)	$\lambda_{em}$ (nm)	PLQY (%)	Ref
Cs <sub>2</sub> NaBiCl <sub>6</sub> :Mn <sup>2+</sup> /Er <sup>3+</sup>	360	1540	14.2	[S1]
Cs <sub>2</sub> AgInCl <sub>6</sub> :Na <sup>+</sup> /Bi <sup>3+</sup> /Nd <sup>3+</sup>	392	890/1063/1351	30.3	[S2]
Cs <sub>2</sub> NaYCl <sub>6</sub> :Sb <sup>3+</sup> /Tm <sup>3+</sup>	320	1220	20.2	[S3]
Cs <sub>2</sub> NaInCl <sub>6</sub> :Er <sup>3+</sup> /Yb <sup>3+</sup>	273	1540	7.9	[S4]
Cs <sub>2</sub> Ag <sub>0.2</sub> Na <sub>0.8</sub> BiCl <sub>6</sub> :Yb <sup>3+</sup> /Er <sup>3+</sup>	360	995/1540	19.0/4.3	[S5]
Cs <sub>2</sub> AgInCl <sub>6</sub> :Cr <sup>3+</sup> /Er <sup>3+</sup>	360	1540	29.0	[S6]
Cs <sub>2</sub> NaInCl <sub>6</sub> : Cr <sup>3+</sup> /Tm <sup>3+</sup>	290	1220	31.9	[S7]
Cs <sub>2</sub> Ag <sub>0.6</sub> Na <sub>0.4</sub> InCl <sub>6</sub> : Cr <sup>3+</sup> /Tm <sup>3+</sup>	340	1226	35.8	This work

Table S3 The goodness-of-fit of the lifetime data for  $\text{Cs}_2\text{Ag}_{0.6}\text{Na}_{0.4}\text{InCl}_6:30\%\text{Cr}^{3+}/x\%\text{Tm}^{3+}$  samples with varying  $\text{Tm}^{3+}$  concentration (x%).

x%	Lifetime ( $\mu\text{s}$ )	$R^2$
0%	15.55	0.998
10%	15.07	0.998
20%	14.79	0.998
30%	13.77	0.999
40%	11.65	0.999
50%	8.66	0.998

Table S4 Energy transfer efficiency ( $\eta_{\text{ET}}$ ) for  $\text{Cs}_2\text{Ag}_{0.6}\text{Na}_{0.4}\text{InCl}_6:30\%\text{Cr}^{3+}/x\%\text{Tm}^{3+}$  samples with varying  $\text{Tm}^{3+}$  concentration (x%).

x%	Energy transfer efficiency
10%	3.06%
20%	4.89%
30%	11.46%
40%	25.06%
50%	44.32%

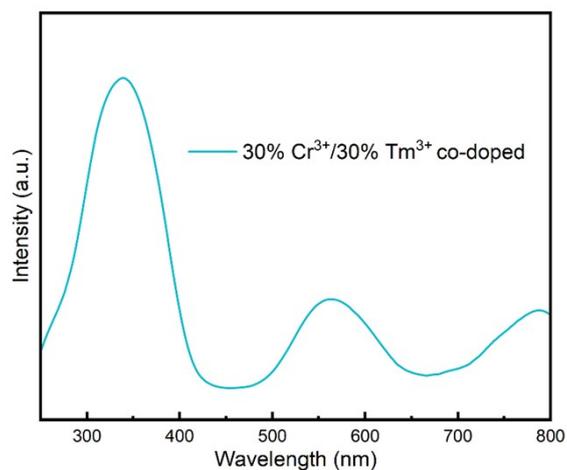


Fig.S1 Photoluminescence excitation (PLE) spectrum of Cr<sup>3+</sup>/Tm<sup>3+</sup> co-doped Cs<sub>2</sub>Ag<sub>0.6</sub>Na<sub>0.4</sub>InCl<sub>6</sub> monitored at the Tm<sup>3+</sup> emission wavelength ( $\lambda_{em} = 1226$  nm).

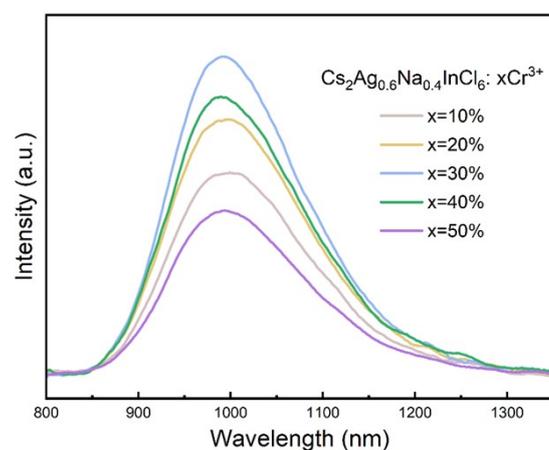


Fig.S2 Photoluminescence (PL) spectrum of Cs<sub>2</sub>Ag<sub>0.6</sub>Na<sub>0.4</sub>InCl<sub>6</sub>:Cr<sup>3+</sup> under 340 nm excitation, showing the broadband NIR emission.

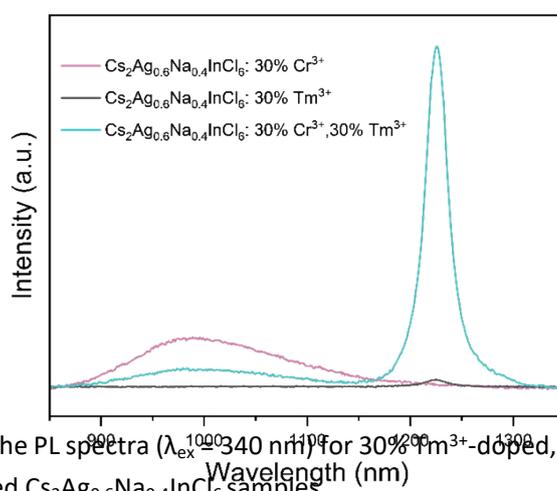


Fig.S3 Comparison of the PL spectra ( $\lambda_{ex} = 340$  nm) for 30% Tm<sup>3+</sup>-doped, 30% Cr<sup>3+</sup>-doped, and 30% Cr<sup>3+</sup>/30% Tm<sup>3+</sup> co-doped Cs<sub>2</sub>Ag<sub>0.6</sub>Na<sub>0.4</sub>InCl<sub>6</sub> samples.

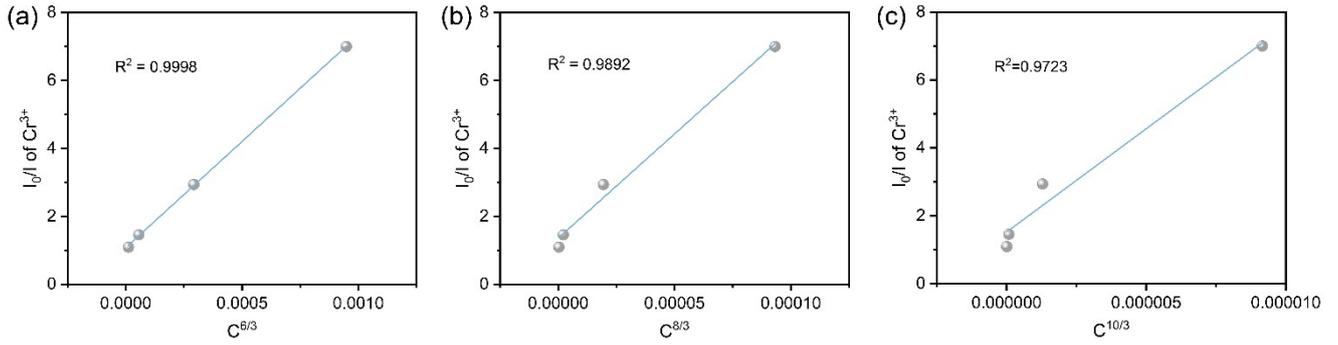


Fig.S4 Dependence of  $(I_0/I)$  values on (a)  $C^{6/3}$ , (b)  $C^{8/3}$ , and (c)  $C^{10/3}$ . Corresponding correlation coefficient  $R^2$  indicates the fitting behavior with the straight blue line in  $\text{Cs}_2\text{Ag}_{0.6}\text{Na}_{0.4}\text{InCl}_6:30\%\text{Cr}^{3+}/30\%\text{Tm}^{3+}$ .

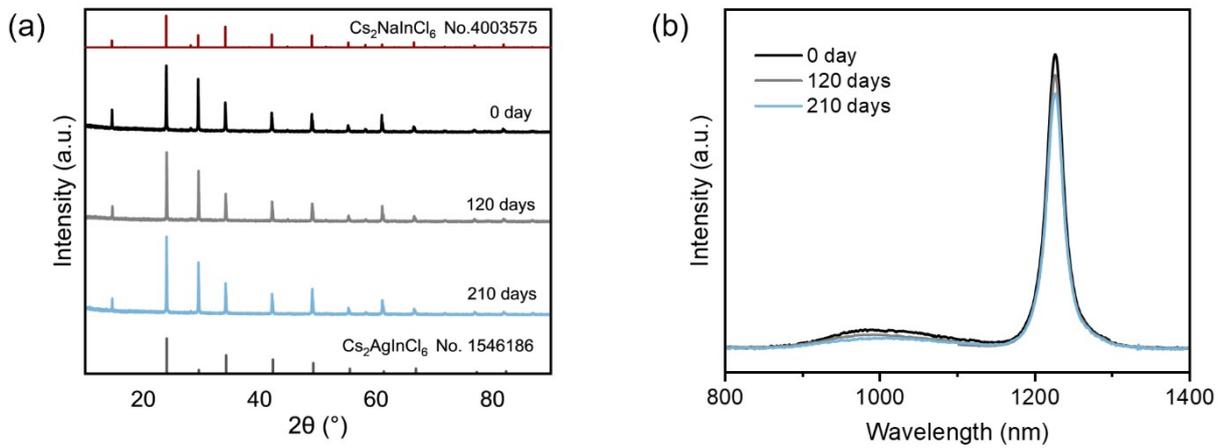


Fig.S5 Stability assessment of  $\text{Cs}_2\text{Ag}_{0.6}\text{Na}_{0.4}\text{InCl}_6:30\%\text{Cr}^{3+}/30\%\text{Tm}^{3+}$ : (a) XRD patterns and (b) normalized PL spectra ( $\lambda_{\text{ex}} = 340$  nm) before and after 120 days and 210 days of storage under ambient conditions (20-70% relative humidity,  $293 \pm 5$  K).

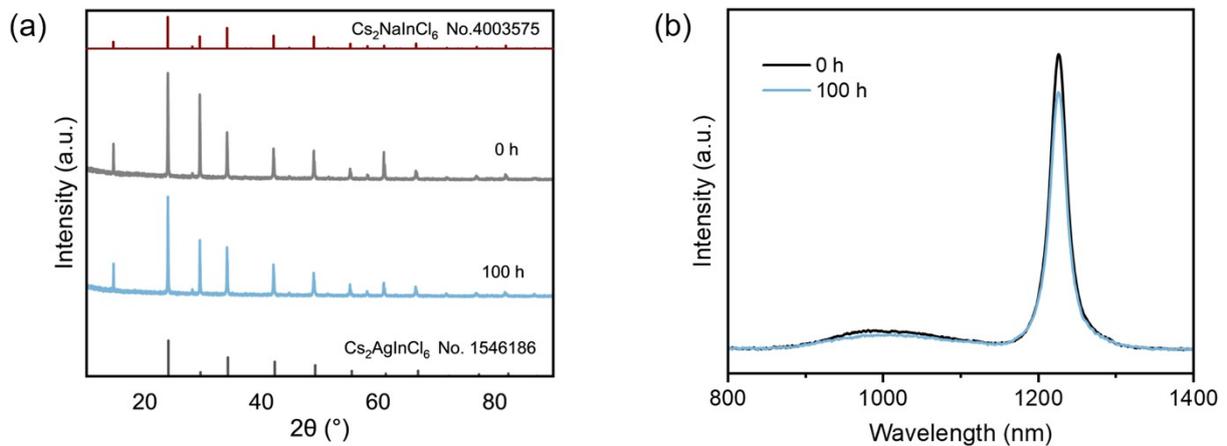


Fig.S6 Stability assessment of  $\text{Cs}_2\text{Ag}_{0.6}\text{Na}_{0.4}\text{InCl}_6:30\%\text{Cr}^{3+}/30\%\text{Tm}^{3+}$ : (a) XRD patterns and (b) normalized PL spectra ( $\lambda_{\text{ex}} = 340$  nm) before and after 100 hours of storage under humid conditions (70% relative humidity, 313 K).

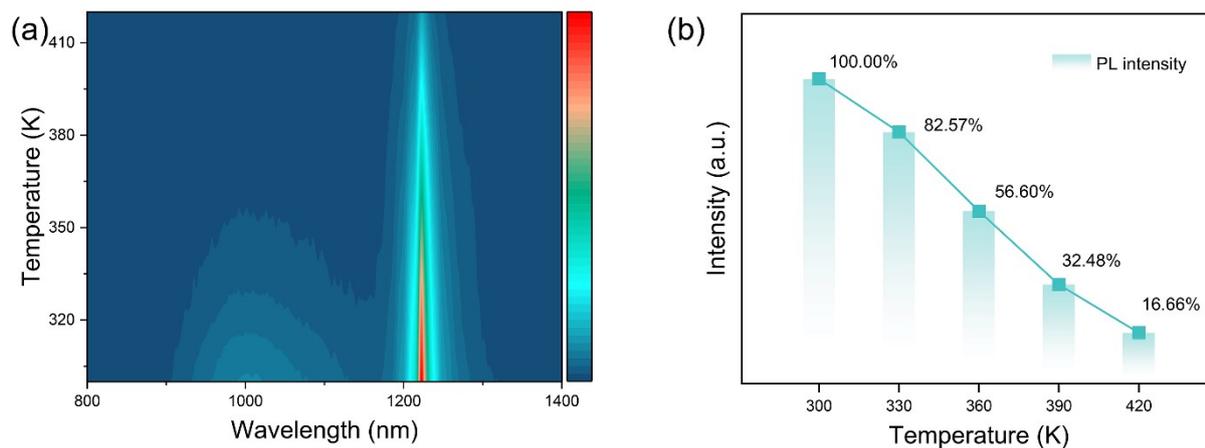


Fig.S7 (a) Contour plots of temperature-dependent PL spectra ( $\lambda_{ex} = 340$  nm) for  $\text{Cs}_2\text{Ag}_{0.6}\text{Na}_{0.4}\text{InCl}_6:30\%\text{Cr}^{3+}/30\%\text{Tm}^{3+}$  over the temperature range of 300-420 K. (b) Corresponding normalized thermal quenching behavior of  $\text{Tm}^{3+}$  band.

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