Electronic Supplementary Material (ESI) for Nanoscale.
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Supporting Information

Highly efficient and stable red perovskite quantum dots through encapsulation and sensitization from porous CaF_2: Ce, Tb nanoarchitectures

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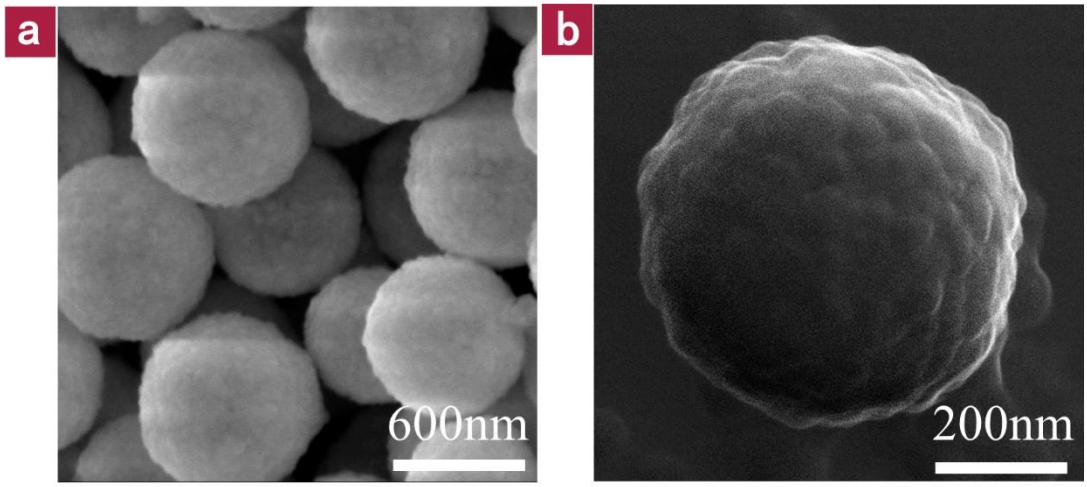

Figure S1. a) SEM of CaF_2: Ce, Tb&$CsPbI_3$ composites. b) An enlarged SEM image of the CaF_2: Ce, Tb&$CsPbI_3$ composite nanosphere.

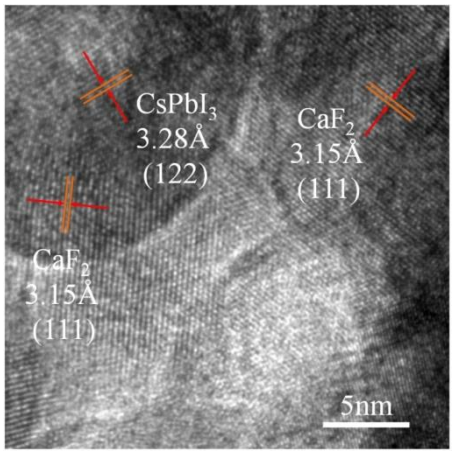

Figure S2. HR-TEM image of CaF_2:Ce,Tb&$CsPbI_3$ composite.

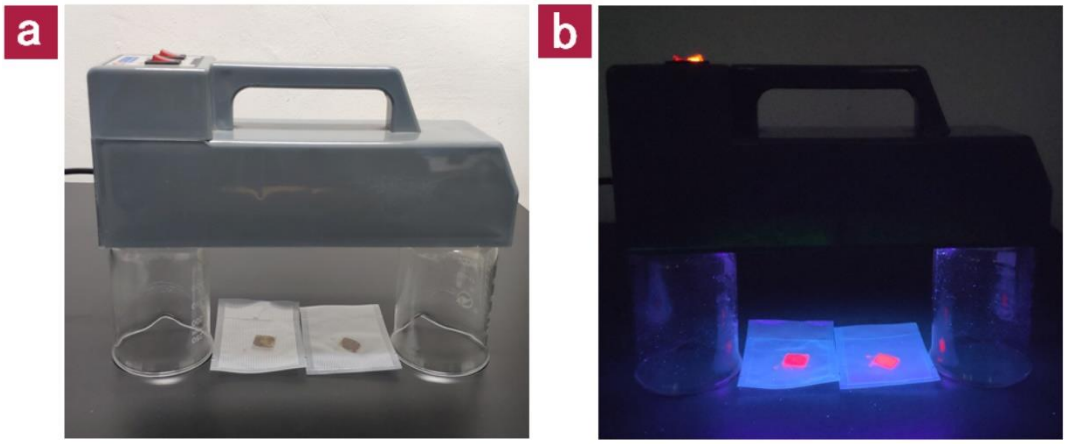

Figure S3. a) Photostability test for $CsPbI_3$ QDs and CaF_2: Ce, Tb&$CsPbI_3$ composite films under sun lights. b) Photostability test for $CsPbI_3$ QDs and CaF_2: Ce, Tb&$CsPbI_3$ composite films under ultraviolet lamp. In order to avoid the factors of water and oxygen, the sample films are encapsulated in a vacuum bag.

Table S1. Time-resolved PL decay curves for CaF_2 nanospheres doped with varying Tb^{3+} and Ce^{3+} compositions are fitted with a monoexponential function:

Ce:Tb	τ（μs）
7:1	13690
7:3	14810
7:5	15690
7:7	17520
7:9	16430
7:11	14220

Ce:Tb	τ（μs）
1:7	14930
3:7	15940
5:7	16290
7:7	17520
9:7	15250
11:7	14580

Table S2. The energy transfer efficiency η_T from Tb^{3+} ions to $CsPbI_3$ PQDs can be obtained by from formula**:**

$$\eta_T=1-\frac{\tau_x}{\tau_0}$$

Samples	τ（μs）
CaF_2:Ce,Tb	1608
CaF_2:Ce,Tb&$CsPbI_3$	1426

$$\eta_T=1-\frac{\tau_x}{\tau_0}=1-\frac{1426*10^{-6}}{1608*10^{-6}}=1-0.887=0.113=11.3\%$$

Table S3. PL parameters of CaF_2:7%Ce,7%Tb&$CsPbBr_xI_{3-x}$ PQDs with varying halide compositions upon UV excitation at 300 nm: emission peak wavelength, and absolute PLQY.

$CsPbBr_xI_{3-x}$ PQDs	Emission Peak (nm)	PLQY (%)
$CsPbBr_3$	521	81.2±0.5
$CsPbBr_{2.5}I_{0.5}$	550	77.1±0.5
$CsPbBr_{1.8}I_{1.2}$	580	67.3±0.4
$CsPbBr_{1.2}I_{1.8}$	627	65.2±0.4
$CsPbBr_{0.5}I_{2.5}$	650	62.4±0.3
$CsPbI_3$	706	60.8±0.6

Table S4. Time-resolved PL decay curves for CaF_2:Ce,Tb&$CsPbBr_xI_{3-x}$ with varying halide compositions are fitted with a bi-exponential function. The average lifetimes can be calculated by the formula:

$$\tau_{avg} = \frac{A_1\tau_1^2 + A_2\tau_2^2}{A_1\tau_1 + A_2\tau_2}$$

$CsPbBr_xI_{3-x}$	τ_1 (ns)	τ_2 (ns)	A_1 (%)	A_2 (%)	τ_{avg} (ns)
$CsPbBr_3$	1105	9365	53.21	46.79	8387.781
$CsPbBr_{2.5}I_{0.5}$	1097	9230	52.31	47.69	8292.019
$CsPbBr_{1.8}I_{1.2}$	1087	9299	52.39	47.61	8363.076
$CsPbBr_{1.2}I_{1.8}$	1070	9281	51.52	48.48	8384.8
$CsPbBr_{0.5}I_{2.5}$	1076	9398	51.96	48.04	8481.002
$CsPbI_3$	1256	9652	51.30	48.70	8639.853