Supplementary Information

Effective blue-violet photoluminescence through the lanthanum and fluorine ions co-doping in $CsPbCl_3$ perovskite quantum dots

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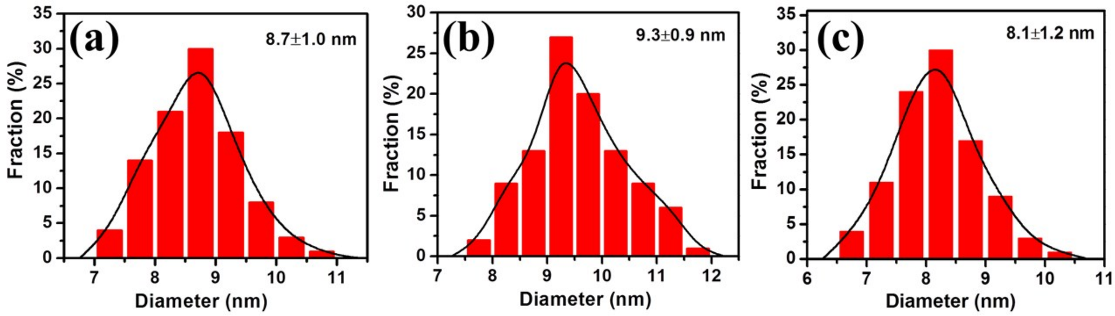

Fig. S1 The statistics on the dimensions of $CsPbCl_3$ and $CsPb(Cl/F)_3$ QDs with different Cl-to-F molar feed ratios; a, 1:0; b, 1:0.2 and c,1:0.8.

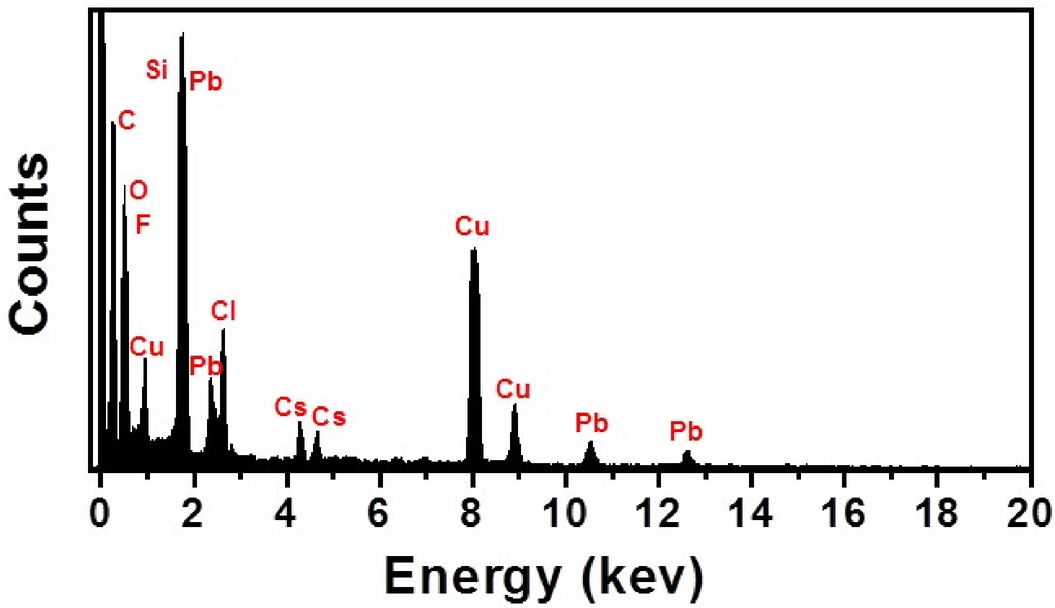

Fig. S2 EDX pattern of $CsPb(Cl/F)_3$ QDs prepared with Cl-to-F molar feed ratio of 1:0.8.

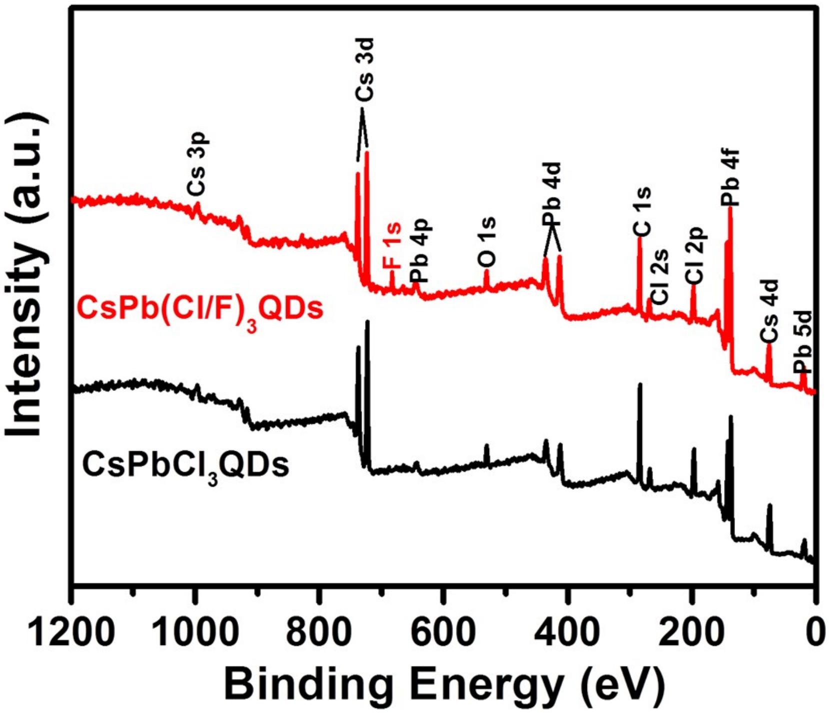

Fig. S3 XPS spectra for $CsPbCl_3$ and $CsPb(Cl/F)_3$ QDs prepared with Cl-to-F molar feed ratio of 1:0.8.

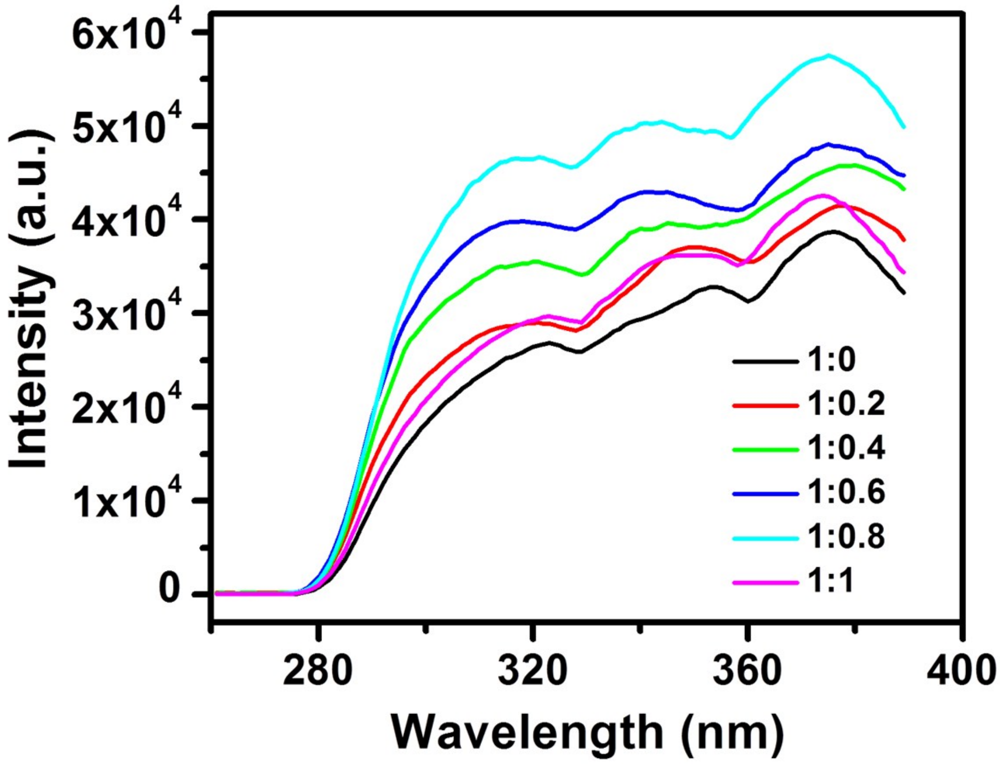

Fig. S4 Excitation spectra of $CsPbCl_3$ and $CsPb(Cl/F)_3$ QDs under monitored wavelength of 410 nm.

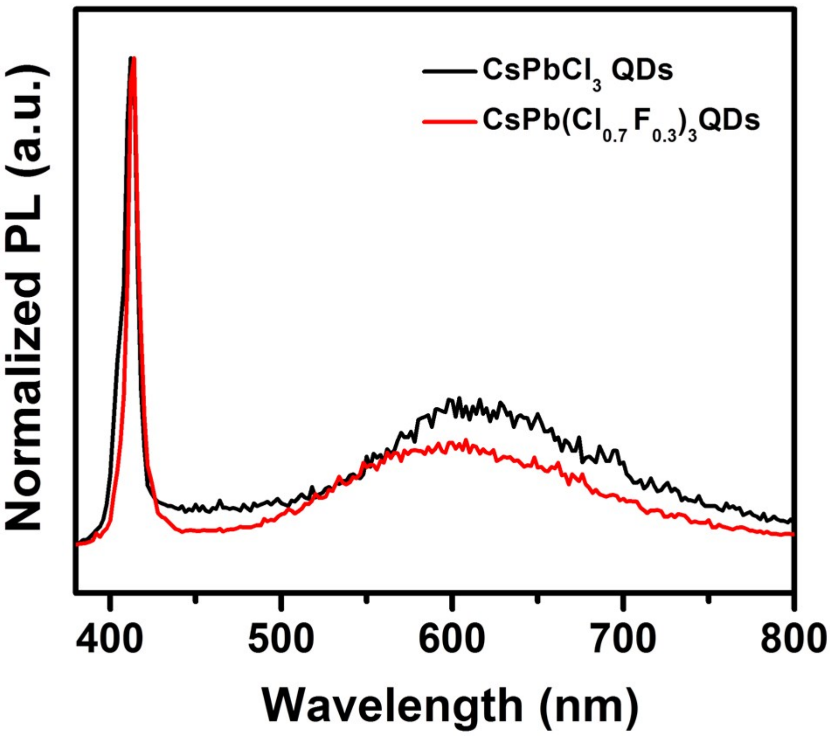

Fig. S5 Low temperature fluorescence spectroscopy of $CsPbCl_3$ and $CsPb(Cl_{0.7}F_{0.3})_3$ QDs measured at 10K.

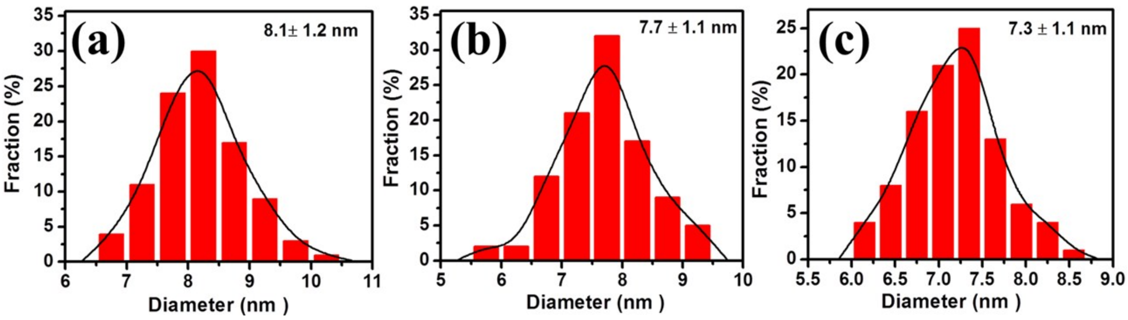

Fig. S6 The statistics on the dimensions of $CsPb(Cl_{0.7}F_{0.3})_3:La^{3+}$ QDs prepared with La^{3+} ions doping concentration of 3.1, 7.2 and 14.4%.

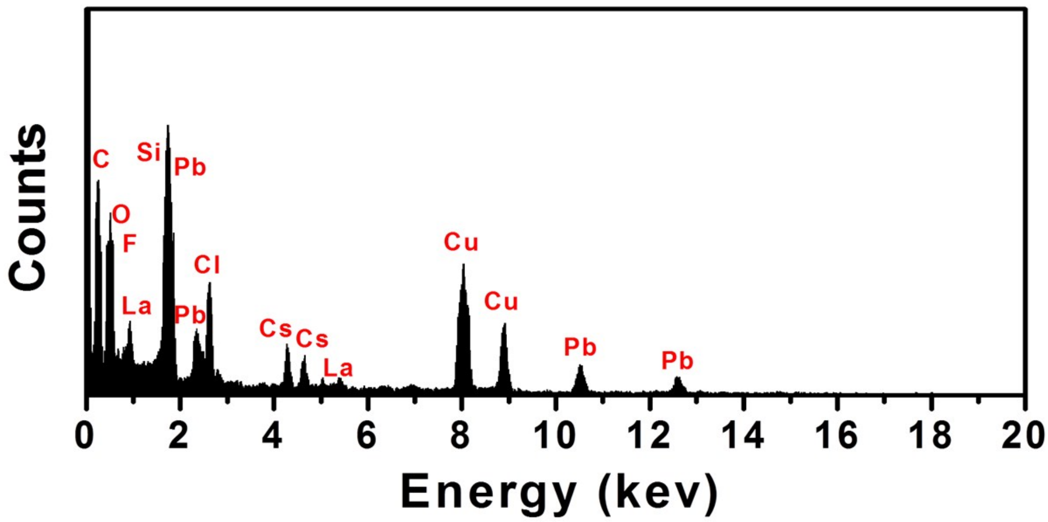

Fig. S7 EDX pattern of $CsPb(Cl_{0.7}F_{0.3})_3$:La^{3+} QDs with the 14.4% La^{3+} ions doping concentration.

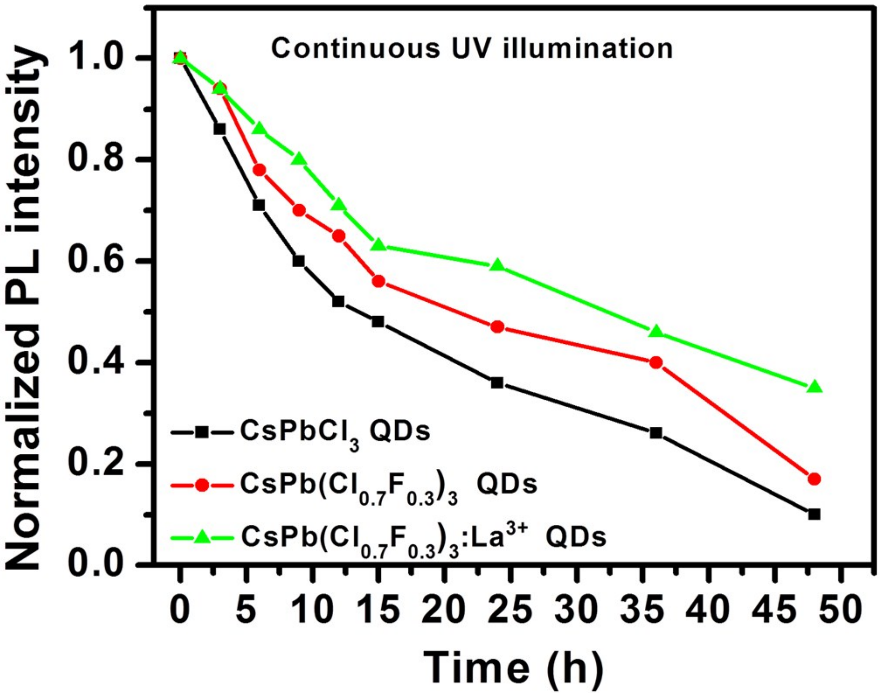

Fig. S8 The normalized fluorescent emission intensity as a function of UV irradiated time for the $CsPbCl_3$, $CsPb(Cl_{0.7}F_{0.3})_3$ and $CsPb(Cl_{0.7}F_{0.3})_3$:La^{3+}QDs.

The 365 nm UV lamp with the power of 6W is used to detect the photoluminescence stability of three samples. After irradiating 48 h, the result shows that the photoluminescence stability of the perovskite NCs improved obviously as introducing of F^- and La^{3+} ions.

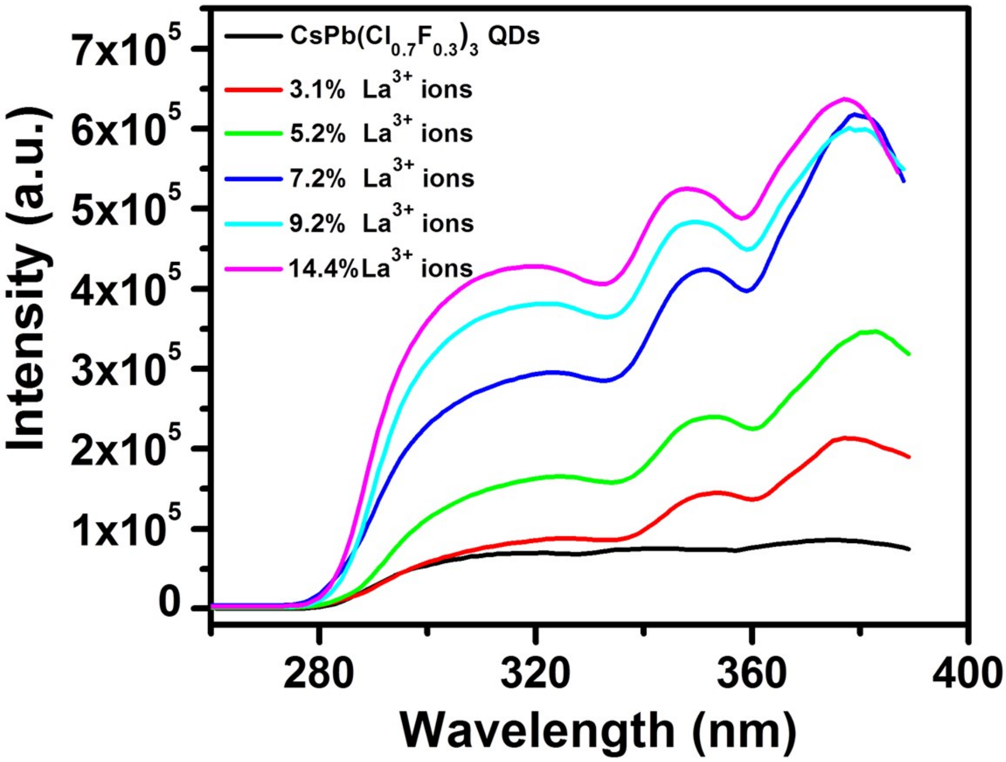

Fig. S9 Excitation spectra of $CsPb(Cl_{0.7}F_{0.3})_3$:La^{3+} QDs under monitored wavelength of 410 nm.

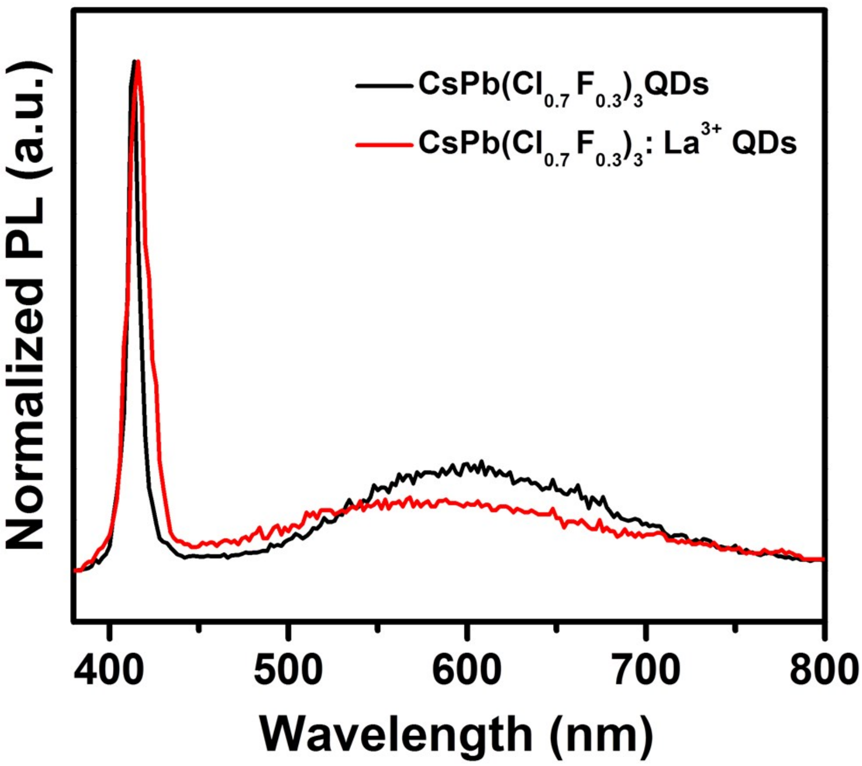

Fig. S10 Low temperature fluorescence spectroscopy of $CsPb(Cl_{0.7}F_{0.3})_3$ and $CsPb(Cl_{0.7}F_{0.3})_3$:La^{3+} QDs measured at 10K.

Table S1 The lattice lattice constant of $CsPbCl_3$ and $CsPb(Cl/F)_3$ QDs with different Cl-to-F molar feed ratios.

	1:0	1:0.2	1:0.4	1:0.6	1:0.8	1:1
(110)	3.97	4.00	4.00	4.00	4.01	4.01
(200)	2.82	2.83	2.84	2.84	2.84	2.85
(211)	2.28	2.30	2.30	2.31	2.31	2.30

Table S2 Lifetime values of $CsPbCl_3$ and $CsPb(Cl/F)_3$ QDs monitored at 410 nm as well as the corresponding radiative recombination rate and nonradiative recombination rate calculated from the experimental values of photolumincescence QY and decay lifetimes.

Sample	τ_1 (ns)	a_1 (%)	τ_2 (ns)	a_2 (%)	τ_{avg} (ns)	radiative recombination rate (s^{-1})	nonradiative recombination rate (s^{-1})
1:0	0.7	74.6	6.9	25.4	5.5	6.2×10^6	1.7×10^8
1:0.2	0.8	65.1	7.1	34.9	6.0	6.3×10^6	1.6×10^8
1:0.4	0.8	63.0	9.8	37.0	8.7	6.6×10^6	1.1×10^8
1:0.6	0.8	59.7	10.3	40.3	9.3	7.1×10^6	1.0×10^8
1:0.8	0.9	54.8	11.6	45.2	10.7	8.7×10^6	8.5×10^7
1:1	0.8	60.1	10.2	39.9	9.2	5.0×10^6	1.1×10^8

Table S3 The La^{3+} ion doping concentration (%) from ICP characterization, lattice constant (110) and the photoluminescence QYs under the excitation wavelength of 365 nm of $CsPb(Cl_{0.7}F_{0.3})_3:La^{3+}$ QDs prepared at different hot injection temperature.

Injection temperature (℃)	La^{3+} ions concentration (%) used in feed solution	La^{3+} ions doping concentration (%) from ICP characterization	lattice constant (110) (Å)	photoluminescence QYs (%)
160	65.2	3.1	3.97	22.6
180	65.2	5.2	3.95	28.6
200	65.2	14.4	3.95	36.5
220	65.2	9.2	3.96	36.2
240	65.2	7.2	3.96	31.5

Table S4 Lifetime values of $CsPb(Cl_{0.7}F_{0.3})_3$: La^{3+} QDs prepared with different La^{3+} ions doping concentration under monitored wavelength of 410 nm as well as the corresponding radiative recombination rate and nonradiative recombination rate calculated from the experimental values of photoluminescence QY and decay lifetimes.

Sample	τ_1 (ns)	a_1 (%)	τ_2 (ns)	a_2 (%)	τ_{avg} (ns)	radiative recombination rate (s^{-1})	nonradiative recombination rate (s^{-1})
$CsPb(Cl_{0.7}F_{0.3})_3$ QDs	0.9	54.8	11.6	45.2	10.7	8.7×10^6	8.5×10^7
3.1 %	1.6	34.6	27.6	65.4	26.8	8.4×10^6	2.9×10^7
5.2 %	1.5	36.4	26.5	63.6	25.7	1.1×10^7	2.8×10^7
7.2 %	1.4	35.6	26.0	64.4	25.3	1.3×10^7	2.7×10^7
9.2 %	1.4	36.6	24.3	63.4	23.6	1.5×10^7	2.7×10^7
14.4 %	1.4	36.7	23.6	63.3	22.9	1.6×10^7	2.7×10^7