

Supplementary Table. 1 | The carrier lifetime of Ca²⁺-CsPbI₃ materials was obtained through a double-exponential fit.

Sample	τ_1(ns)	A₁(%)	τ_2(ns)	A₂(%)	τ_{avg}(ns)
Ca ²⁺ -CsPbI ₃	105.5	54.82	105.5	45.18	105.62

Supplementary Table. 2 | By gradually altering the voltage (V), the corresponding current value (I) and optical power value (P_{opt}) are obtained.

Voltage (V)	Current (A)	Power (W)	EQE (%)
16.6	0.00002	4.48×10^{-6}	8.232
16.7	0.00005	7.79×10^{-6}	5.726
16.8	0.00007	1.360×10^{-5}	7.140
16.9	0.00011	2.35×10^{-5}	7.850
17.0	0.00019	4.07×10^{-5}	7.872
17.1	0.00031	7.06×10^{-5}	8.369
17.2	0.00044	1.213×10^{-4}	10.131
17.3	0.00076	2.06×10^{-4}	9.961
17.4	0.00119	3.45×10^{-4}	10.655
17.5	0.00180	5.70×10^{-4}	11.638
17.6	0.00270	9.17×10^{-4}	12.481
17.7	0.00397	1.422×10^{-3}	13.163
17.8	0.00570	2.11×10^{-3}	13.604
17.9	0.00803	3.06×10^{-3}	14.000
18.0	0.01098	4.27×10^{-3}	14.292
18.1	0.01447	5.67×10^{-3}	14.400
18.2	0.01884	7.48×10^{-3}	14.591
18.3	0.02305	9.22×10^{-3}	14.700
18.4	0.02796	1.122×10^{-2}	14.747
18.5	0.03276	1.338×10^{-2}	15.010
18.6	0.03844	1.575×10^{-2}	15.058
18.7	0.04456	1.815×10^{-2}	14.969
18.8	0.05093	2.05×10^{-2}	14.792
18.9	0.05793	2.32×10^{-2}	14.718
19.0	0.06553	2.58×10^{-2}	14.469
19.1	0.07308	2.86×10^{-2}	14.382

19.2	0.08043	3.12×10^{-2}	14.256
19.3	0.08767	3.38×10^{-2}	14.168
19.4	0.09544	3.64×10^{-2}	14.016
19.5	0.10361	3.90×10^{-2}	13.833