Supporting Information

X-ray Detector with Ultra-low Detection Limit based on Bulk Two-dimensional Perovskite PEA_2PbBr_4 Single Crystals Grown in HBr Solution

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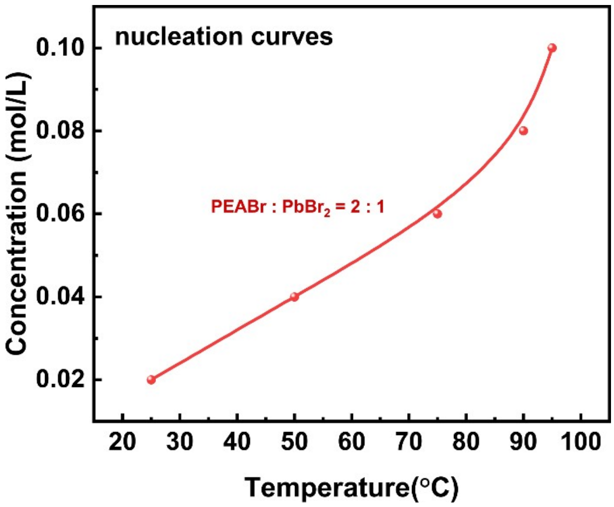
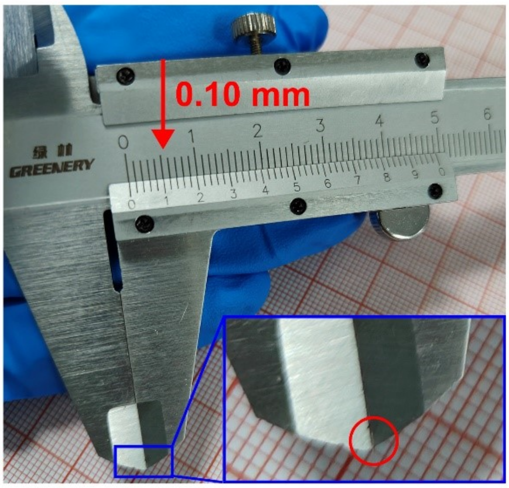
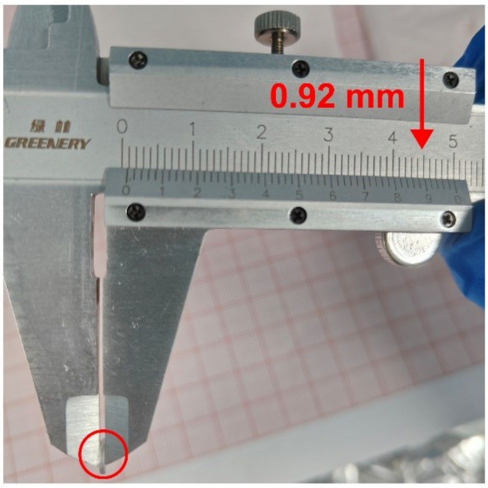


Fig. S1. Nucleation curve of PEA_2PbBr_4 precursor with solute ratios of PEABr:$PbBr_2$ = 2:1 in HBr.



fragile PEA_2PbBr_4



bulk PEA_2PbBr_4

Fig. S2. Crystal thickness comparison of fragile and bulk PEA_2PbBr_4. The fragile PEA_2PbBr_4 are grown from the precursor solution with stoichiometric ratio of PEABr:PbBr2 = 2:1. The bulk PEA_2PbBr_4 are grown from the precursor solution with stoichiometric ratio of PEABr:PbBr2 = 2:3.

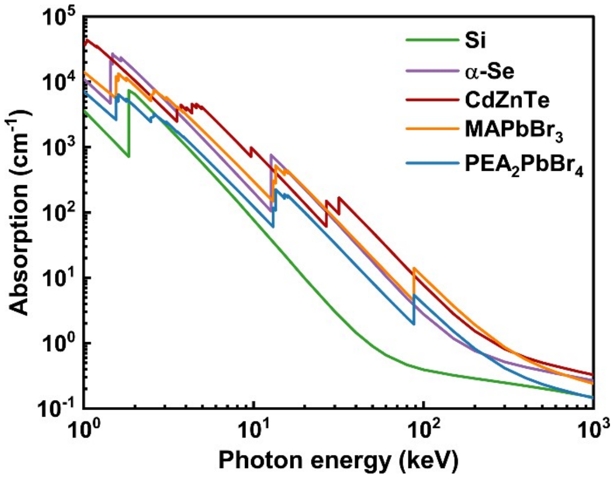


Fig. S3. Linear attenuation coefficients (absorption) of PEA_2PbBr_4, Si, α-Se, CdZnTe and $MAPbBr_3$ versus different X-ray photons energy.

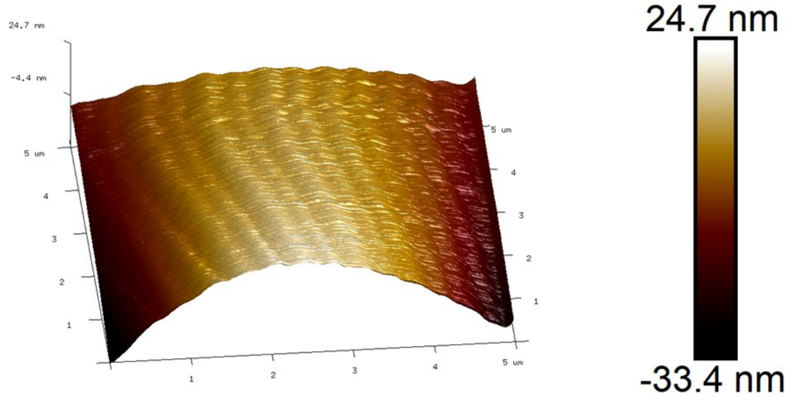


Fig. S4. AFM morphology images of bulk PEA_2PbBr_4 single crystal

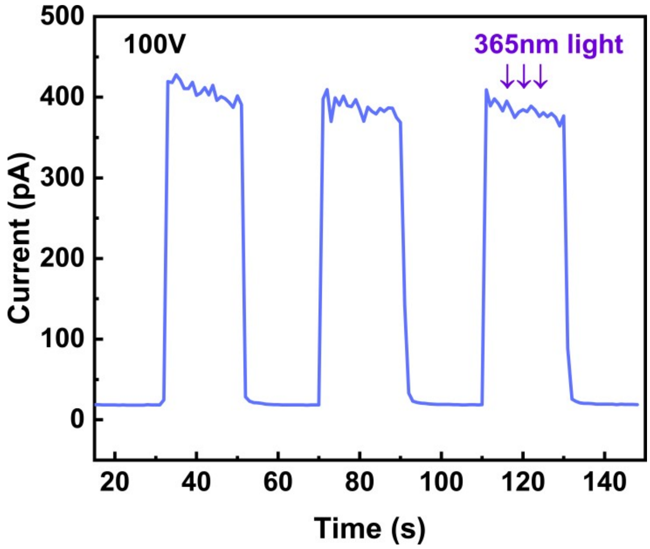


Fig. S5. 365 nm ultraviolet light responses of Au/PEA_2PbBr_4/Au. This measurement serves as a preliminary assessment to determine whether the device exhibits a valid photo response.

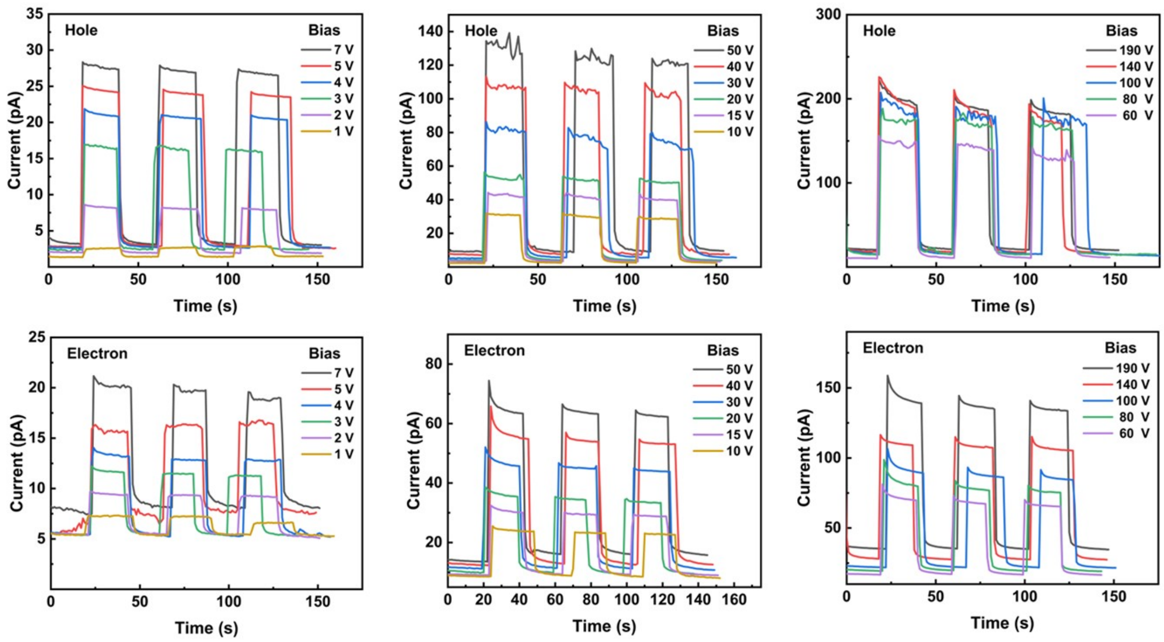


Fig. S6. 365 nm ultraviolet light responses (0.13 mW cm^{-2}) of Au/PEA_2PbBr_4/Au

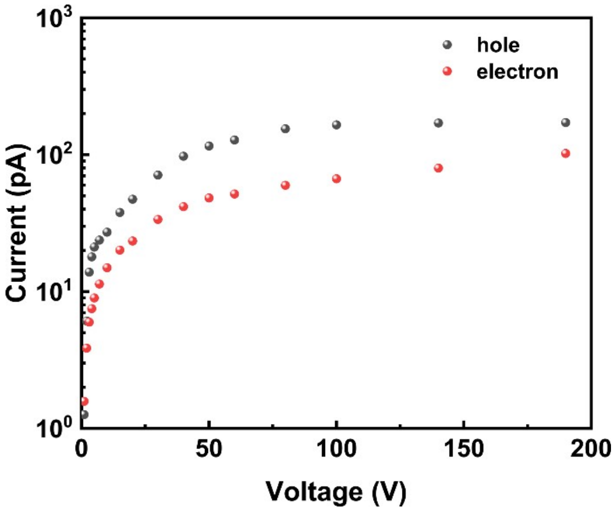


Fig. S7. hole and electron signal currents of Au/PEA_2PbBr_4/Au under 365 nm ultraviolet light

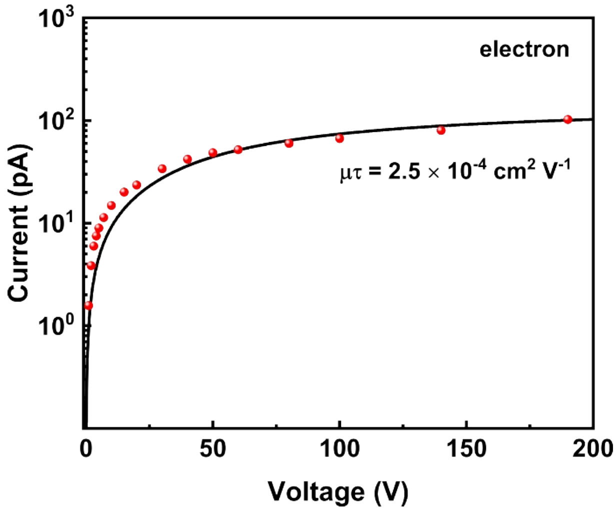


Fig. S8. Photoconductivity measurement for electron under 0.13 mW cm^{-2} ultraviolet LED (365 nm) illumination

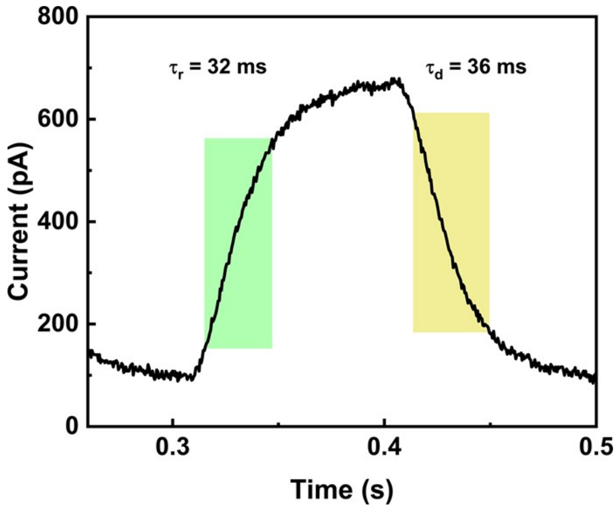


Fig. S9. Temporal response of Au/PEA_2PbBr_4/Au device under ultraviolet LED (365 nm) pulsed illumination

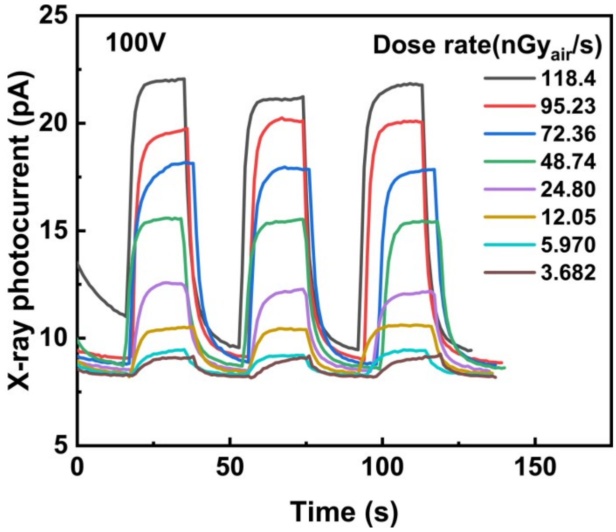


Fig. S10. X-ray responses of Au/PEA_2PbBr_4/Au with dose rates from 118.4 to 3.682 $nGy_{air}\ s^{-1}$ at 100V

Table S1. Summary of performance for X-ray detectors based on 2D perovskite single crystals.

Device structure	Crystal growth method	Crystal Thickness [mm]	Resistivity [Ω cm]	Noise current [nA $Hz^{-1/2}$]	$\mu\tau$ product [cm^2 V^{-1}]	Sensitivity [μC Gy_{air}^{-1} cm^{-2}]	Bias for sensitivity [V]	Detection limit [nGy_{air} s^{-1}]	X-ray [keV]	Ref.
Au/ $(F\text{-}PEA)_2PbI_4$/ C60/BCP/Cr	STL[a)] in GBL	2	1.36×10^{12}	<0.25	5.1×10^{-4}	3,402	200	23	120	1
Au/ $[Cu(O_2C\text{-}(CH_2)_3\text{-}(NH_3)_2]PbBr_4$/ C60/BCP/Cr	slow evaporation	1.2	8.85×10^{11}	10^{-4}	/	114,000	960	56	120	2
Au/BA_2PbBr_4/Au	STL in HBr	0.16	8.51×10^{11}	/	1.1×10^{-5}	726.18	150	8.2	50	3
planar Au/ $(PA)_4AgBiBr_8$	slow evaporation	2.2	/	/	/	6.89	40	<5,000,000	40	4
Au/ $(BDA)PbI_4$/ Au	STL in HI	/	/	/	4.43×10^{-4}	242	10	430	40	5
Au/ $BA_2EA_2Pb_3Br_{10}$/ Au	STL in HBr	2	4.5×10^{10}	/	1.0×10^{-2}	6,800	10	5,500	70	6
Au/ $(BA)_2CsAgBiBr_7$/ Au	STL in HBr	3	1.5×10^{11}	/	1.21×10^{-3}	4.2	10	/	70	7
planar Au/ $(DGA)PbI_4$	STL in HI	/	/	/	4.12×10^{-3}	4869	60	95.4	40	8
Au/ PEA_2PbBr_4/Au	STL in HBr	1	1.25×10^{12}	10^{-5}	1.0×10^{-3}	2998	100	0.79	30	This work

[a)]Abbreviations: STL, Solution temperature-lowering.

Table S2. Summary of detection limit for typical 3D perovskite SC X-ray detectors.

Device structure	Detection limit [$nGy_{air}\,s^{-1}$]	X-ray [keV]	Ref.
Au/Al/BCP/C_{60}/$CsPbBr_3$/Au	200	30	9
Au/$MAPbI_3$/Au	1.5	22	10
Au/$MAPbBr_3$/C_{60}/BCP/Ag or Au	500	22	11
Cr/$MAPbBr_{2.94}Cl_{0.06}$/C_{60}/BCP/Cr	7.6	8	12
Au/$Cs_2AgBiBr_6$/Au	45.7	50	13

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