## **Supporting Information for**

## High-Performance Optoelectronics Enabled by Synergistic Integration of 2D Heterostructures with Perovskite Quantum Dots

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Fig. S1 Surface potentials of MoS<sub>2</sub>, WS<sub>2</sub> and BP before (a) and after (b) decoration with CsPbBr<sub>3</sub> QDs.



Fig. S2 PL spectra comparisons of CsPbBr3 , CsPbI3 and MAPbBr3 with different durations



Fig. S3 Time-resolved PL for CsPbBr<sub>3</sub> and CsPbBr<sub>3</sub>/MoS<sub>2</sub>, CsPbBr<sub>3</sub>/WS<sub>2</sub> and CsPbBr<sub>3</sub>/BP, respectively.



Fig. S4 Output curves for MoS<sub>2</sub>, WS<sub>2</sub>, and BP before (a) and after (b) decoration with CsPbBr<sub>3</sub>.



Fig. S5 Repeatability dynamic optical responses of MoS<sub>2</sub>, WS<sub>2</sub> and BP FETs before and after CsPbBr<sub>3</sub> decoration, respectively.



Fig.S6 calculated work functions and density of states plots of WS<sub>2</sub>/MOS<sub>2</sub>, CsPbBr<sub>3</sub>/WS<sub>2</sub>/MoS<sub>2</sub>, BP/MoS<sub>2</sub> and CsPbBr<sub>3</sub>/BP/MoS<sub>2</sub>, respectively.



Fig. S7 Repeatability of dynamic optical responses for (a) CsPbBr<sub>3</sub>/WS<sub>2</sub>/MoS<sub>2</sub> and (b) CsPbBr<sub>3</sub>/BP/MoS<sub>2</sub> FETs.



Fig. S8 Current noise power spectral density within the frequency range from 1 Hz to 100 kHz in the dark.

A bi-exponential decay model ( $F(t) = \sum a_i e^{-(t-t_0)/\tau_i}$ , i = 1,2) was used to fit the PL decay curves. Fast decay time  $\tau_1$  and slow decay time  $\tau_2$  were obtained from the fitting profile. The average

$$\tau = \sum \frac{A_i \tau_i^2}{A_i \tau_i}$$

PL lifetime  $\tau$  is calculated as

 $\overline{A_i \tau_i}$ . All values are summarized in Table S1.

Table S1 PL lifetimes calculations of CsPbBr<sub>3</sub> and CsPbBr<sub>3</sub>/MoS<sub>2</sub>, CsPbBr<sub>3</sub>/WS<sub>2</sub> and CsPbBr<sub>3</sub>/BP, respectively.

Sample	$\tau_{1}(s)$	$\tau_{2}(s)$	$A_1$ (%)	A <sub>2</sub> (%)	$ au_{(s)}$
CsPbBr <sub>3</sub>	5.0	27.9	36.1	63.9	32.9
CsPbBr <sub>3</sub> /MoS <sub>2</sub>	3.2	15.7	74.3	25.7	18.9
CsPbBr <sub>3</sub> /WS <sub>2</sub>	3.7	16.8	72.7	27.3	20.4
CsPbBr <sub>3</sub> /BP	4.9	19.7	62.6	37.4	24.6