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A multifunctional display based on photo-responsive perovskite light-emitting diodes

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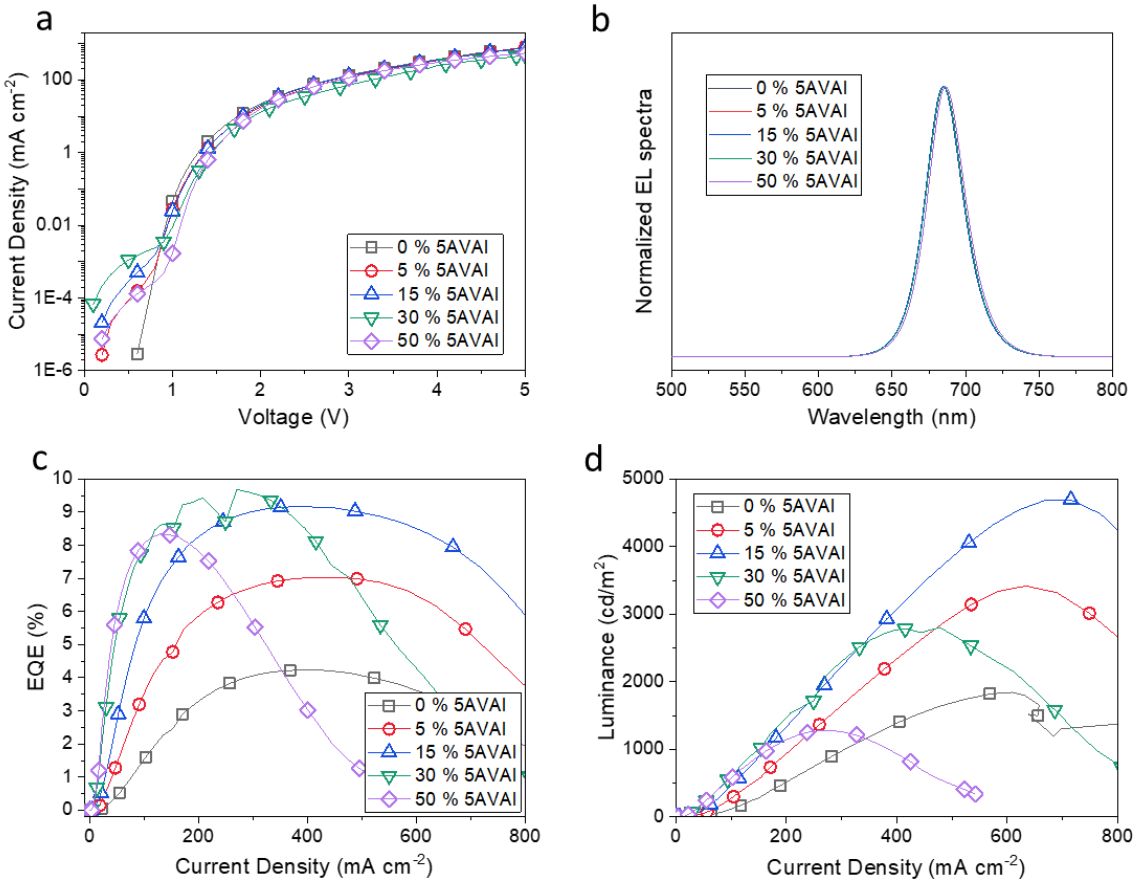
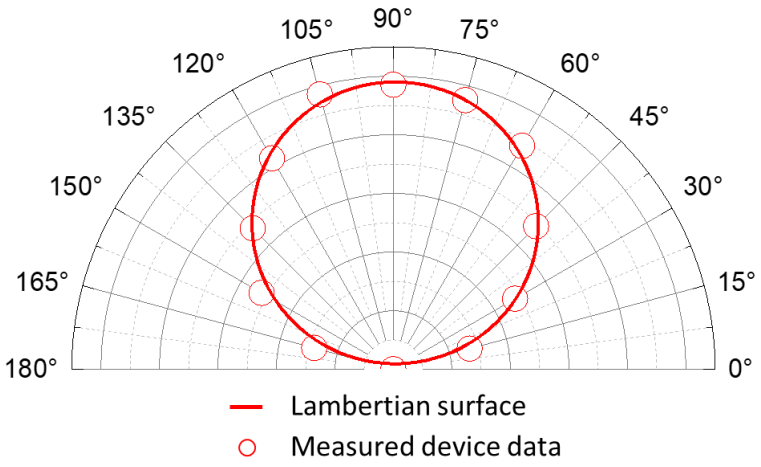
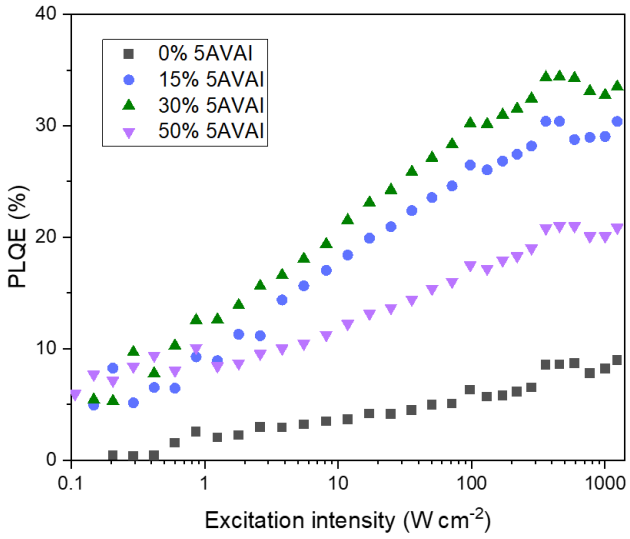


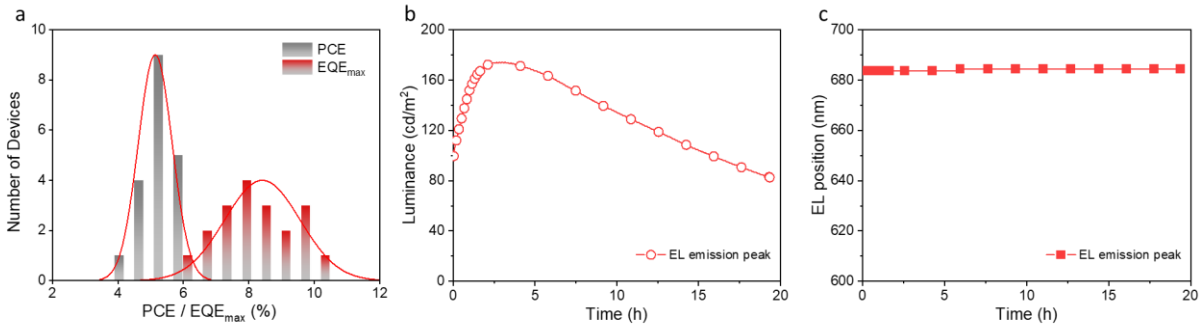
Supplementary Fig. 1: Electroluminescence performance of photo-responsive red LEDs based on $CsPbI_{3-x}Br_x$ emitters with different amounts of 5AVAI. a. current density-voltage (*J-V*) curves, **b.** normalized emitting spectra, **c.** current density dependent EQE (*EQE-J*) curves and **d.** current density dependent luminance (*L-J*) of the perovskite LEDs with different additive amounts.



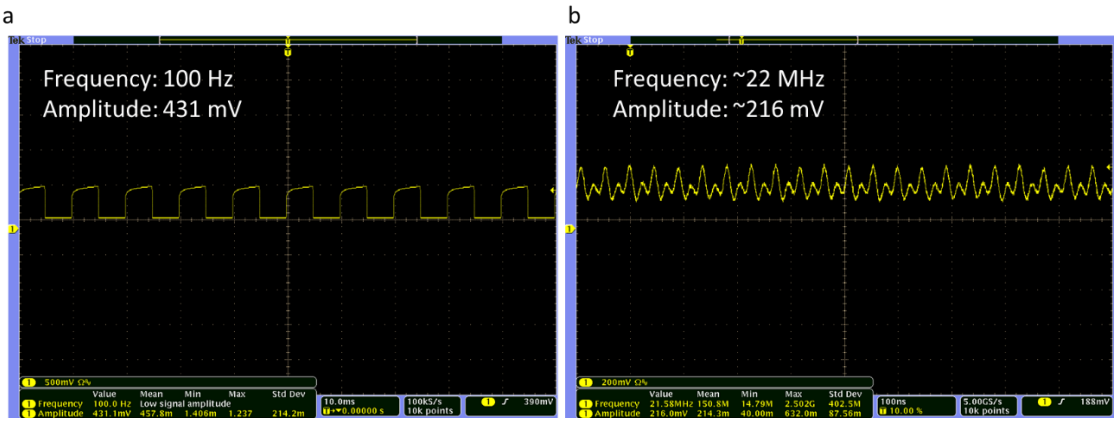
Supplementary Fig. 2: The angular distribution of the EL intensity of our red PeLEDs.



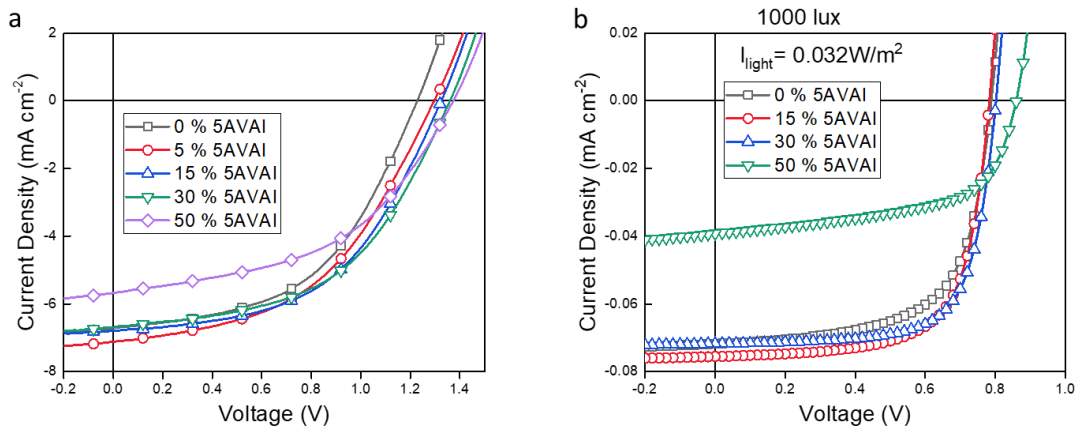
Supplementary Fig. 3: (a) Photoluminescence quantum efficiencies (PLQEs) of $CsPbI_{3-x}Br_x$ emitters with different amounts of 5AVAI.



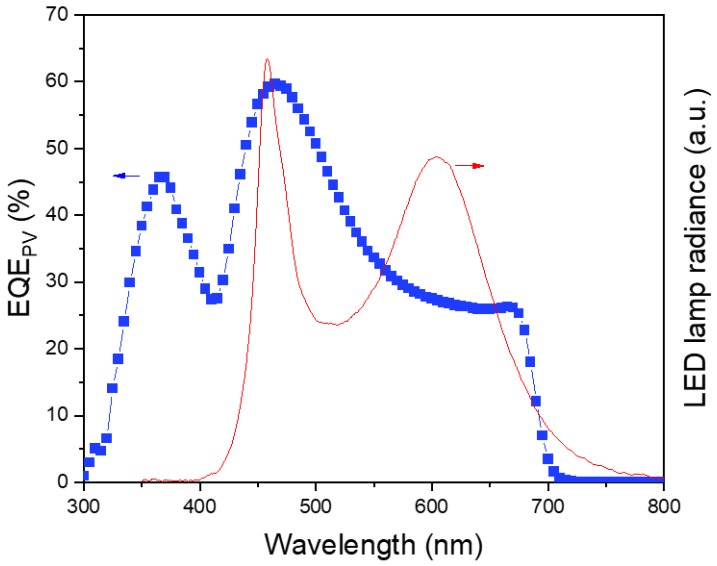
Supplementary Fig. 4: Statistics of EQE (electricity to light conversion) and PCE (light to electricity conversion), and stability of our perovskite deivces. a. maximum EQE and PCE histogram of multifunctional devices functioning as LEDs and solar cells respectively. The totally number of the pixels is 20. **b.** operational stability of PeLEDs emitting in red color. The initial brightness is 100 Cd m^{-2}. **c.** peak position of the EL emission spectra during the operational stability measurement.



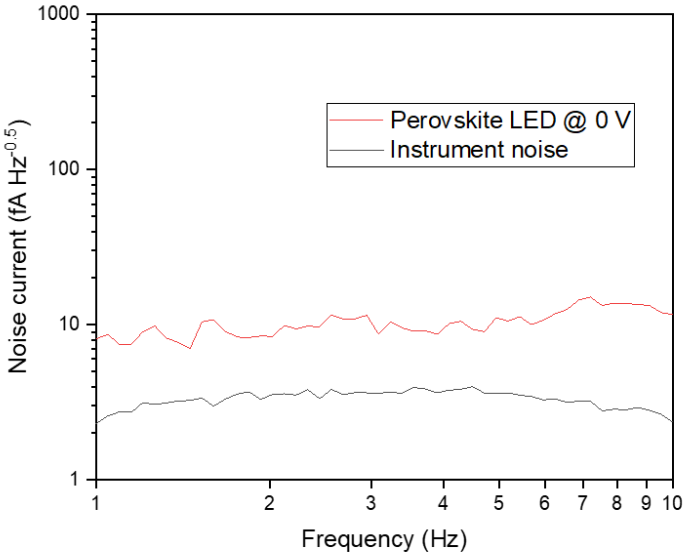
Supplementary Fig. 5: The waveforms of the light emitted from the PeLED with a device area of 0.2 mm^2 driven by a square-wave drive voltage with 100 Hz (**a**) and 22 MHz (**b**).



Supplementary Fig. 6: J-V curves of photo-responsive red LEDs based on $CsPbI_{3-x}Br_x$ emitters with different amounts of 5AVAI when working as solar cells under illumination from the AM1.5G solar simulator (**a**) and 1000 lux white LED (**b**).



Supplementary Fig. 7: EQE spectrum of the perovskite device working at the PV mode and the radiance spectrum of the commercial LED lamp used as light source for indoor-light PV performance measurement.



Supplementary Fig. 8: Noise current spectrum of the photo-responsive perovskite LED when working at zero bias as a photodetector, and the noise baseline of the test instrument.

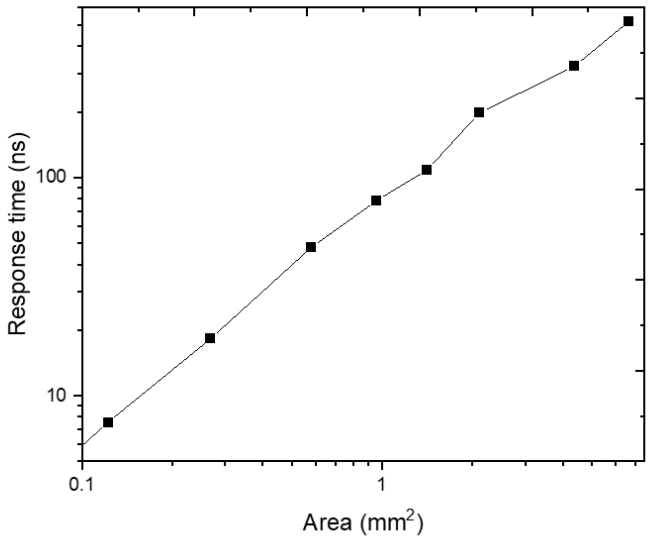
Supplementary Table 1: Performance of some typical fast-response solution-processed photodetectors.

Absorber	D*(Jones)	f_{-3dB}	t_{fall} (ns)	Area (mm^2)	Bias (V)	Reference
Organic	8×10^{12}	15kHz	--	11	--	Science, 2020, 370, 698
Organic	5.6×10^{11}	2MHz	--	2.5	--	Adv. Func. Mater., 2019, 1808948
Organic	2.52×10^{11}	1.7MHz	289	--	-1	Small, 2017,1603260
CdSe CQD	1×10^{7}	50 kHz	--	1.22	--	Appl. Phys. Lett. 2005, 87, 213505
PbS CQD	1×10^{12}	3 MHz	--	1.96	-5	Nat. Nanotech., 2009, 4, 40
Perovskite	7.8×10^{12}	168 MHz[a]	0.95	0.04	0	Adv. Mater.2016, 28, 10794
Perovskite	5.3×10^{12}	65 MHz[b]	3.86	0.1	0	Nat. Electron., 2020, 3, 156
Perovskite	1.5×10^{12}	1.6 GHz[a]	0.1[c]	10^{-4}	0	Nat. Electron. 2022, 5, 511
Perovskite	6.08×10^{12}	142 MHz[b]	3.83[c]	0.06	0	This work

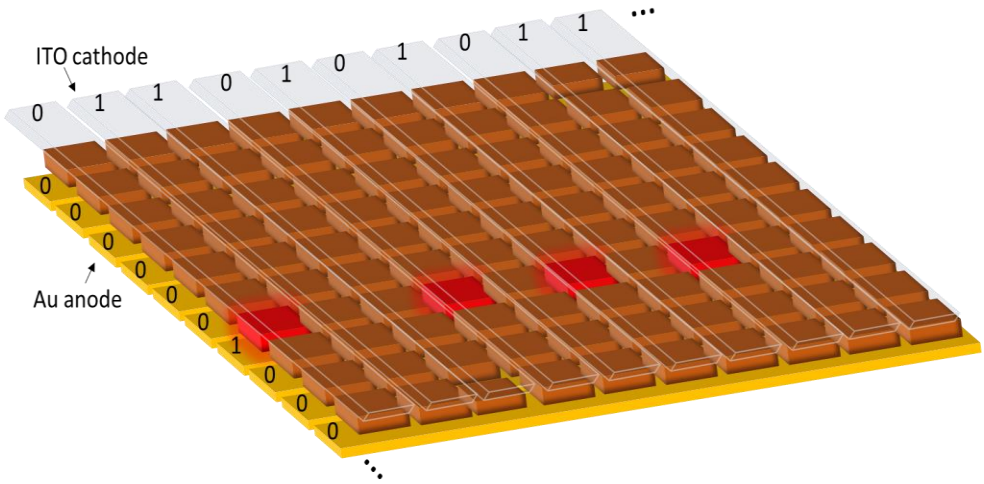
[a] calculated from fall time using $f_{-3dB} = (2\pi RC)^{-1}$

[b] obtained from the FFT of the TPC curve

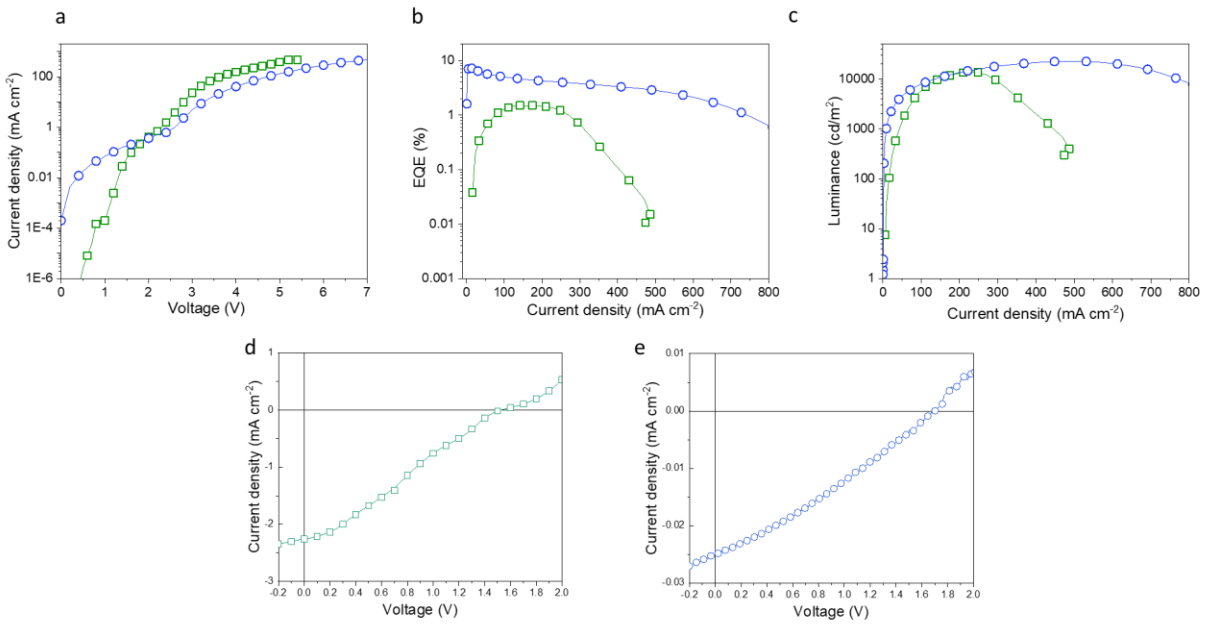
[c] full-width at half-maximum of the TPC curve



Supplementary Fig. 9: The falling time fitted from the transient photocurrent curves of devices with different device areas.



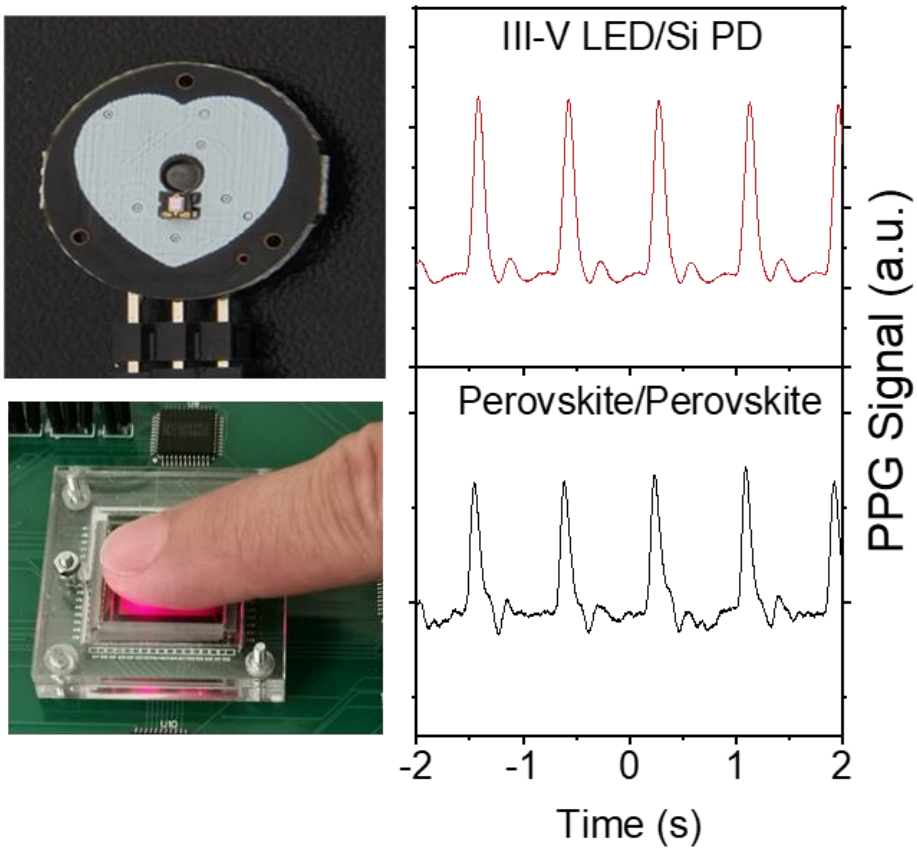
Supplementary Fig. 10： Schematic structure of the proof-of-concept display based on PeLEDs.



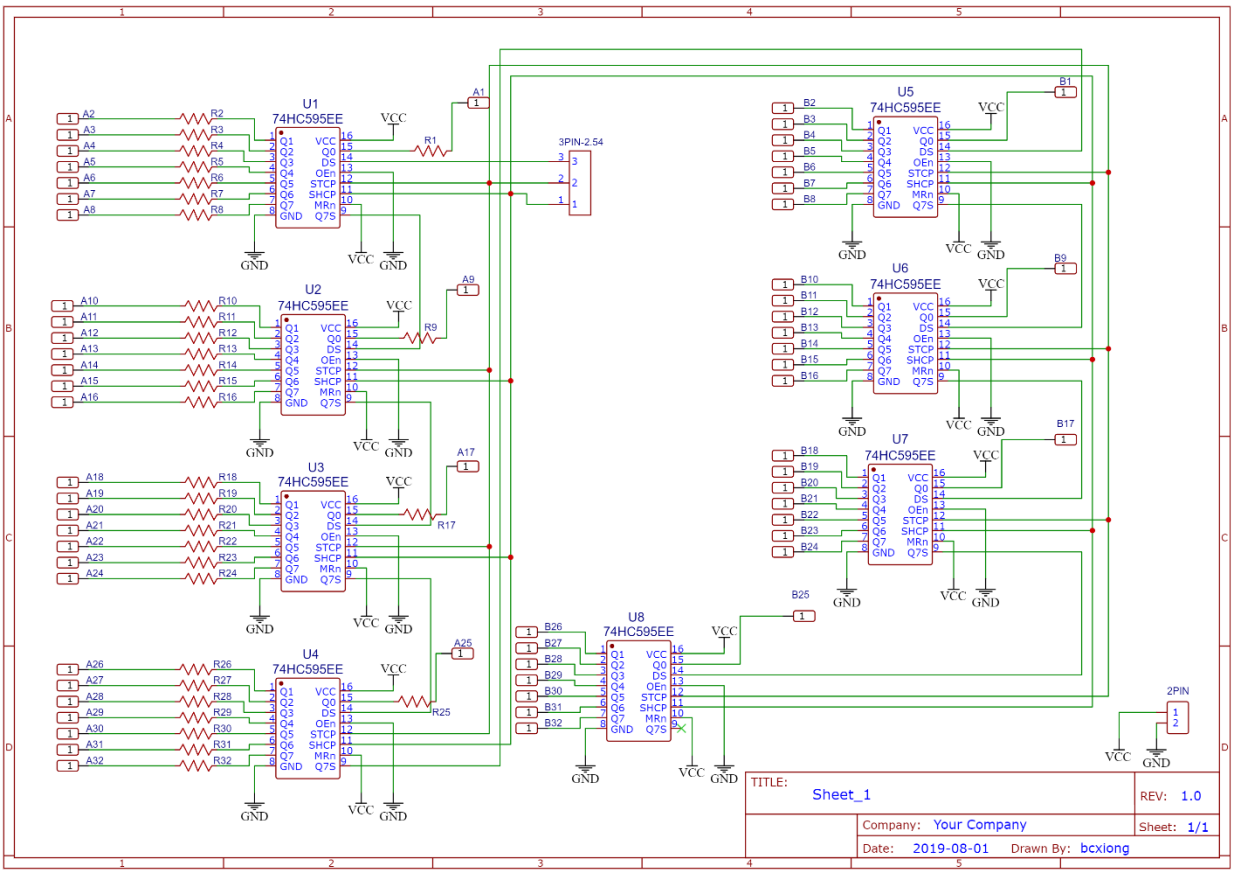
Supplementary Fig. 11: Electroluminescence and photo-response performance of green and blue photo-responsive PeLEDs. **a.** J-V curves under the forward bias, **b.** EQE-current density curves; **c.** Luminance-current density curves. **d** and **e**. J-V curves of PeLEDs under the AM1.5G conditions. The green line and blue line represent PeLEDs emitting at green and blue region.

Supplementary Table 2: Electroluminescence and photo-response performance of red, green and blue photo-responsive PeLEDs.

		LED mode		Solar cell mode			
Color	Device structure	EQE_{EL} (%)	Luminance (cd m^{-2})	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF (%)	PCE (%)
Red	ZnO/$CsPbI_{3-x}Br_x$ /TFB	9.7	4700	1.33	7.9	51	5.34
Green	ZnO/$FAPbBr_3$/TFB	1.5	13834	1.53	2.3	28	0.98
Blue	PTAA/2PACz/PVP/$CsPbBr_{3-x}Cl_x$ /TPBi	7.4	22749	1.7	0.025	28	0.012



Supplementary Fig. 12: Images of a commercial PPG sensor based on III-V LED and Si photodiode (top) and multifunctional perovskite display working as PPG sensor (bottom), as well as the corresponding PPG signals.



Supplementary Fig. 13: **Circuit diagram of the control unit of the PM display demonstration system.** Pins A1-32 and B1-32 are connected to the ITO and Au electrodes of the PM display. Pins DS, STCP and SHCP of the U1 shift register are connected to digital output pins of the Arduino UNO board, which can be controlled by a PC to write data to the shift registers. Pins VCC and GND are connected to a 5 V DC power source.