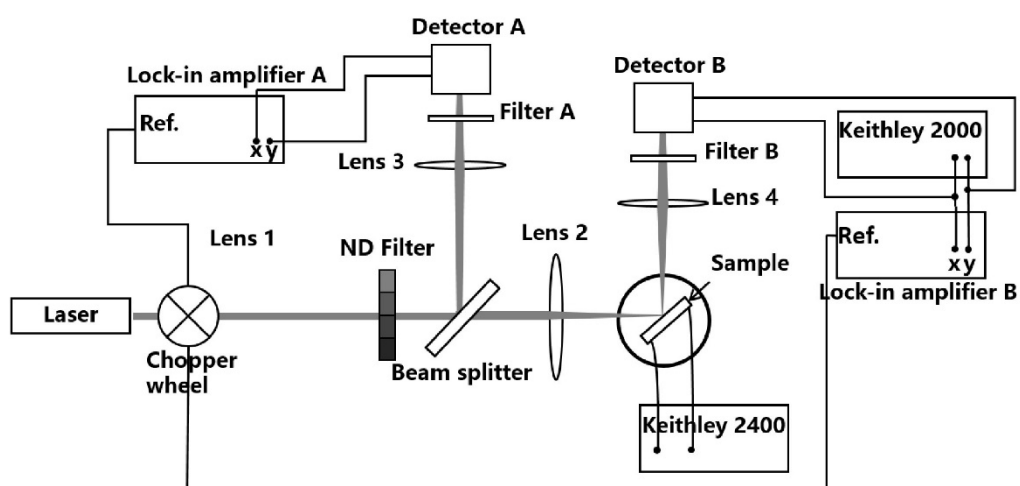
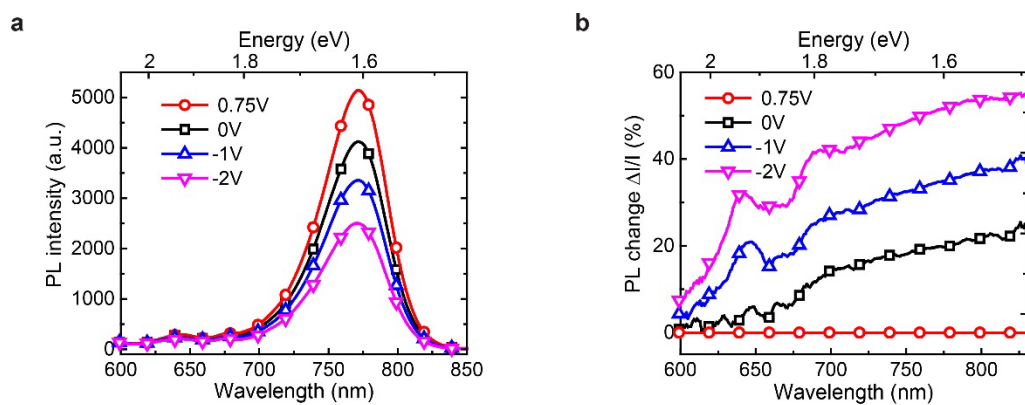
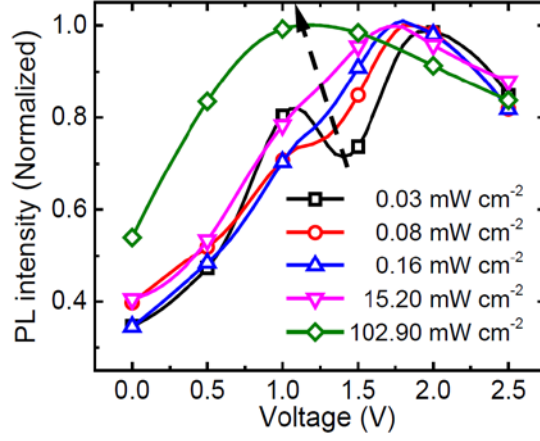




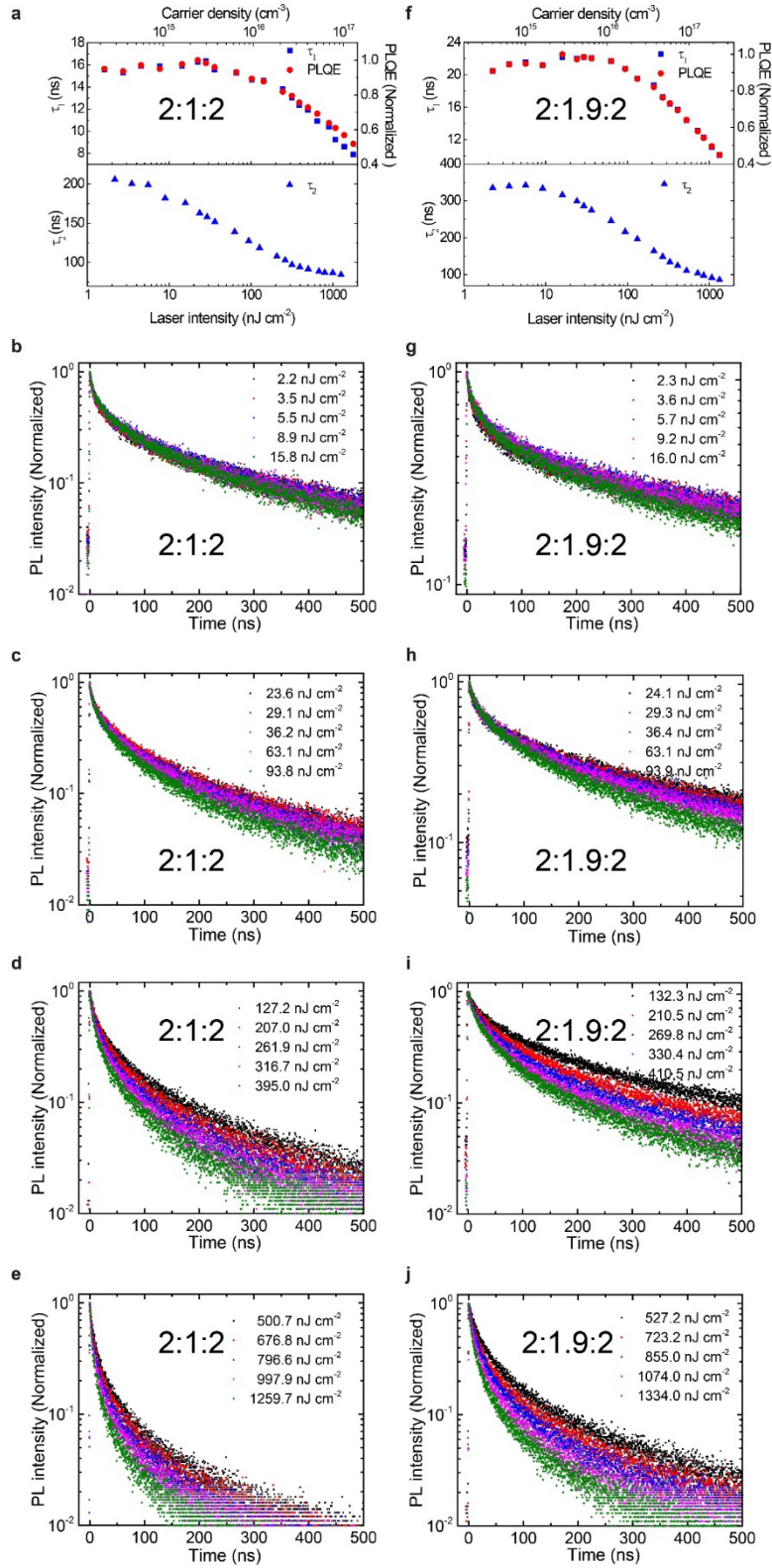
Supplementary Figure 1. Layout of the PL and EQE measurement setup. The PL and EQE of the devices were measured simultaneously by using a chopped laser when the LED device is under operation.



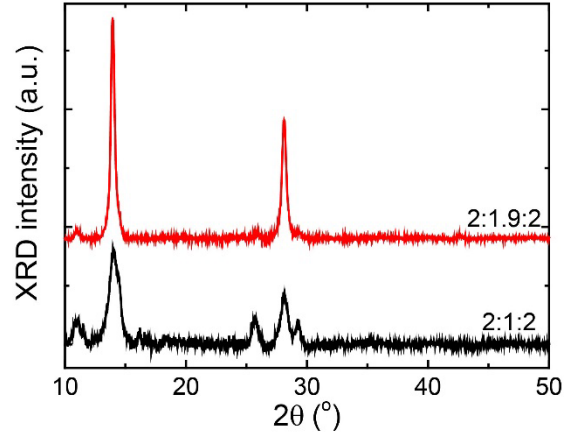
Supplementary Figure 2. PL of MQW perovskite LEDs. (a) PL spectra of the device under different driving voltages. (b) Change of PL intensity at selected driving voltages, relative to the PL intensity at 0.75 V ($(PL(0.75 \text{ V}) - PL(V))/PL(0.75 \text{ V})$).



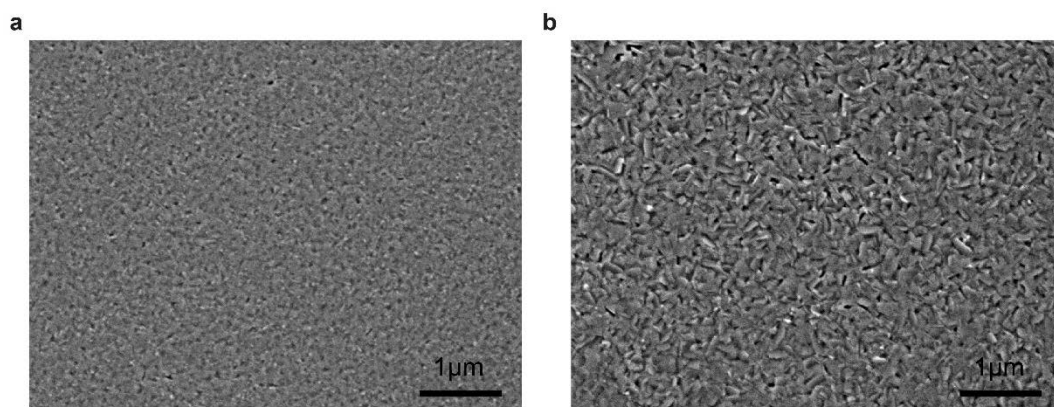
Supplementary Figure 3. Bias-dependent PL intensities (normalized) under various photo-excitation intensities. With increasing excitation intensities, the effect of PL quenching decreases and the trough stemmed from the competition between field-induced quenching and exciton screening gradually disappears.



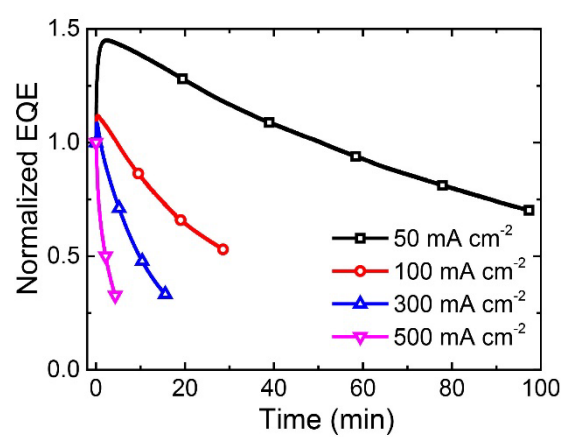
Supplementary Figure 4. Fitting results of PL lifetime change under various excitation intensities. Excitation intensity-dependent PL lifetimes of the (a) 2:1:2 and (f) 2:1.9:2 NFPI₇ MQW films. PL decay traces of the (b,c,d,e) 2:1:2 and (g,h,i,j) 2:1.9:2 NFPI₇ MQW films under different excitation intensities.



Supplementary Figure 5. XRD data of the 2:1:2 and 2:1.9:2 perovskite MQW films. The MQW films consist of small- n layered QWs and large- n QWs^{1,2}. The peaks at 13.9° and 28.1° are consistent with the diffraction peaks from (111) and (222) crystal planes of 3D FAPbI₃.



Supplementary Figure 6. SEM images of the perovskite MQW films. (a) 2:1:2. (b) 2:1.9:2. Scale bar: 1 μm.



Supplementary Figure 7. Stability data of the perovskite MQW LEDs at different constant current densities.

Supplementary References

1. Quan, L. N. *et al.* Ligand-stabilized reduced-dimensionality perovskites. *J. Am. Chem. Soc.* **138**, 2649–2655 (2016).
2. Pang, S. *et al.* $\text{NH}_2\text{CH}=\text{NH}_2\text{PbI}_3$: An alternative organolead iodide perovskite sensitizer for mesoscopic solar cells. *Chem. Mater.* **26**, 1485–1491 (2014).