Scanning Spectroscopy for Next-Generation Solar Cells

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Introduction

Next-generation solar cells, such as those made from flexible, scalable, high-efficiency perovskite materials, are of interest for a variety of applications such as indoor light harvesting and mobile energy generation. The overall performance of these new materials must be evaluated so that improvements in efficiency can be made for deployment.

Here, we evaluate the photoluminescence (PL) of $MAPbI_{2.6}Br_{0.2}Cl_{0.2}$(TA) perovskite solar cells using a custom optoelectronic scanning setup.[1,2] From the experimental PL data, the quasi-Fermi Level Splitting (QFLS) was extracted to evaluate the device performance. The average power conversion efficiency (PCE) of the device was 3.45%.

Photoluminescence (PL) refers to the light emitted from a material following photoexcitation. Quasi-Fermi Level Splitting (QFLS) is the energy difference between quasi-Fermi levels of electrons and holes under non-equilibrium conditions. QFLS reflects the upper limit of the open-circuit voltage (Voc), which is a key factor in determining the performance of solar cells.

Experimental Setup

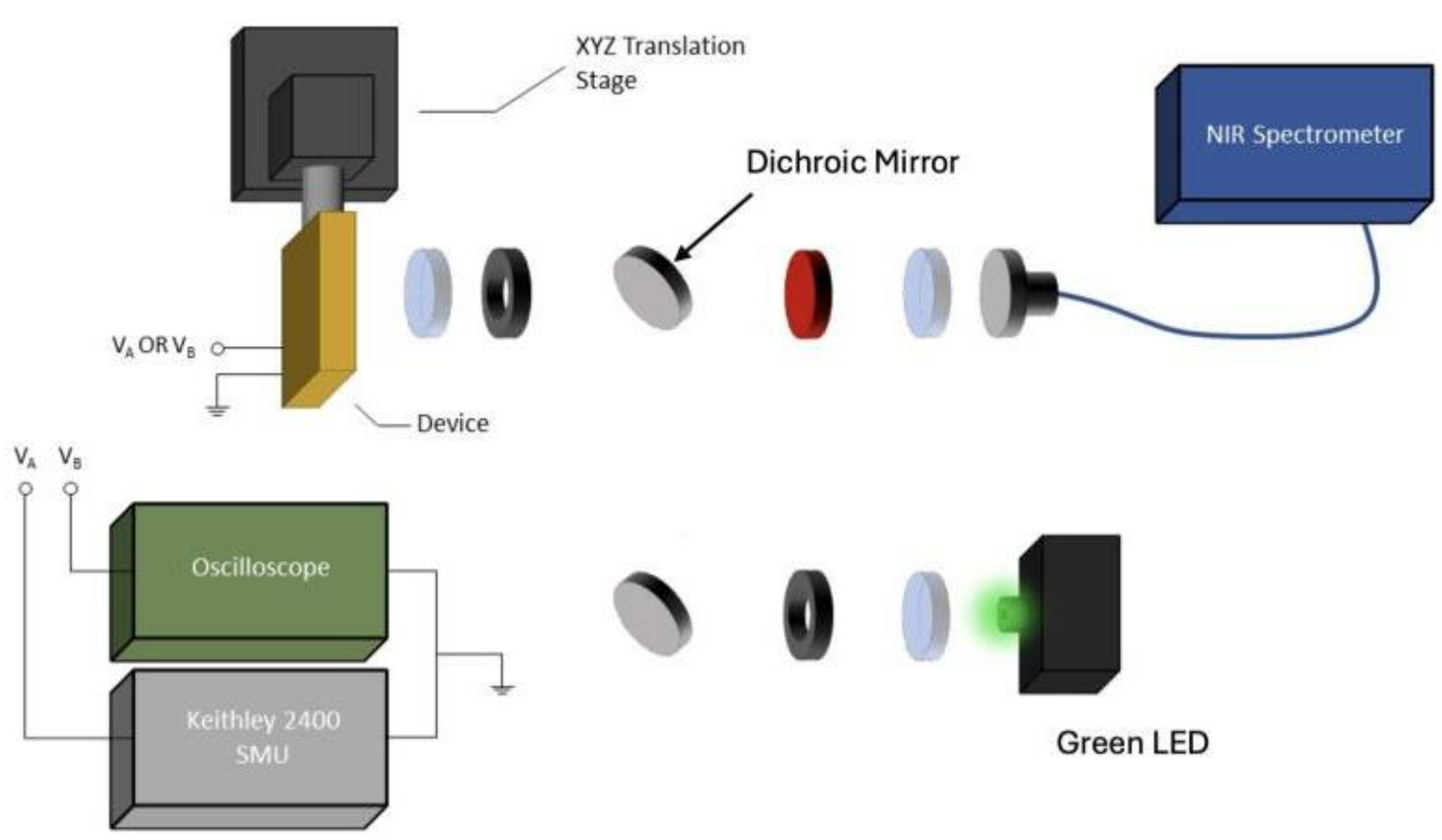

Figure 1. Diagram of the spatially-resolved, optoelectronic scanning setup. Spatial characterization maps were obtained with 25 µm resolution and scanning area of 3.0 mm x 6.0 mm.

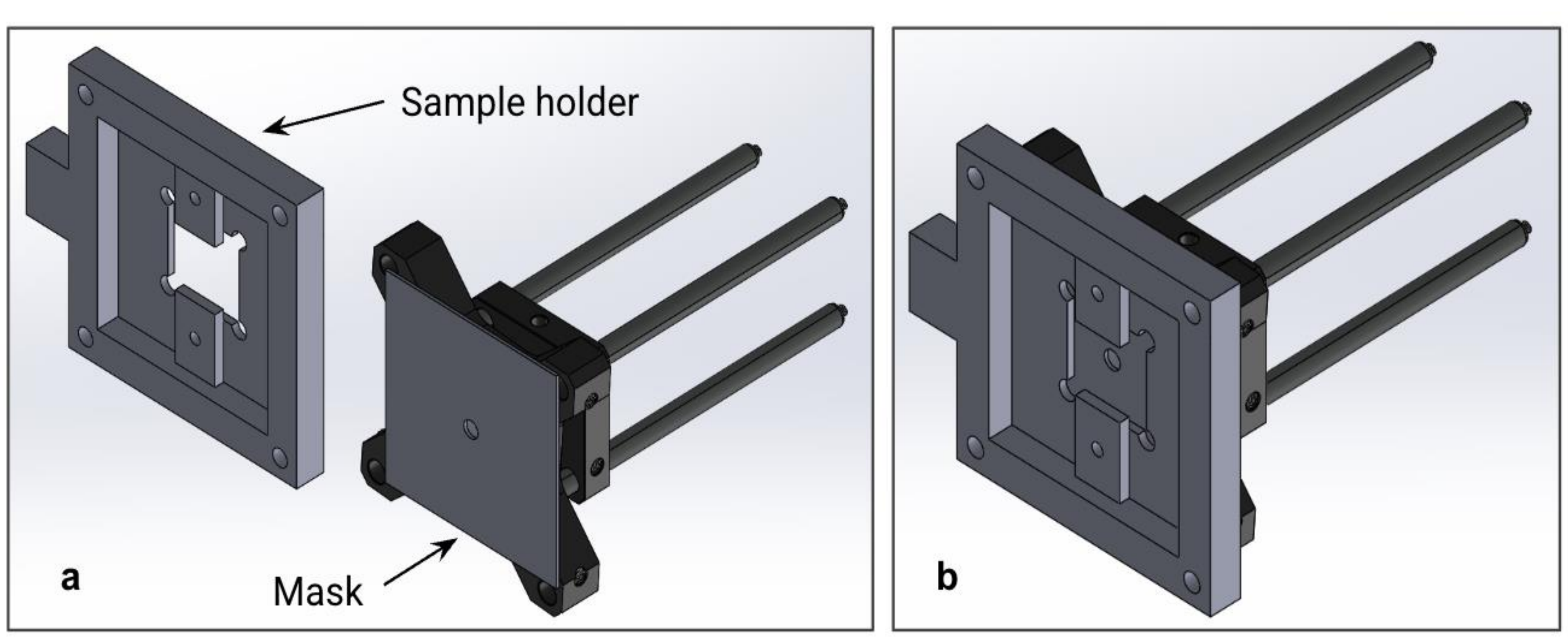

Figure 2. (**a**) Diagram of custom sample holder and mask and (**b**) the full assembly. The mask controls the illumination spot size and allows for the normalization of measurements to a known area.

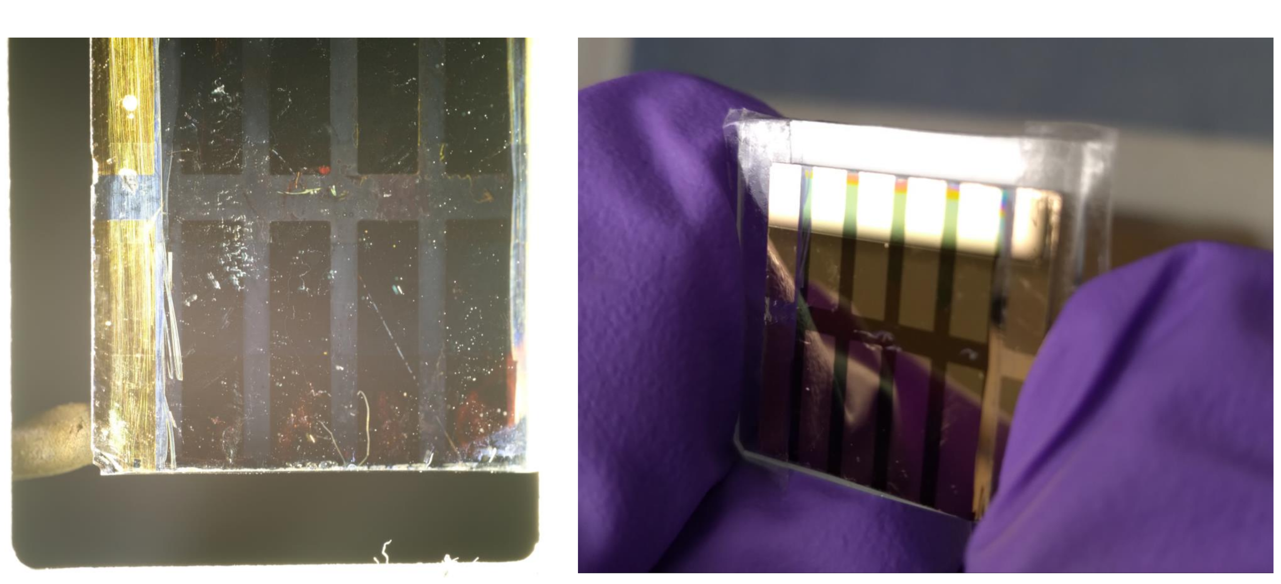

Figure 3. Photographs of TA perovskite solar cells with 3 mm x 6 mm active area.

Methods

$$\ln\left(\frac{I_{\mathrm{PL}}(E)h^3c^2}{2\pi E^2}\right) = -\frac{E}{k_{\mathrm{B}}T} + \frac{\Delta E_{\mathrm{F}}}{k_{\mathrm{B}}T} \qquad [1]$$

QFLS (ΔE_F) was extracted by applying a linear fit to the high-energy portion of the PL spectrum, based on the generalized Planck equation.[3]

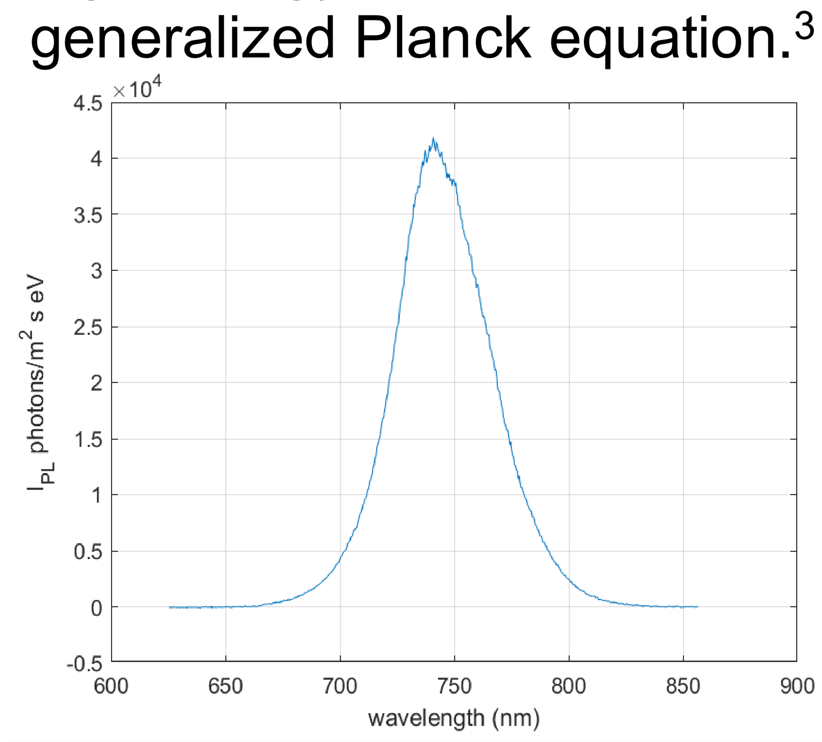

Figure 4. Absolute external radiative emission rate plot for a single point on the solar cell.

Results and Discussion

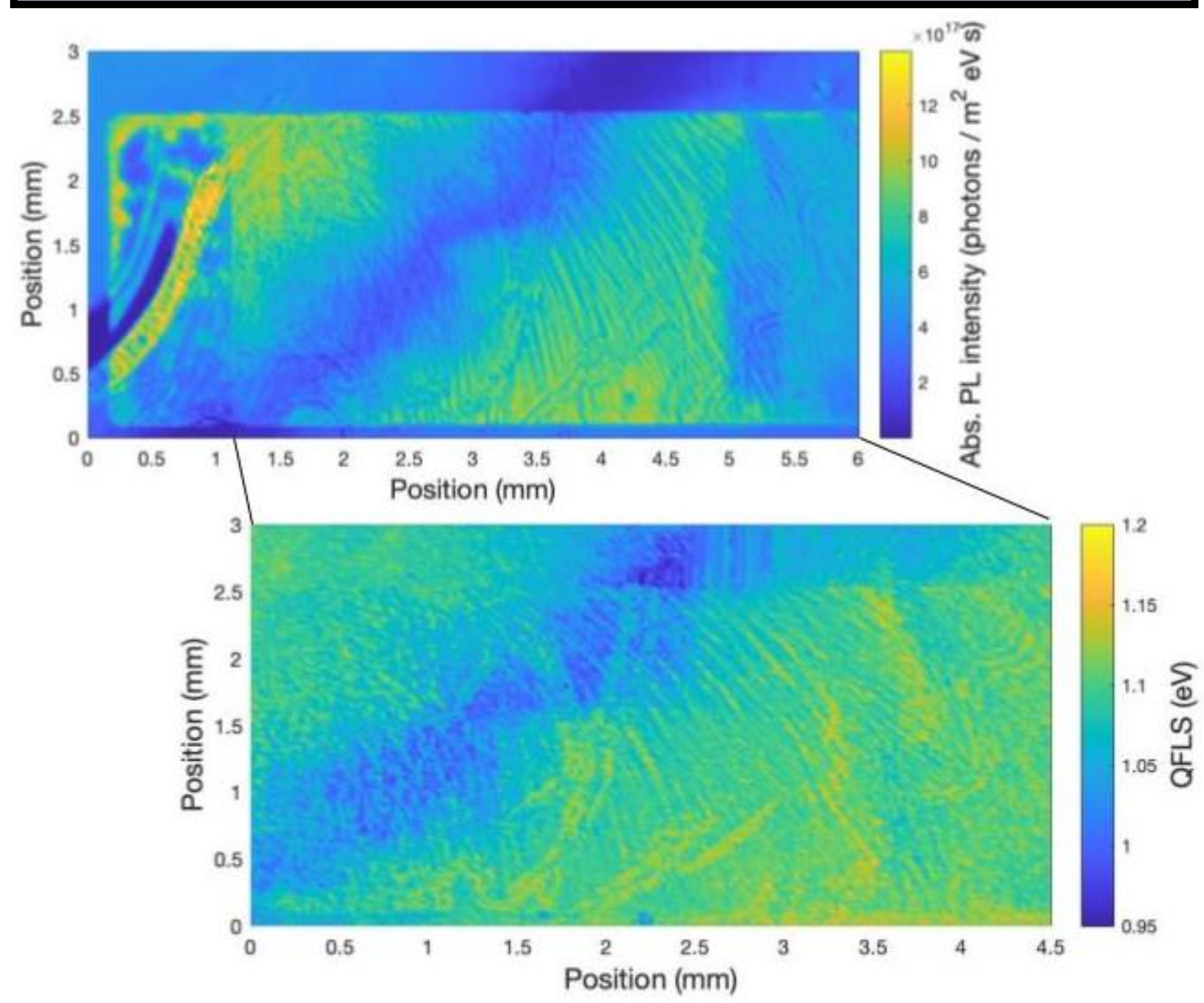

Figure 5. PL (top) and quasi-Fermi level splitting characterization map (bottom) show spatial non-uniformity. Regions of lower QFLS suggest non-radiative recombination and reduced device performance. QFLS values were consistent with literature. These results will be shared with collaborators to improve the performance of the perovskite solar cells for indoor lighting applications.

References

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[3] Stolterfoht, M., Wolff, C.M., Márquez, J.A. et al. *Nat Energy* **3**, 847–854 (2018).

Acknowledgements

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