Supporting information

Dual-sensitized Upconversion-assisted, Triple-band Absorbing Luminescent Solar Concentrators

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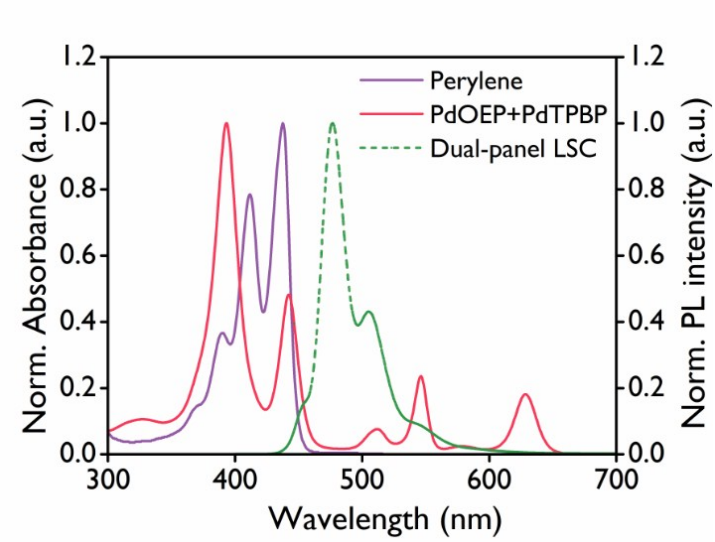


Figure S1. Normalized absorbance (solid lines) and emission (dashed lines) spectra.

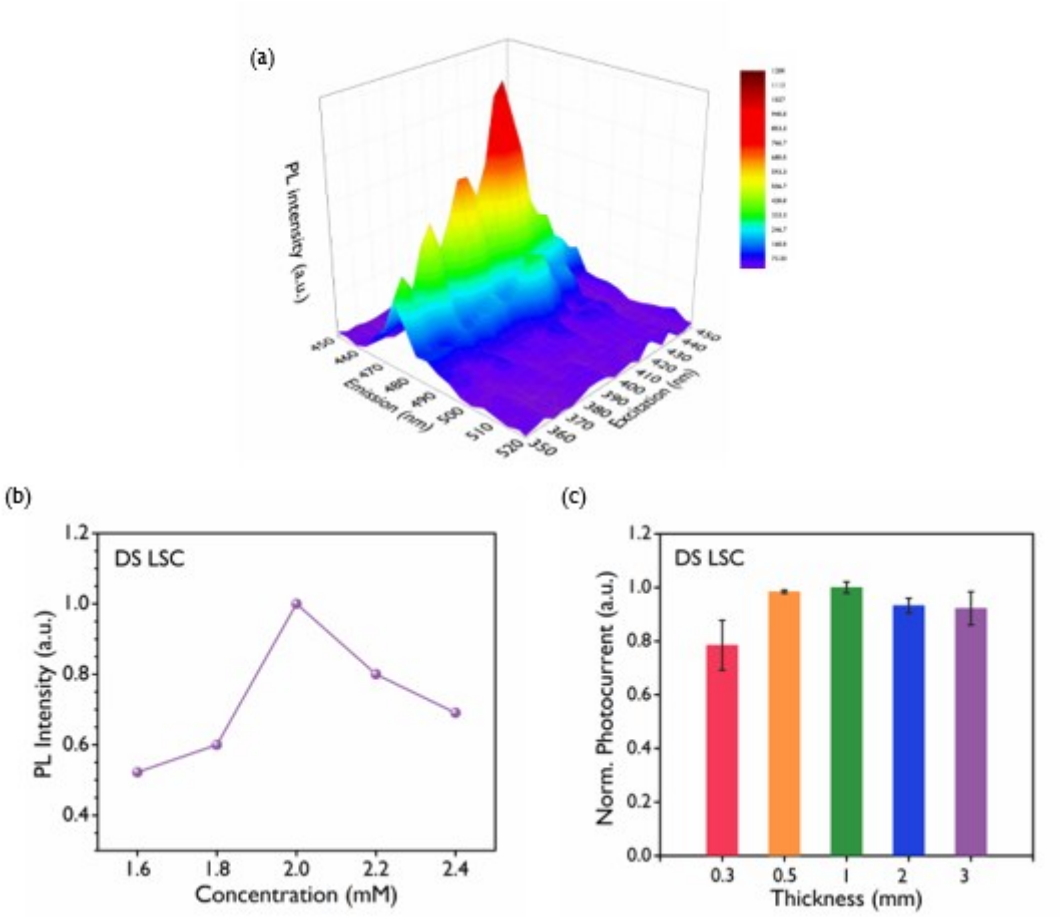
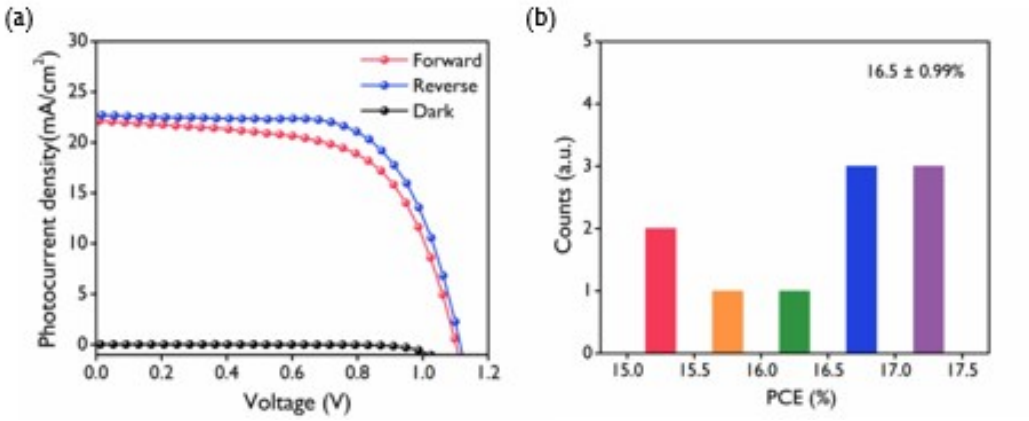
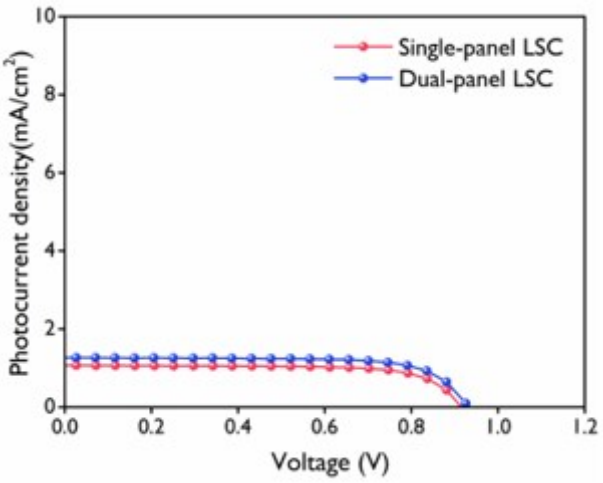


Figure S2. (a) PL spectra of DS LSC by excitation with 350−450 nm wavelength light. (b) PL intensity (excitation wavelength of 410nm) for various concentrations of perylene in DS LSC. (c) Photocurrent output for different thicknesses of DS LSC.



	J_{SC} (mA/cm^2)	V_{OC} (V)	FF	PCE (%)
#1	23.48	1.09	0.68	17.41
#2	22.63	1.10	0.71	17.50
#3	23.15	1.10	0.68	17.37
#4	22.66	1.12	0.67	16.96
#5	22.57	1.09	0.68	16.83
#6	22.55	1.03	0.72	16.72
#7	21.40	1.10	0.69	16.25
#8	20.86	1.07	0.70	15.61
#9	21.42	1.06	0.68	15.42
#10	22.85	1.02	0.65	15.00

Figure S3. Evaluation of the perovskite solar cell used, average PCE is 16.5% (1 sun, AM1.5).



Blank panel	J_{SC} (mA/cm^2)	V_{OC} (V)	FF	P_{max} (mW/cm^2)	PCE_{LSC} (%)
Single	1.07	0.92	0.72	0.71	0.18
Dual	1.27	0.93	0.72	0.86	0.20

Figure S4. J-V curves of the blank LSC panel without any dye.

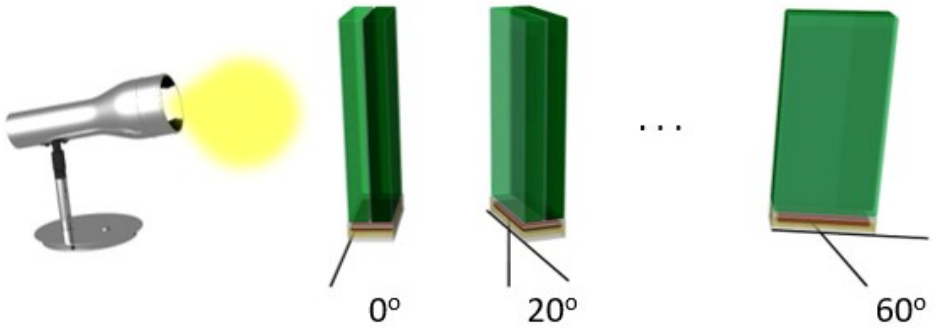


Figure S6. Angular Dependence of *J*sc for dual-panel DS/UC LSC-PSC.

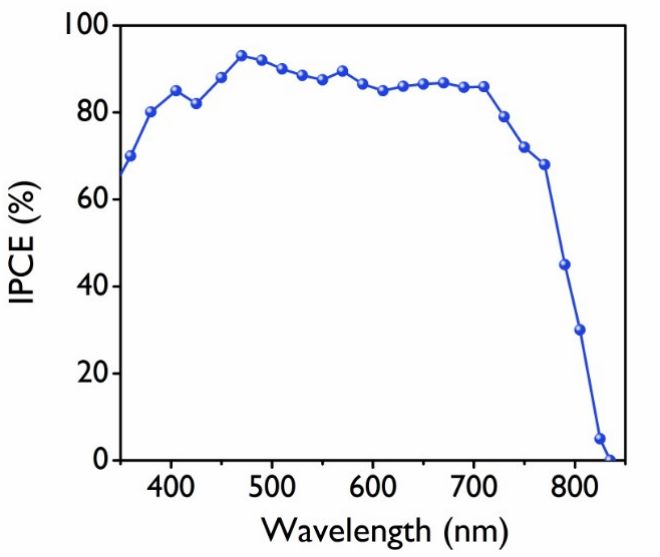


Figure S8. IPCE spectra of the perovskite solar cells.

Supplementary note #1

Single-point measurement was used to determine the fluorescence quantum yield. In the single point method, the UC quantum yield of the unknown sample is calculated using[1]

$$\Phi_{UC} = 2\Phi_{ref}\left(\frac{A_{ref}}{A_{UC}}\right)\left(\frac{I_{UC}}{I_{ref}}\right)\left(\frac{\eta_{UC}}{\eta_{ref}}\right)^2$$

where Φ is fluorescence quantum yield, A is the optical density (absorption), I is the integrated fluorescence intensity, and η is the refractive index of solvent (or host matrix). The subscript "ref" refers to the reference sample which used $3*10^{-6}$ M EtOH solution of Rhodamine B with a fluorescence quantum yield of 50% which excited at 545nm wavelength of light and 10^{-6} M EtOH solution of Methylene Blue with a fluorescence quantum yield of 4% at 633nm wavelength of excitation light. The multiplicative factor 2 for this formula should be considered because the absorption of 2 photon is required for the observation of 1 up-converted photon. We achieve the QY for perylene/PdOEP (14%) or perylene/PdTPBP (5%) using this method. For perleyene/PdTPBP, we measured a value of 2.06 for $\frac{A_{ref}}{A_{UC}}$ and 0.185 for $\frac{I_{UC}}{I_{ref}}$, which yielded a QY of about 5%. For perylene/PdTPBP, we measured a value of 7.28 for $\frac{A_{ref}}{A_{UC}}$ and 0.185 for $\frac{I_{UC}}{I_{ref}}$, which yielded a QY of about 14%. The QY values of PdOEP and PdTPBP correspond well to the values 17.4% and 6.5% in the literature.[2-5]. Note: we only reflect the difference in refractive index between the solution and the polymer film in order to consider the QY of dyes in the polymer film. There may be diffusion resistance of the dye in the polymer film. This can lead to a lower QY than the QY of our calculation. However, considering that the concentration of the dyes we used is high enough, the effect of such a resistance may be limited.

Supplementary note #3

The PCE_{LSC} can be determined from the maximum output power value of the PSCs (P_{max}) when coupled with the LSC and the incident power (P_{in}) amplified by the factor G of the LSC.[6]

$$PCE_{LSC} = \frac{P_{max}}{P_{in} \times G}$$

	J_{SC}[a] (mA/cm^2)	V_{OC} (V)	FF (%)	P_{max}[a] (mW/cm^2)	PCE_{LSC} (%)
perylene	10.15 ± 0.11	1.04 ± 0.01	0.64 ± 0.03	6.71 ± 0.05	1.60
PdOEP 0.06mM	11.10 ± 0.82	1.06 ± 0.01	0.68 ± 0.01	7.92 ± 0.62	1.89
PdTPBP 0.06mM	10.61 ± 0.77	1.05 ± 0.01	0.68 ± 0.03	7.51 ± 0.26	1.79
PdOEP 0.03mM + PdTPBP 0.06mM	12.68 ± 0.18	1.06 ± 0.01	0.65 ± 0.01	8.77 ± 0.03	2.09
PdOEP 0.06mM + PdTPBP 0.03mM	12.92 ± 0.06	1.05 ± 0.01	0.65 ± 0.01	8.99 ± 0.16	2.14
PdOEP 0.06mM + PdTPBP 0.06mM	11.94 ± 0.20	1.05 ± 0.01	0.67 ± 0.03	8.72 ± 0.15	2.08

[a] J_{sc} and P_{max} are determined based on the active area 0.1cm^2 of PSCs under 1 sun conditions.

References

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