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SUPPLEMENTARY INFORMATION
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Enhanced photovoltaic energy conversion using thermally based spectral shaping

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Supplementary Note 1

The theoretical limits for the single cutoff energy scheme as described in the article were determined using a model that includes only essential losses. Both cases (*i.e.,* PV and STPV) follow the same model as described in Wu *et al.* and Lenert *et al.*[1,2] in order to treat the photovoltaic conversion as ideal. When illuminated by the solar spectrum, the model gives the same results as the Shockley-Queisser detailed balance formulation[3]. The ultimate power is calculated by assuming an EQE of unity above the PV's electronic bandgap, E_g

$$p_u = \int_0^{\lambda_g} \varepsilon_\lambda Q_{b,\lambda} \frac{\lambda}{\lambda_g} d\lambda \tag{S1}$$

where $\lambda_g = hc/E_g$ (h is Planck's constant and c is the speed of light in vacuum) and $Q_{b,\lambda}$ is the spectral emissive power, determined by the blackbody temperature of the emitting body and its spectral emittance. This ultimate power, as in the previously mentioned publications, is reduced in two ways: X, the open circuit voltage (V_{oc}) is below the bandgap voltage (V_g) (equation (S2)) and Y, the impedance must be matched to define the maximum output power that may be extracted from the single junction (equation (S3)):

$$X = \frac{V_{oc}}{V_g} = \frac{k_b T_{PV}}{E_g} \ln\left(f \frac{R_{e,E>Eg}}{R_{PV,E>Eg}} \right) \tag{S2}$$

where $R_{E>Eg}$ is the flux of emitted photons with energies above the bandgap.

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$$Y = \frac{z_m^2}{(1 + z_m - e^{-z_m})(z_m + \ln(1 + z_m))} \tag{S3}$$

Defined by the relation

$$z_m + \ln(1 + z_m) = \frac{eV_{oc}}{k_b T_{PV}} \tag{S4}$$

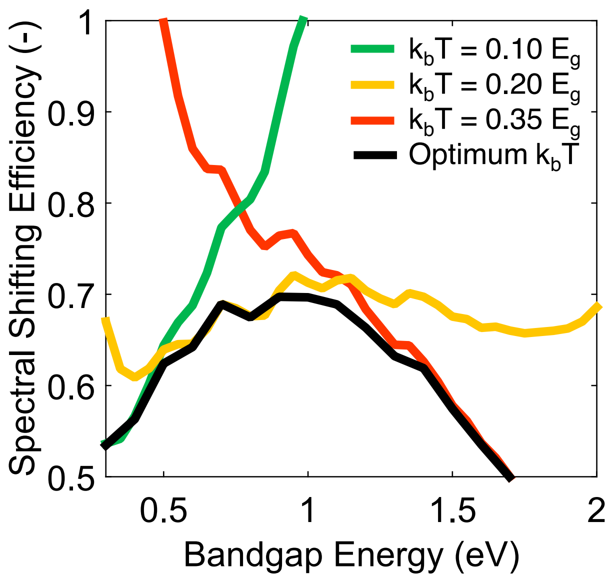
Thus the final power density that may be extracted from the PV converter is given by

$$P_{\max} = p_u XY \tag{S5}$$

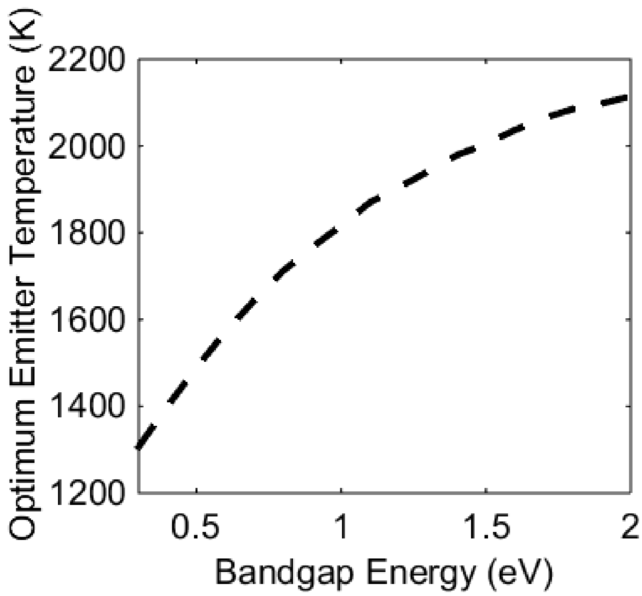
The incoming power is simply the spectral integration of the incoming photon spectrum, $Q_{b,\lambda}$. The efficiency is the ratio of the maximum power, P_{max}, to the incoming power. For STPVs, this efficiency is multiplied by the essential photo-thermal efficiency which is derived in the blackbody limit. It is given by

$$\eta_{abs} = 1 - \left(\frac{T_{emmiter}}{T_{sun}}\right)^4 \tag{S6}$$

The heat generation rate is calculated using a First Law analysis, requiring the difference in the input power and the sum of the electrical power density and essential losses to be generated as thermal energy.



Supplementary Figure 1 | Ratio of the theoretical conversion efficiencies of solar PV to STPV represents the required performance of a realistic (with parasitic losses) spectral converter to match the solar PV efficiency.



Supplementary Figure 2 | Optimum emitter temperature as a function of PV bandgap for a single cutoff emitter. Monotonic increase in temperature is expected in order to populate higher energy states.

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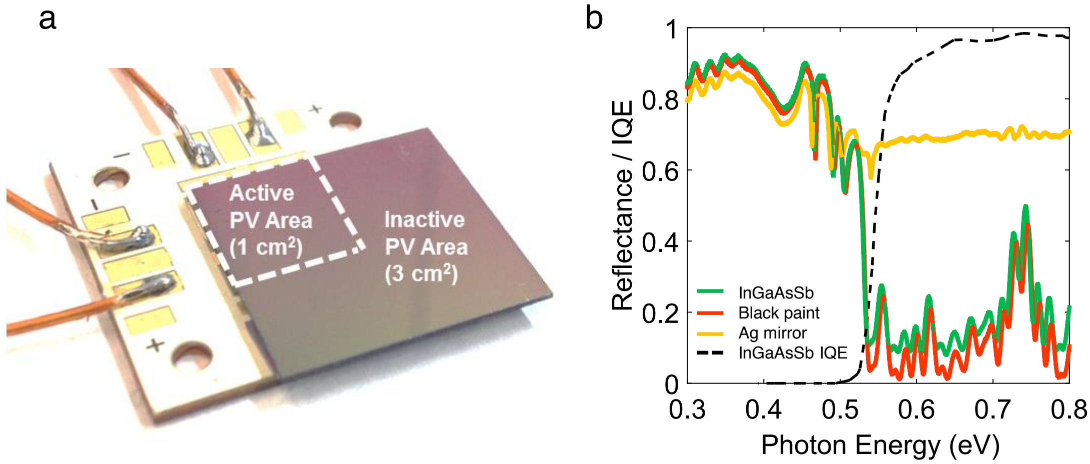
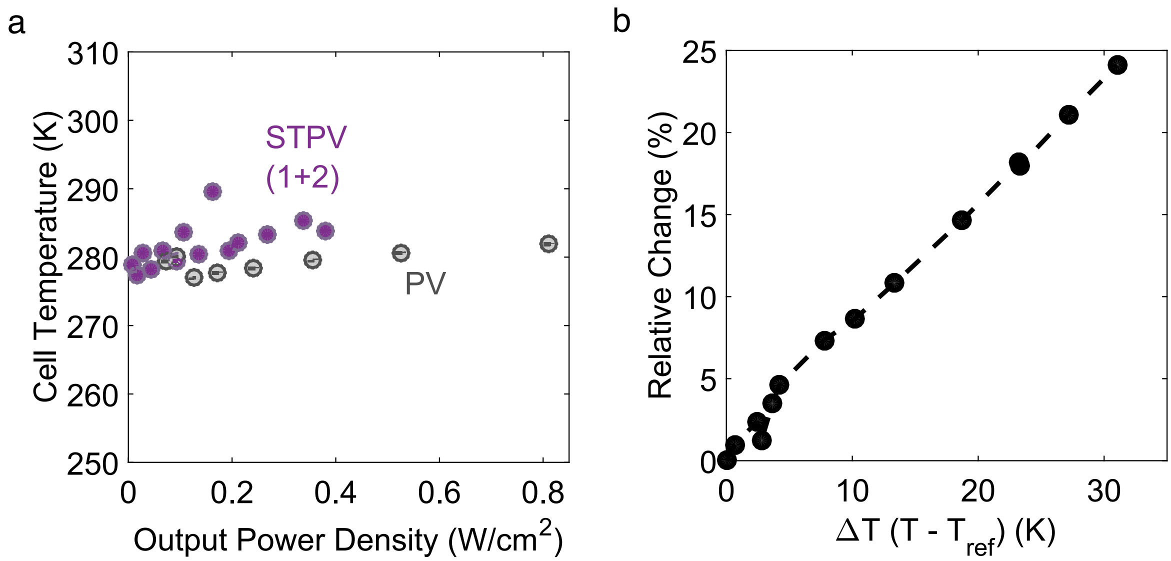
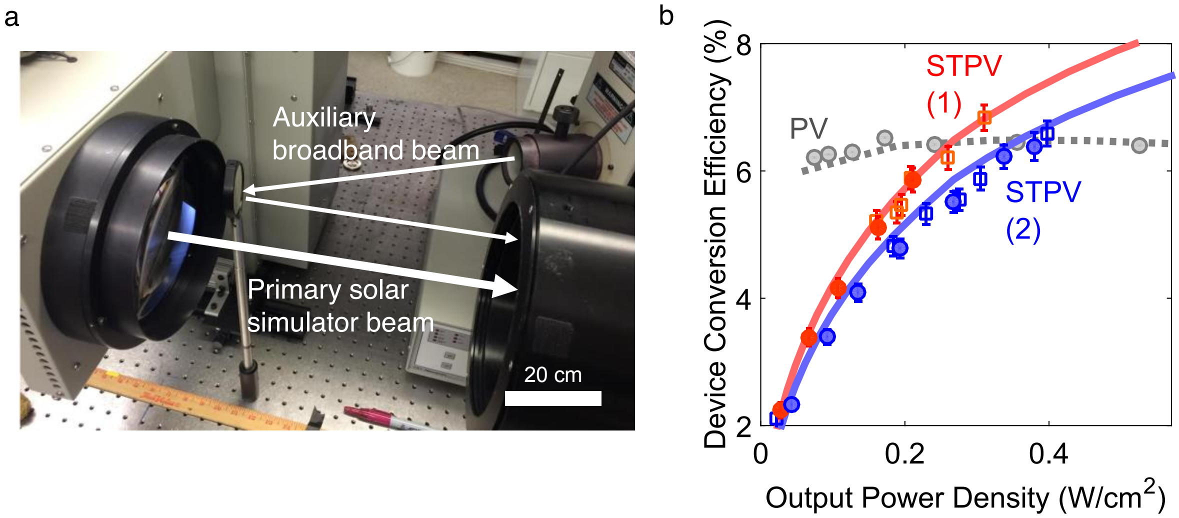


Supplementary Figure 3 | (a) The 4 cm^2 PV, with a bonded optical filter covering the 4 cells. The active PV participates radiatively and electrically while the inactive PV participates only radiatively. (**b**) FTIR reflectance spectra of the rugate filter bonded to different substrates. The optical properties of the rugate / black paint combination are much closer to those of the rugate / Ag combination. Also shown is the spectral response of the underlying InGaAsSb PV converter.



Supplementary Figure 4 | Cell temperature dependence. (**a**) Temperature obtained by a type J thermocouple sandwiched between the PV cell and the copper cooling block during the recording of each data point. Cell temperatures do not vary more than 6 K between the large absorber STPV and PV runs, with the STPV cell being slightly warmer. (**b**) Relative change in power produced by the PV cell for a given constant input spectrum while varying the temperature.



Supplementary Figure 5 | Increasing input power. (**a**) Optical image of the configuration which allows ~20% increase in input broadband white light to the absorber plane. (**b**) Data from manuscript Figure 4a which shows which optical configuration each data point was recorded at. Open squares represent the combined light sources while closed circles represent the primary solar simulator beam only.

Supplementary References

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