Supplementary Information:

Detailed-balance calculations for the current-voltage properties of the light absorbers:

From the definition of detailed-balance, the current density at an operating photovoltage is the current density due to the incident solar and thermal radiation minus the current density of radiative emission:

$$J = J_{ph} + J_{th} - J_{rad} \qquad (6)$$

in which

$$J_{ph} = e\int_{E_g/\hbar}^{\infty} \mathrm{d}\hbar\omega \, \frac{n_{ph}}{\mathrm{d}\hbar\omega} \qquad \text{(S1)}$$

assuming 100% of above band gap photons are absorbed and collected. The quantity. nTh_{ph} is the wavelength-dependent photon flux in the AM 1.5 solar spectrum. To calculate the term for the radiative current density, the thermal radiation and the radiation emitted from the top surface and bottom surface of each junction must be considered. The steady-state photon emission current density for each cell can be calculated from the law of thermodynamics and statistical mechanics, assuming that both the top cell and bottom cell of the light absorber are planar:[29,45]

$$J_{rad} = \frac{e(n_{top}^2 + n_{bottom}^2)}{4\,\pi^2 c^2}\int_{E_g/\hbar}^{\infty} \mathrm{d}\omega\, \omega^2 \exp(\frac{eV - \hbar\omega}{kT}) \qquad \text{(S2)}$$

where n_{top} and n_{bottom} is the refractive index of the media on the top and bottom of the junction of interest, respectively, E_g is the band gap of the cell, $E_g/\hbar$ is the cut-off frequency for emission, *V* is the operating voltage, *T* is the absolute temperature, *e* is the unsigned charge on an electron, and *c* is the speed of light. The absorbed thermal radiation, or incident radiation in dark, is equal to J_{rad} with *V*=0:

$$J_{th} = \frac{e(n_{top}^2 + n_{bottom}^2)}{4\,\pi^2 c^2} \int_{E_g/\hbar}^{\infty} \mathrm{d}\omega\, \omega^2 \exp\left(-\frac{\hbar\omega}{kT}\right) \qquad \text{(S3)}$$

To generalize and compare this expression across various configurations, the light absorber stack was chosen to consist of an air/top junction/bottom junction/back reflector, with the refractive indices of the top junction and bottom junction set at values of those for representative III-V and Si semiconductors, i.e. n_{GaAs}=3.3, n_{Si}=3.42. Using these values, the ideal *J-V* behavior of the top and bottom cells in the tandem light absorber can be calculated using Equation (6) and (S1)–(S3), with $n_{1,top} = 1$ (air), $n_{1,bottom} = 3.42$ (bottom junction), $n_{2,top} = 3.3$ (top junction), and $n_{2,bottom} = 0$ (perfect back reflector).