Modeling of Near-Field Concentrated Solar Thermophotovoltaic Microsystem

nano & micro Systems Research Laboratory

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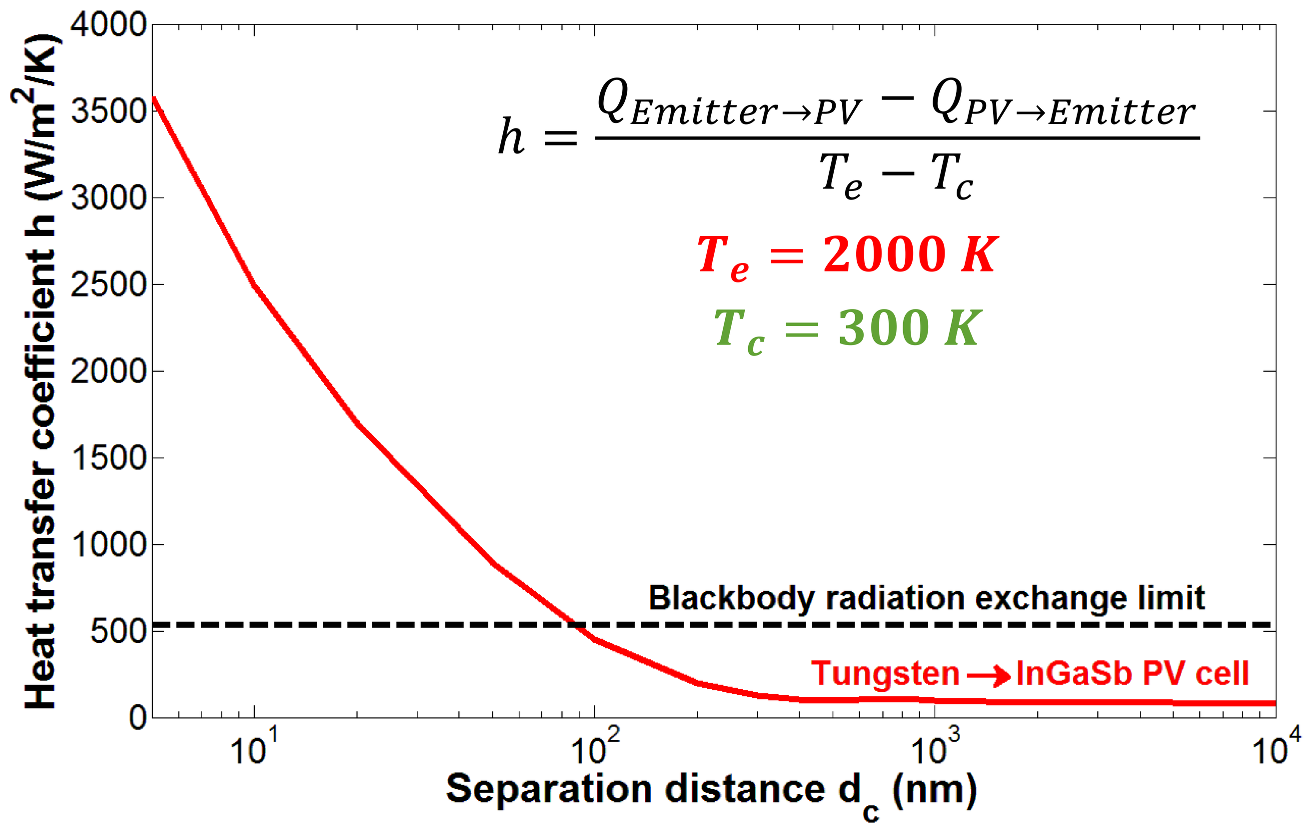
Introduction

- Solar Thermophotovoltaic cell (STPV) tailors solar spectrum to better match with PV cell quantum efficiency.
- Enhancement in radiation flux between two closely separated surface ($\sim\lambda_{radiation}$) can be orders of magnitudes higher than the **blackbody** limit, which can increase cell output power density.
- Flexible system; Solar energy.



Modeling

- Emitter/Absorber is made of Tungsten, selective absorber has a 2D Photonic crystal.
- PV cell is single PN junction ($In_{0.18}Ga_{0.82}Sb$) with bandgap $0.56\ eV$.
- Near-field radiation is originated from source at $\mathbf{z}'$ and calculated at PV cell at point $\boldsymbol{z}$

$$q(z,\omega) = \frac{2k_v^2\Theta(\omega,T)}{\pi} Re\left\{i\varepsilon_r''(\omega)\int_V dV' G_{m\alpha}^{E}(\mathbf{z},\mathbf{z}',\omega) G_{n\alpha}^{H*}(\mathbf{z},\mathbf{z}',\omega)\right\}$$

- Electron/hole generation rate in PV cell,

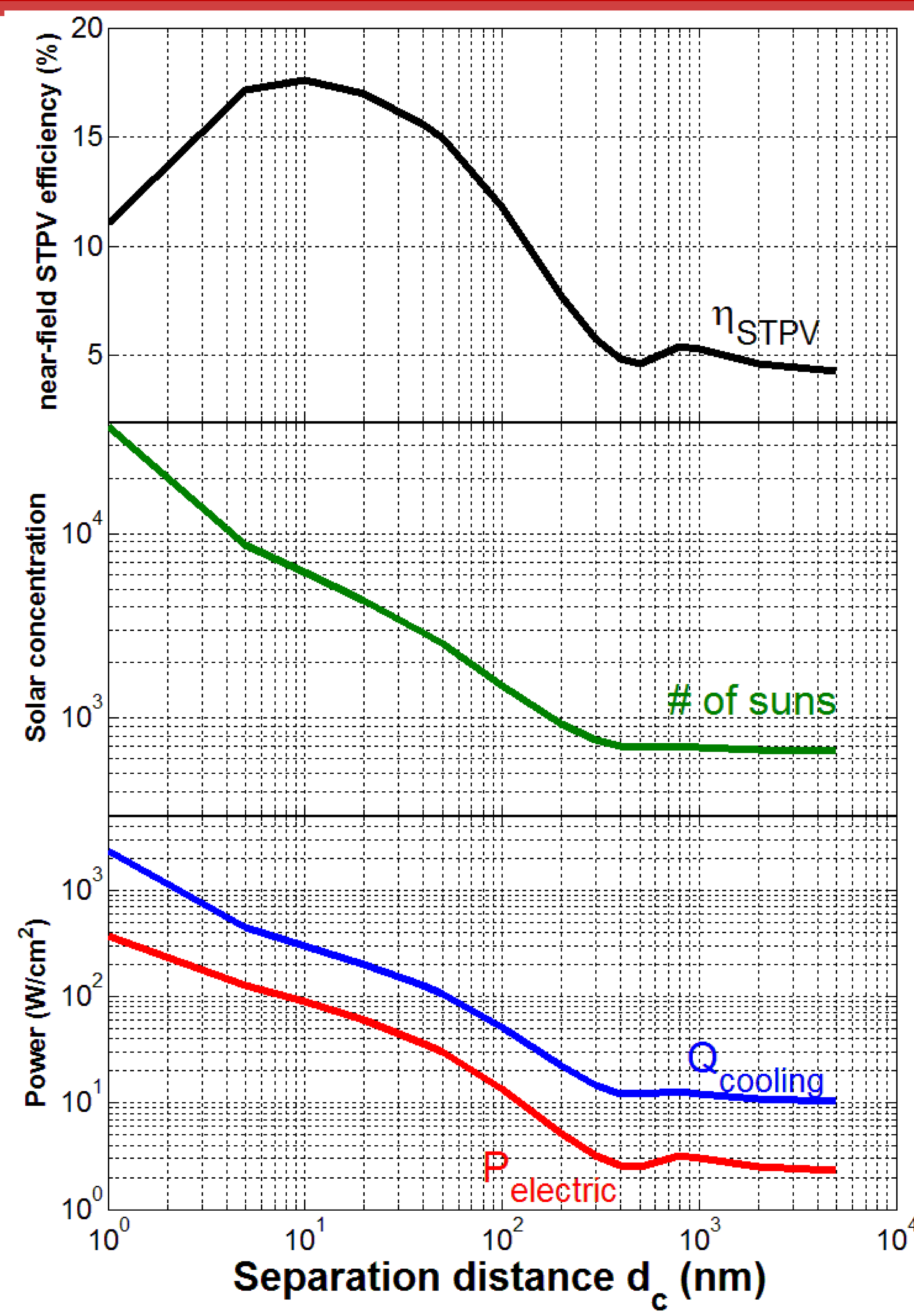
$$G(z,\omega) = -\frac{1}{\hbar\omega}\frac{\partial q(z,\omega)}{\partial z}$$

- Solving minority carrier diffusion equation, photocurrent is calculated,

$$D_{e,h}\frac{\partial^2 \Delta_{e,h}(z,\omega)}{\partial z^2} + G(z,\omega) - \frac{\Delta_{e,h}(z,\omega)}{\tau_{e,h}} = 0$$

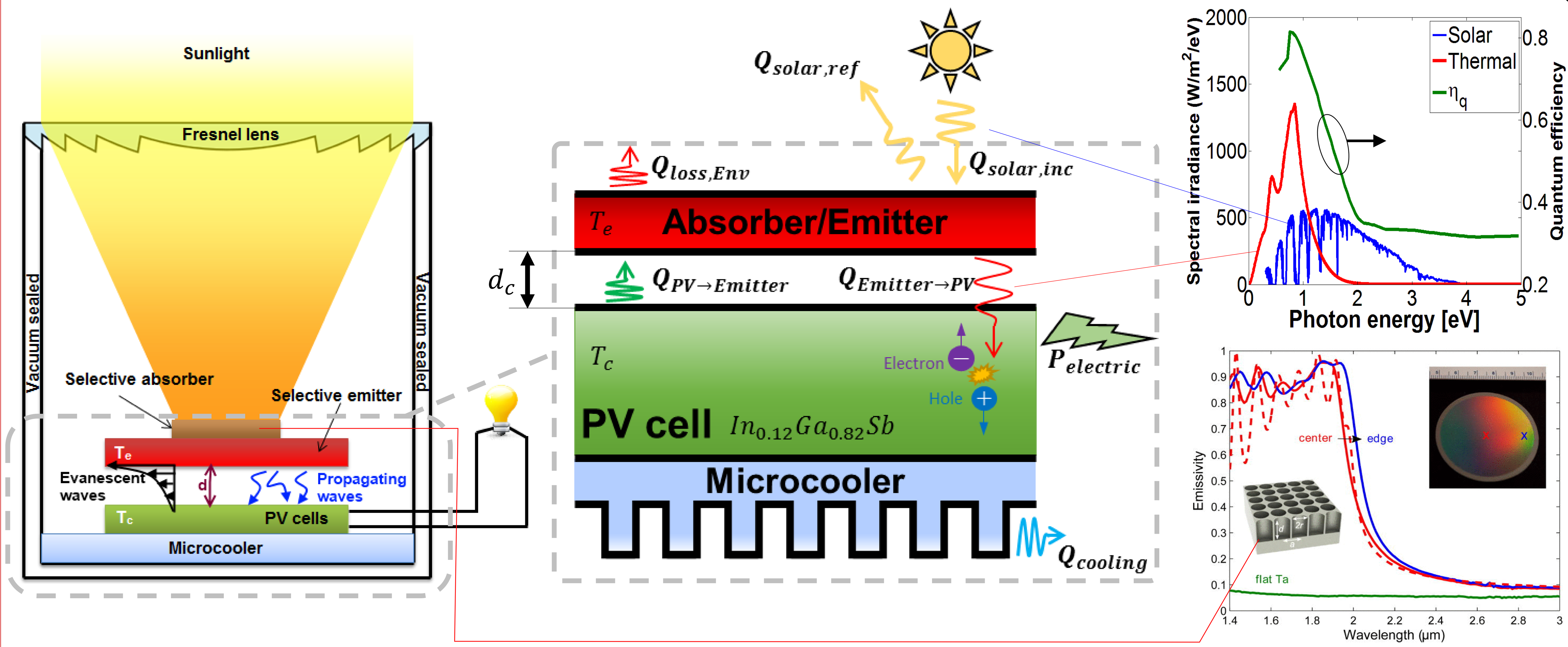
- Electron hole recombination is considered $\tau_{e,h}$ is lifetime of electron/hole.
- $\eta_{STPV} = \frac{Q_{solar,inc}}{P_{electric}}$

Results & conclusion



- Near-field STPV have potential for high power density ($\mathbf{100}\ \boldsymbol{W/cm^2}$) compared to conventional PV cell ($\mathbf{0.845}\ \boldsymbol{W/cm^2}$), with conversion efficiency $\mathbf{17.5}\%$.
- Efficiency can be increased by employing special enclosure.
- Cooling may be a concern.

Model layout



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