Thermophotovoltaic Back-Mirrored Cells as Spectral Filters

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Abstract:

Thermophotovoltaic cells convert thermal radiation from local 1500-1800 K hot sources to electricity. Obstacles to efficient photovoltaic energy conversion include sub-bandgap photon loss, carriers from high-energy photons thermalizing to the band edge, and low external luminescent efficiency. We propose that single-bandgap thermophotovoltaic cells can surpass the 23.6% efficiency record through the use of spectrum-appropriate semiconductors and a reflecting back mirror. Indium-gallium-arsenide (InGaAs) cells have a 0.74 eV bandgap optimal for spectral filtering at thermal radiation energies. Adding a gold back mirror to the cell reduces sub-bandgap photon loss, and increases operating power by boosting the external luminescent efficiency.

Background:

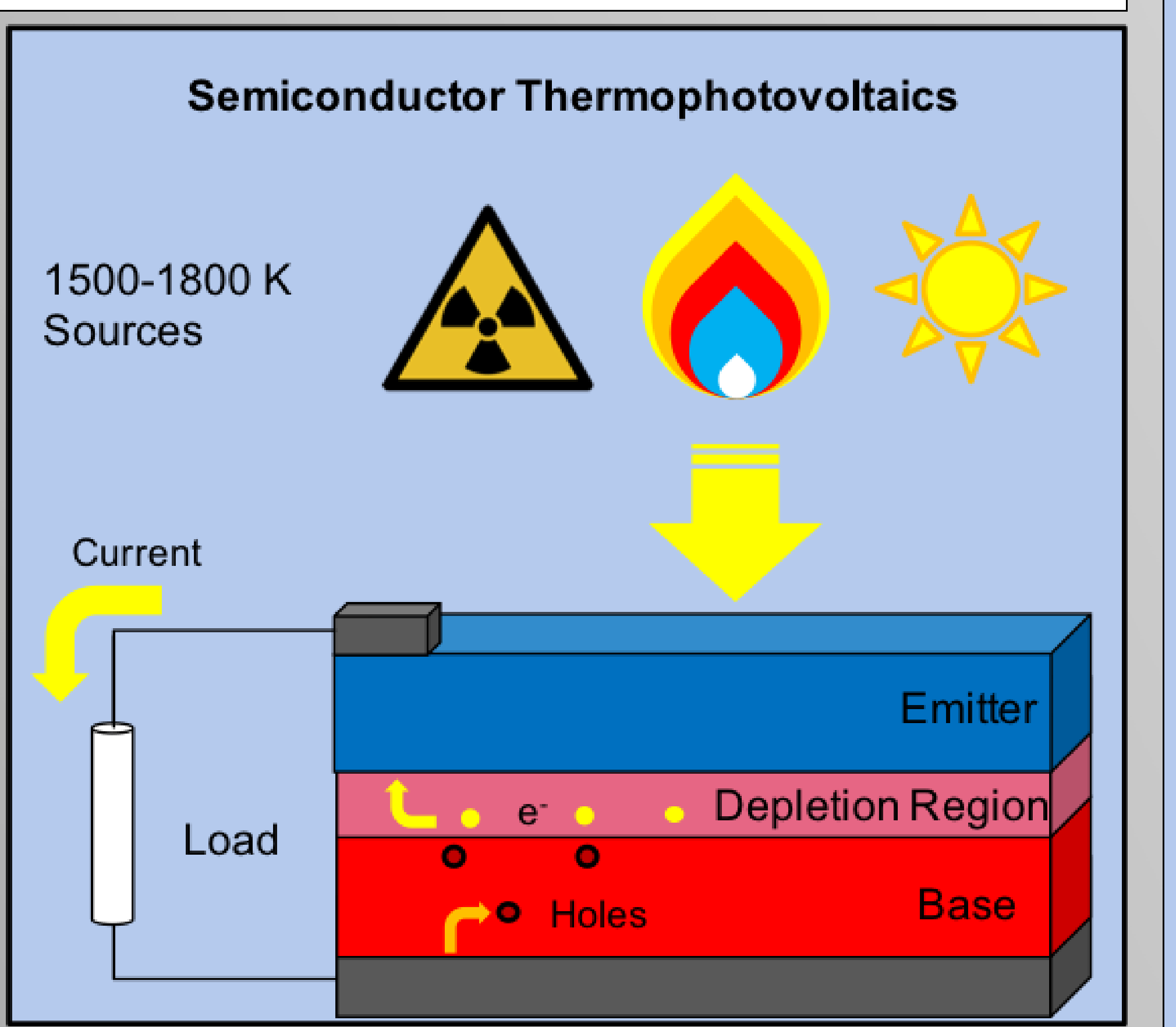

Fig.1: Thermophotovoltaic Semiconductor Technology for 1500-1800 K sources

Absorption and Loss:

- Bandgap energy: energy difference between the valence and conduction bands

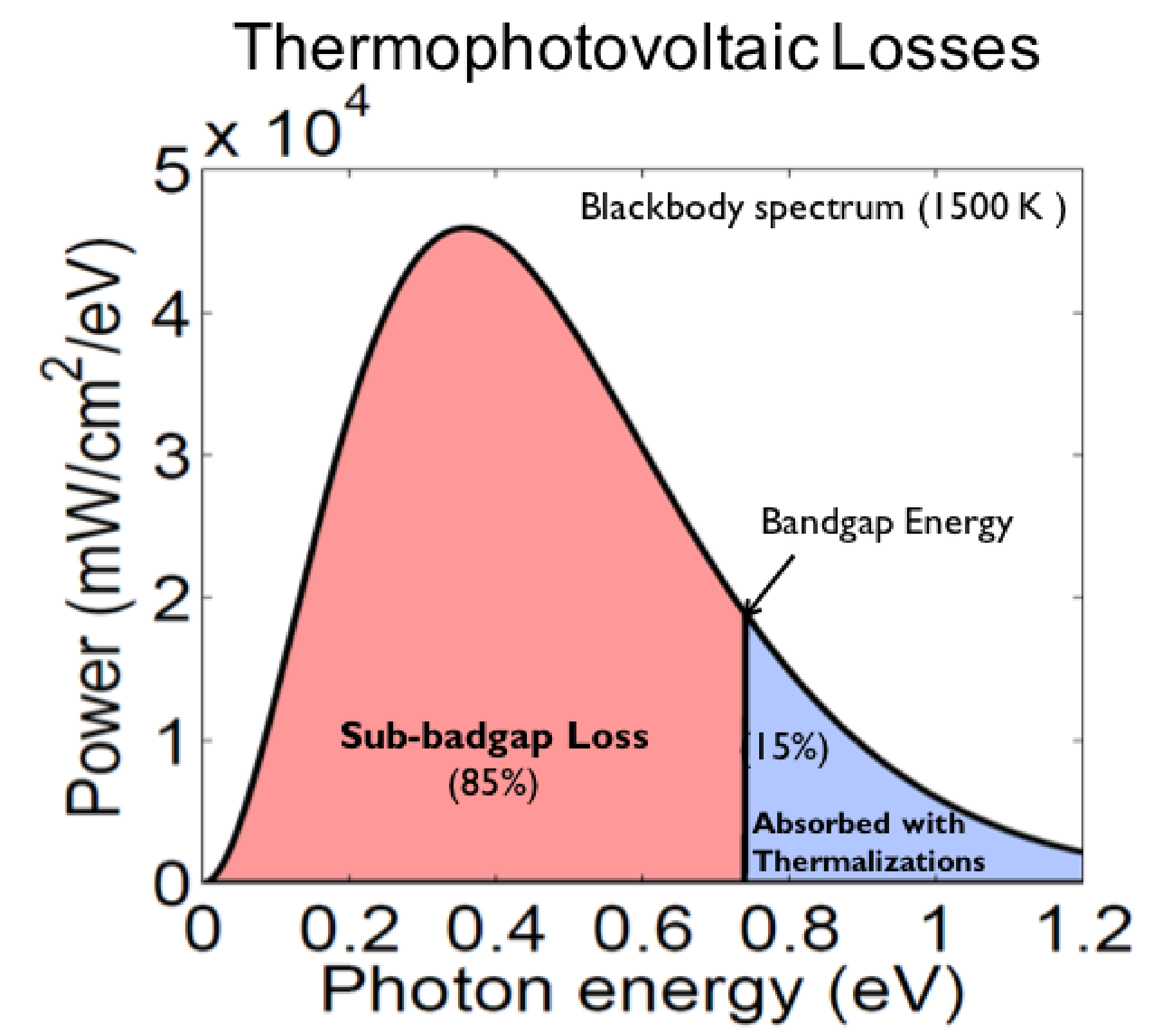

Fig.2: Thermophotovoltaic power losses from a blackbody emitter as determined by semiconductor bandgap

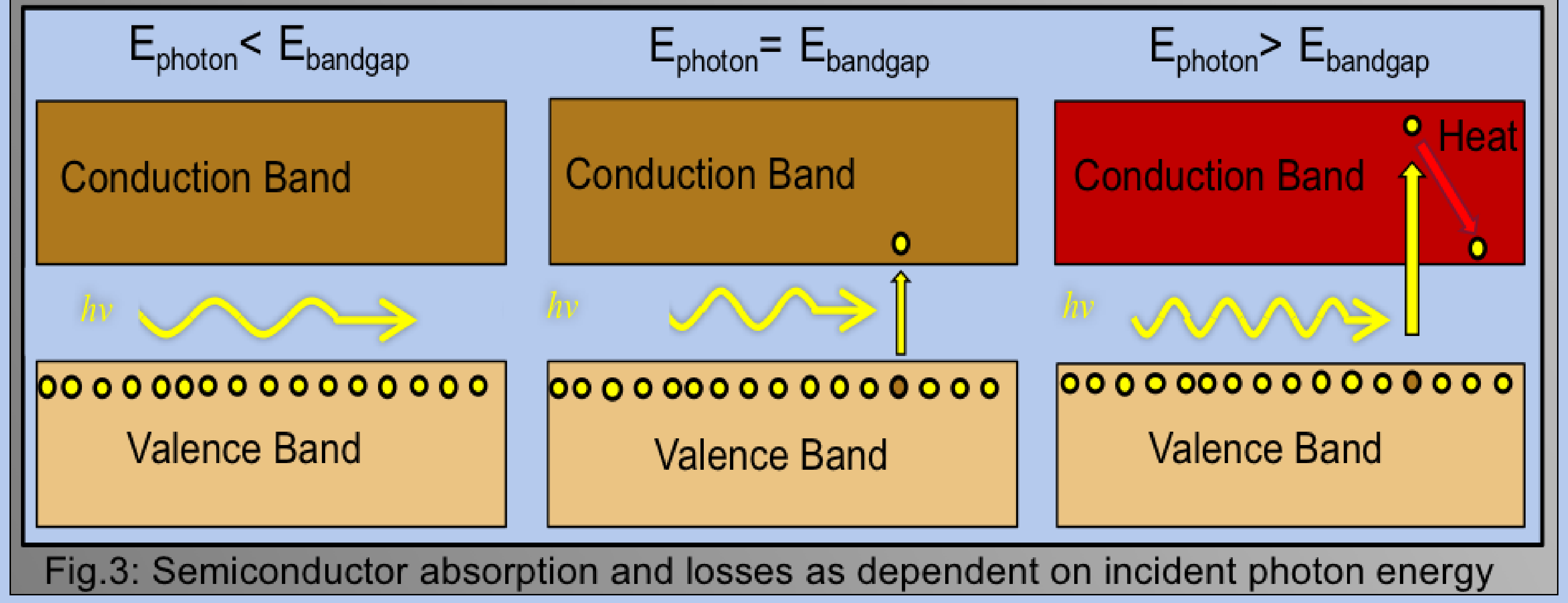

Fig.3: Semiconductor absorption and losses as dependent on incident photon energy

Benefits of a High-Reflectivity Back-Mirror:

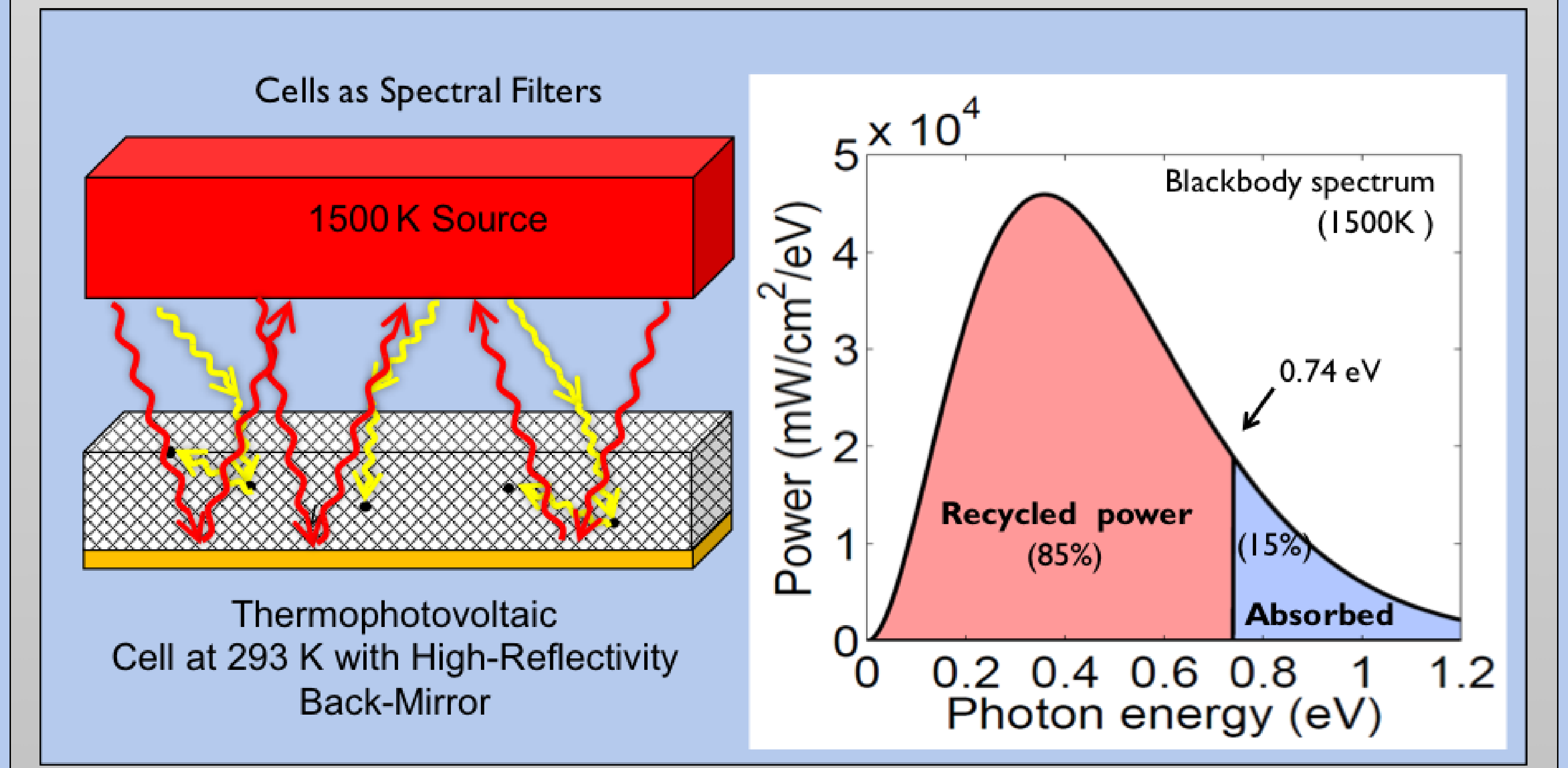

Fig.4: Diagram of a high-reflectivity back-mirrored cell functioning as a spectral filter and accompanying black body curve recycling plot

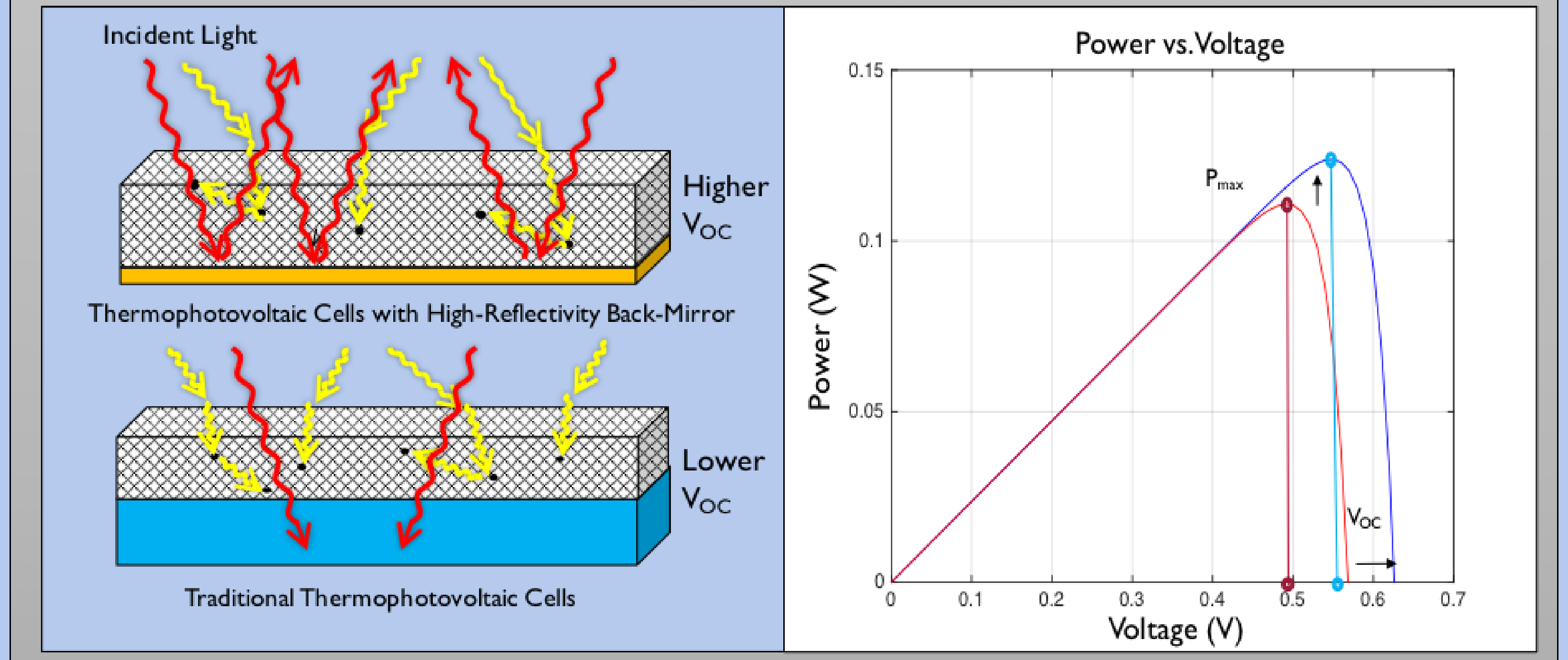

Fig.5: Effects of a high-reflectivity back-mirror on the cell photon concentration and resulting power output increase

Experimental Setup:

Efficiency Calculation:

Photovoltaic power from measured I-V curve

$$\frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{SB} - R * P_{SB}}$$

Blackbody power from measured temperature

Measured photovoltaic reflectivity

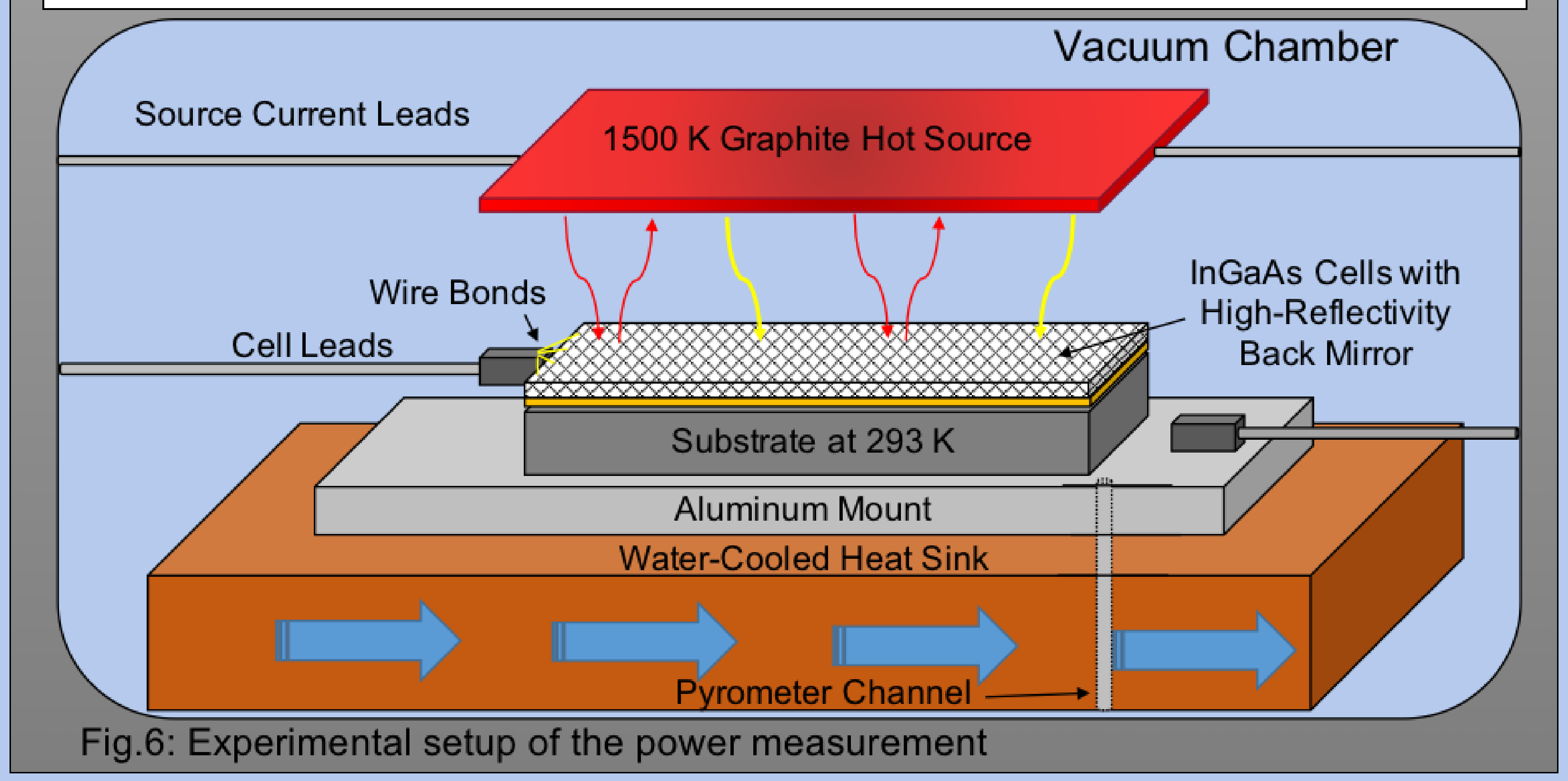

Fig.6: Experimental setup of the power measurement

Results and Future Work:

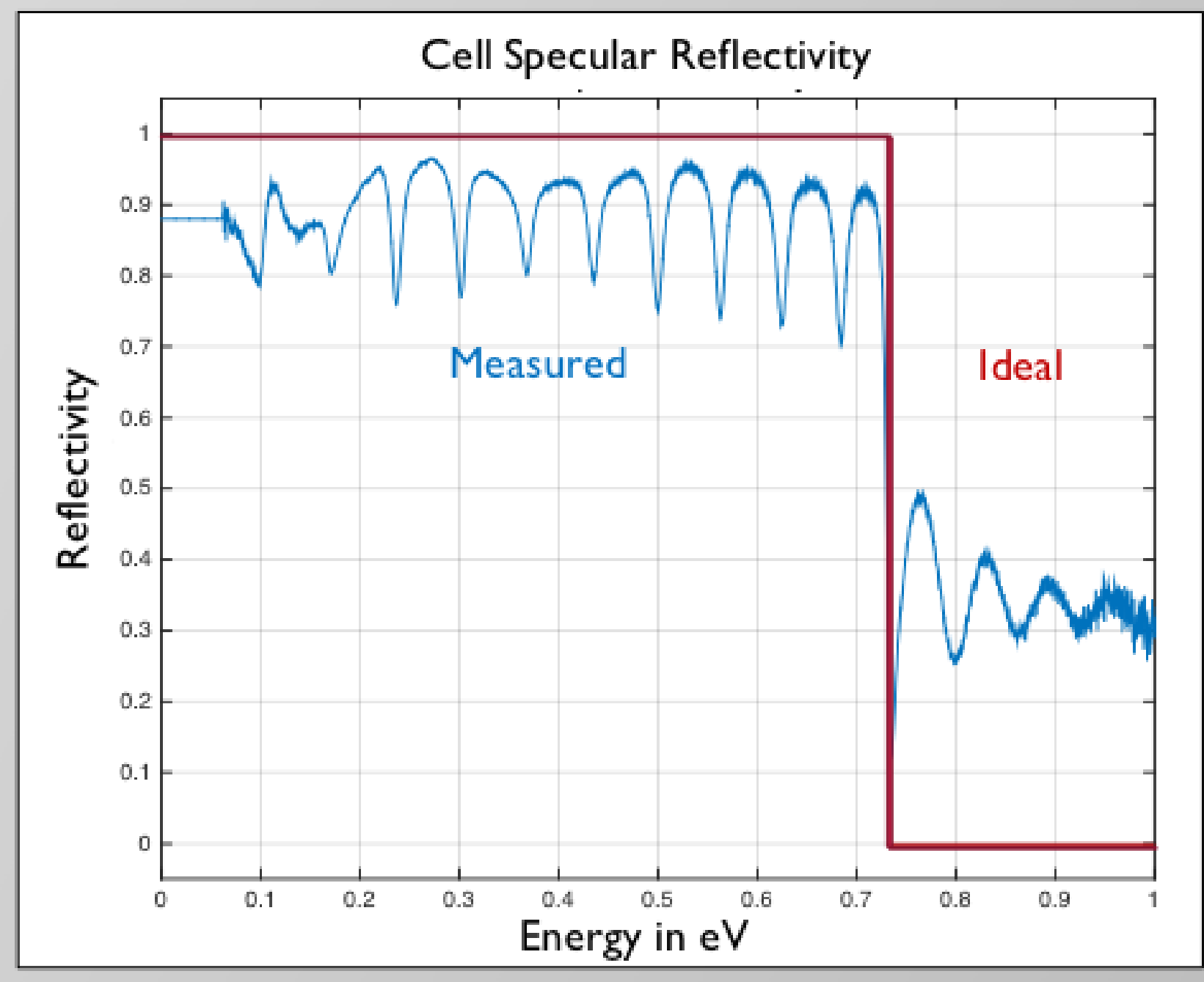

Fig.7: Reflectivity of the InGaAs Cell

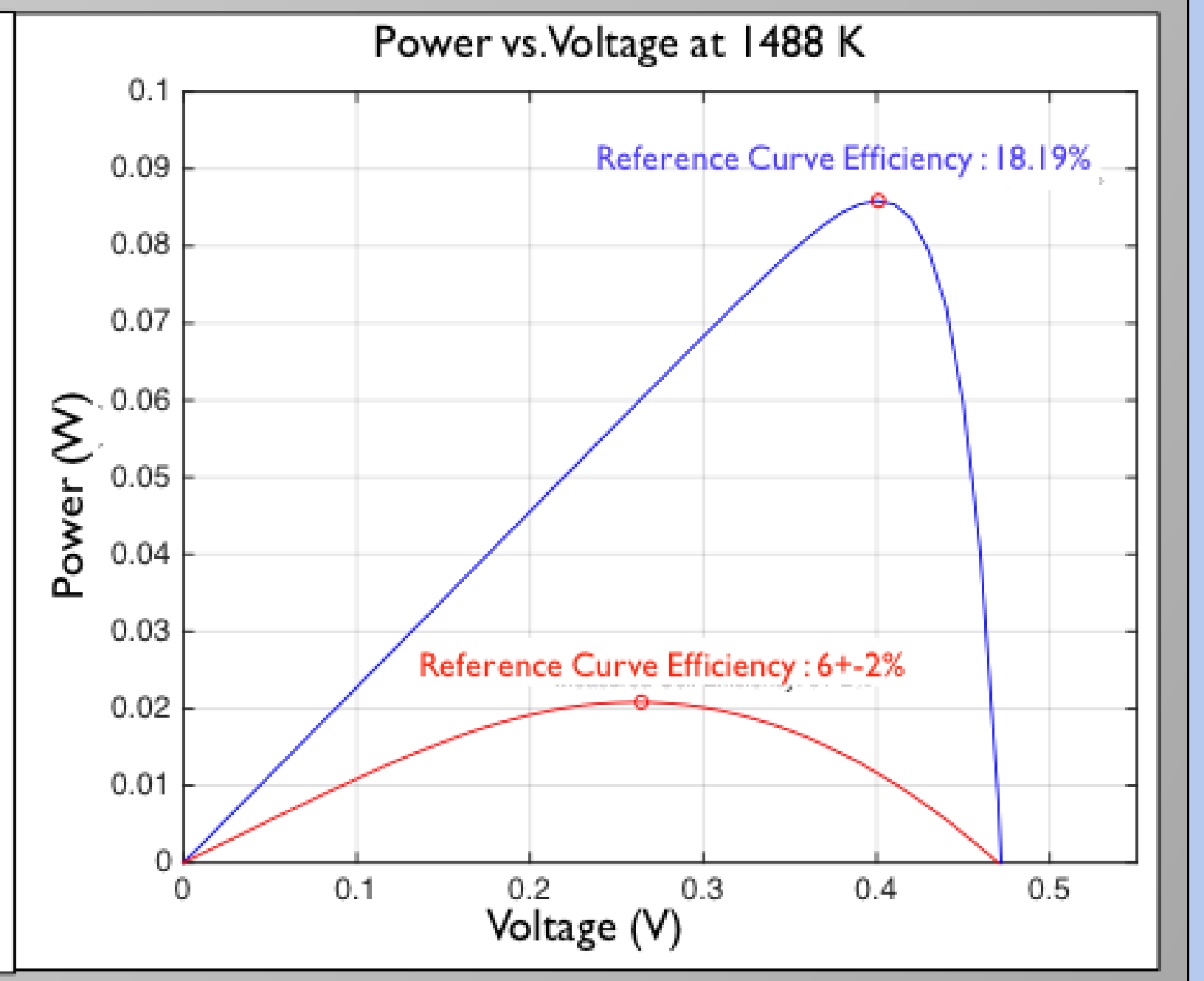

Fig.8: Efficiency of the InGaAs Cell

Example Application:

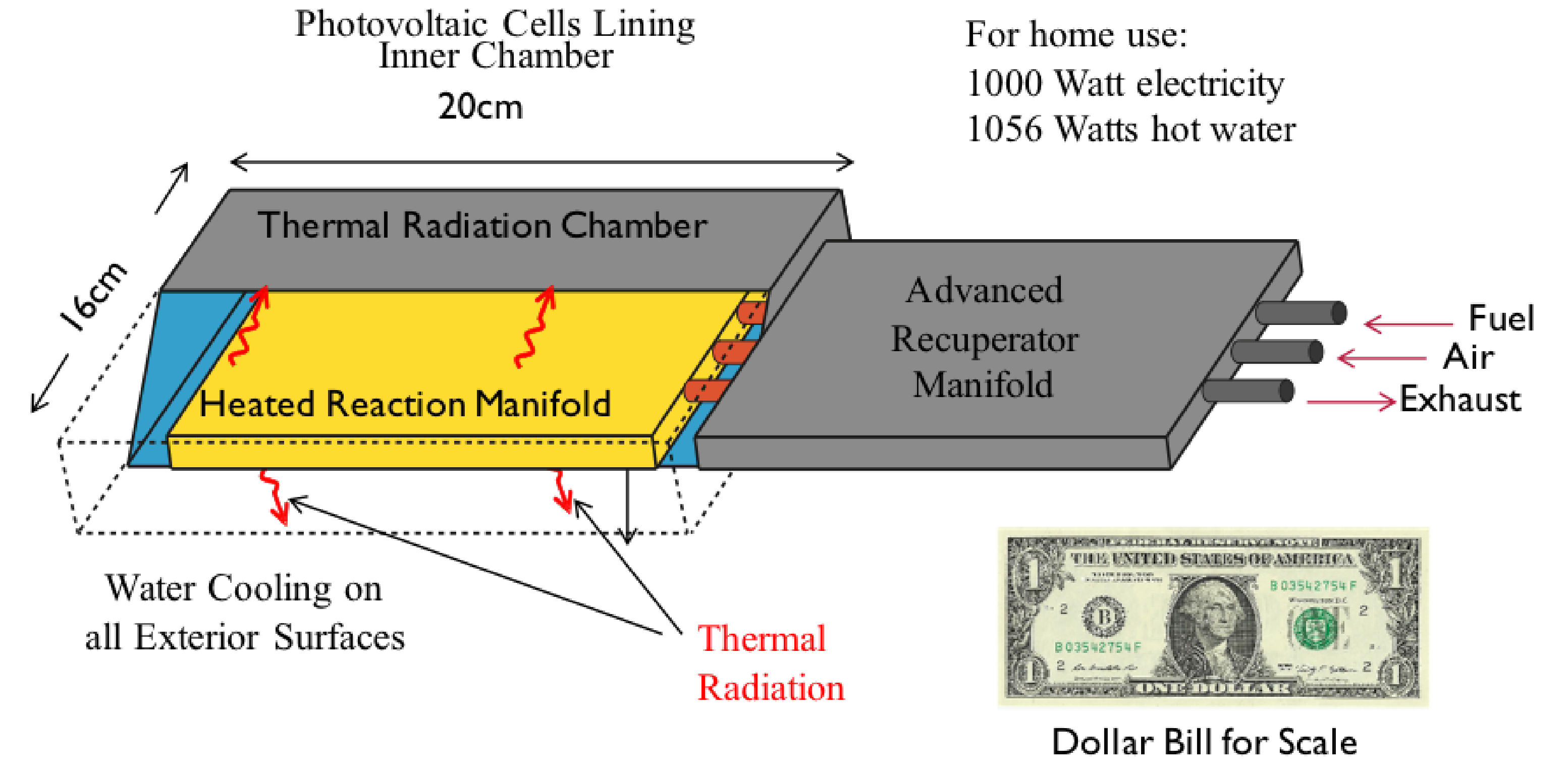

Fig.9: Diagram of a thermophotovoltaic water heater and power source

Acknowledgements:

-This work was funded by National Science Foundation Award ECCS 0939514
-National Science Foundation
-Center for Energy Efficient Electronics Science at UC Berkeley
-Theoretical Background: Vidya Ganapati, Patrick Xiao
-Laboratory Facilities: Per Peterson, Eli Yablonovitch
-Cell Design and Fabrication: Myles Steiner at the National Renewable Energy Laboratory (NREL), John Lloyd at the California Institute of Technology (Caltech)
-Laboratory Equipment Construction: John Holzrichter, Edward Pierce

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