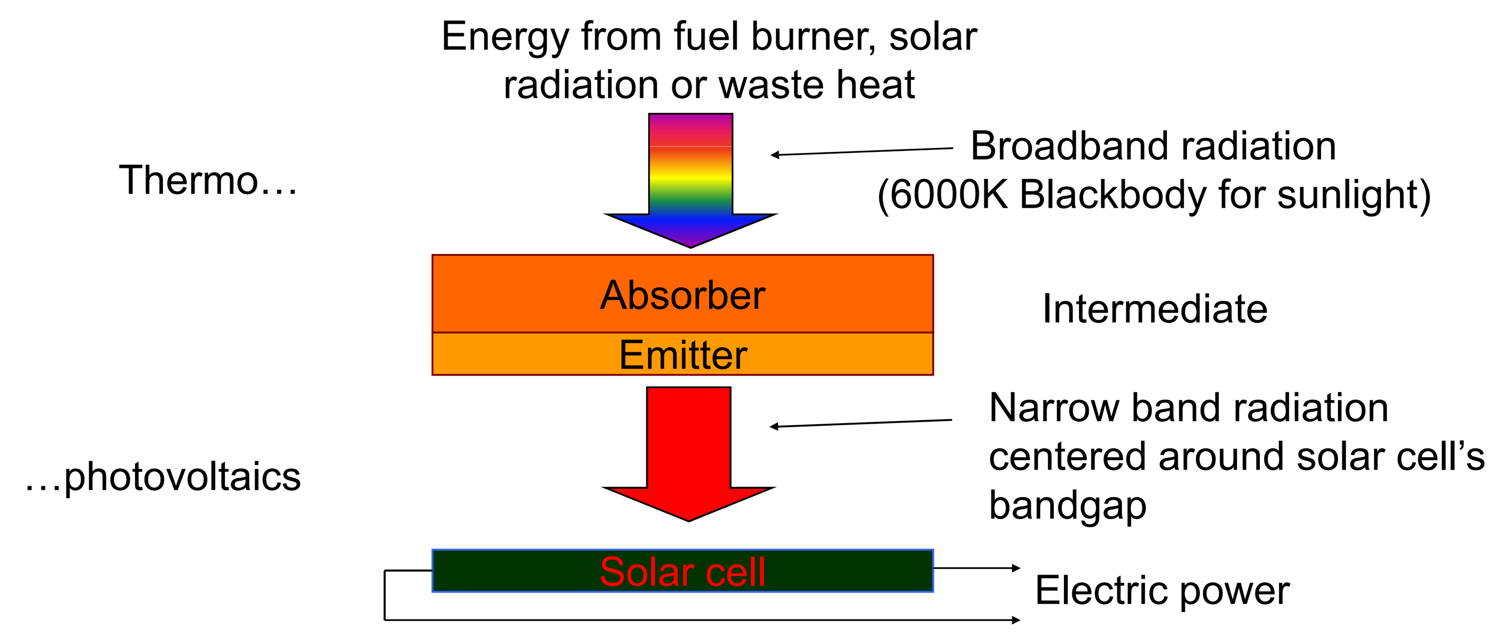
Stanford Electronic Organics Lab

Nanophotonic approaches to thermophotovoltaics and solar thermal

Nicholas Sergeant, Olivier Pincon and Peter Peumans
ppeumans@stanford.edu
http://peumans-pc.stanford.edu

Introduction to thermophotovoltaics (TPV)

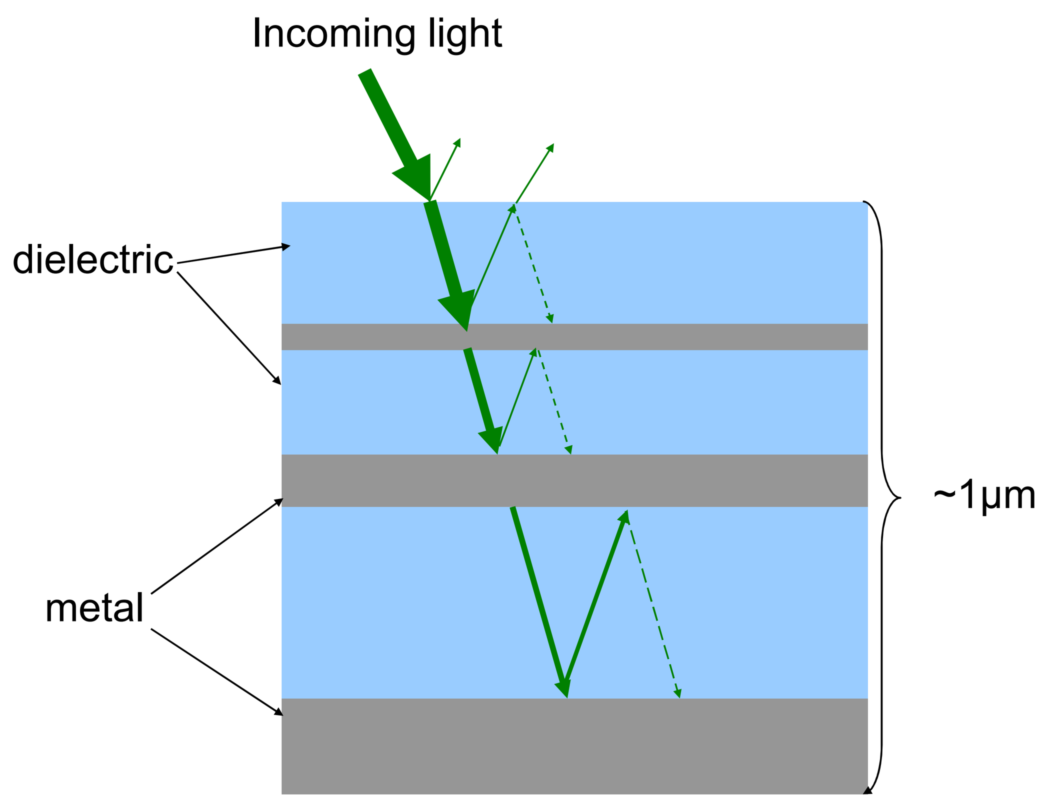
A thermophotovoltaic system turns heat into electricity using a solar cell which is irradiated by a hot body.



Advantage of TPV:
TPV devices circumvents the inherent inefficiency of photovoltaics by concentrating the power emitted to the solar cell above its bandgap. Thermodynamic system efficiency limits are 85% with full concentration and 54% with no concentration.

Solution: metal-dielectric stacks

When light is impinging on a metal-dielectric stack, it is absorbed, reflected and transmitted by the metallic layers. They are spaced by generally thicker dielectric layers that enable interference effects that only act upon some wavelengths.

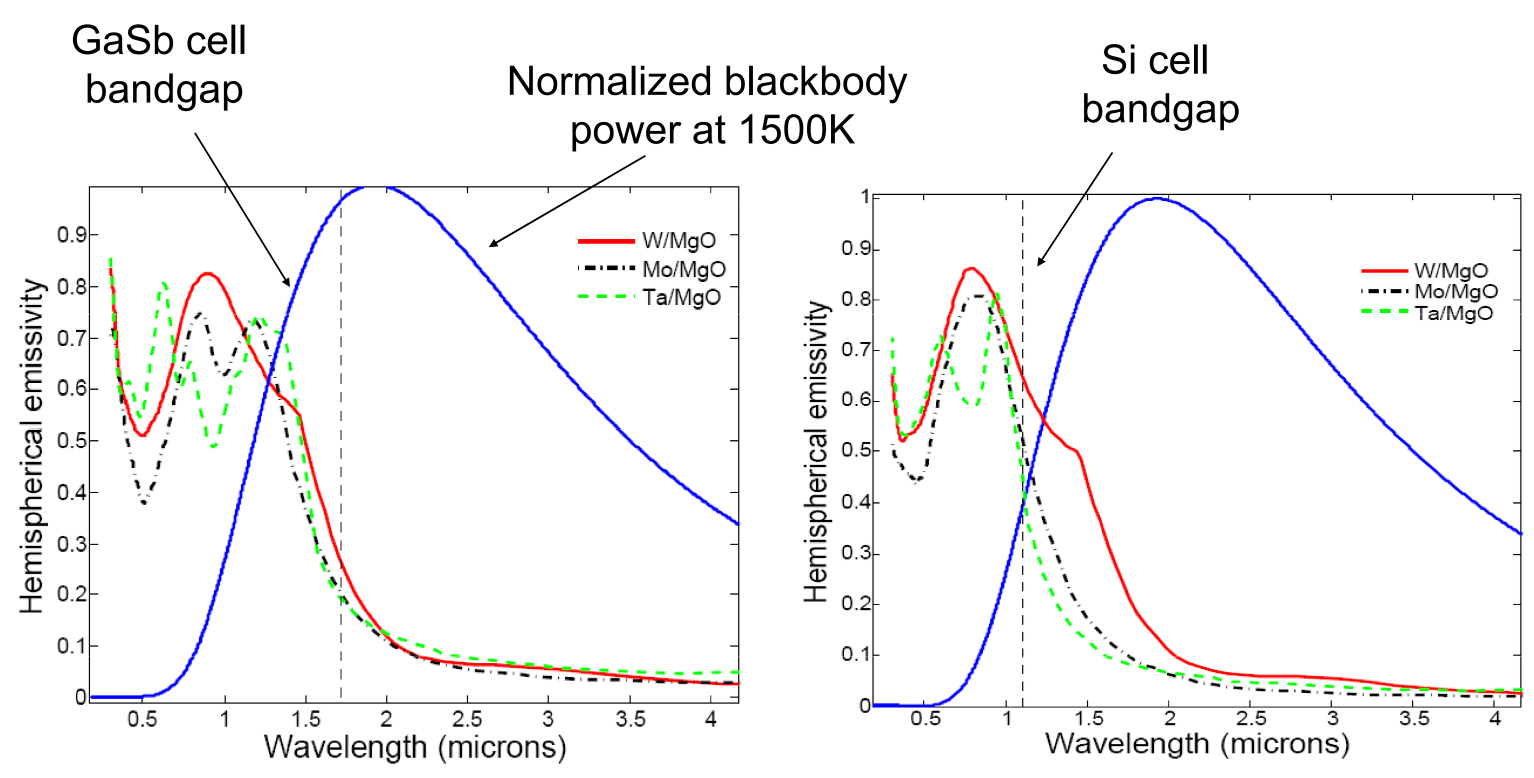


By selecting the materials and the thicknesses of each layer, one can therefore alter the absorption spectrum of an aperiodic metal-dielectric stack. Assuming equivalence of emissivity and absorptivity, those stacks can also be used to design TPV emitters.

Stacks as TPV emitters

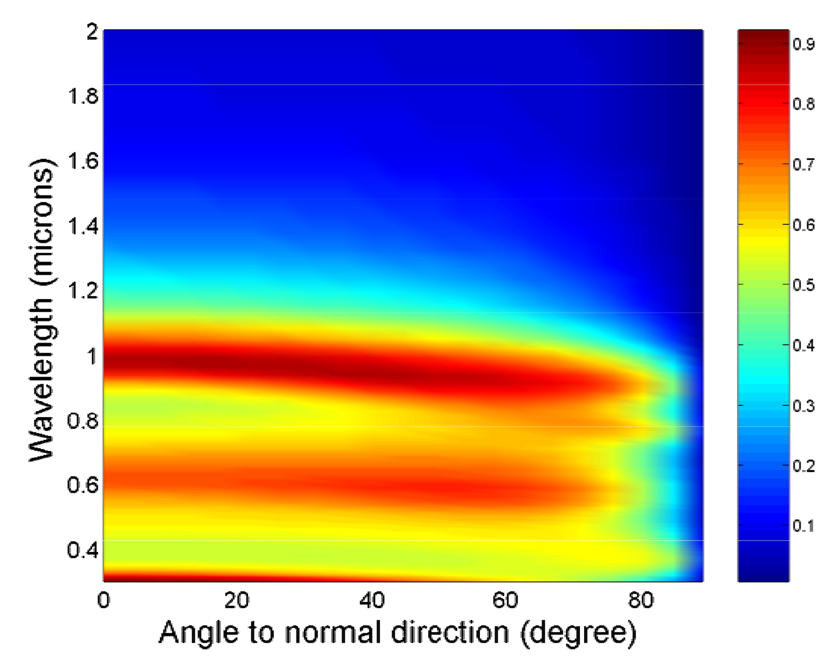
Optimization Problem: Design an emitter material that has an emissivity spectrum peaked just above the bandgap energy and has low emissivity for other wavelengths?

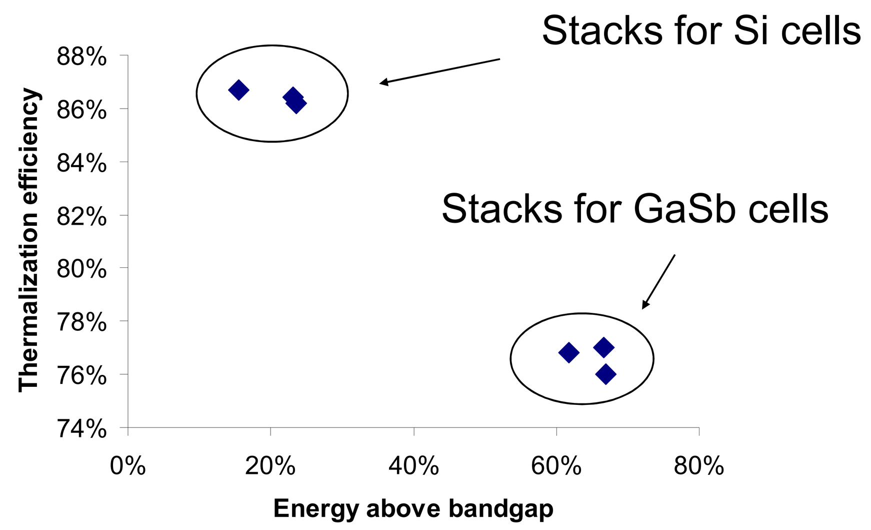
We simulated stacks using the transfer-matrix method and improved them with a needle optimization technique. We used tungsten (W), tantalum (Ta) and molybdenum (Mo) as metals, and magnesium oxide (MgO) as the dielectric.



Emissivities of metal-dielectric stacks emitting to a GaSb and Si cell

Emissivity of the Ta/MgO stack designed for Si cells is very angle-independent up to 80°.



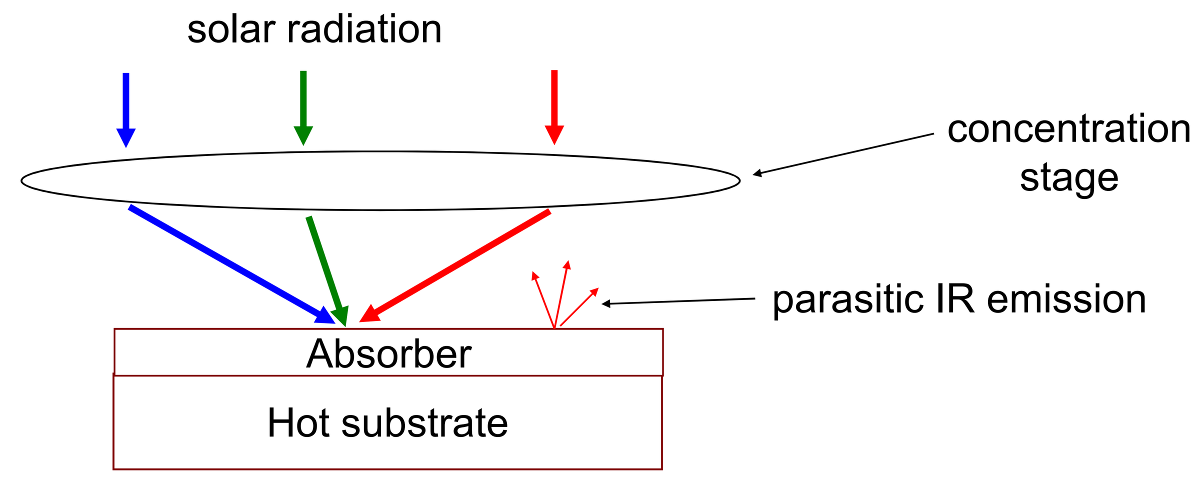


The high bandgap of silicon makes TPV emitters rather inefficient (only ~20% of radiated power over the bandgap), but this can be improved by a filter.

On the other hand, emitters for GaSb feature significantly more thermalization losses.

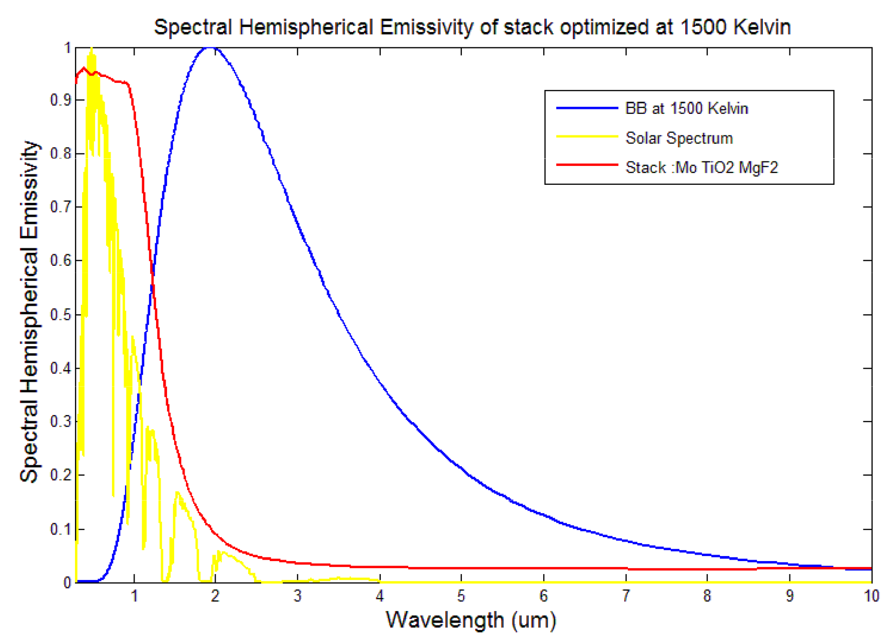
Stacks as TPV and solar thermal absorbers

Optimization Problem: Design an emitter material that has maximized absorptivity in the solar spectrum and has low emissivity for other wavelengths (low parasitic IR emission).

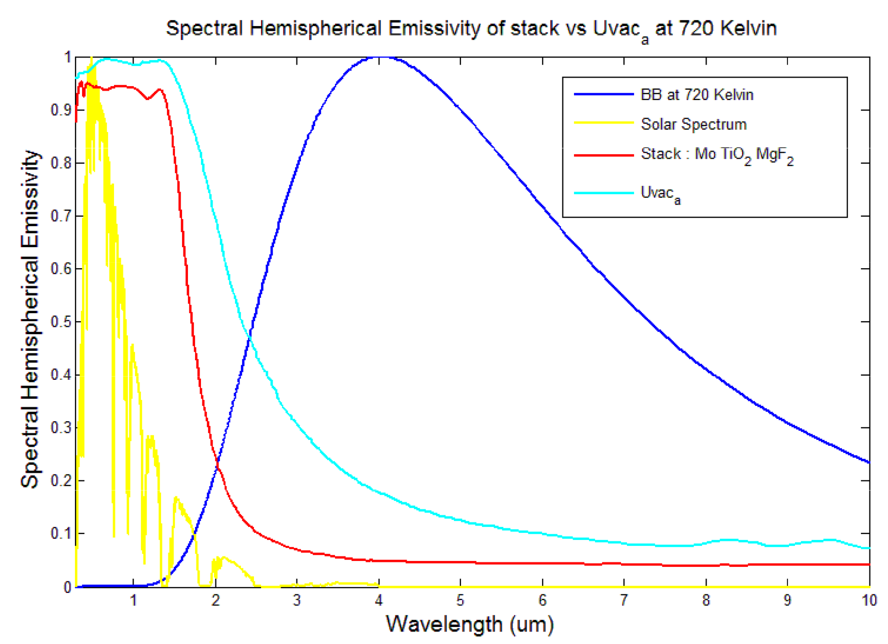


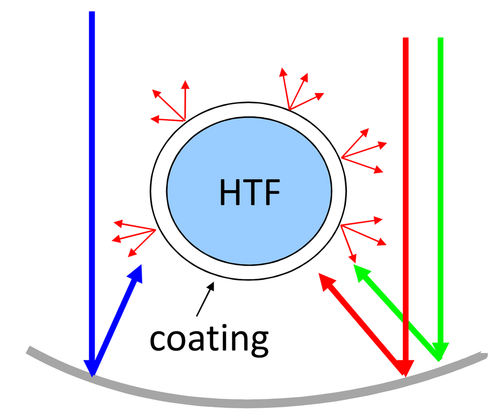
We again simulated stacks using the transfer-matrix method and improved them with needle optimization technique. In this case Mo is used as metal and MgF2 and TiO2 are used as dielectric materials.

TPV absorbers optimized at 1500K



Solar thermal absorbers optimized at 720K





Acknowledgments

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