Nanostructured Metamaterials and Nanoparticles Engineering to Efficiently and Reliably Harness the Solar Spectrum

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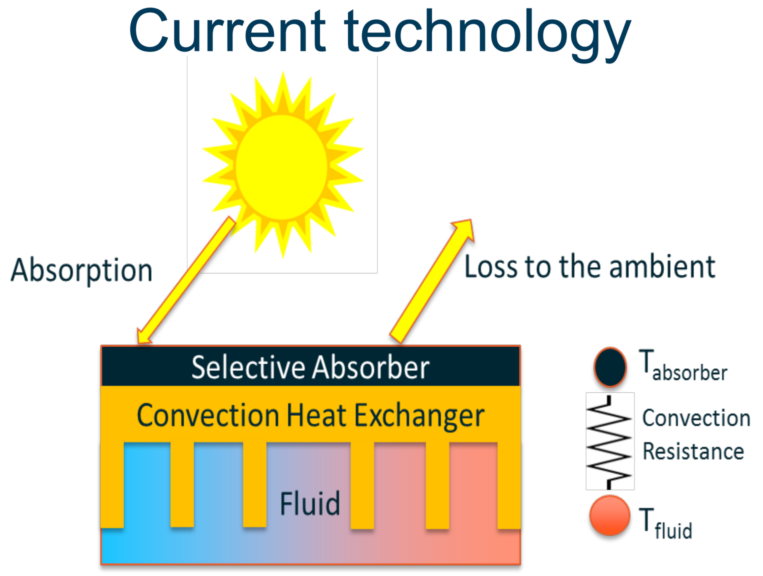
Abstract

- Two problems currently exist with solar-based renewable energy:
  (1) Low efficiency
  (2) Reliability at high temperatures
- We propose using **nanoparticles and metamaterials/photonic structures** to address both these problems

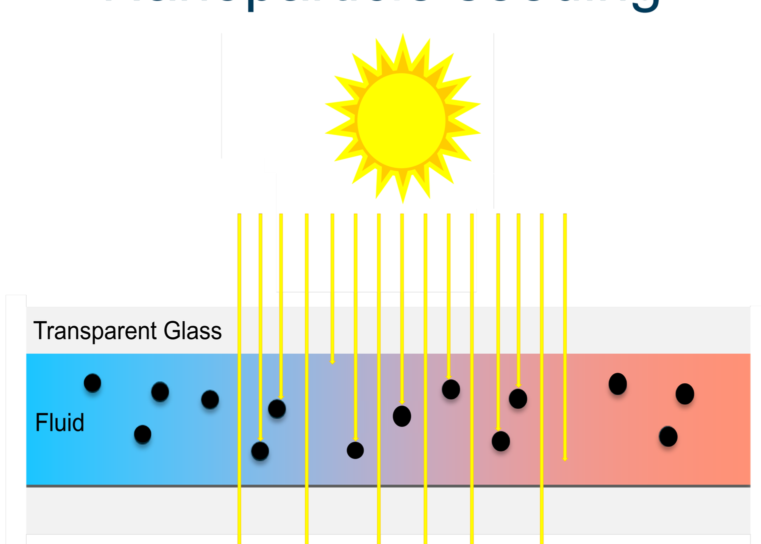
Direct volumetric absorption via nanoparticle seeding

Difficulties with **current technology:**
(1) Inefficient heat transfer into the fluid
(2) Expense due to the use of **heat exchangers**

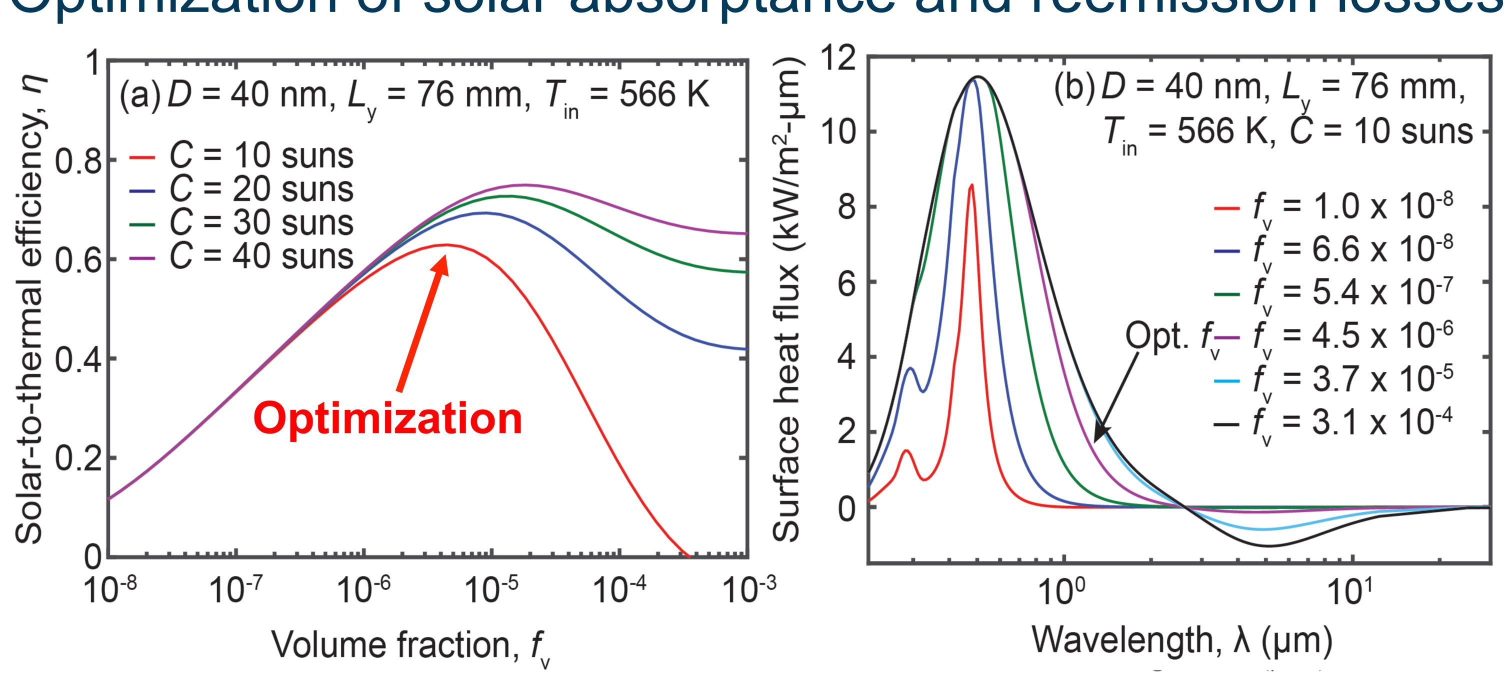
Current technology



Nanoparticle seeding



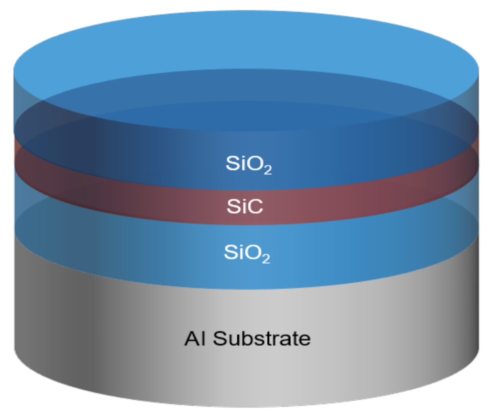
Optimization of solar absorptance and reemission losses



Maximization of solar-to-thermal **efficiency** by maximizing solar absorptance and minimizing re-emitted thermal radiation

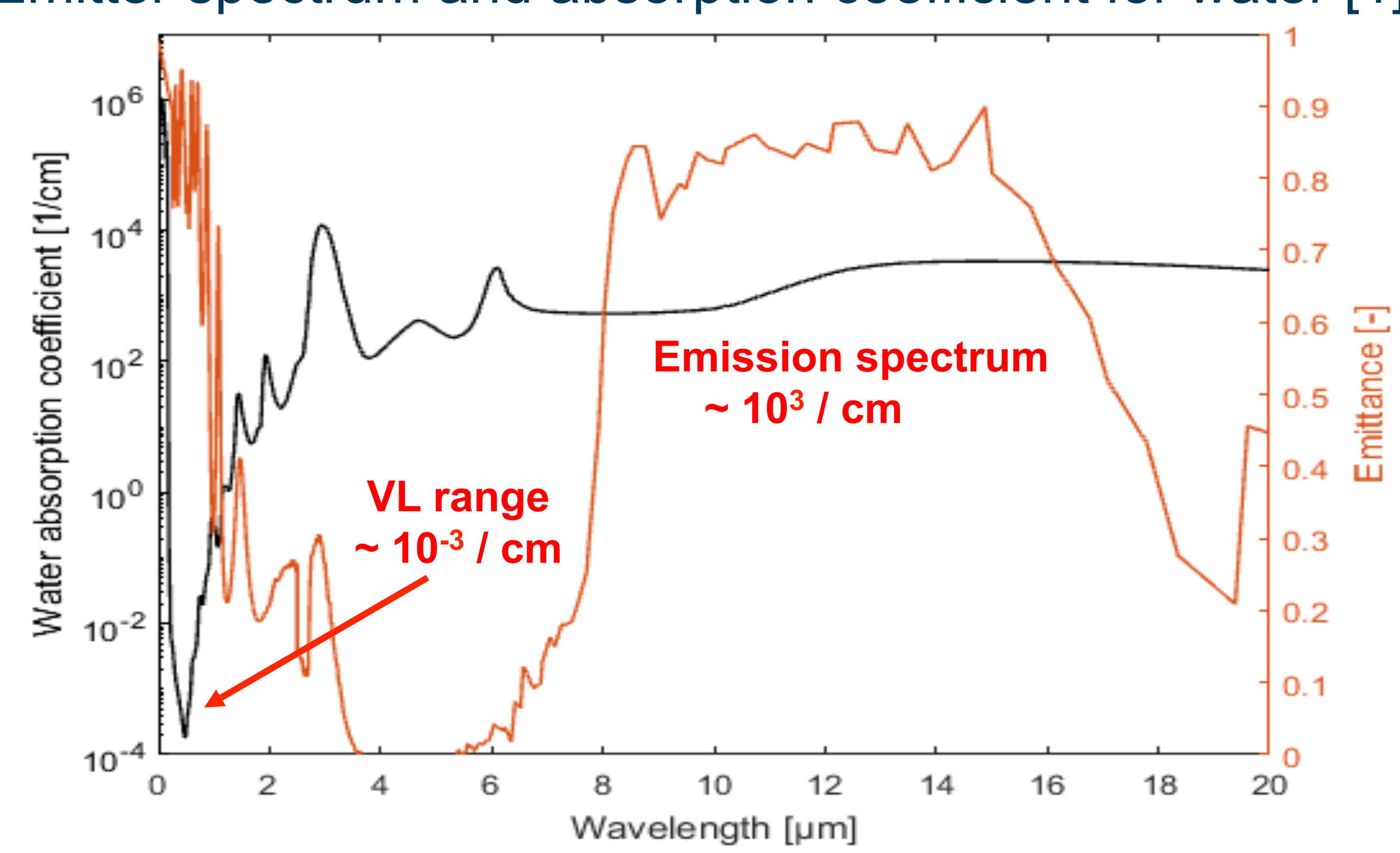
Surface based heating without the use of any heat exchanger

Our photonic emitter for water



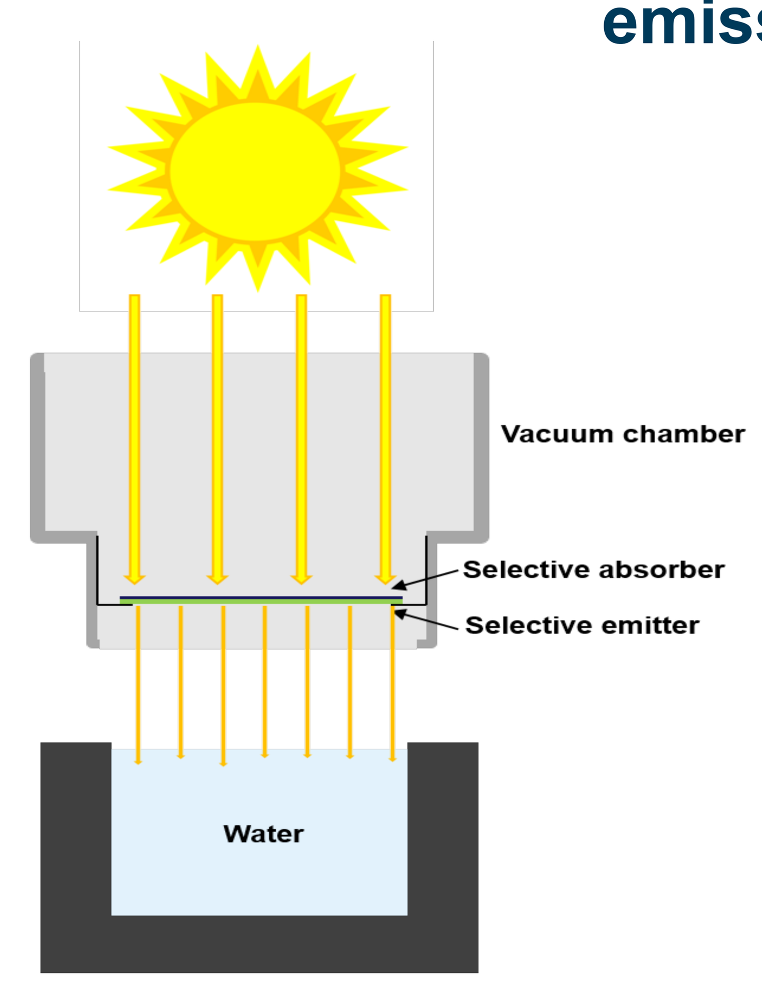
- Emission spectrum where water is **10^6 more absorptive** than for visible light
- **Minimized penetration depth**

Emitter spectrum and absorption coefficient for water [1]



[1]. Segelstein, University of Missouri-Kansas City, 1981.

Surface based water evaporation via selective emission



Selective absorber
The solar spectrum is absorbed with minimized reradiation losses

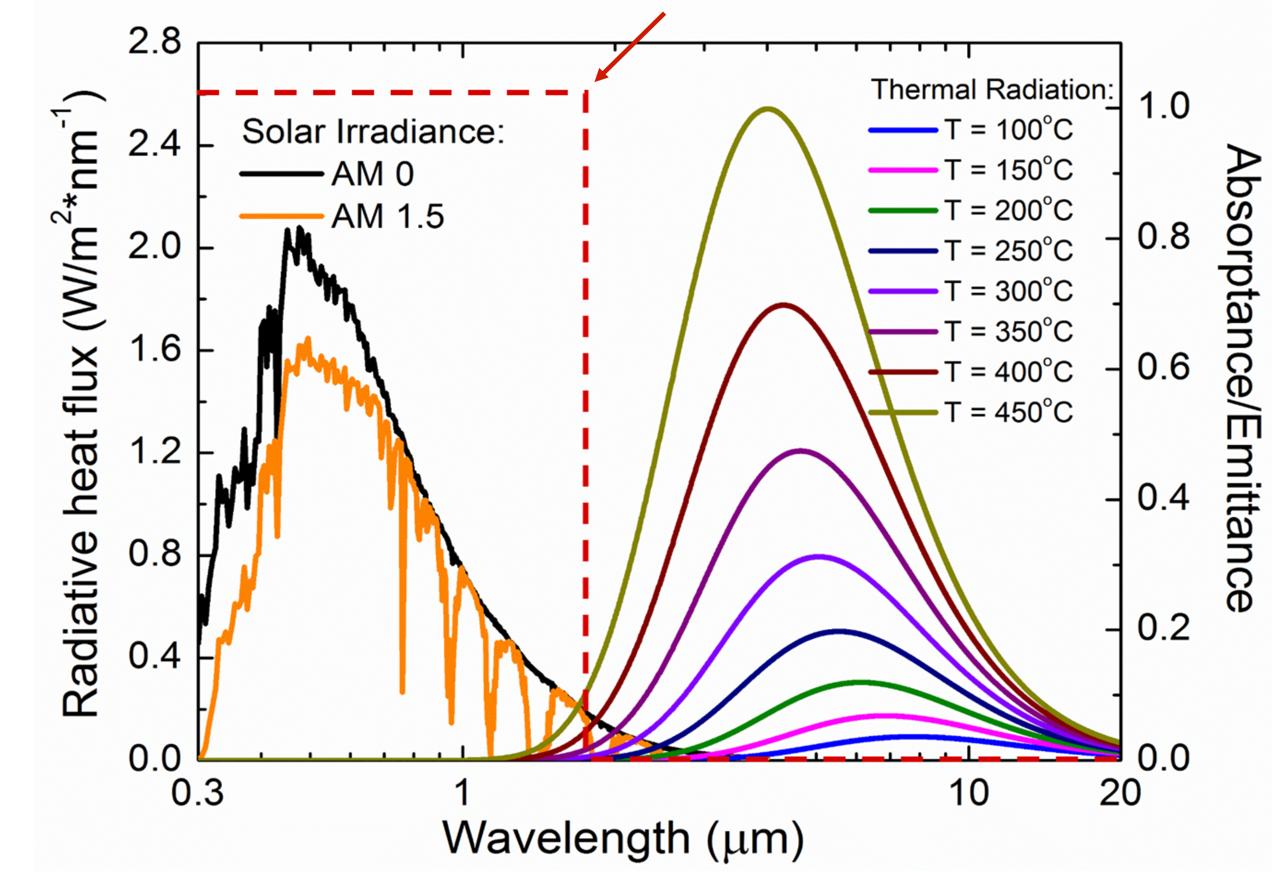
Selective emitter
The emission spectrum is shifted such that it is better absorbed by the water

Spectrally selective emitter based on the fluid properties **minimizes penetration depth (<40μm)**

Metamaterials for selective solar absorbers

Maximal absorption at minimal reradiation
(1) Visible/NIR: High absorptance
(2) IR: Low emittance

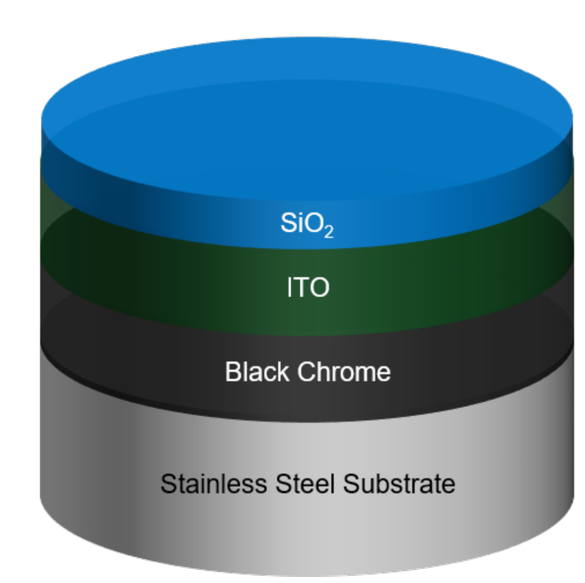
Ideal solar absorber

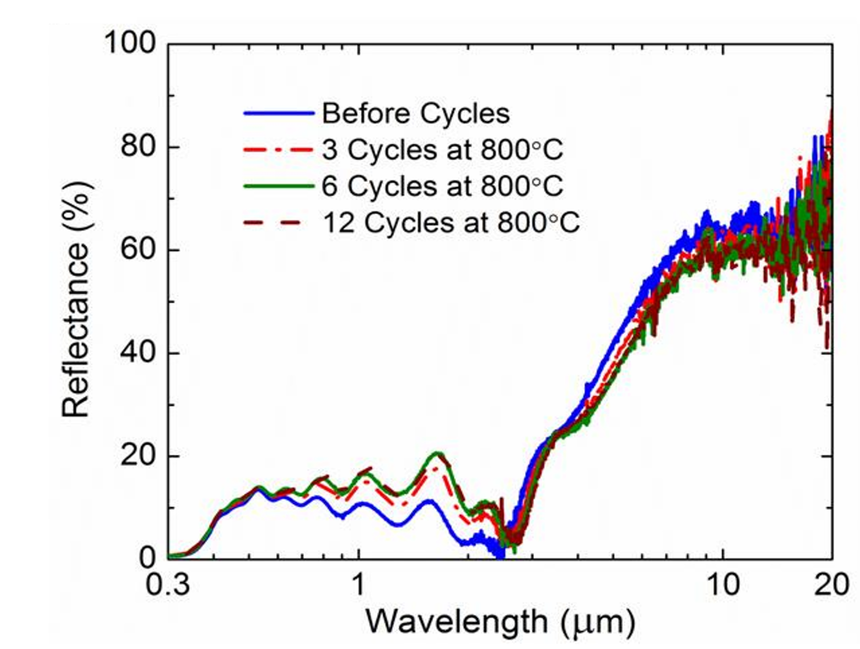


High-temperature reliability of selective absorber

The higher the α/ε ratio, the lower the stabilized temperature (= lower Carnot efficiency)

Our high-temperature absorber





- **Black chrome:** Highly absorptive up to 10 μm
- **ITO:** Transparent in VL/NIR, reflective for IR
- **SiO_2:** Antireflection coating

- **Highly stable up to 900°C in ambient**
- **α = 0.9** in VL/NIR, **ε = 0,4** in IR (half of state-of-the-art below 750°C under ambient)

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Funded by a Berkeley LDRD