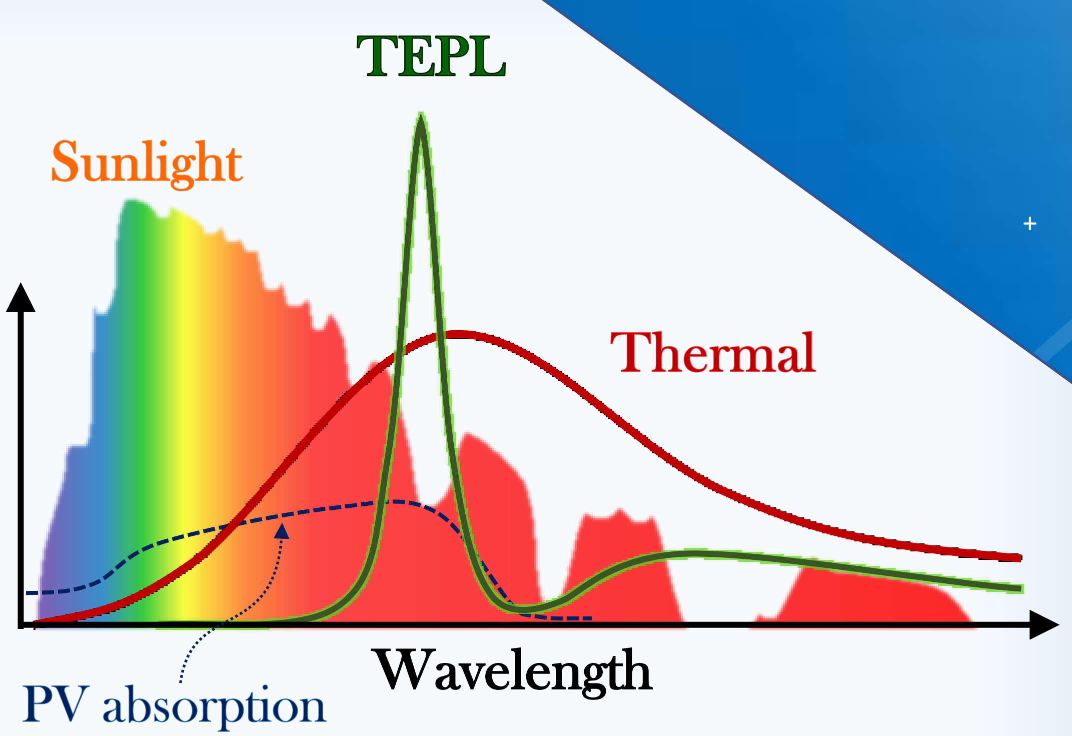
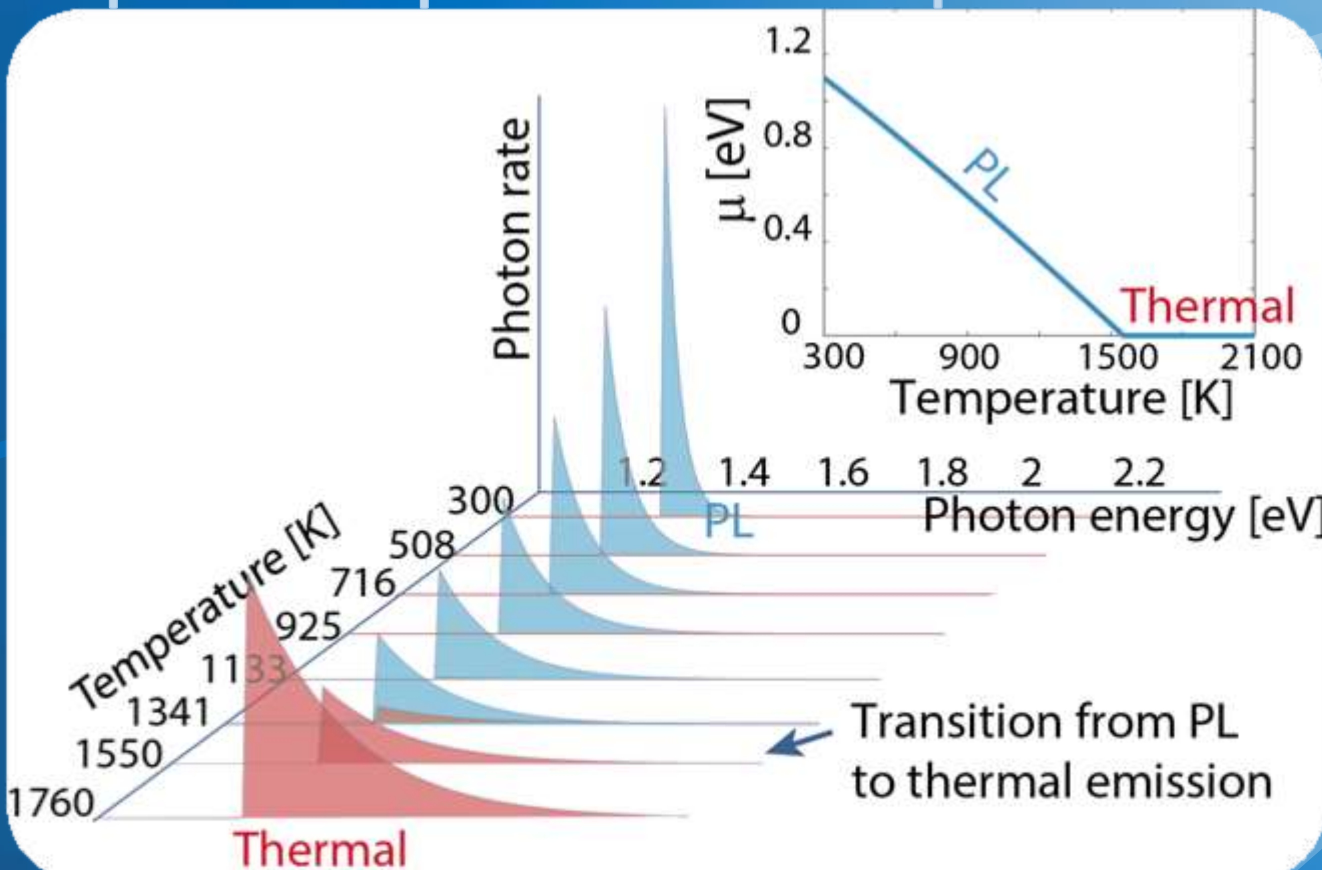
Thermally Enhanced Photo-Luminescence Device for Solar Energy Under Practical Conditions



Nimrod Kruger

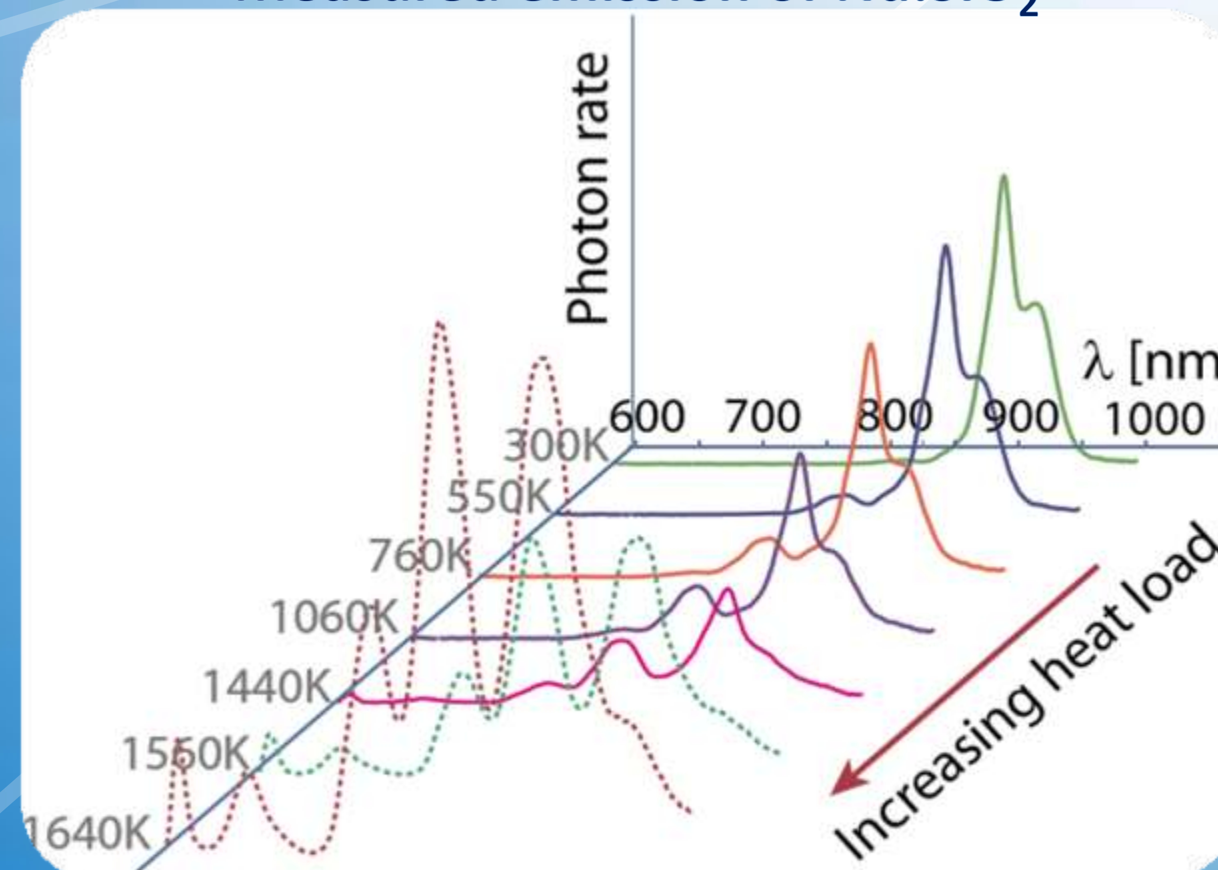
Thermally Enhanced Photo-Luminescence (TEPL)

Temperature dependent emission spectrum model



Manor el at, *Optica* 2, 585-588 (2015)

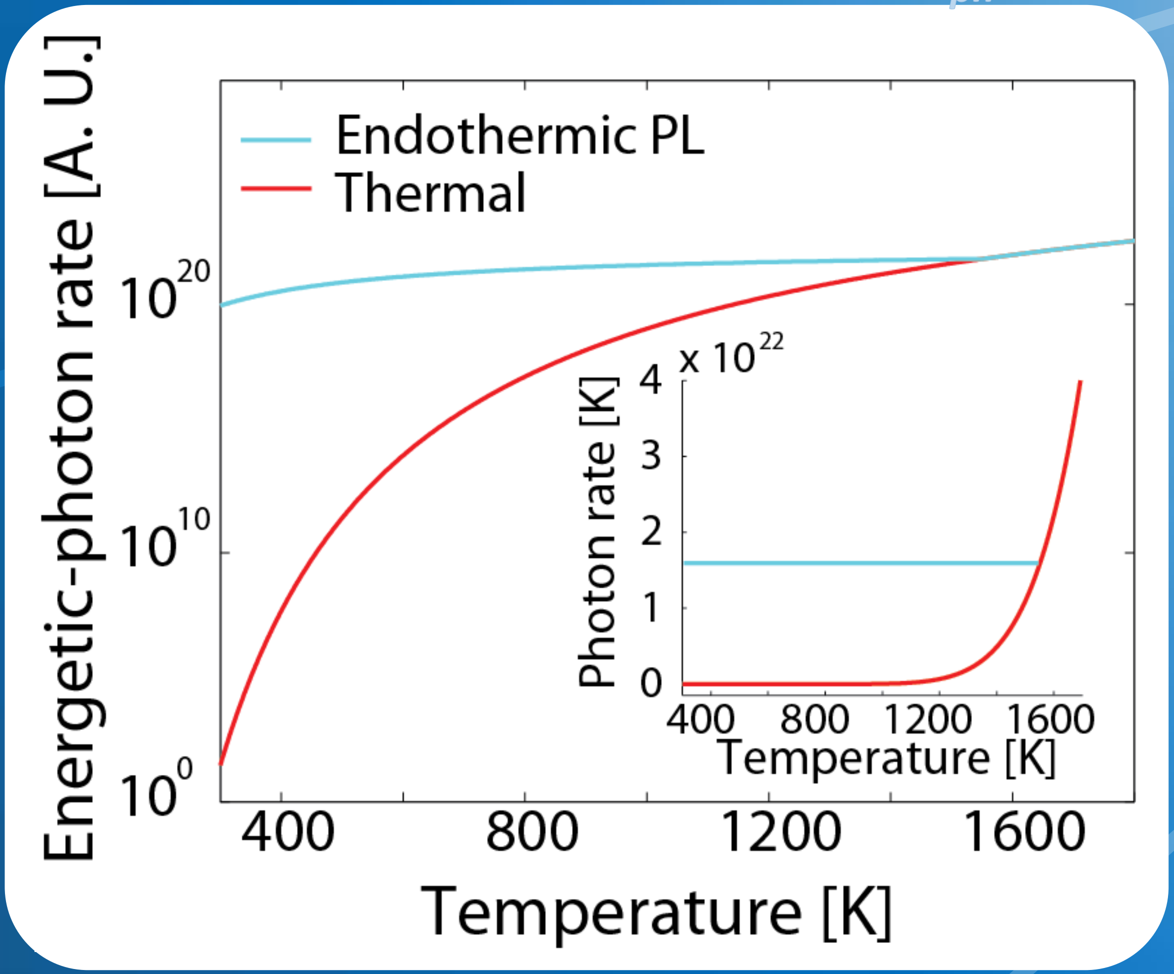
Measured emission of Nd:SiO_2



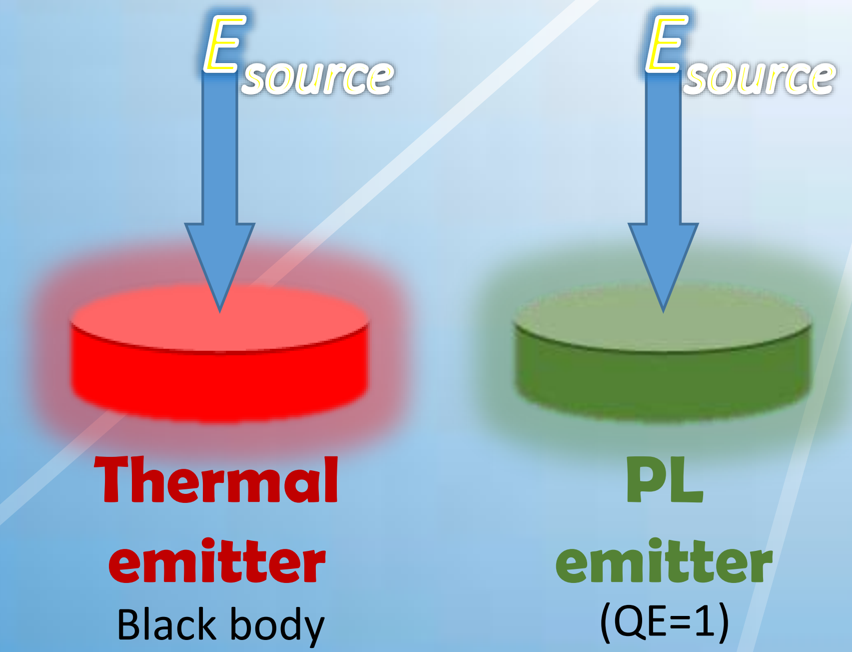
$$R(\hbar\omega, T, \mu) = \varepsilon(\hbar\omega) \cdot \frac{(\hbar\omega)^2}{4\pi^2\hbar^3c^2} \frac{1}{e^{\frac{\hbar\omega-\mu}{K_BT}} - 1} \cong \underbrace{\varepsilon(\hbar\omega) \cdot R_0}_{\text{Thermal}} \cdot \underbrace{e^{\frac{\mu}{K_BT}}}_{\text{PL}}$$

Thermally Enhanced Photo-Luminescence (TEPL)

Modeled number of photons with $E_{ph}>1.4eV$



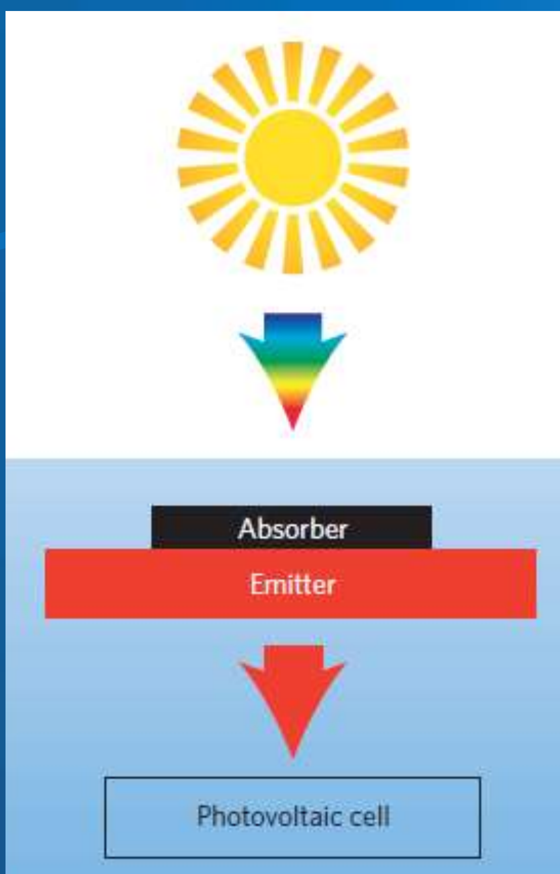
Manor el at, *Optica* 2, 585-588 (2015)



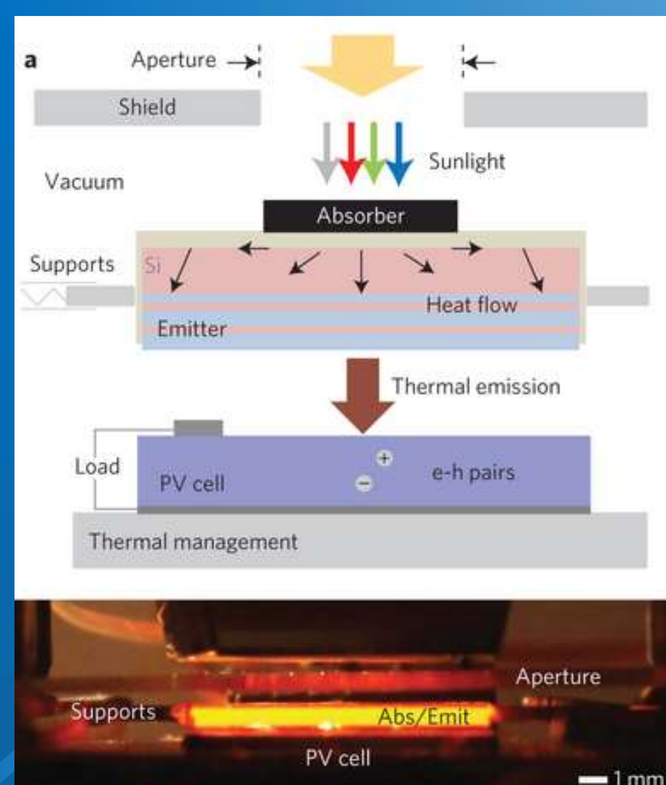
How can this be used as a device?

Our competition: Solar-Thermal Photovoltaics

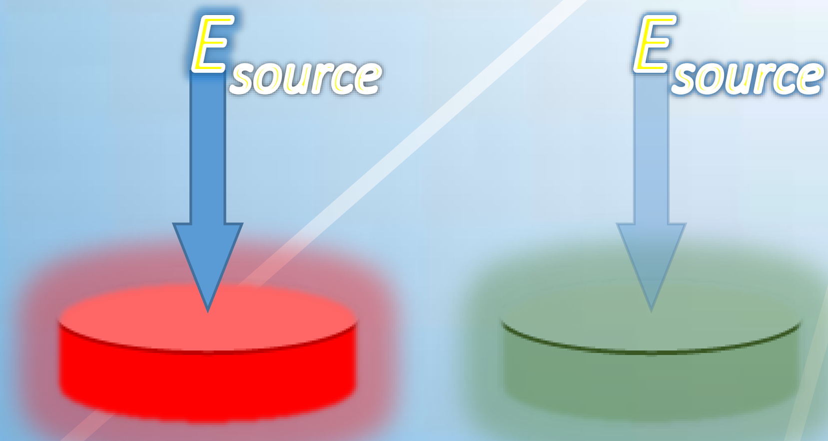
STPV



S. Fan, Nature Nanotechnology 9, 92-93 (2014)



Lenert el at, Nature Nanotechnology 9, 126-130 (2014)



Thermal emitter
Black body

PL emitter
(QE=1)

3.2% efficiency
for 0.55eV band-gap
at over 1200K

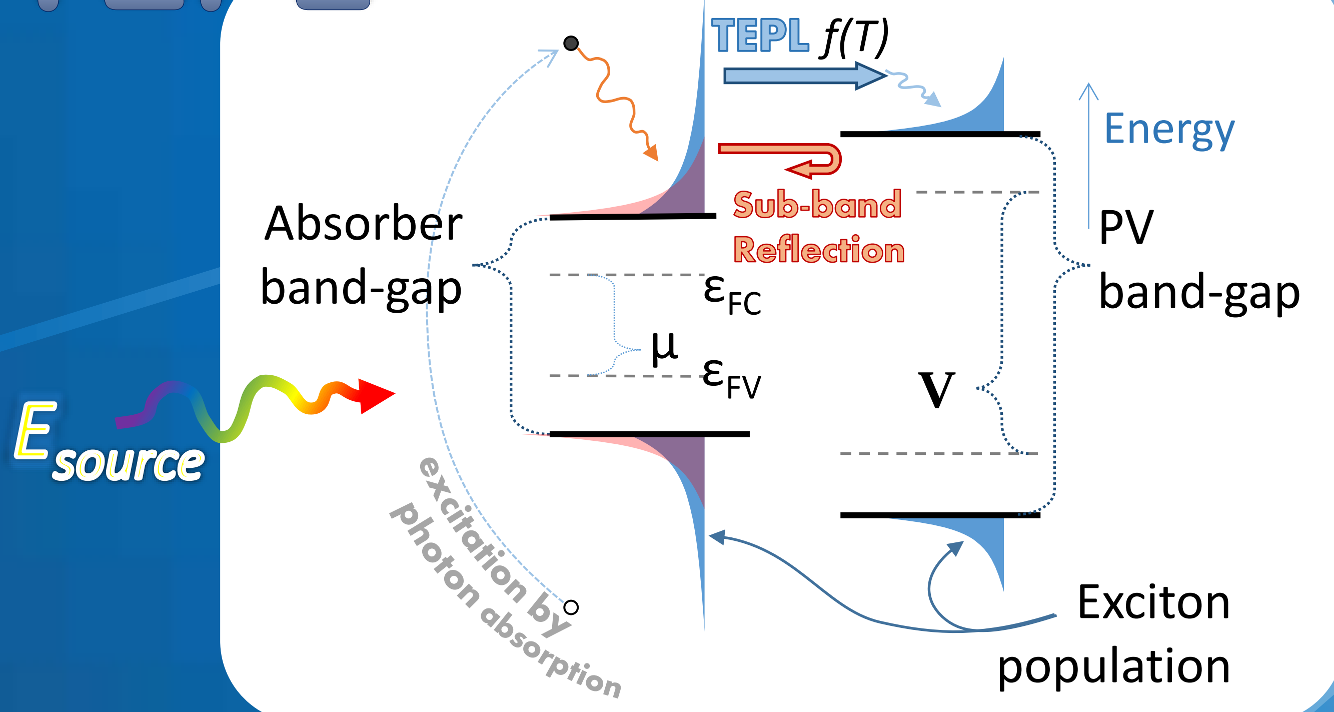
According to Wien's law:

$$T_{opt} = 2336\left[{}^{K}/_{eV}\right] \cdot E_g$$

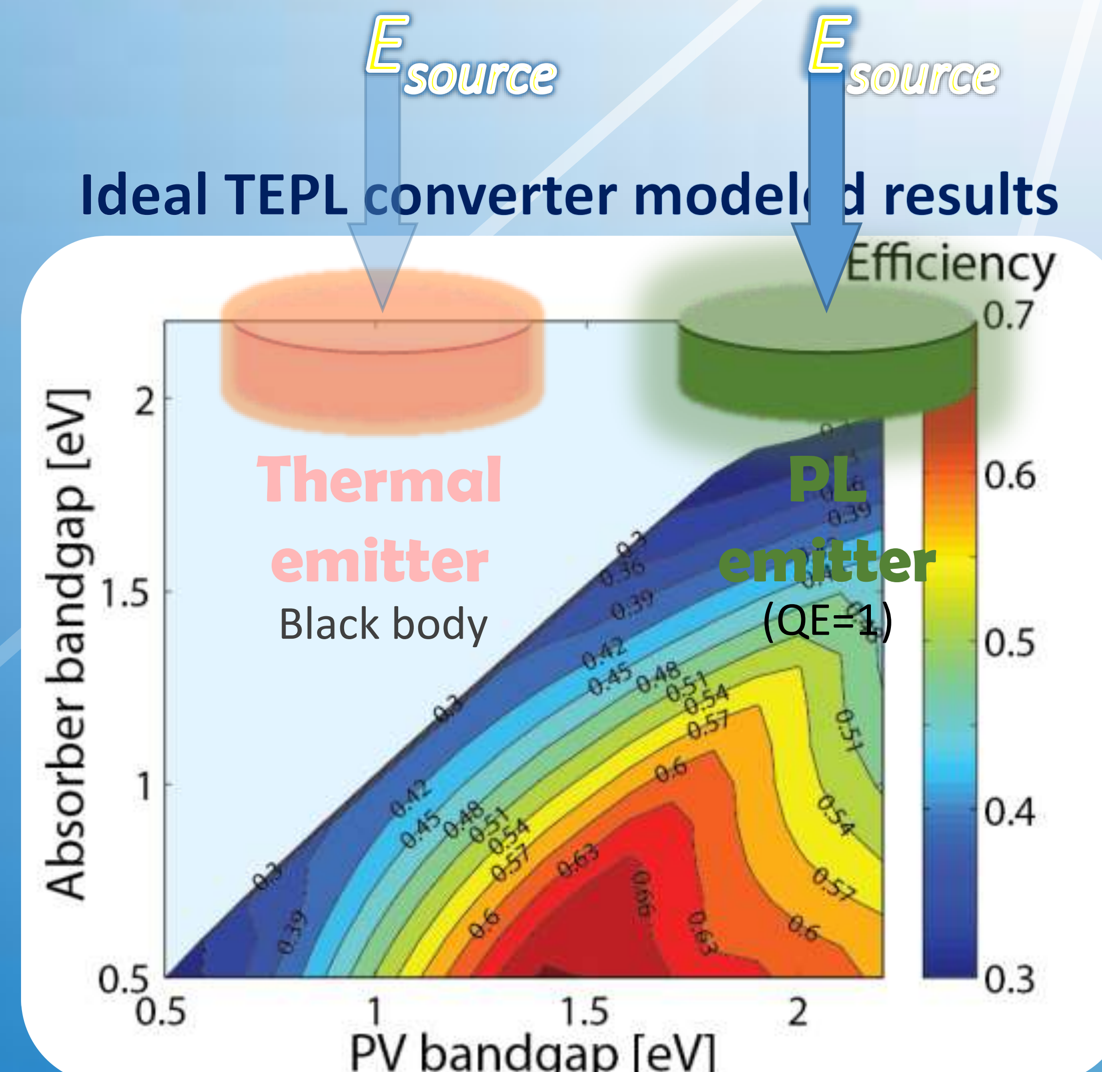
TEPL Solar Converter: Ideal Device

TEPL

TEPL Energy diagram



Ideal TEPL converter modeled results



Manor el at, Nat. Comm., *Accepted* (2016)

Absorber:

$$X\cdot\Omega_{sun}\cdot\int_{E_{g,Abs}}^{\infty}\overbrace{R_{sun,AM1.5}\,\mathrm{d}\hbar\omega}^{\text{from sun}}+(2\pi-X\cdot\Omega_{sun})\int_{E_{g,PV}}^{\infty}\overbrace{R_{PV}(300,\mathrm{V})\,\mathrm{d}\hbar\omega}^{\text{from PV}}=$$

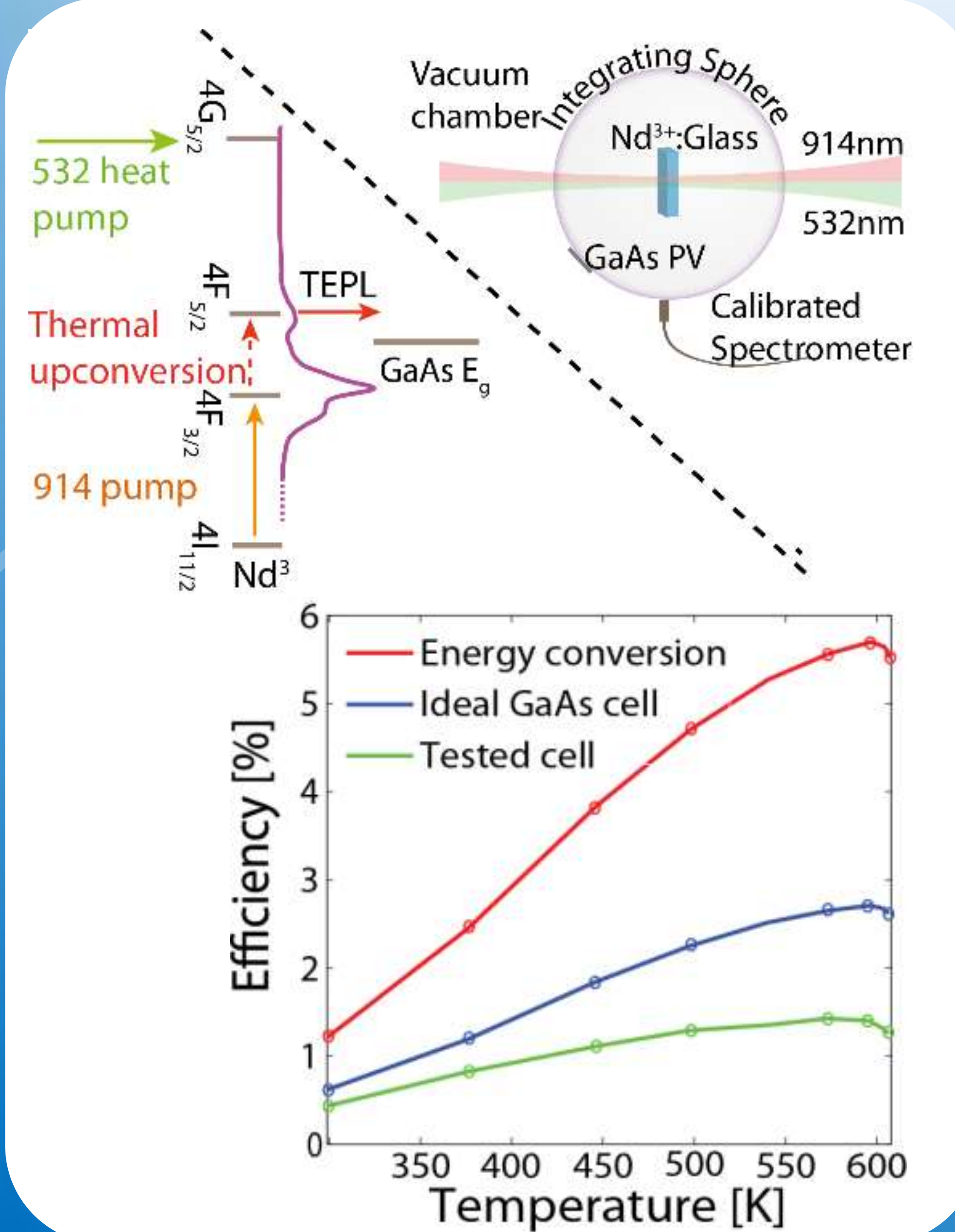
$$(2\pi-X\cdot\Omega_{sun})\int_{E_{g,PV}}^{\infty}\overbrace{R_{abs}(\mathrm{T},\mu)\,\mathrm{d}\hbar\omega}^{\text{to PV (above-band)}}+X\cdot\Omega_{sun}\cdot\int_{E_{g,Abs}}^{\infty}\overbrace{R_{abs}(\mathrm{T},\mu)\,\mathrm{d}\hbar\omega}^{\text{to sun}}$$

PV:

$$(2\pi-X\cdot\Omega_{sun})\cdot\int_{E_{g,PV}}^{\infty}\overbrace{R_{abs}(\mathrm{T},\mu)\,\mathrm{d}\hbar\omega}^{\text{from absorber}}=(2\pi-X\cdot\Omega_{sun})\cdot\int_{E_{g,PV}}^{\infty}\overbrace{R_{PV}(300,\mathrm{V})\,\mathrm{d}\hbar\omega}^{\text{to absorber}}+\frac{I}{e}$$

TEPL Solar Converter: Proof of concept

Up-Conversion (UC) experiment:



State of the art thermal UC:

ARTICLE

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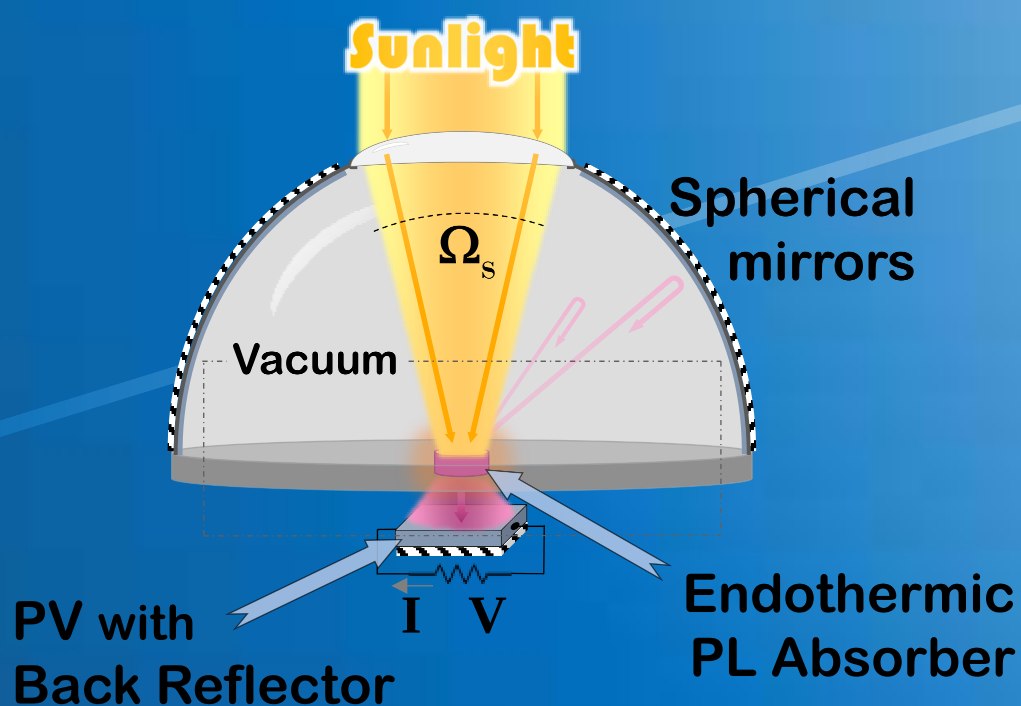
Photon energy upconversion through thermal radiation with the power efficiency reaching 16%

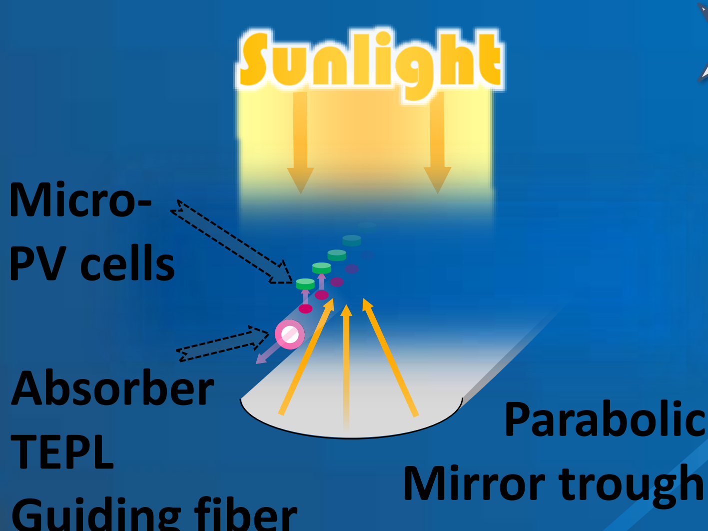
16% at 2900K

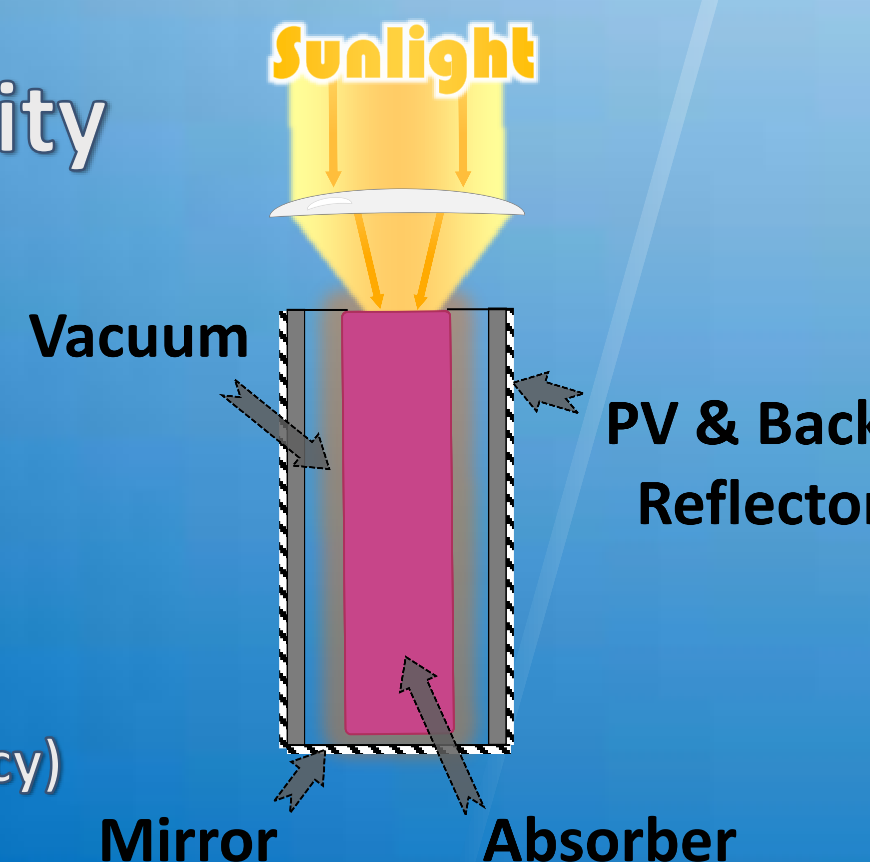
But at 600K would yield 10^{-5}%!

TEPL Solar Converter: Practical considerations

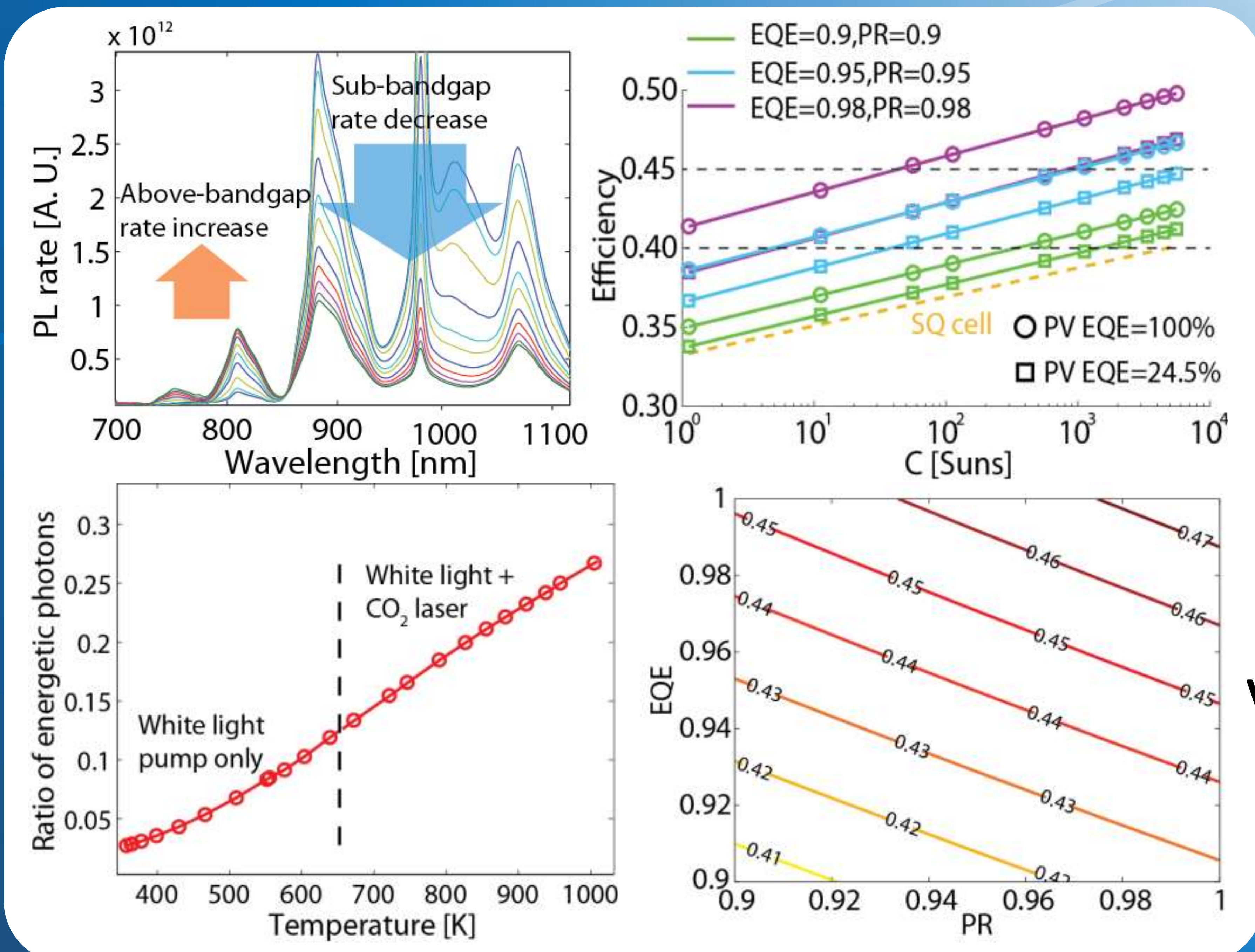


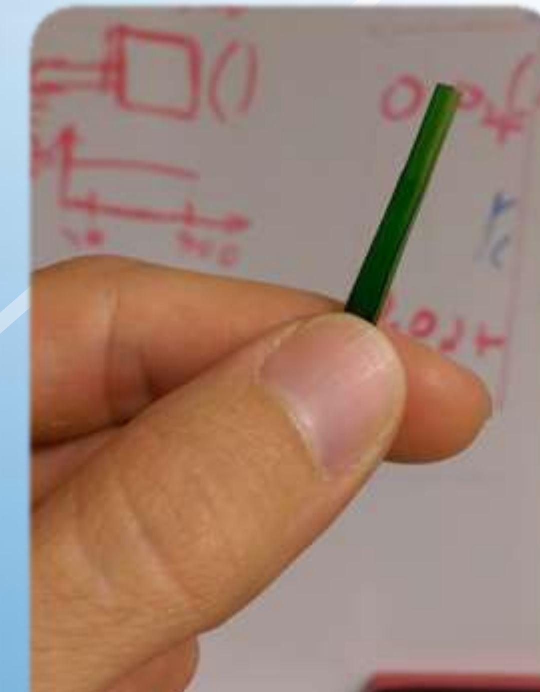
- Full Solar Absorption
- Thermal Insulation
  - Optical design
- Mirrors Reflectivity
- Absorber-PV spectral Matching
- Absorber EQE (External Quantum Efficiency)

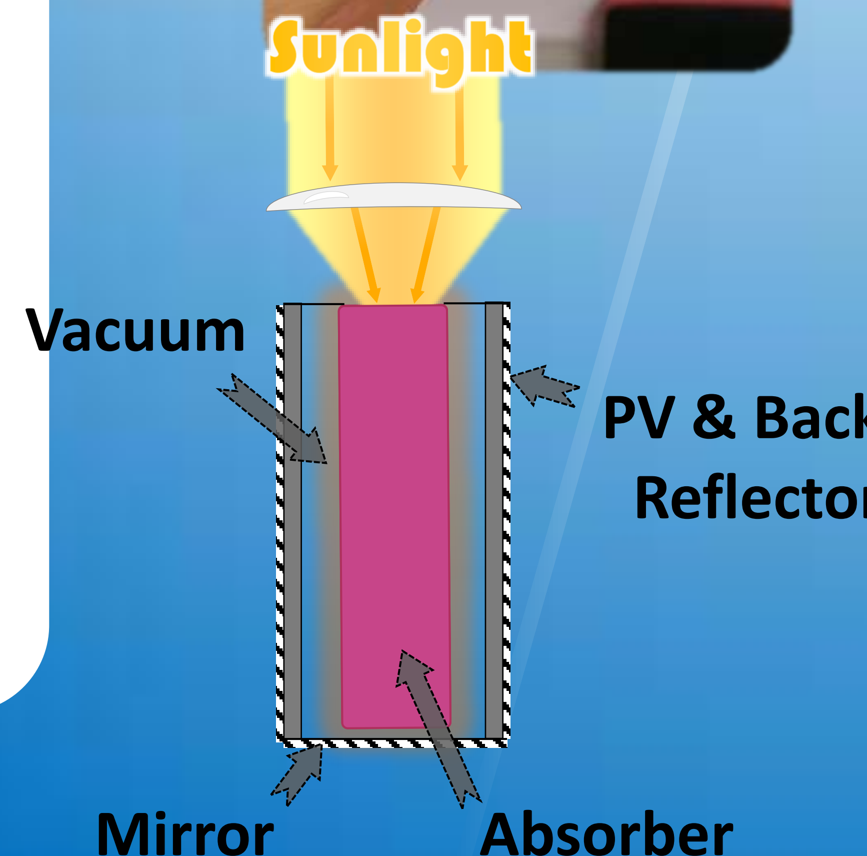




TEPL Solar Converter: Practical model







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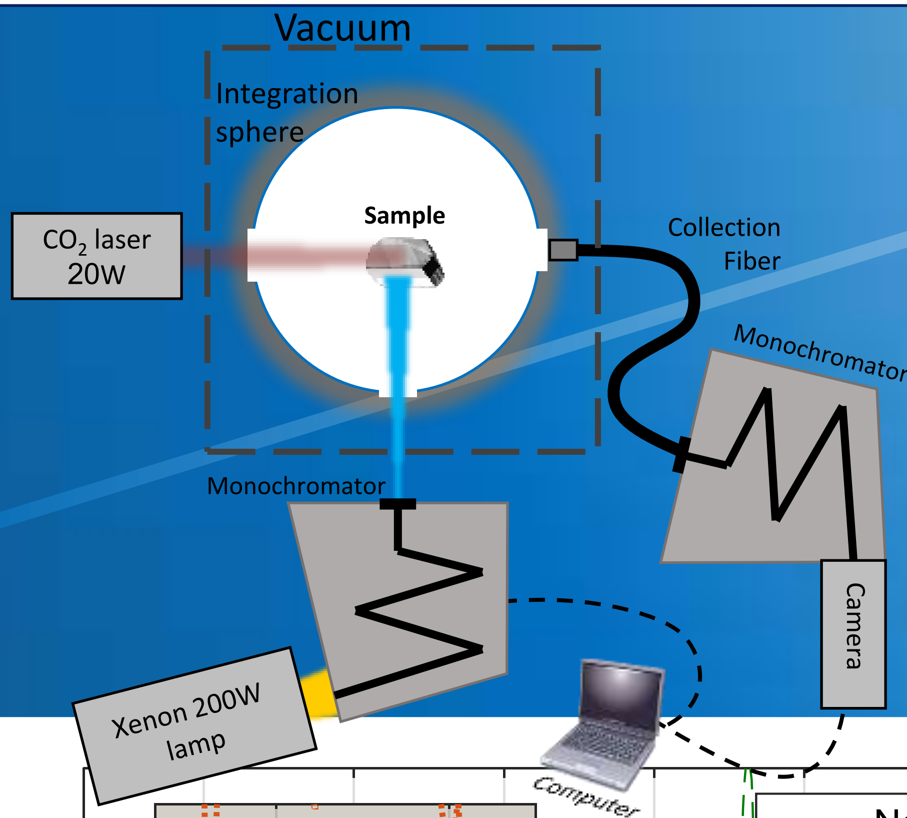
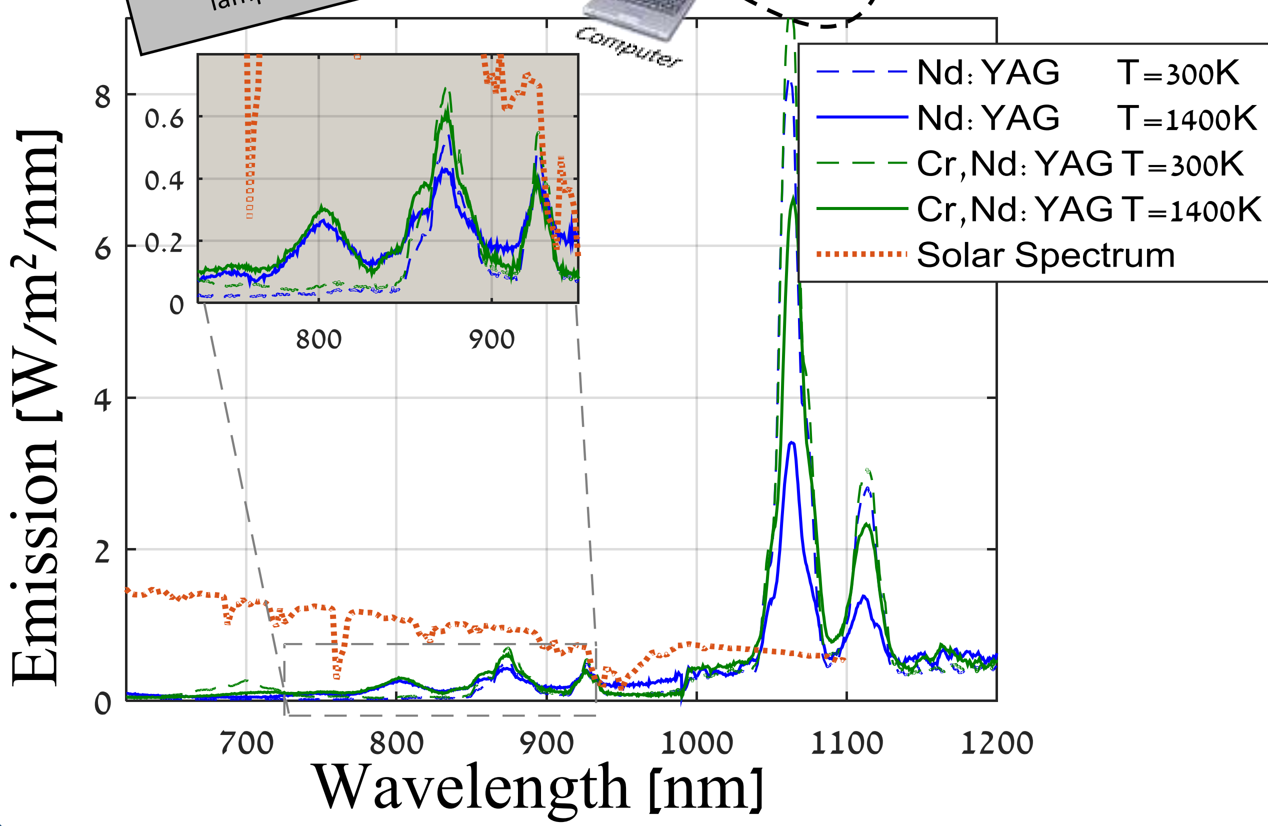
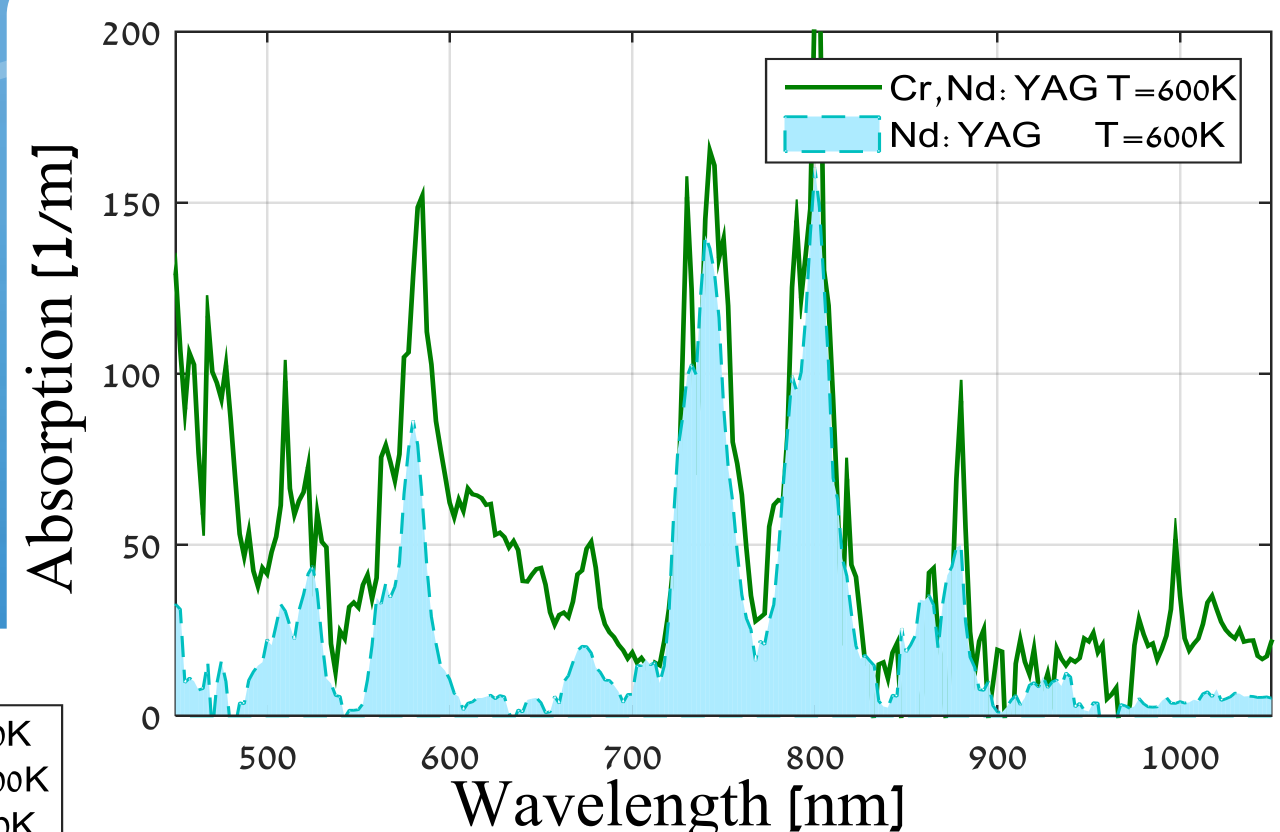
TEPL material characterization





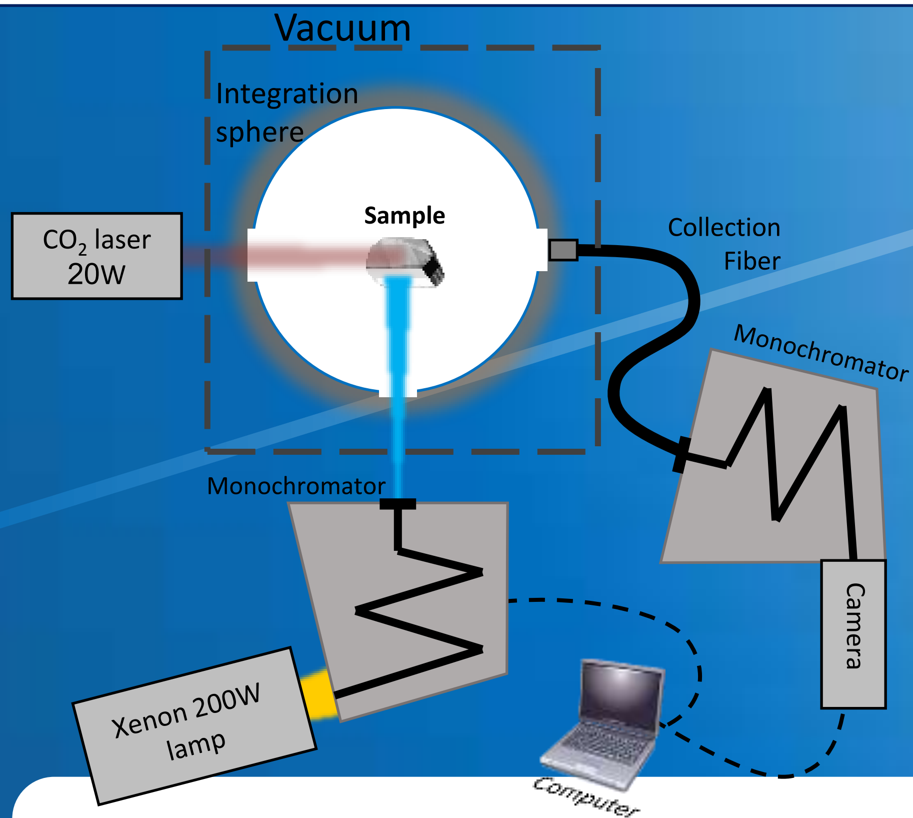


TEPL material characterization

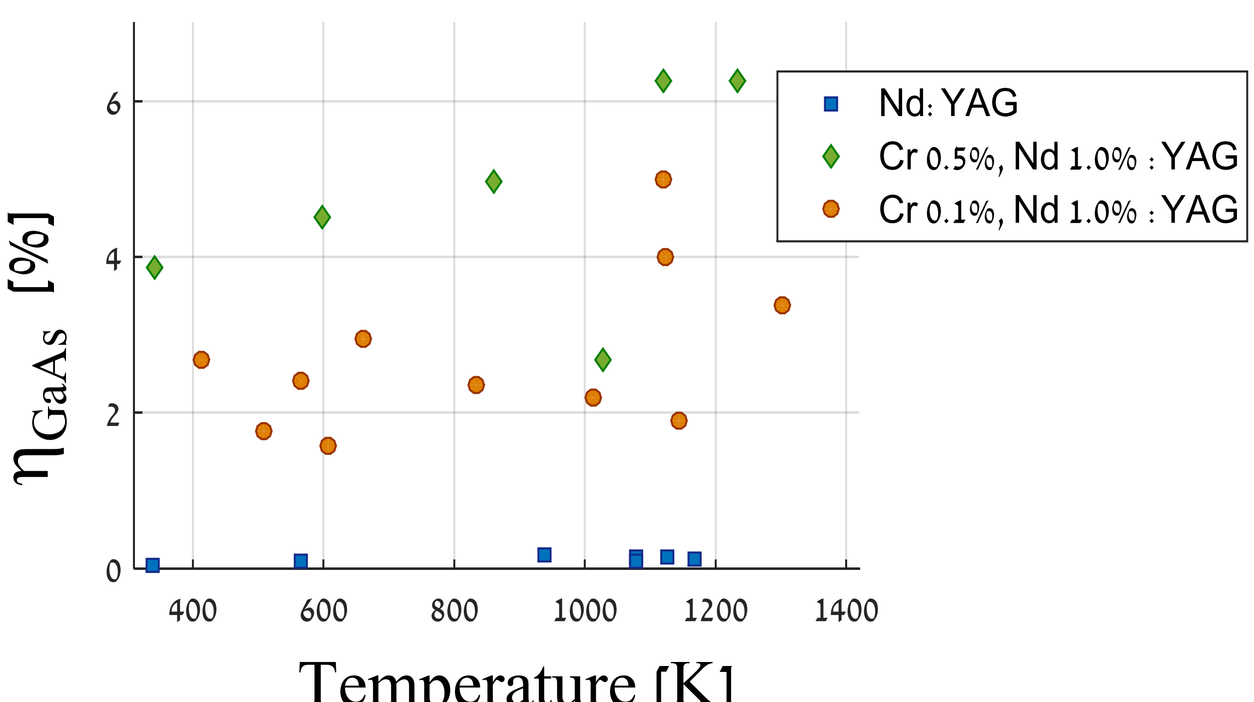
excitonics Lab

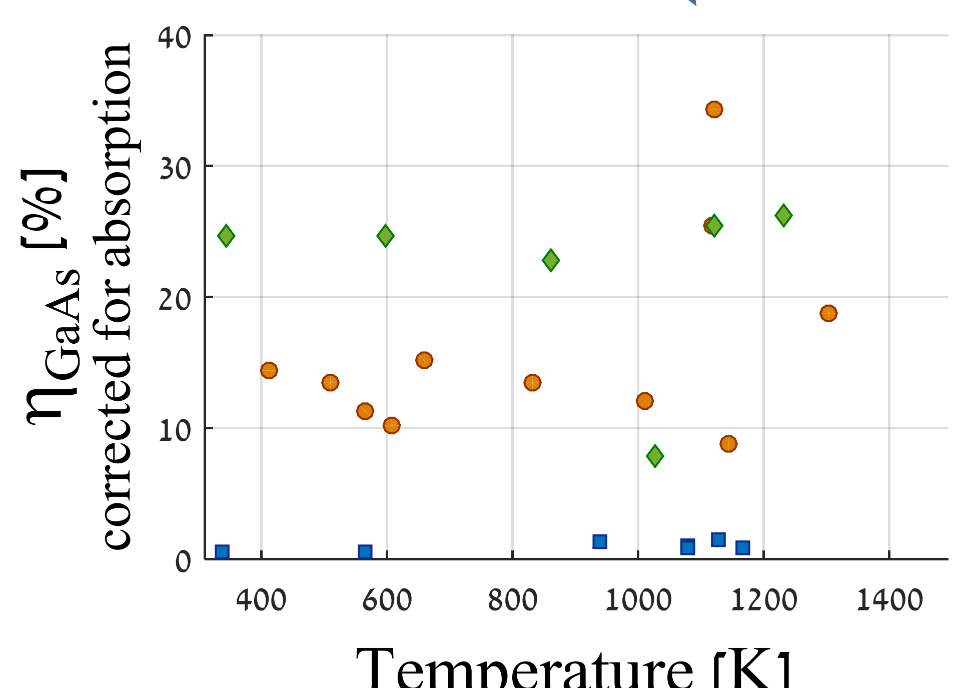
GTEP Grand Technion Energy Program

תוכנית האנרגיה ע"ש גרנד



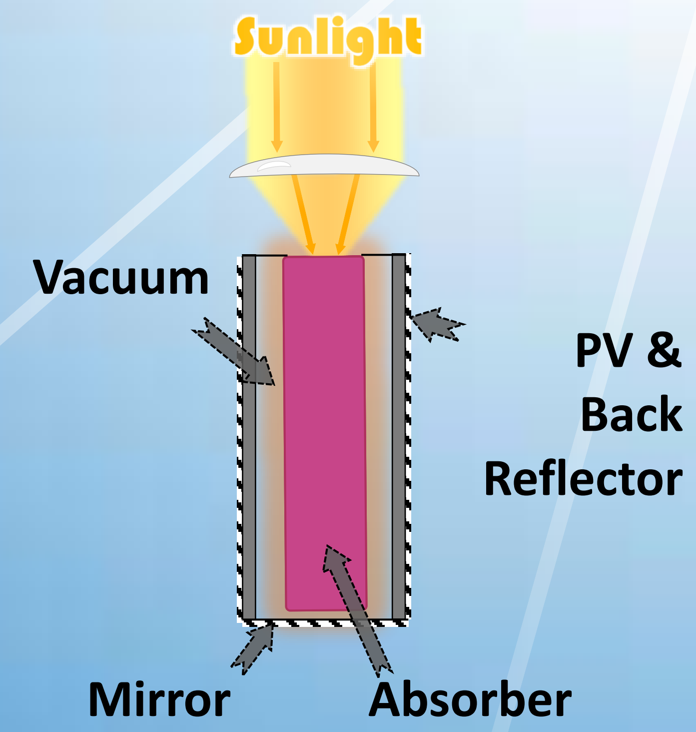
Modeled total (ideal) GaAs PV power output out of the total sun power / total absorbed power



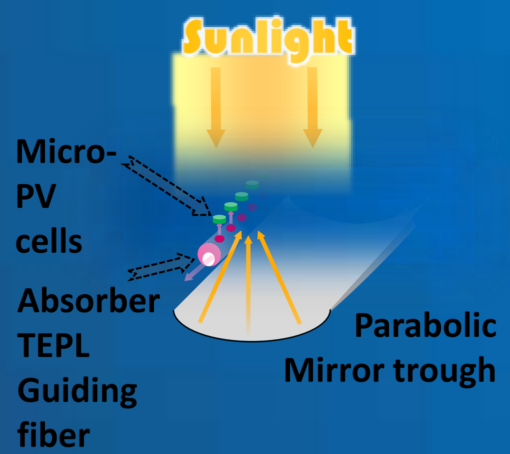


To Conclude:

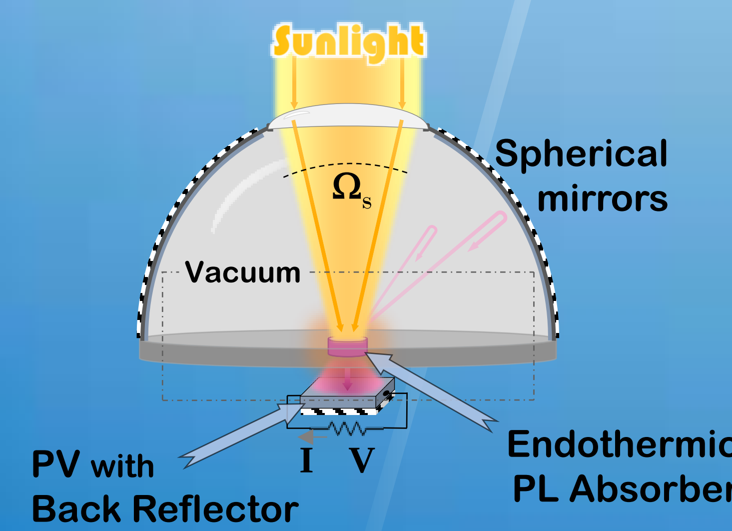
➢ We describe a TEPL conversion device and the considered parameters



➢ We modeled a practical model estimating over 43% conversion efficiency is in reach



➢ TEPL materials Absorption and emission characterization



➢ Cr,Nd,Yb:glass - Int. efficiency up to 30%

➢ Cr,Nd:YAG

Ext. efficiency up to 6%

Ext. efficiency ~25% absorption corrected

Thanks also to the generous contributors from

Thanks!