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

Temperature dependent emission spectrum model

\[ R(\hbar \omega, T, \mu) = \varepsilon(\hbar \omega) \cdot \frac{(\hbar \omega)^2}{4\pi^2 \hbar^3 c^2} \cdot \frac{1}{\frac{\hbar \omega - \mu}{e^{\frac{\hbar \omega - \mu}{K_B T}}}} \simeq \varepsilon(\hbar \omega) \cdot R_0 \cdot e^{\frac{\mu}{K_B T}} \]

Thermally Enhanced Photo-Luminescence (TEPL)

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

- Endothermic PL
- Thermal

Temperature [K] vs. Energetic-photon rate [A. U.]

$10^0$ $10^5$ $10^{10}$ $10^{20}$

$400$ $800$ $1200$ $1600$

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

How can this be used as a device?
Our competition: Solar-Thermal Photovoltaics

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

According to Wien’s law:

\[ T_{opt} = \frac{2336 \left[ \frac{K}{eV} \right]}{E_g} \]
Absorber:

\[ X \cdot \Omega_{sun} \cdot \int_{E_{g,abs}}^{\infty} R_{sun,AM1.5} \, d\hbar \omega + (2\pi - X \cdot \Omega_{sun}) \int_{E_{g,pv}}^{\infty} R_{pv}(300, V) \, d\hbar \omega = \]

\[ (2\pi - X \cdot \Omega_{sun}) \int_{E_{g,pv}}^{\infty} R_{abs}(T, \mu) \, d\hbar \omega + X \cdot \Omega_{sun} \int_{E_{g,abs}}^{\infty} R_{abs}(T, \mu) \, d\hbar \omega \]

PV:

\[ (2\pi - X \cdot \Omega_{sun}) \int_{E_{g,pv}}^{\infty} R_{abs}(T, \mu) \, d\hbar \omega = (2\pi - X \cdot \Omega_{sun}) \int_{E_{g,pv}}^{\infty} R_{pv}(300, V) \, d\hbar \omega + \frac{I}{e} \]
State of the art thermal UC:

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

Manor et al, Nat. Comm., Accepted (2016)
TEPL material characterization

- CO₂ laser 20W
- Monochromator
- Vacuum Integration sphere
- Sample
- Collection Fiber
- Camera

Absorption [1/m]

Wavelength [nm]

Emission [W/m²/nm]

Wavelength [nm]

8/10
Temperature \([\text{K}]\)

\[ \eta_{\text{GaAs}} \[\%\] \]

corrected for absorption

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

\[ \eta_{\text{GaAs}} \[\%\] \]

\[ \eta_{\text{GaAs}} \text{ corrected for absorption} \[\%\] \]

Temperature \([\text{K}]\)
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.
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