Thermally enhanced photoluminescent for PVs: First demonstration

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Photoluminescence (PL) is a fundamental light-matter interaction, which conventionally involves the absorption of energetic photon, thermalization and the emission of a red-shifted photon. Conversely, in optical-refrigeration the absorption of low energy photon is followed by endothermic-PL of energetic photon. Both aspects were mainly studied where thermal population is far weaker than photonic excitation, obscuring the generalization of PL and thermal emissions. In recent experimental study, we showed how endothermic-PL, in accordance with theory, conserves the number of emitted photons when heated, while each photon is blue shifted. Further rise in temperature leads to an abrupt transition to thermal emission where the photon rate increases sharply. We also showed how endothermic-PL generates orders of magnitude more energetic photons than thermal emission at similar temperatures. Relying on these observations, we proposed and theoretically studied thermally enhanced PL [TEPL] for highly efficient solar-energy conversion, with thermodynamic maximal efficiency limit of 70% and comparably low operating temperatures.

Here we demonstrate the first proof-of-concept of the various features in the TEPL. These features include: **i.** Measuring the ETPL effect at different solar concentrations (equivalent power levels). **ii.** Harvesting of sub-bandgap photons by GaAs. **iii.** Demonstrating the role of photon recycling in the TEPL effect.

As shown in figure 1, we begin with constructing TEPL device with Nd:Glass absorber, surrounded by reflecting mirrors for photon recycling within a vacuum chamber. The PL is coupled to a GaAs solar cell (Fig. 1a).

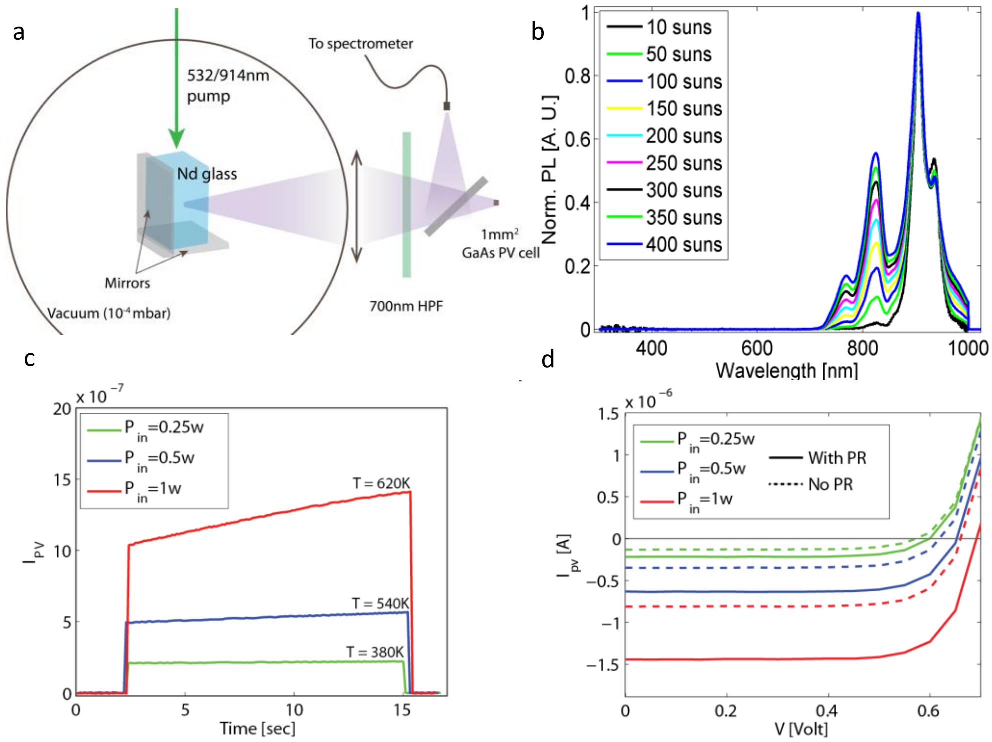

Figure 1: The TEPL: GaAs setup (a), power spectrum (b), Current (c) and I-V curves (d) versus pump power.

We first test our device by pumping the PL-absorber with 532nm excitation at various power levels and measuring the shift in the power spectrum due to the temperature rise at the absorber (Fig. 1b). As evident, at low pump power the PL photons are at wavelength longer than 850nm, the bandgap of GaAs. When increasing the pump power to the equivalent of 400 suns, a significant amount of photons are emitted at shorter wavelength than 850, therefore become accessible to the GaAs cell. Figure 1c shows the current at the GaAs cell as function of time for various pump powers, showing the temperature contribution to the current. Figure 1d shows the I-V curve after 15 sec of pump operation. Figure 1d also shows the contribution of the photon recycling [PR] on the current, by comparing the I-V curve in the case of two reflecting mirrors (no PR) to the case of four face mirrored (with PR). As can be seen the current is doubled when the PR restriction angle is doubled.

Next, using pump combination of a higher bandgap excitation (532nm) and a lower-bandgap excitation (914nm) (figure 2a), we show how sub bandgap photons are harvested by the GaAs based TEPL. Figure 2b shows how the rise in temperature, by the thermalization of the pump photons, increases the current in the PV over time, while figure 2c shows the I-V curves after 25 seconds of pump operation. Again, doubling the restriction angle of the PR doubles the current in the I-V curve.

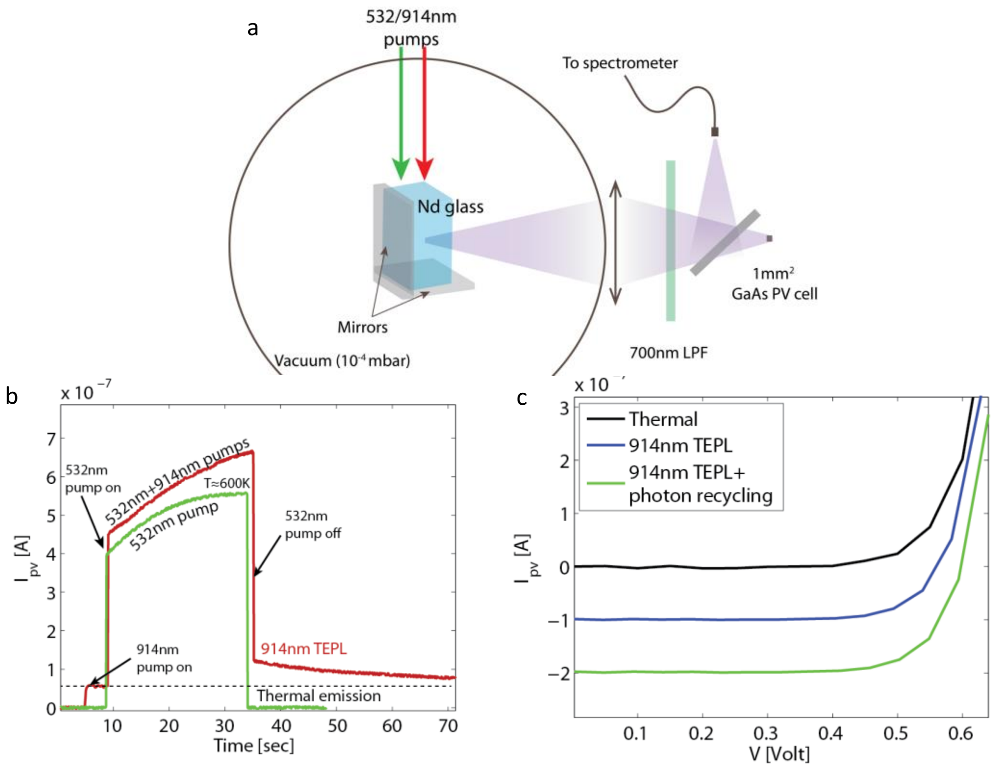

Figure 2: 532nm and 914nm excitation of TEPL (a). Blue-shifted sub bandgap photons enhance the current over time (b) and at the I-V curves (c).

To conclude, we have demonstrated a proof of concept for the TEPL for solar energy. We measure the required solar concentration for significant spectral shift, the role of photon recycling and the ability to harvest sub-bandgap photons. Our next effort is to enhance the conversion efficiency by improving the photon recycling and increasing the absorbed portion of the solar spectrum.