Detailed balance calculations for hot-carrier solar cells: coupling high absorptivity with low thermalization through light trapping

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Hot carrier solar cells promise efficiencies way above the single junction limits [1], but face many challenges, one of them being the establishment of a hot-carrier population under continuous illumination. In conventional cells under reasonable concentration, the extra kinetic energy of the absorbed photons (the difference with the band gap energy) is lost through scattering with phonons in a process called thermalization. In order to reach a hot carrier regime, one must increase the intensity of absorbed light and/or decrease the thermalization rate. Because the latter scales with the volume of absorber [2], hot carrier solar cells fundamentally require to maximize the density of carriers generated per unit of volume. We report here the calculation of the Fermi energy and temperature of the hot carrier population generated under continuous illumination. Those simulations are made based on a detailed balance model [3], supposing open-circuit condition and taking into account losses through a thermalization factor Q. The model is currently being updated to consider distinct behaviors for electrons and holes [4]. In this work, we highlight the relation between density of generated carriers, thermalization rate and temperature, and show the influence and necessity of light trapping for hot-carrier solar cells.

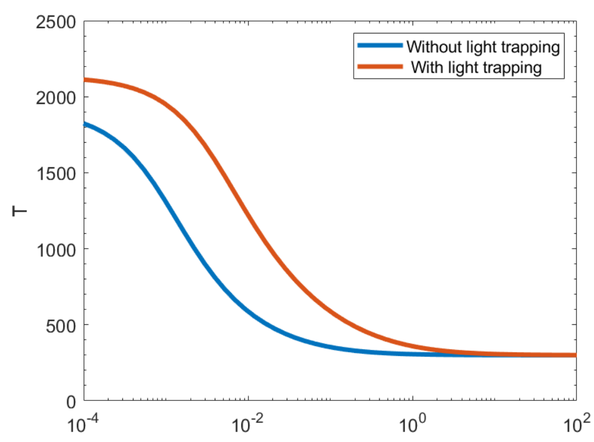

Figure 1: Hot-carrier temperature T reached in a 20 nm GaAs absorber under 700 nm laser illumination of $4.5\ \mathrm{W.cm^{-2}}$ as a function of the thermalization factor Q, with and without a Fabry-Perot resonance at the excitation wavelength.

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