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Reversible electron-hole separation in a hot carrier solar cell

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Hot-carrier solar cells are envisioned to utilize energy filtering to extract power from photogenerated electron-hole pairs before they thermalize with the lattice, and thus potentially offer higher power conversion efficiency compared to conventional, single absorber solar cells. The efficiency of hot-carrier solar cells can be expected to strongly depend on the details of the energy filtering process, a relationship which to date has not been satisfactorily explored. Here, we establish the conditions under which electron-hole separation in hot-carrier solar cells can occur reversibly, that is, at maximum energy conversion efficiency. We find that, under specific conditions, the energy conversion efficiency of a hot-carrier solar cell can exceed the Carnot limit set by the intra-device temperature gradient alone, due to the additional contribution of the quasi-Fermi level splitting in the absorber. To achieve this, we consider a highly selective energy filter such as a quantum dot embedded into a one-dimensional conductor. We also establish that the open-circuit voltage of a hot-carrier solar cell is not limited by the band gap of the absorber, due to the additional thermoelectric contribution to the voltage. Additionally, we find that a hot-carrier solar cell can be operated in reverse as a thermally driven solid-state light emitter. In addition this theoretical analysis, I will also report on first experimental results in a nanowire-based energy filter device. Ref: S Limpert, S Bremner, and H Linke, New J. Phys 17, 095004 (2015)