High-efficiency photovoltaic concepts to improve the performance of thermophotovoltaics devices

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Thermophotovoltaics (T-PV) generalizes the concept of solar photovoltaics (S-PV) to the conversion of any thermal radiation into electric power. The field has gained a lot of traction recently thanks to its potential not only for solar energy conversion using an intermediate absorber[1], but also for thermal storage and waste heat recovery[2,3]. In particular, an impressive T-PV conversion efficiency of 40% was reported earlier this year using a tandem GaAs-GaInAs (1.4 eV - 1.2 eV) PV cell[4].

T-PV differs from S-PV in one fundamental way: the spectral shape of the radiation incident on the cell can be engineered. In particular, if a source only emits photons at the bandgap energy of a single-junction T-PV cell, thermalization losses are suppressed, enabling a conversion efficiency close to the Carnot limit in the radiative limit. However, in this narrowband limit, the power density becomes zero. Therefore, there is a trade-off in T-PV between high efficiency and high power (Fig. 1, left). Advanced PV concepts, such as multi-junction and hot carriers, can help T-PV achieve higher power for a given efficiency (Fig. 1, right).

In this talk, I will first discuss the origins of the trade-off between efficiency and power in T-PV, developing a model to determine the highest efficiency achievable for a given power. I will then show in which ways tandem devices can provide a significant improvement over single-junction T-PV. I will also introduce the analytical modeling of such devices, as well as additional ways to improve the figure of merit, namely using hot carriers and near-field effects. The aim of this talk is to engage the JNPV community with the very promising field of T-PV by highlighting the connections between both fields.

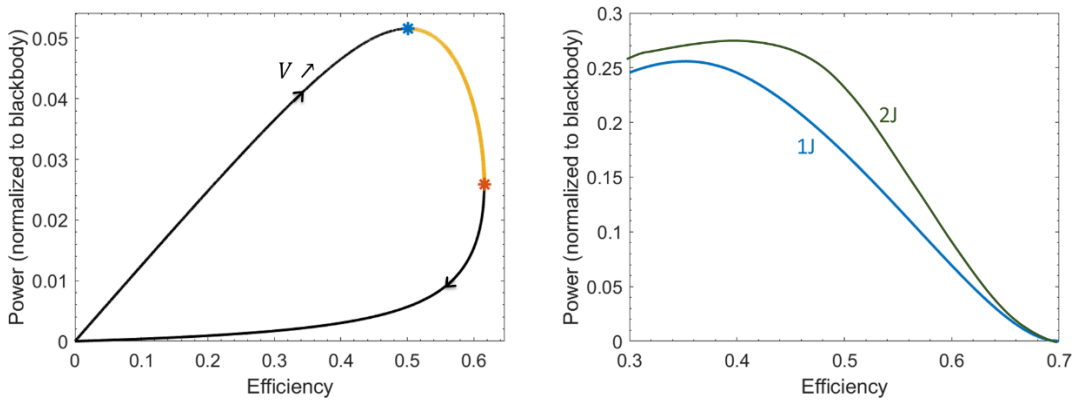

Figure 1: (Left) Power generation versus efficiency as the voltage is varied across a TPV cell. The maximum power point (in blue) differs significantly from the maximum efficiency point (in red). The optimal region of operation is highlighted in yellow. (Right) Maximum power achieveable for a given efficiency for single-junction and tandem TPV devices.

1 Harder, N.-P. *et al. Semicond. Sci. Technol.* 18, S151–S157 (2003)
2 Burger, T. *et al. Joule* 4, 1660–1680 (2020)
3 Datas, A. *et al. Sol. Energy Mater. Sol. Cells* 240, 111711 (2022)
4 LaPotin, A. *et al. Nature* 604, 287–291 (2022)