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Hot-Carrier Multi-Junction Solar Cells: The Best of Both Worlds

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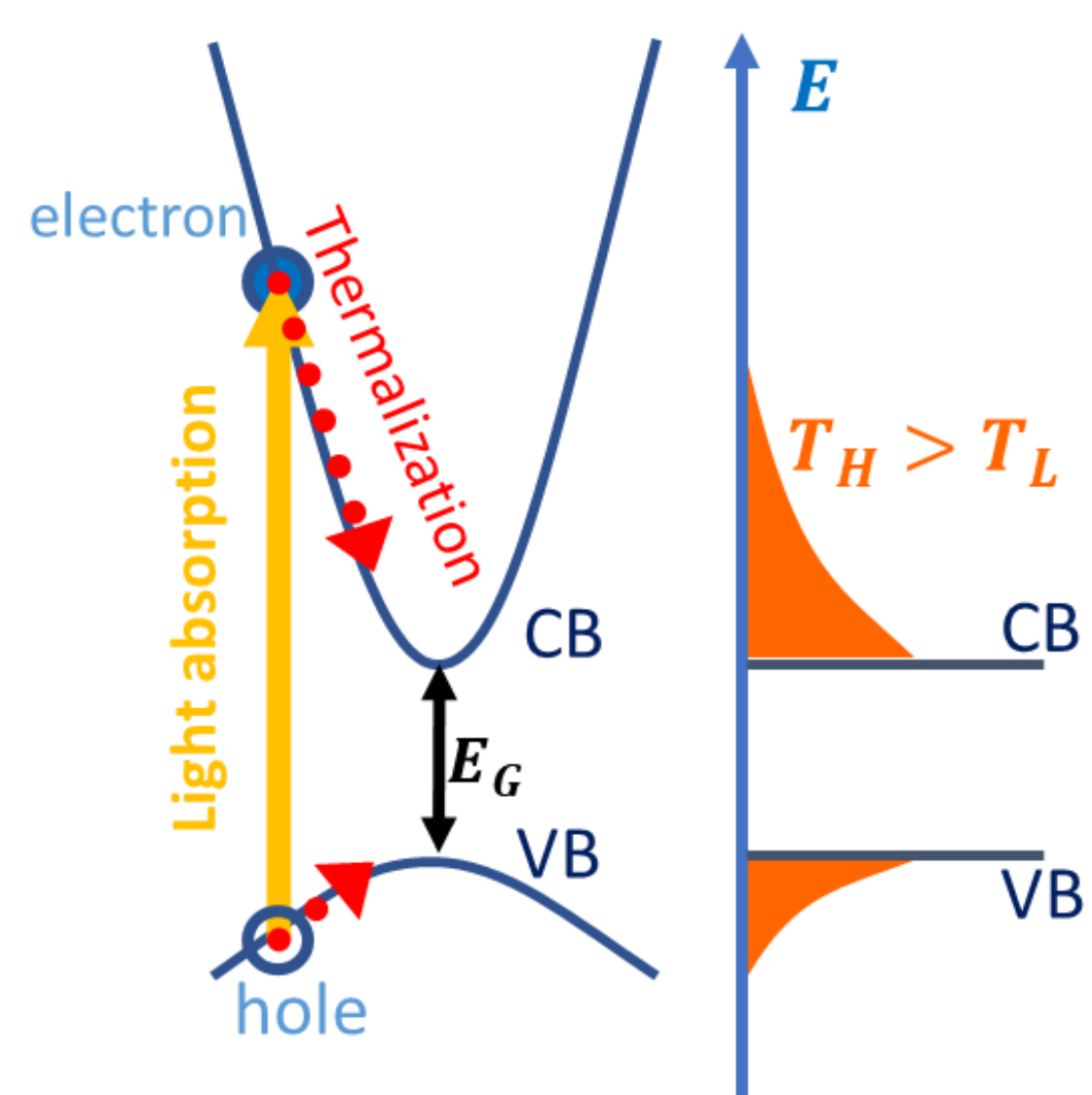
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Conventional solar cells are limited to ~33% efficiency due to the mismatch between the broadband solar spectrum and the fixed bandgap of the cell. Multi-junction solar cells (MJSCs) can overcome this limit by combining multiple subcells with decreasing bandgaps. An alternative approach is hot-carrier solar cells (HCSCs), which convert the extra kinetic energy of the (hot) carriers into electricity before it is dissipated by interaction with the lattice. Here, we propose a hybrid concept called hot-carrier multi-junction solar cells (HCMJSCs) [1,2,3] which synergize the key aspects of each technology.

Hot carriers require ultrathin absorbers...

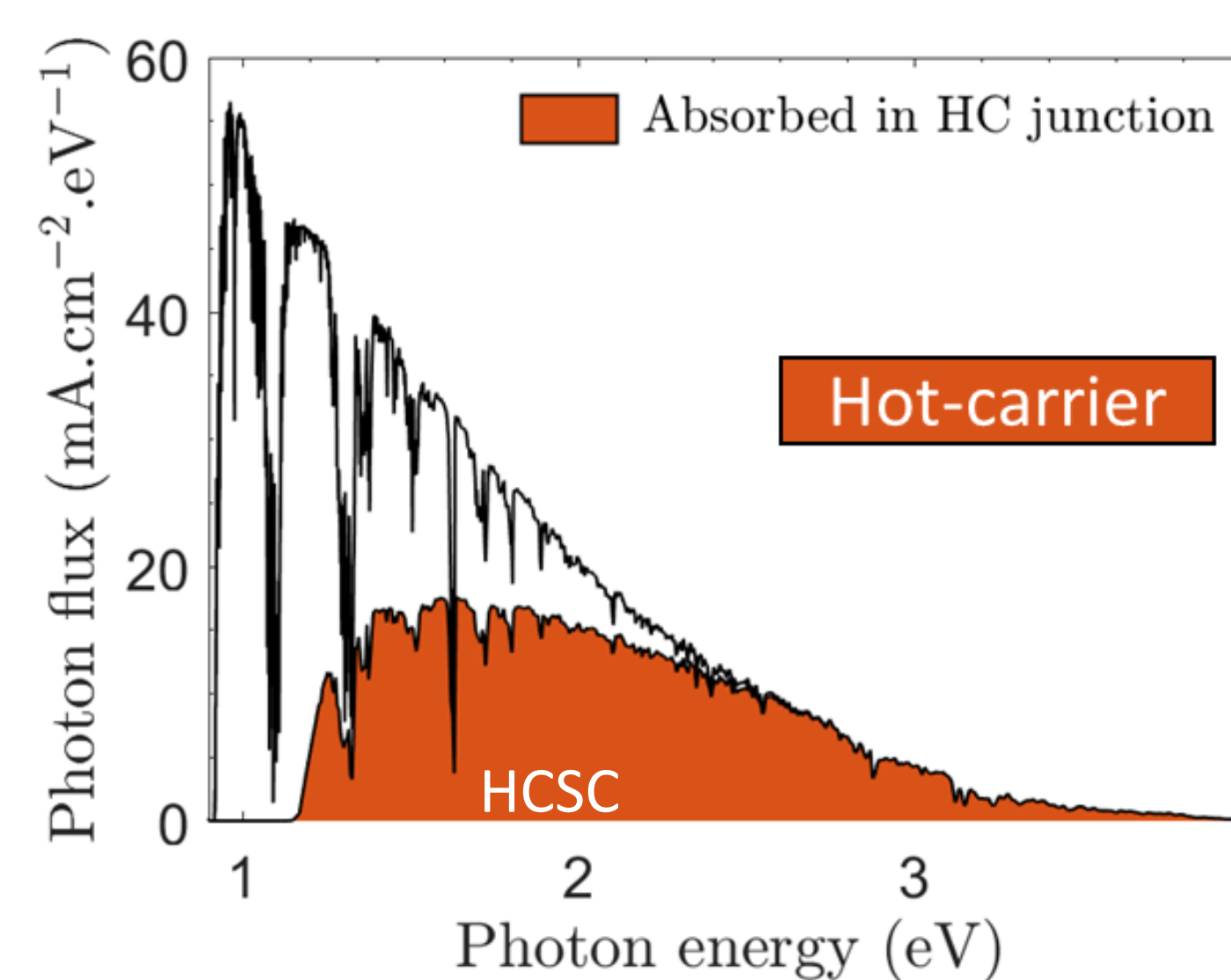


Thermalized power:

$$P_{th} = q_V d (T_H - T_L)$$

q_V : volume thermalization coefficient
 d : absorber thickness
 T_H : hot-carrier temperature
 T_L : lattice temperature

...which cannot efficiently absorb sunlight



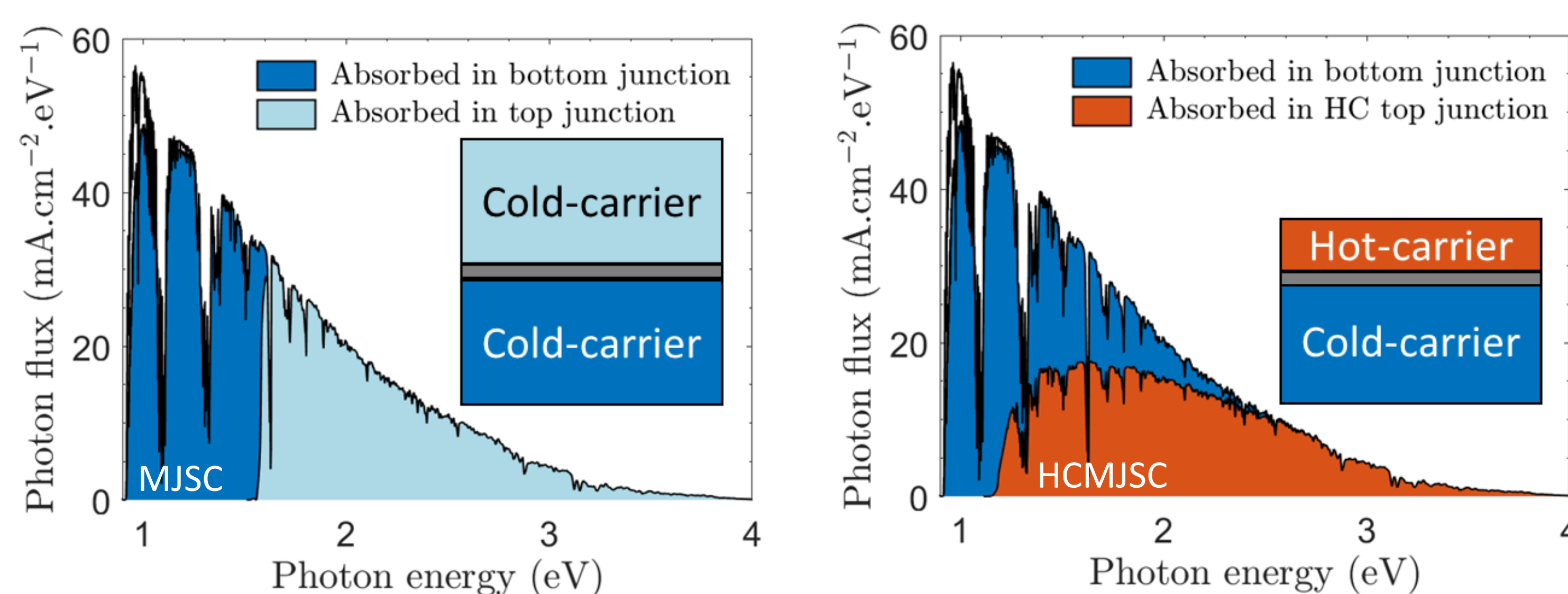
Absorption:

$$A = 1 - \exp(-F\alpha d)$$

α : absorption coefficient
 F : light trapping factor
 d : absorber thickness

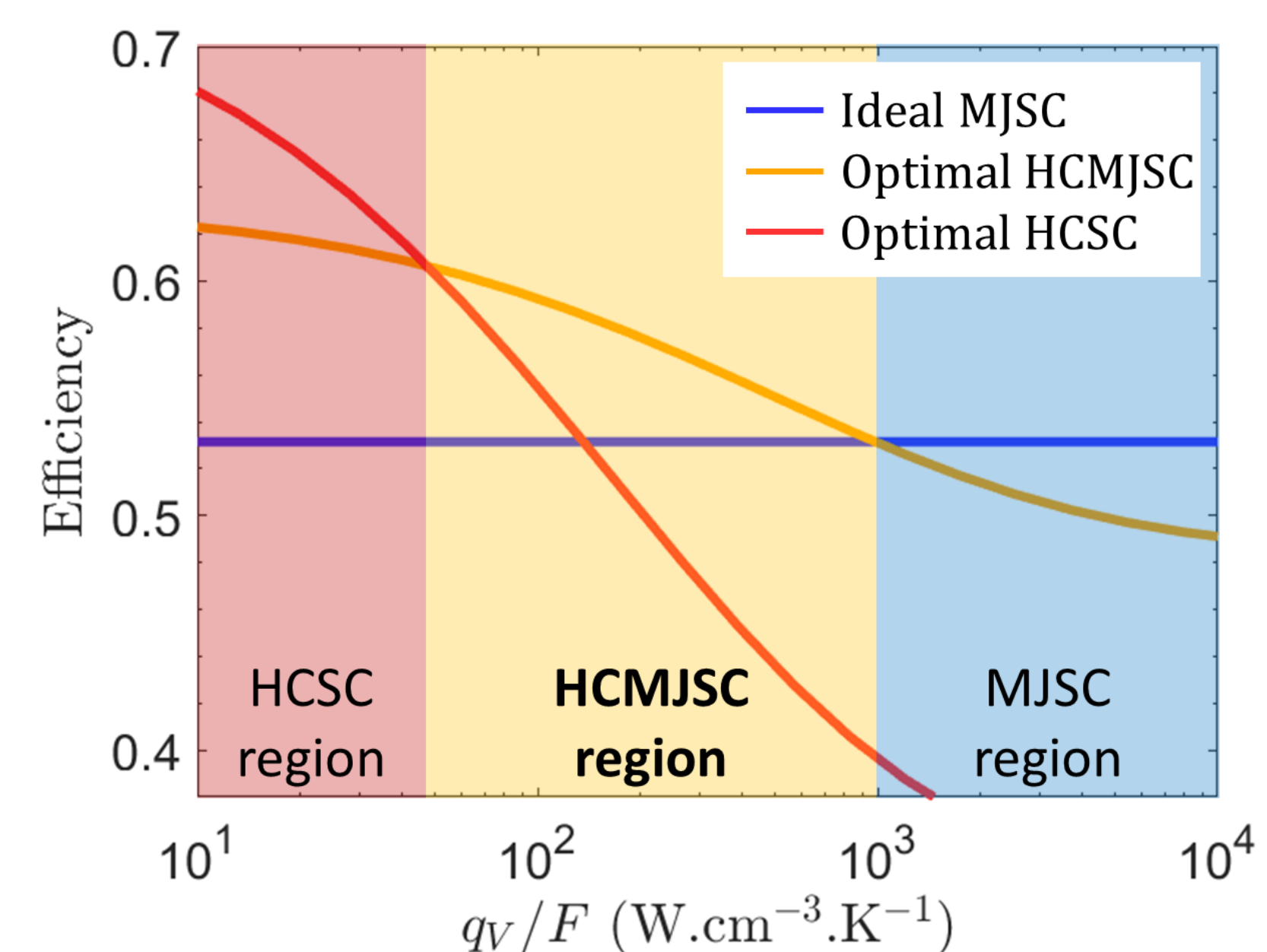
Low absorption \Rightarrow
 Low efficiency

MJSCs with an ultrathin hot-carrier top cell



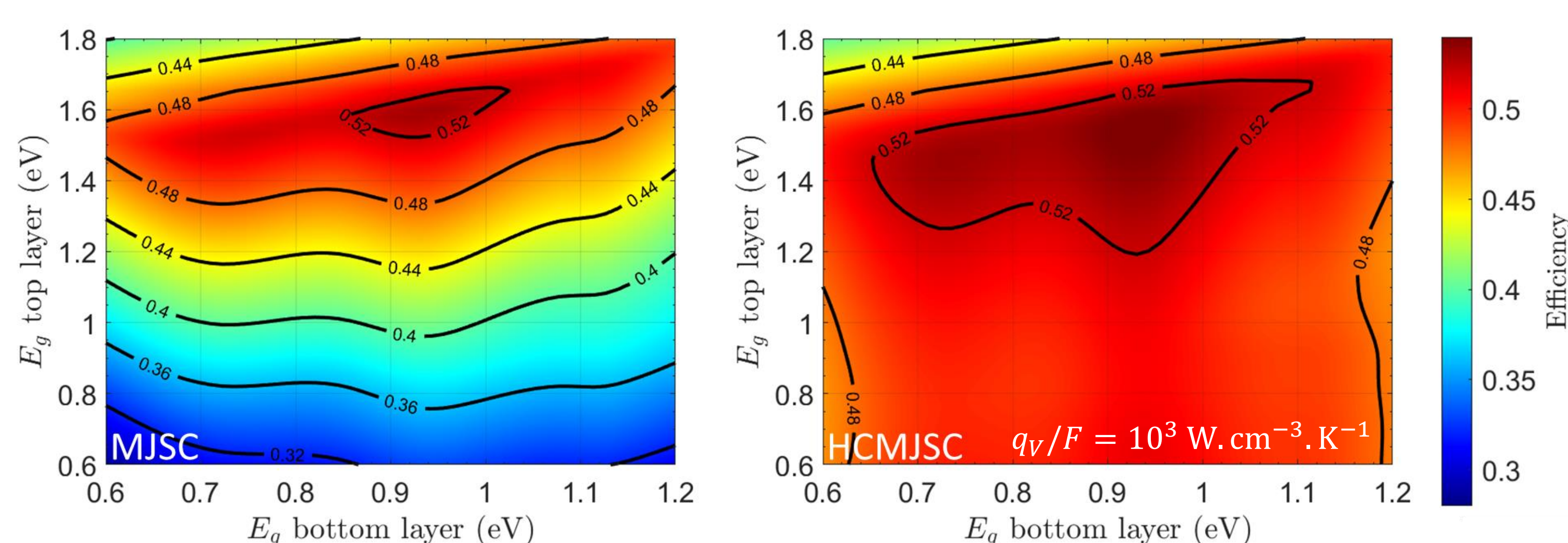
Photons not absorbed in the ultrathin hot-carrier cell can be harvested by the bottom subcell, not sacrificing absorption

Easier to benefit from hot carrier effects



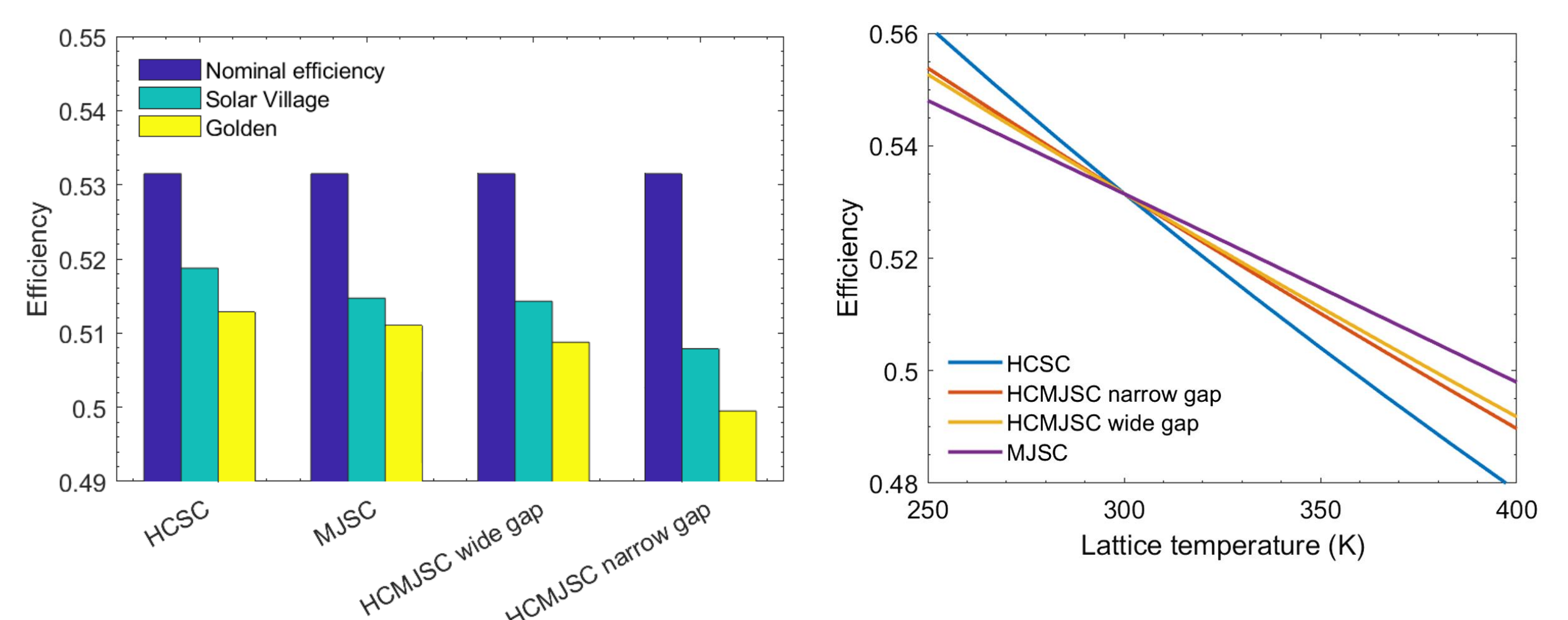
Large efficiency gains for realistic thermalization rates

No constraint on the top-cell material



HCMJSCs can be designed for whatever bandgap combination is most practically achievable

Resilience vs operation conditions



Year-averaged efficiencies

Temperature dependence

Similar dependence \Rightarrow non-idealities do not stack

- HCMJSC: a concept that facilitates the harnessing of hot-carriers without compromising on absorption.
- Much easier to benefit from hot-carrier effects than HCSCs, leading to large efficiency gains for realistic thermalization rates.
- New promising material combinations, in particular double-homojunction configurations in which both subcells use the same material.
- Resilience to non-ideal operation conditions comparable to the individual concepts (especially the wide-gap case).

The first fully operational hot-carrier solar cell should be a HCMJSC

[1] Giteau, M., Almosni, S. & Guillemoles, J.-F., Hot-carrier multi-junction solar cells: A synergistic approach, *Appl. Phys. Lett.* **120**, 213901 (2022).

[2] Almosni, S., Giteau, M., Guillemoles, J.-F. & Suchet, D., CELLULES SOLAIRES MULTI-JONCTIONS A PORTEUR CHAUD, French patent filed on 19/05/2022 (application number FR2204325)

[3] Giteau, M., Almosni, S., Guillemoles, J.-F. & Suchet, D., Hot-carrier multijunction solar cells: sensitivity and resilience to nonidealities, *JPE* **12**, 032208 (2022).