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

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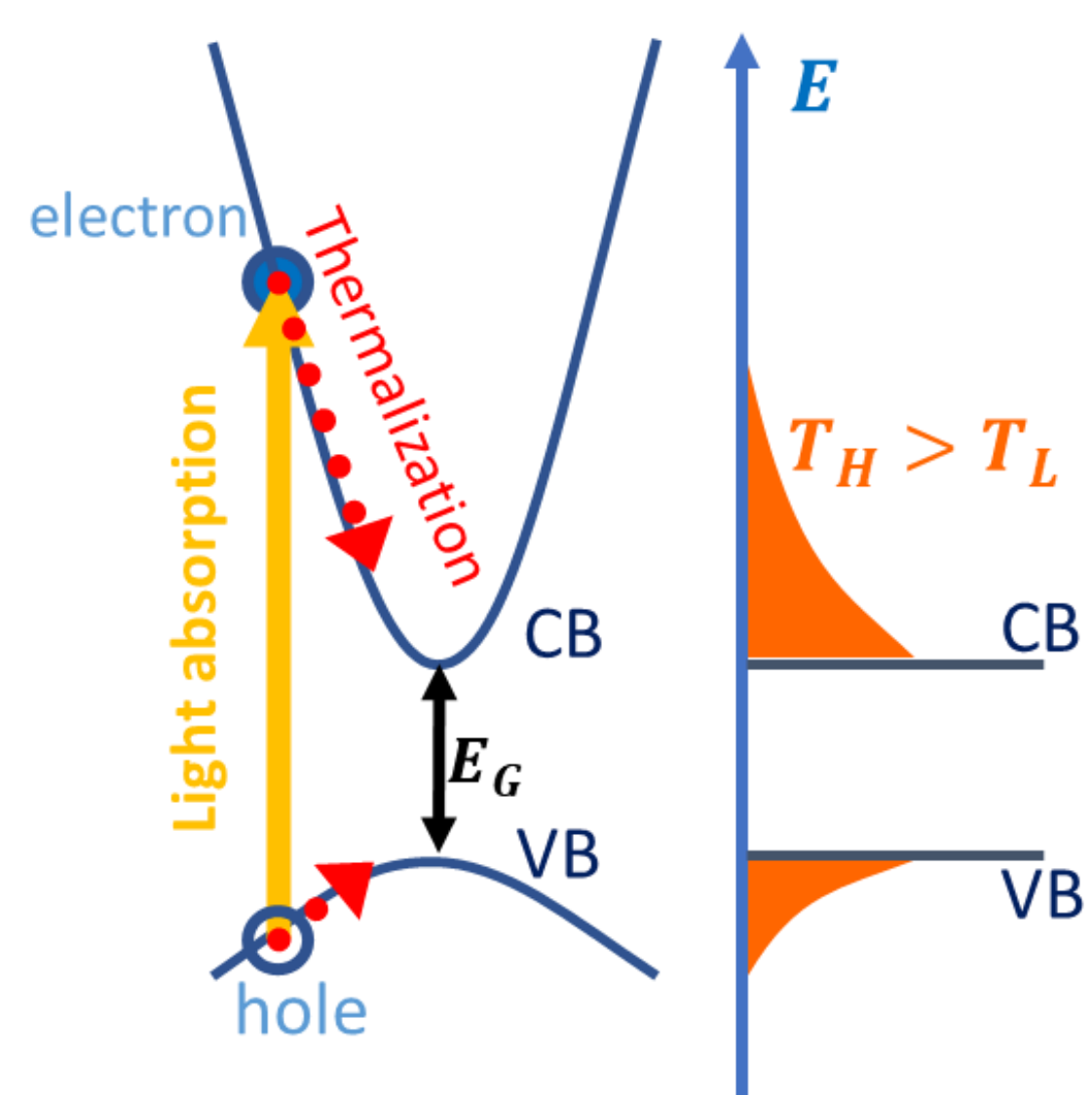
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Conventional solar cells are limited to ~33% efficiency due to the mismatch between the broadband solar spectrum and the fixed bandgap of the cell. Multi-junction solar cells (MJSCs) can overcome this limit by combining multiple subcells with decreasing 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...

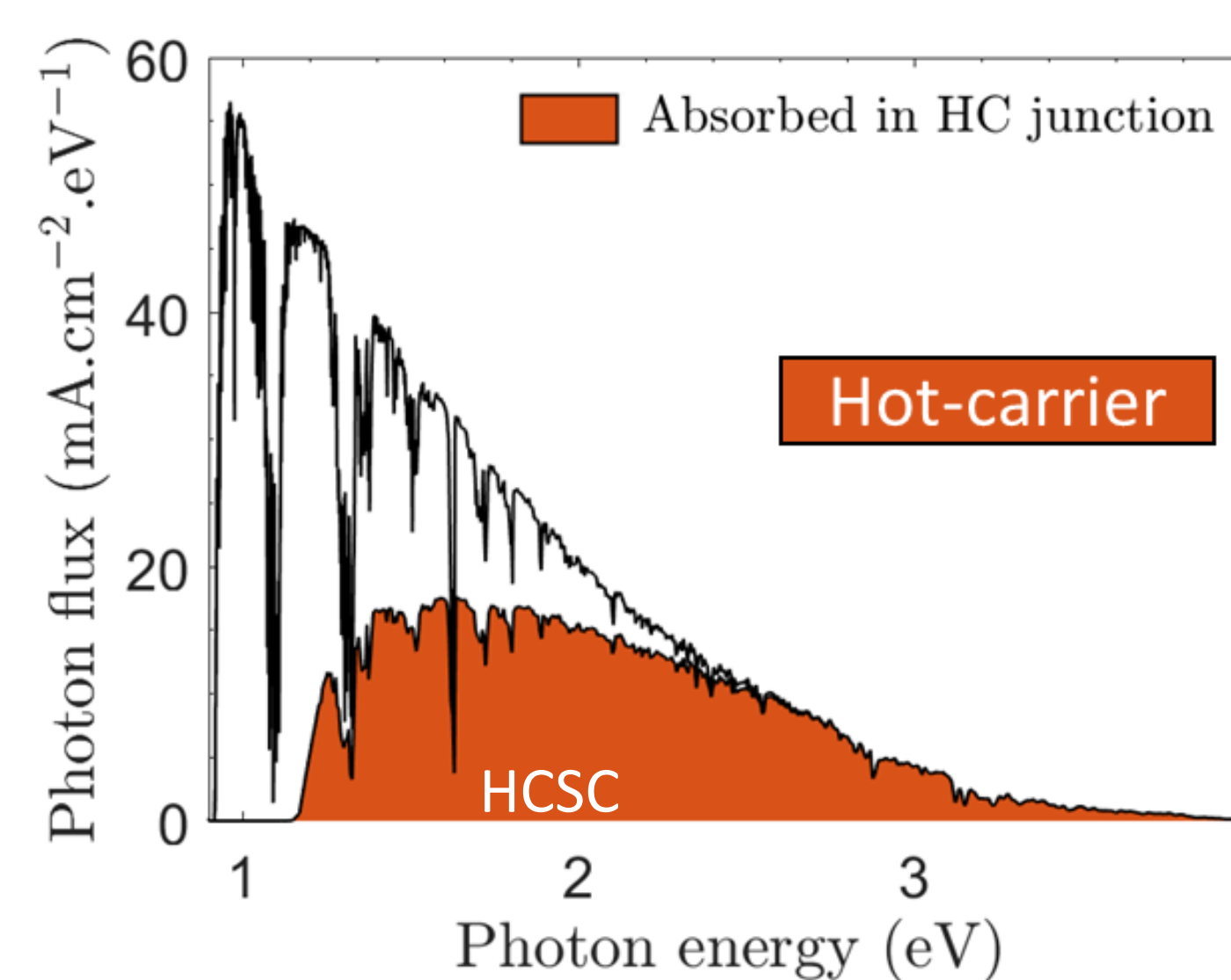


Thermalized power:  

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

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

## ...which cannot efficiently absorb sunlight



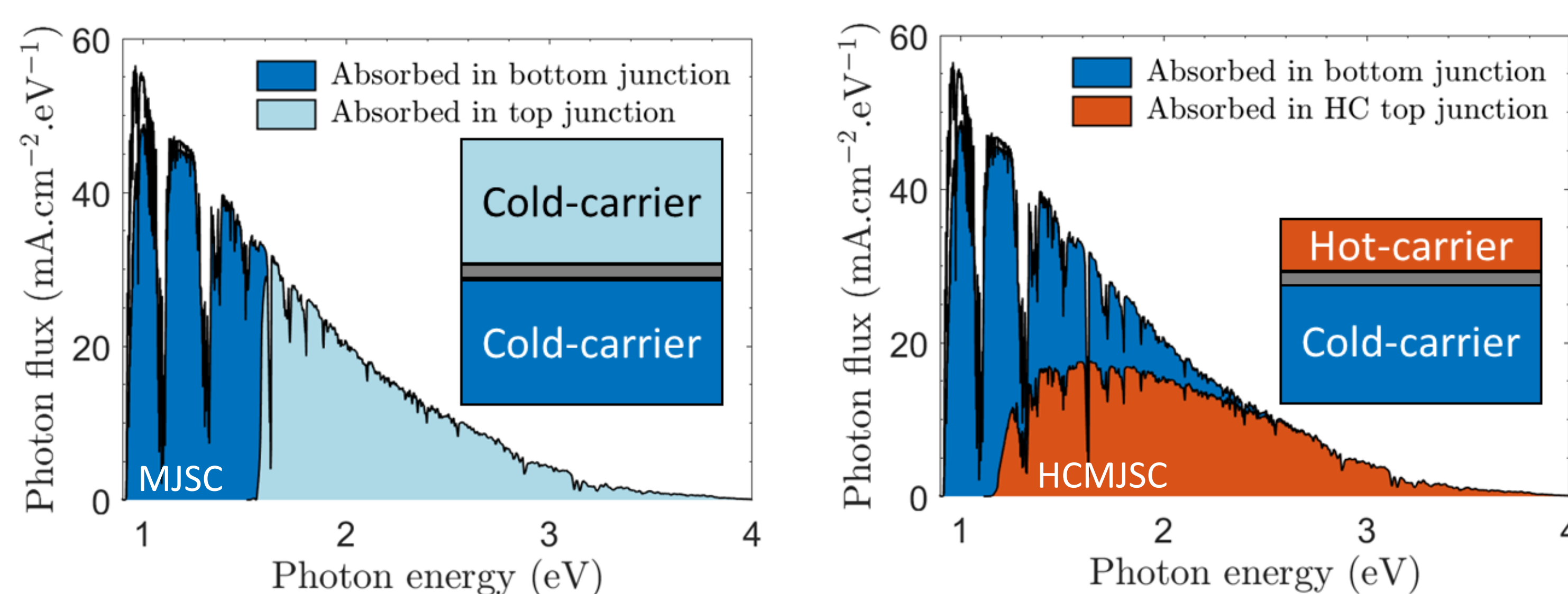
Absorption:  

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

$\alpha$ : absorption coefficient  
 $F$ : light trapping factor  
 $d$ : absorber thickness

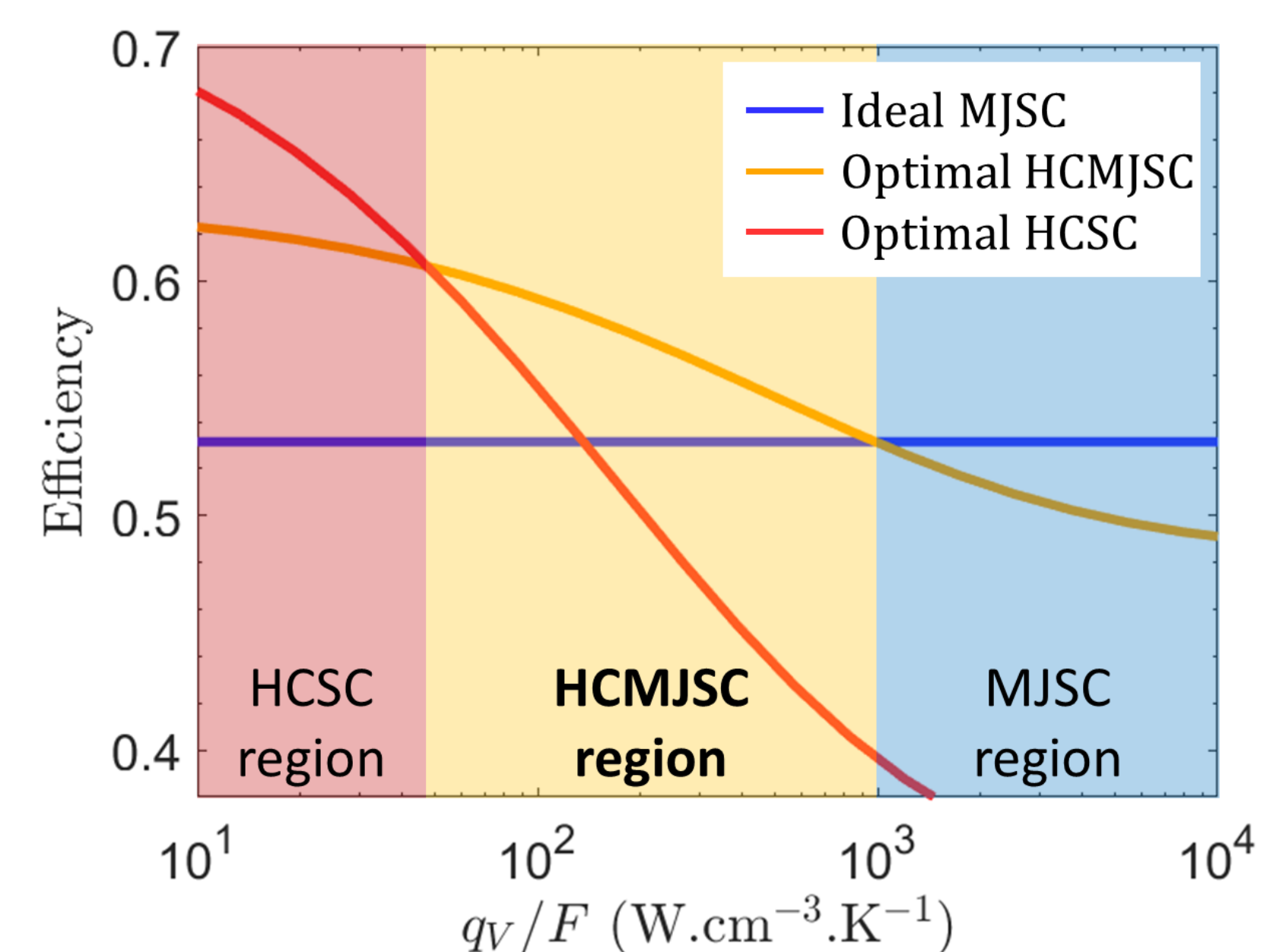
Low absorption  $\Rightarrow$   
 Low efficiency

## MJSCs with an ultrathin hot-carrier top cell



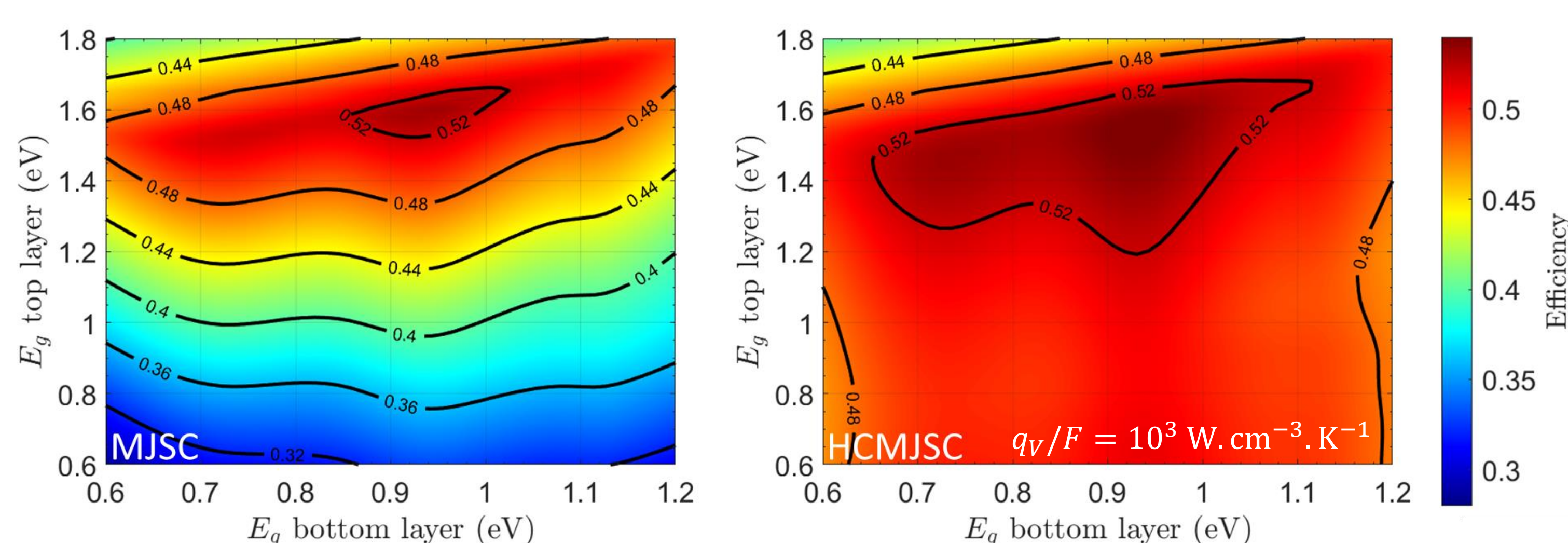
Photons not absorbed in the ultrathin hot-carrier cell can be harvested by the bottom subcell, not sacrificing absorption

## Easier to benefit from hot carrier effects



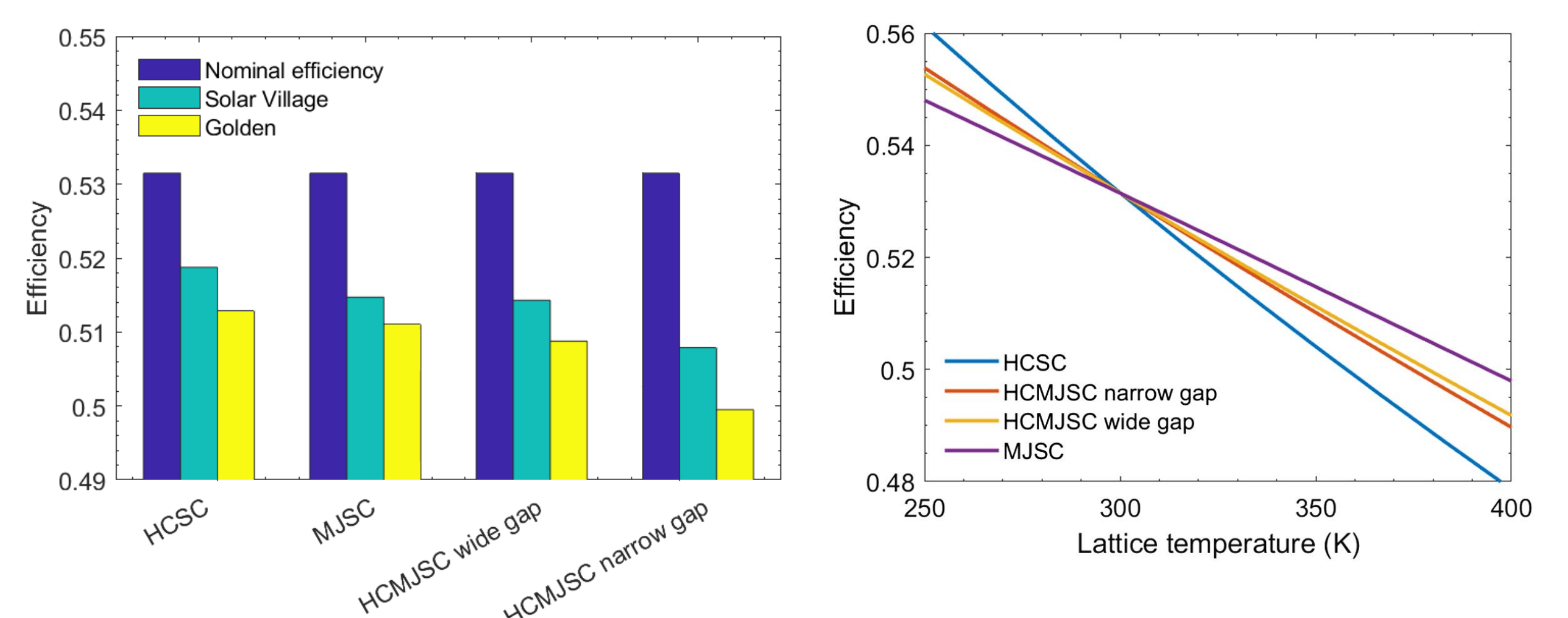
Large efficiency gains for realistic thermalization rates

## 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).