# Solar Cell Operation

## Design Rules: utilization of band gap energy

*Week 3.4*

Arno Smets

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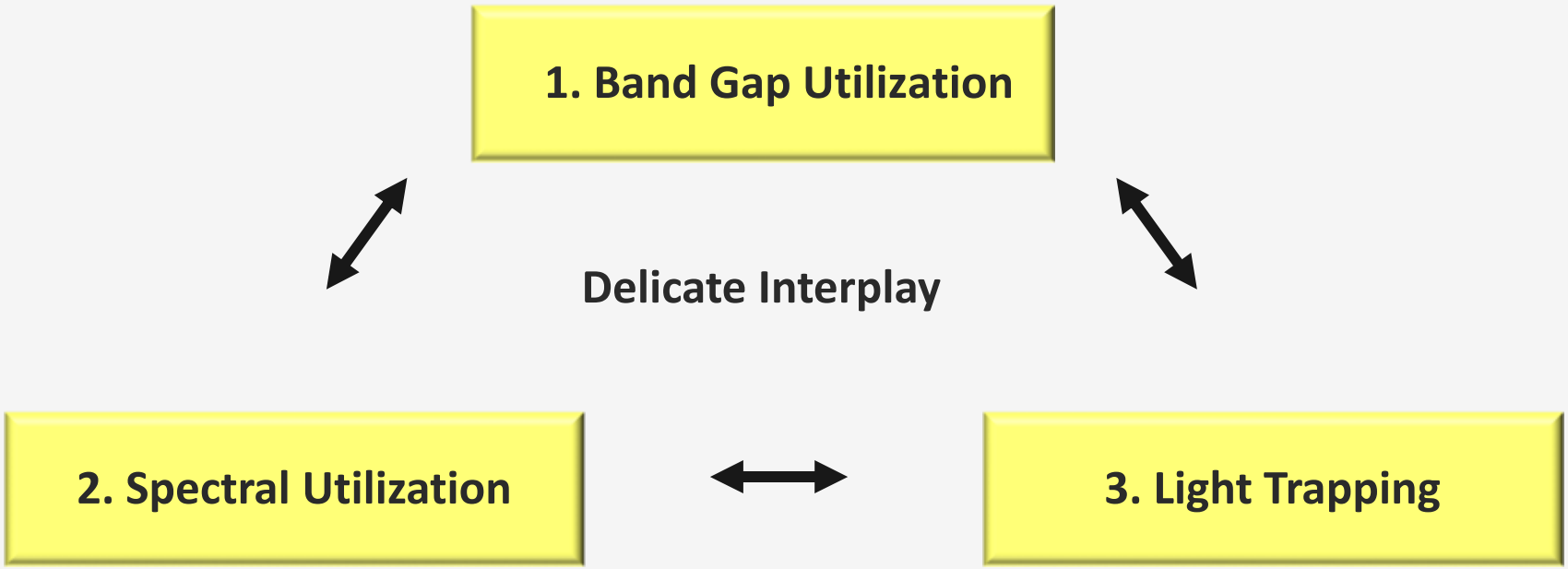
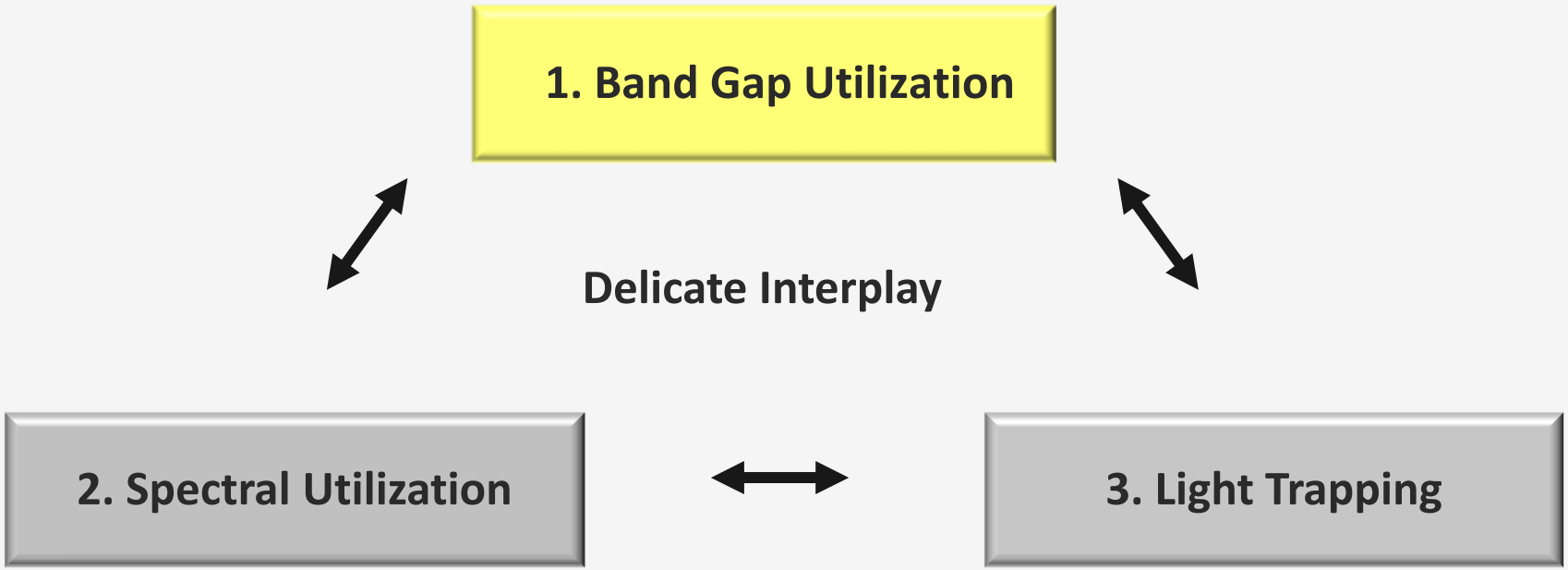
Challenge the future

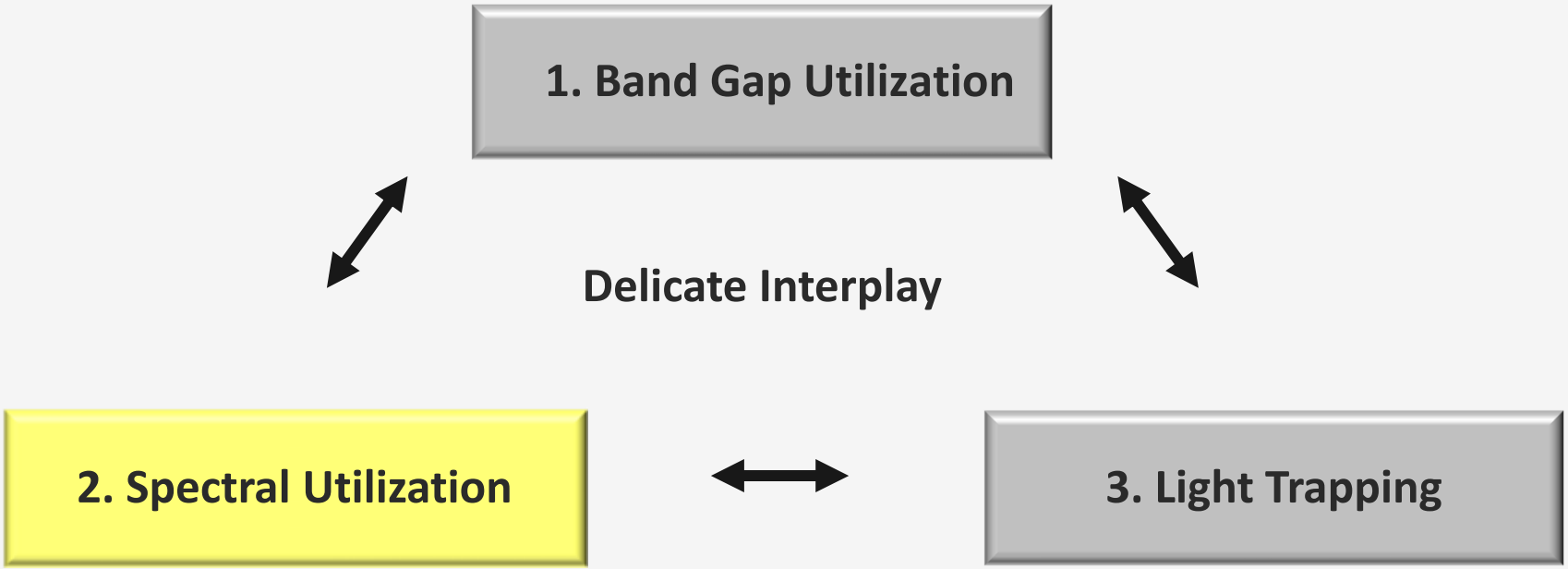
# Design Rules Solar Cells



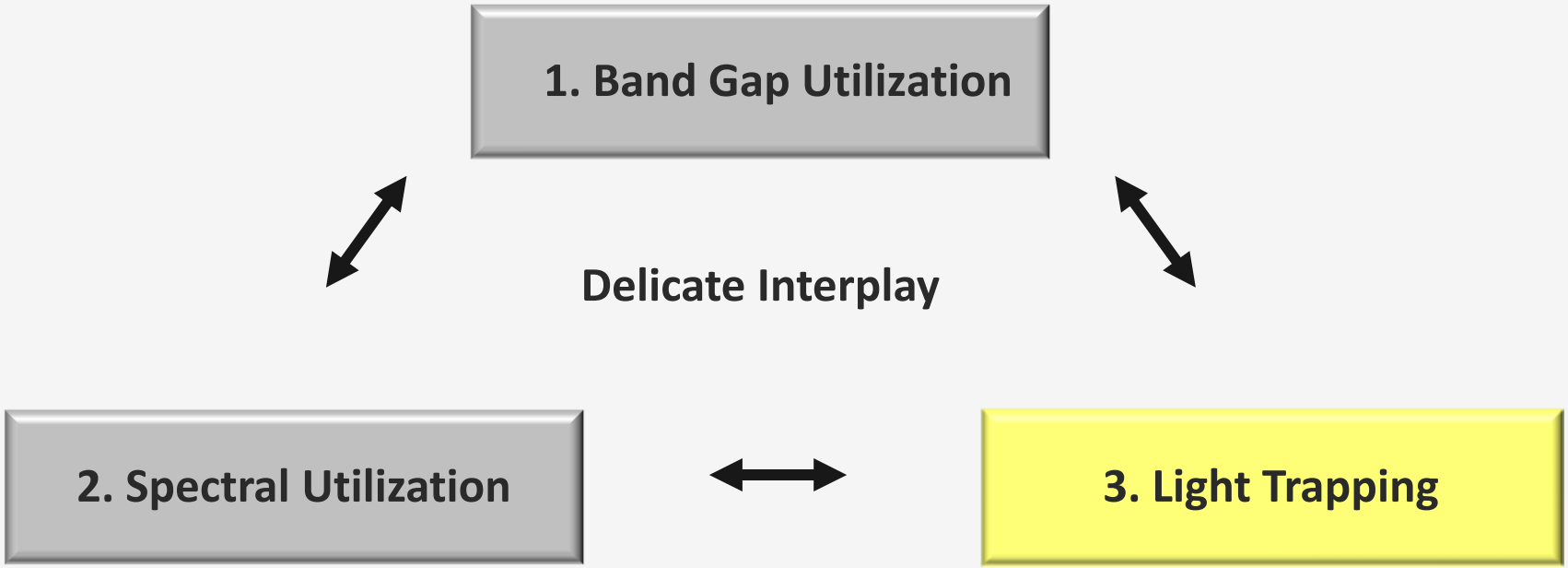
# Design Rules Solar Cells



# Design Rules Solar Cells

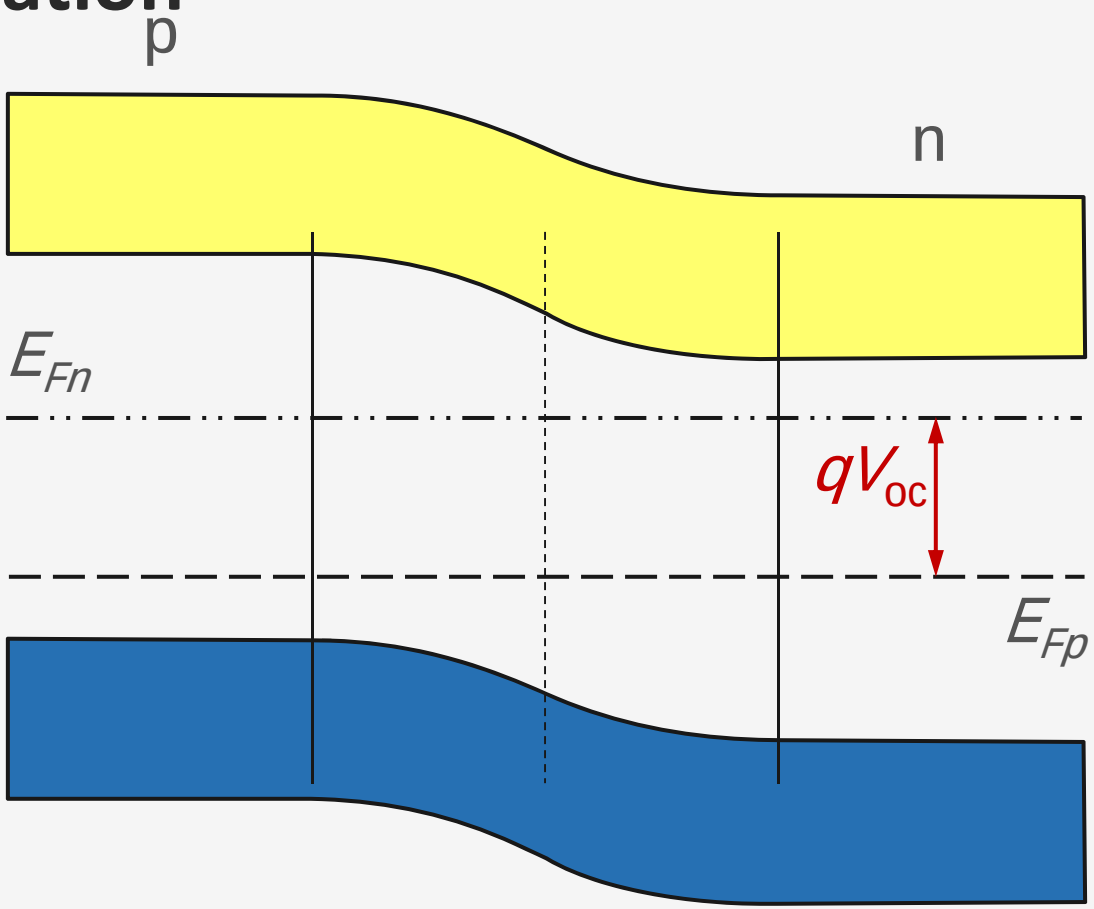


# Design Rules Solar Cells



# Band gap utilization

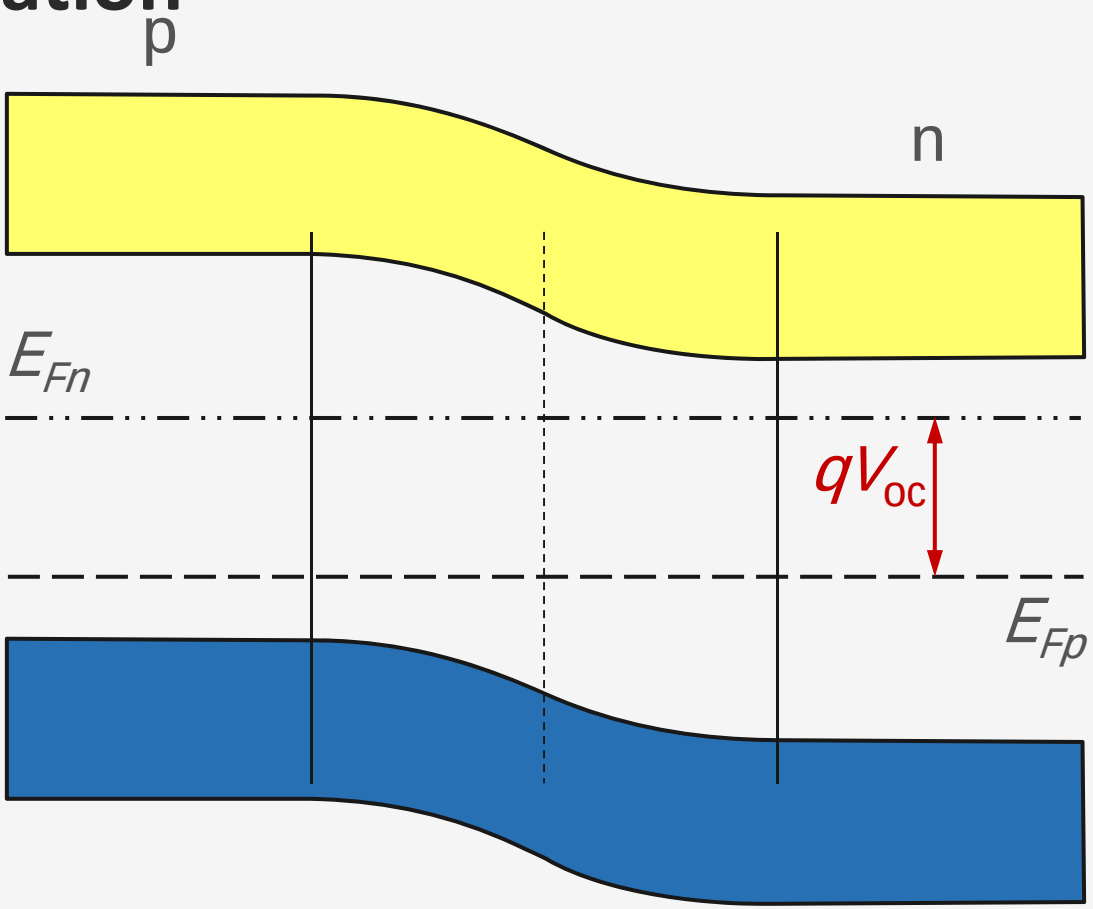
$$V_{OC} = \frac{k_B T}{q} \ln\left(\frac{J_{PH}}{J_0} + 1\right)$$



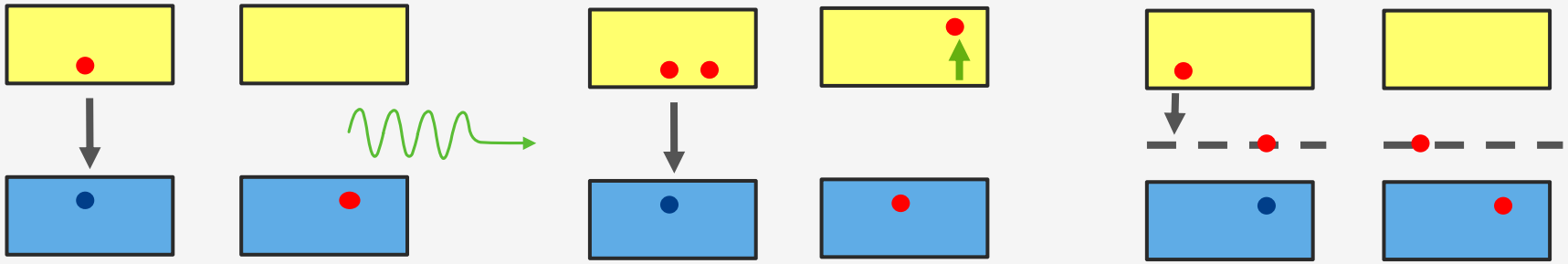
# Band gap utilization

$$V_{OC} = \frac{k_B T}{q} \ln\left(\frac{J_{PH}}{J_0} + 1\right)$$

$$V_{oc} = \frac{2kT}{q} \ln\left(\frac{G_L \tau_0}{n_i}\right)$$



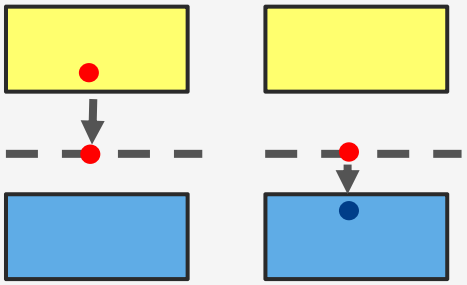
# Charge Carrier Recombination



Radiative Auger SRH

# Charge Carrier Recombination

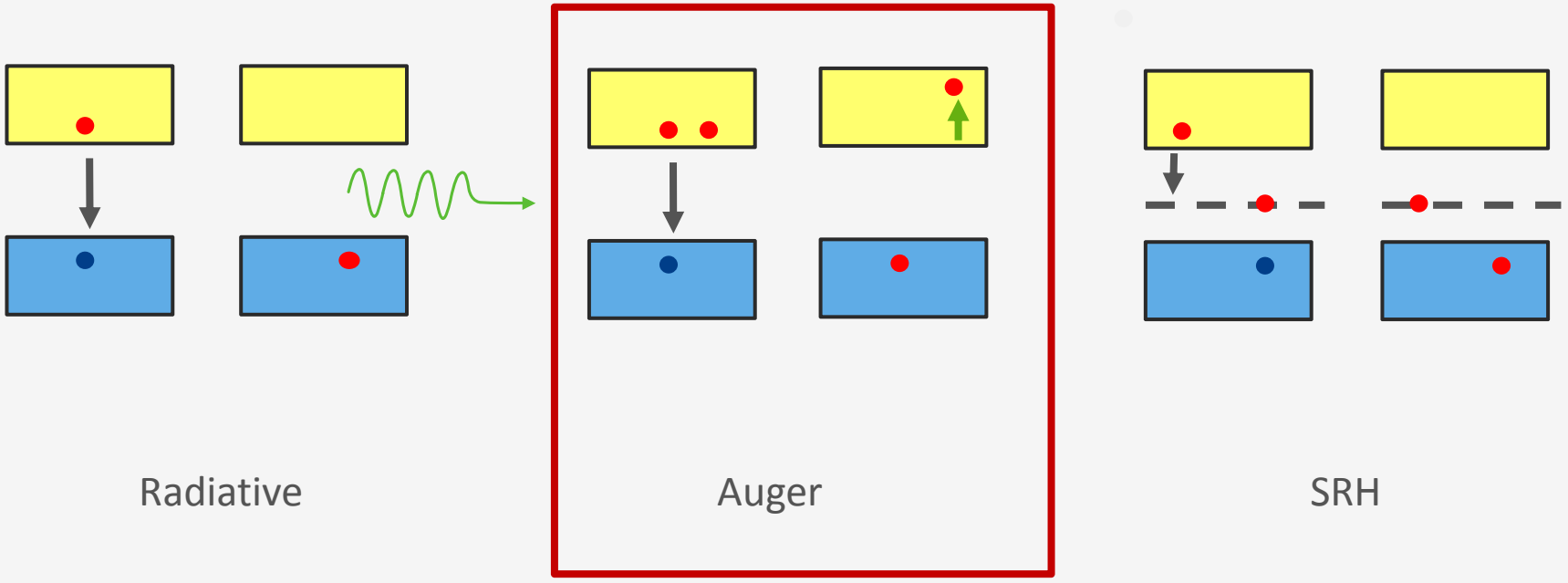
Shockley Read Hall



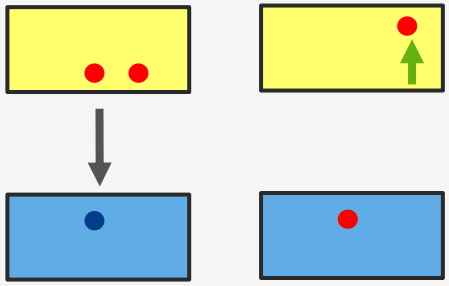
$$\tau_0 \propto N_t^{-1}$$

$$V_{oc} = \frac{2kT}{q} \ln\left(\frac{G_L \tau_0}{n_i}\right)$$

# Charge Carrier Recombination



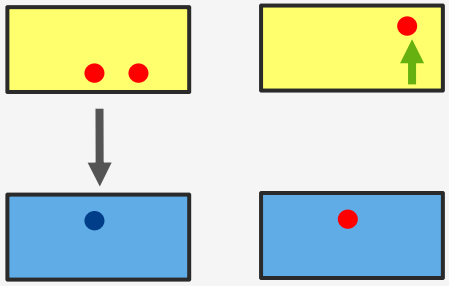
# Charge Carrier Recombination



$$R_{electron} = kn^2p$$

$$R_{hole} = kp^2n$$

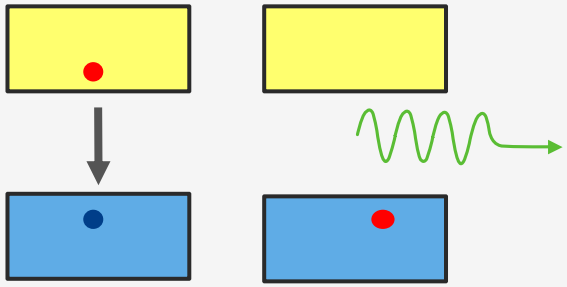
# Charge Carrier Recombination



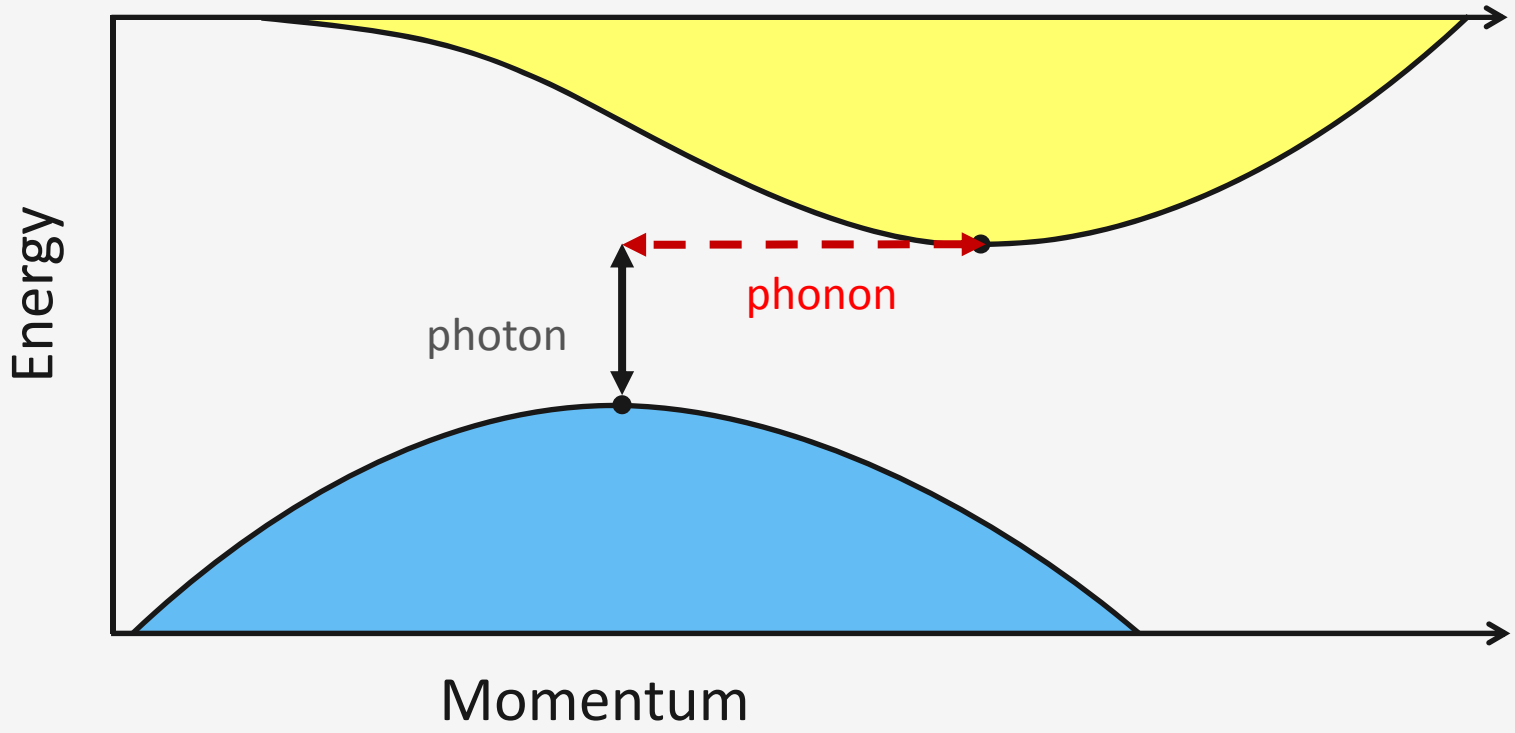
$$R_{electron} = kn^2 p \qquad \tau_{e,Aug} \propto \frac{p}{R} = \frac{1}{kn^2}$$

$$R_{hole} = kp^2 n \qquad \tau_{h,Aug} \propto \frac{n}{R} = \frac{1}{kp^2}$$

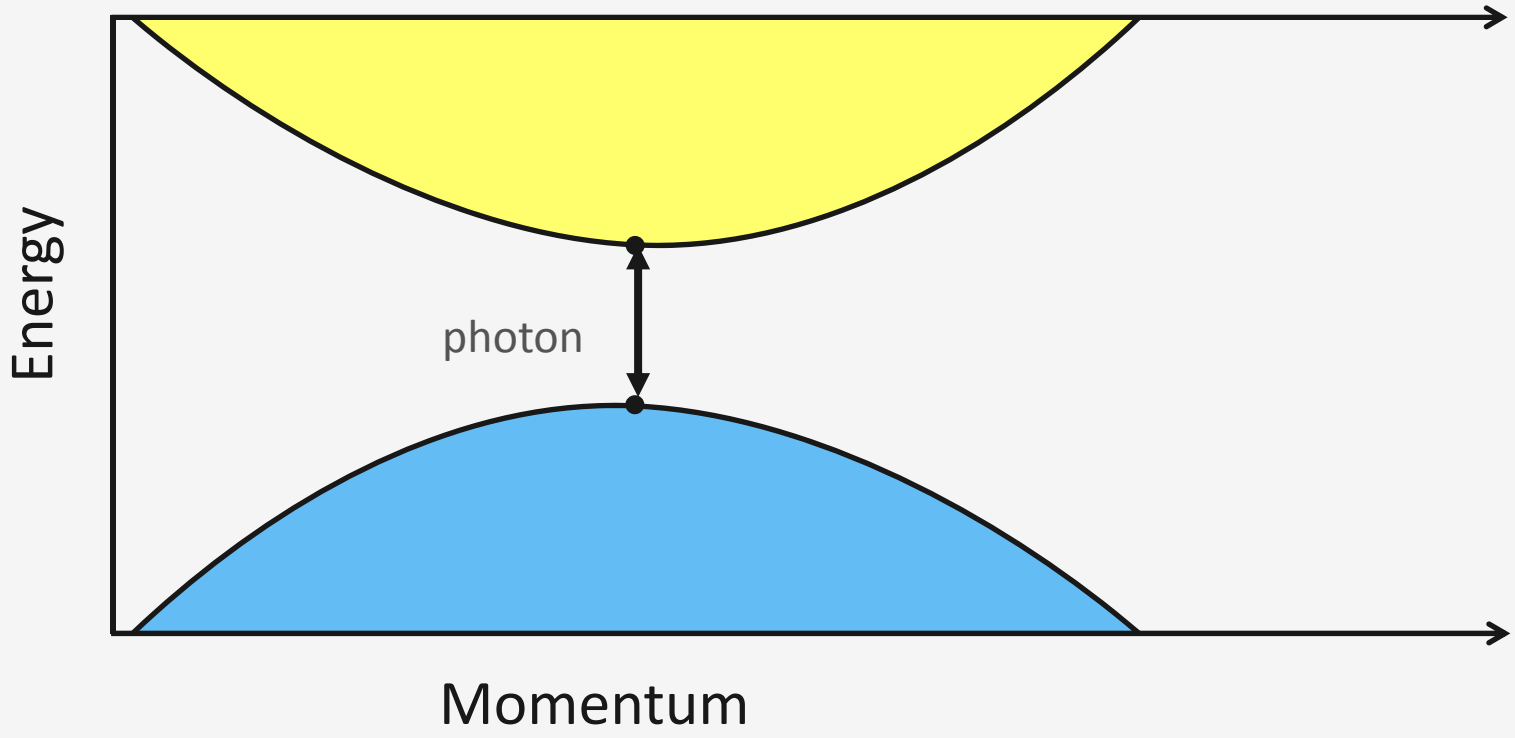
# Charge Carrier Recombination



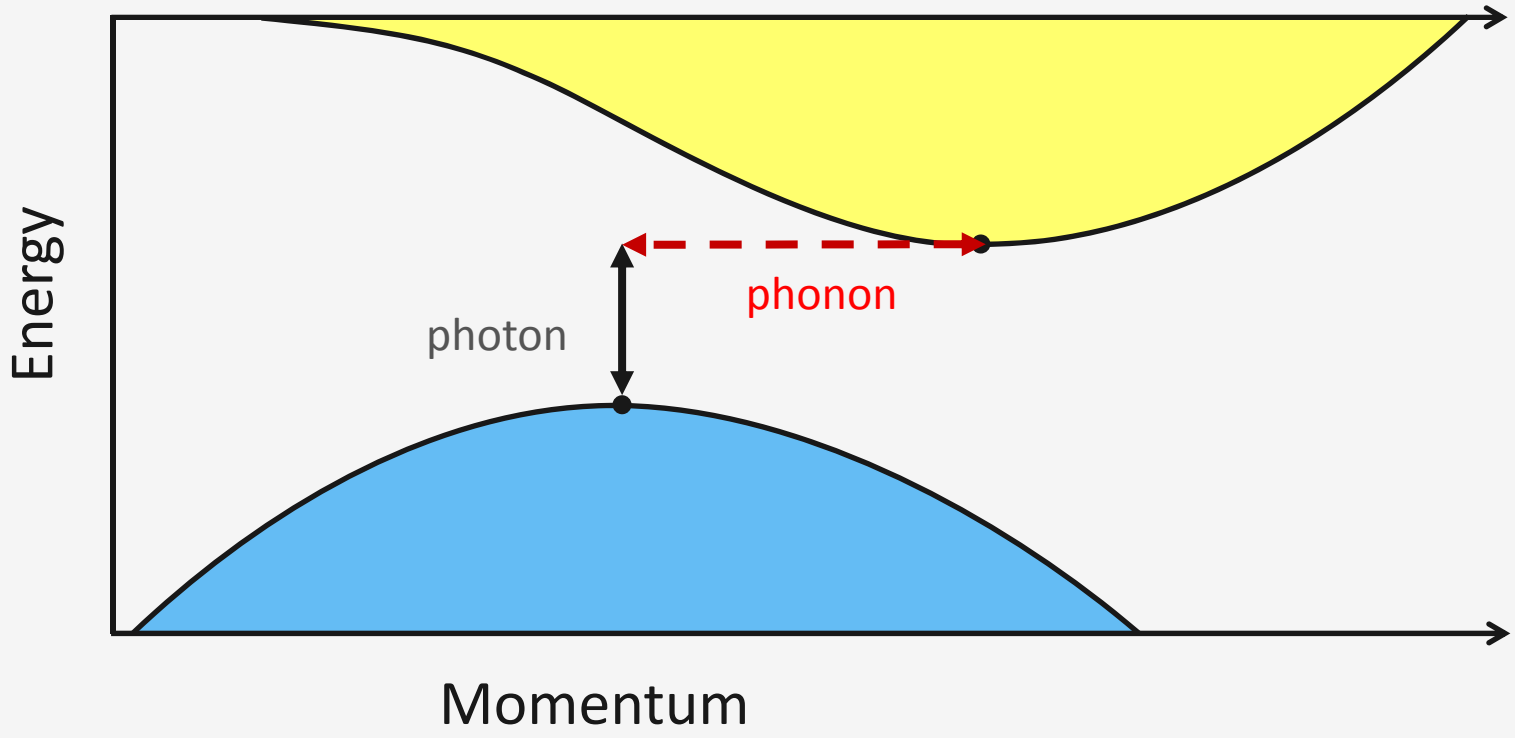
# Indirect band gap



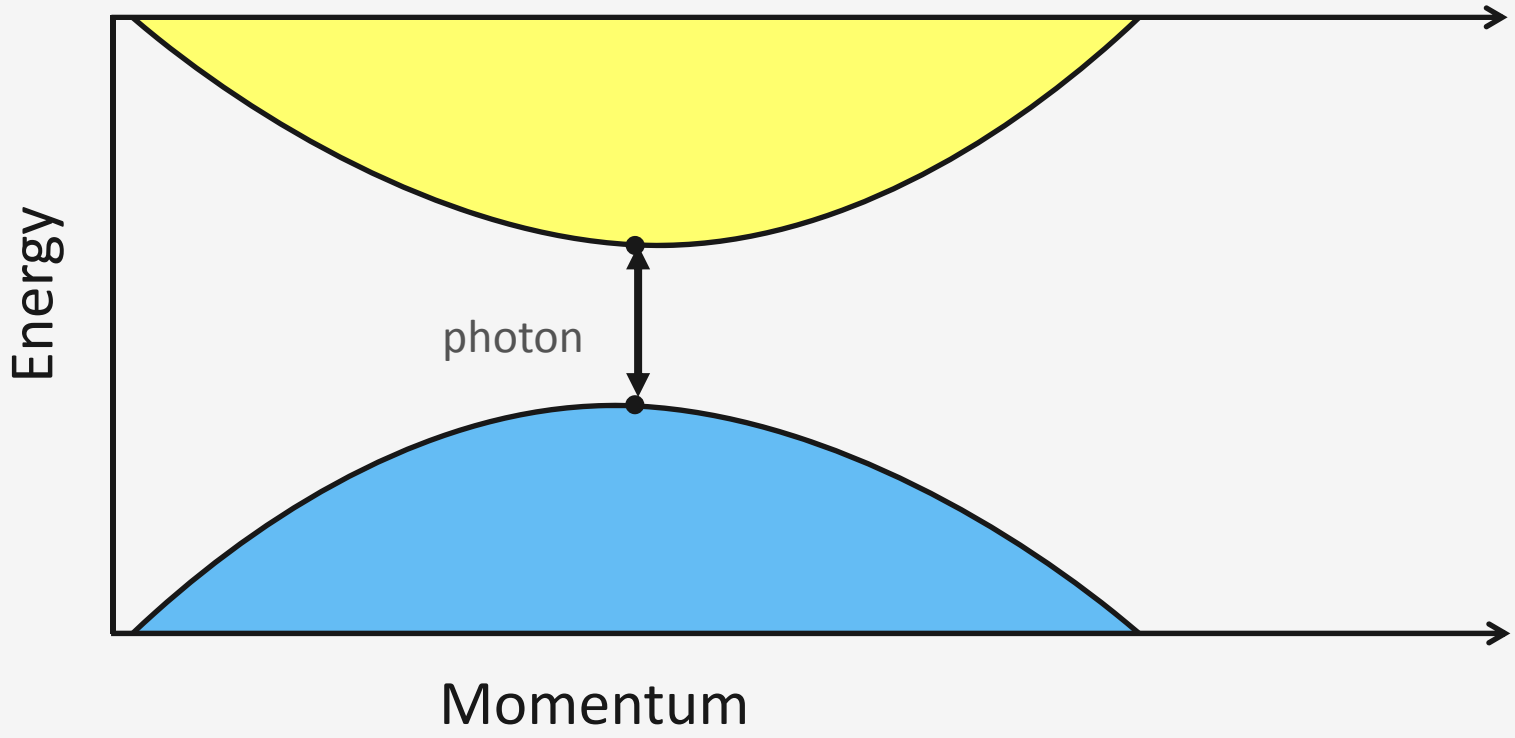
# Direct band gap



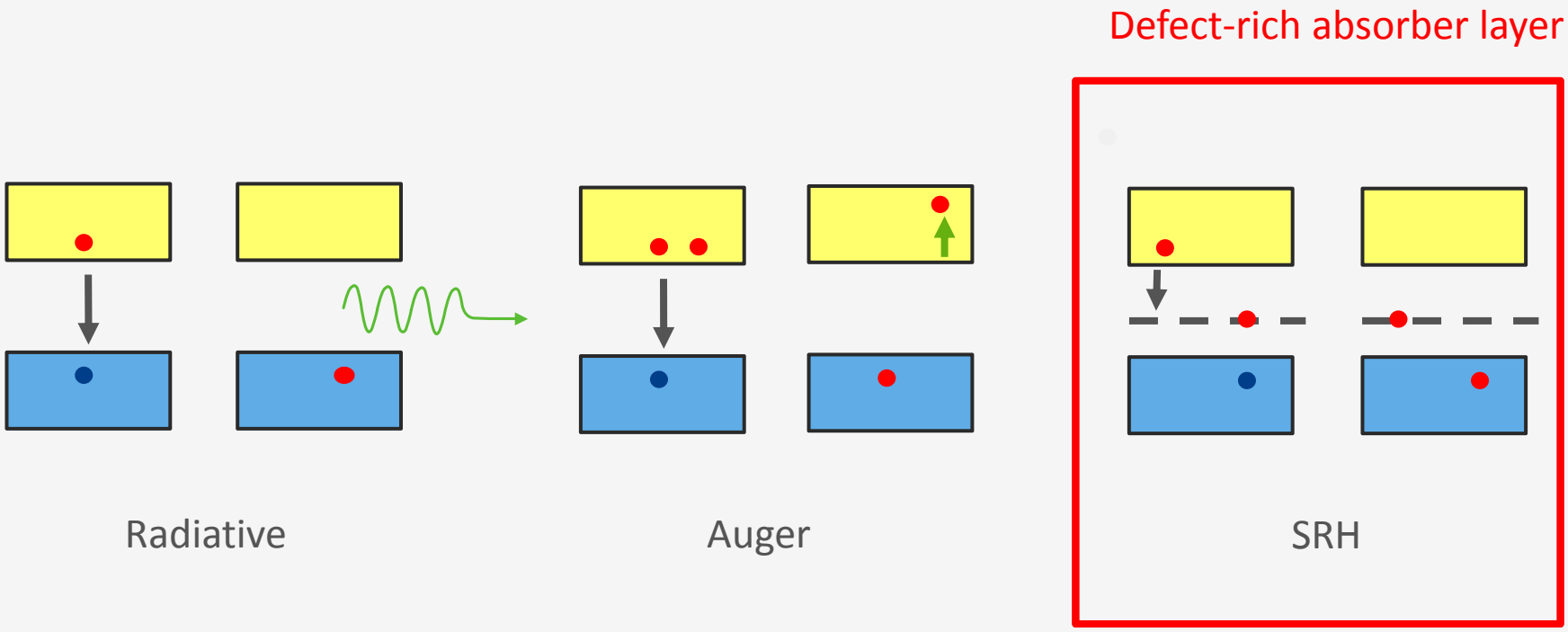
# Indirect band gap: c-Si



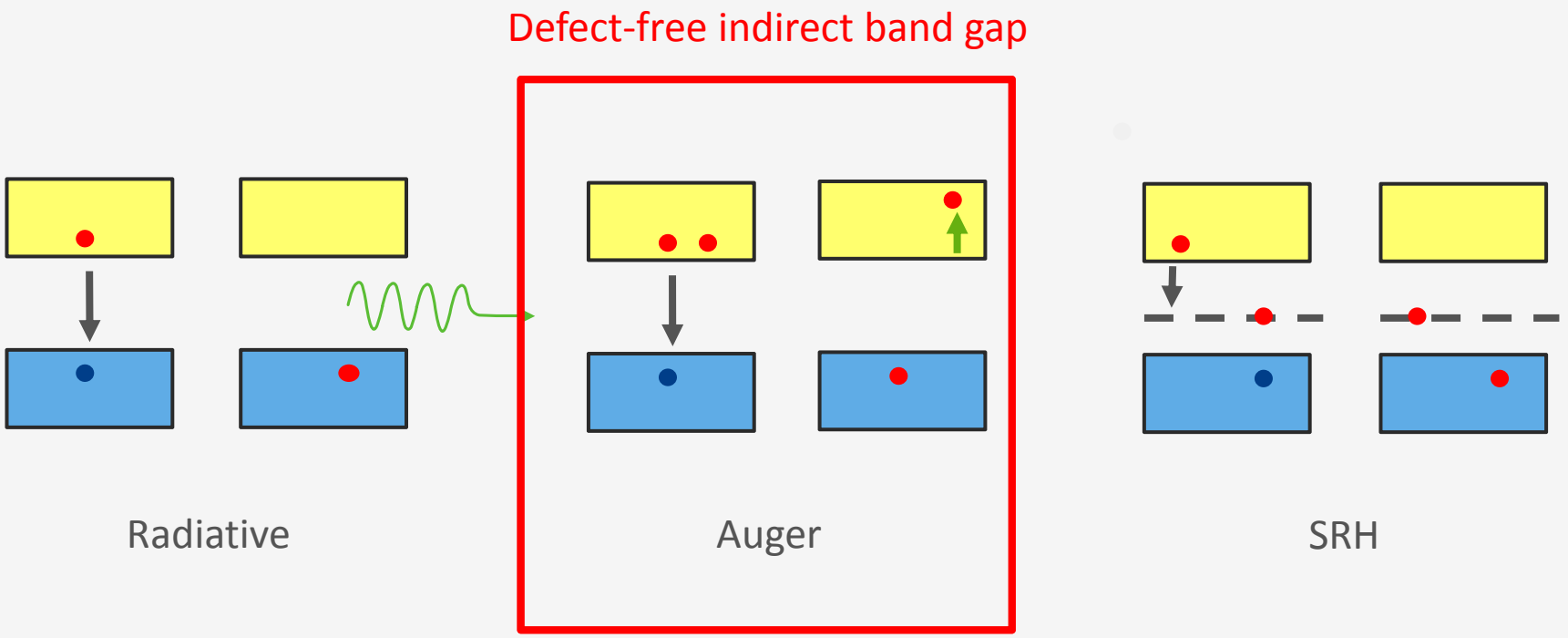
# Direct band gap: GaAs



# Band gap utilization: .....the $V_{oc}$ is limited by

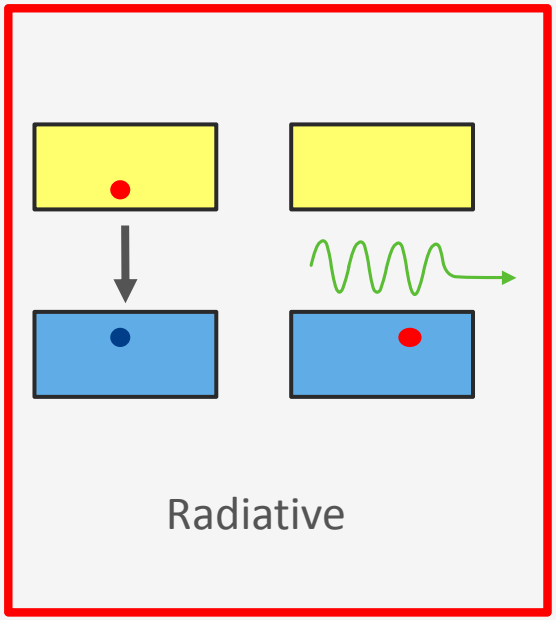


# Band gap utilization: .....the $V_{oc}$ is limited by

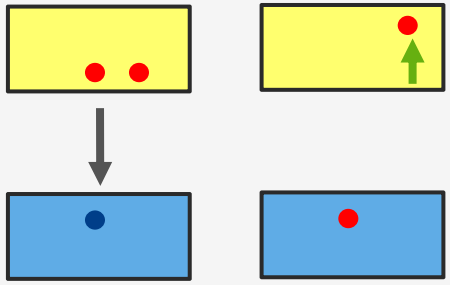


# Band gap utilization: .....the $V_{oc}$ is limited by

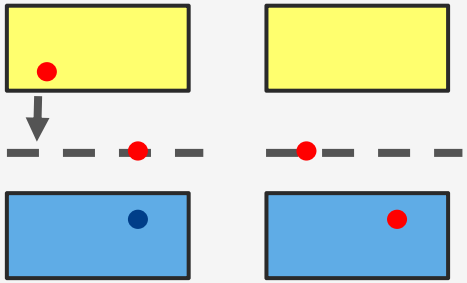
Defect-free direct band gap



Radiative

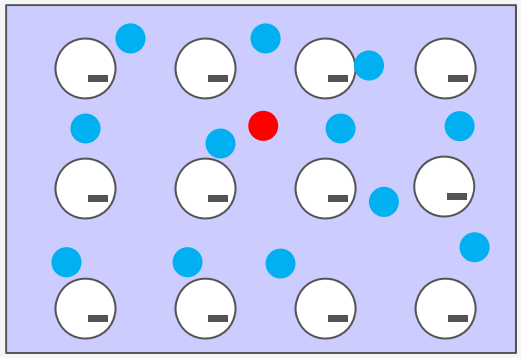


Auger

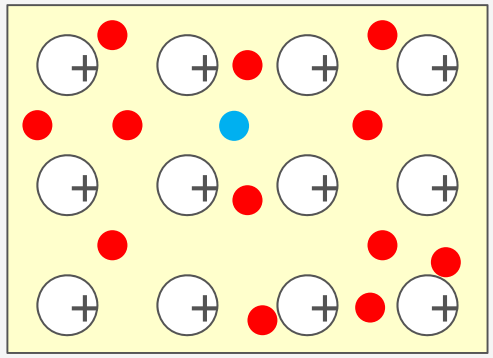


SRH

# Diffusion Length



p-doped



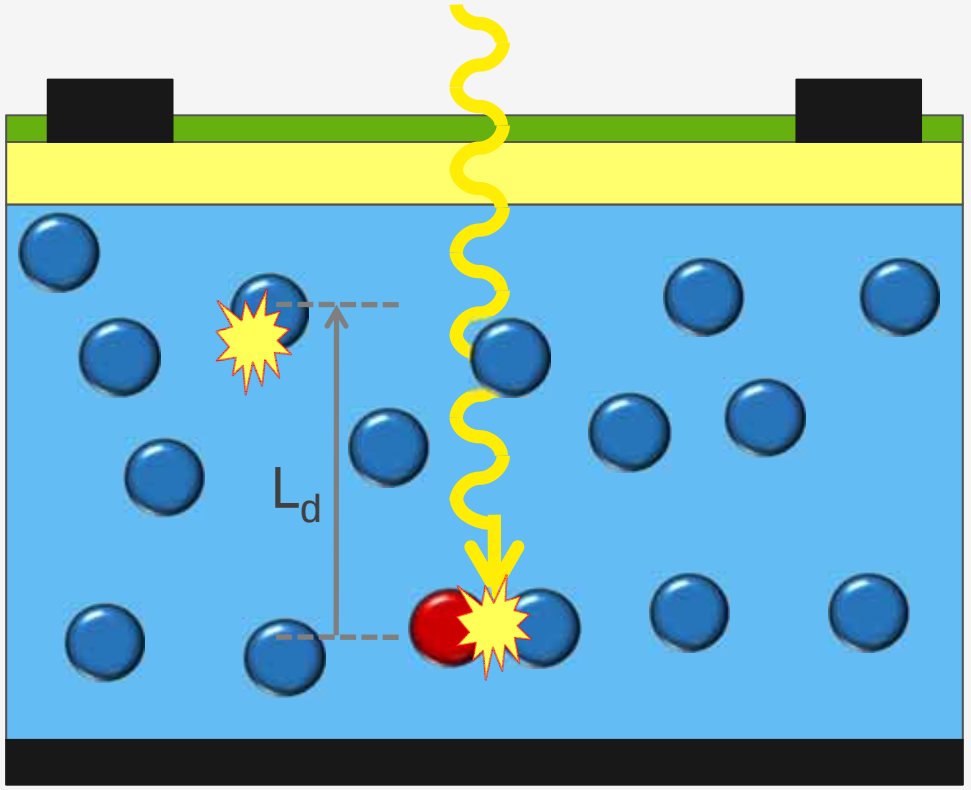
n-doped

**Diffusion length:**

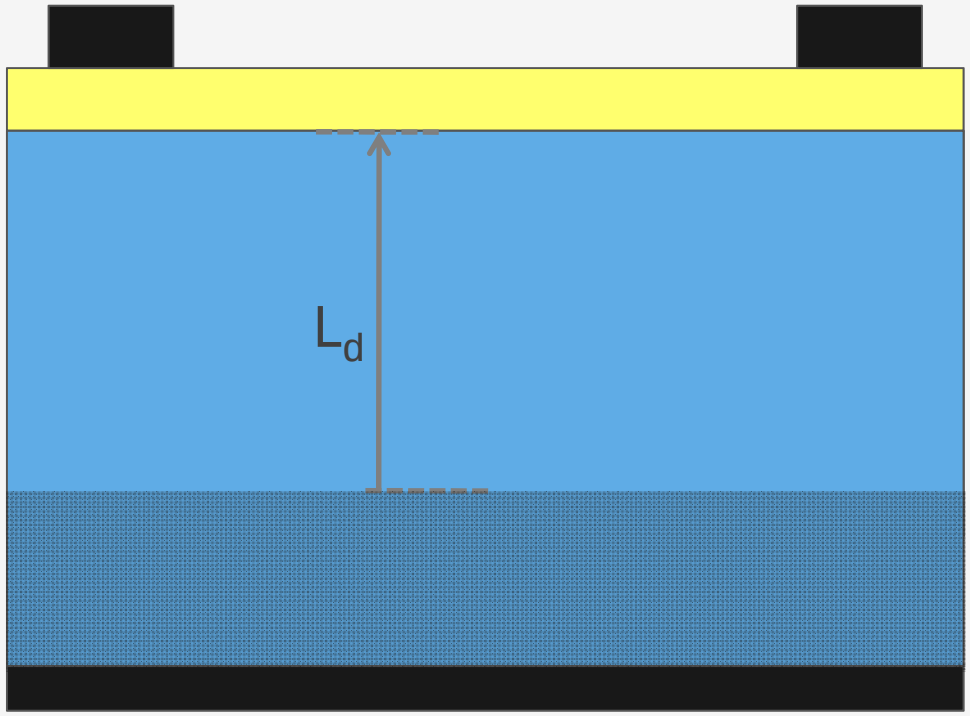
$$L_e = \sqrt{D_e \tau_e} < L_h$$

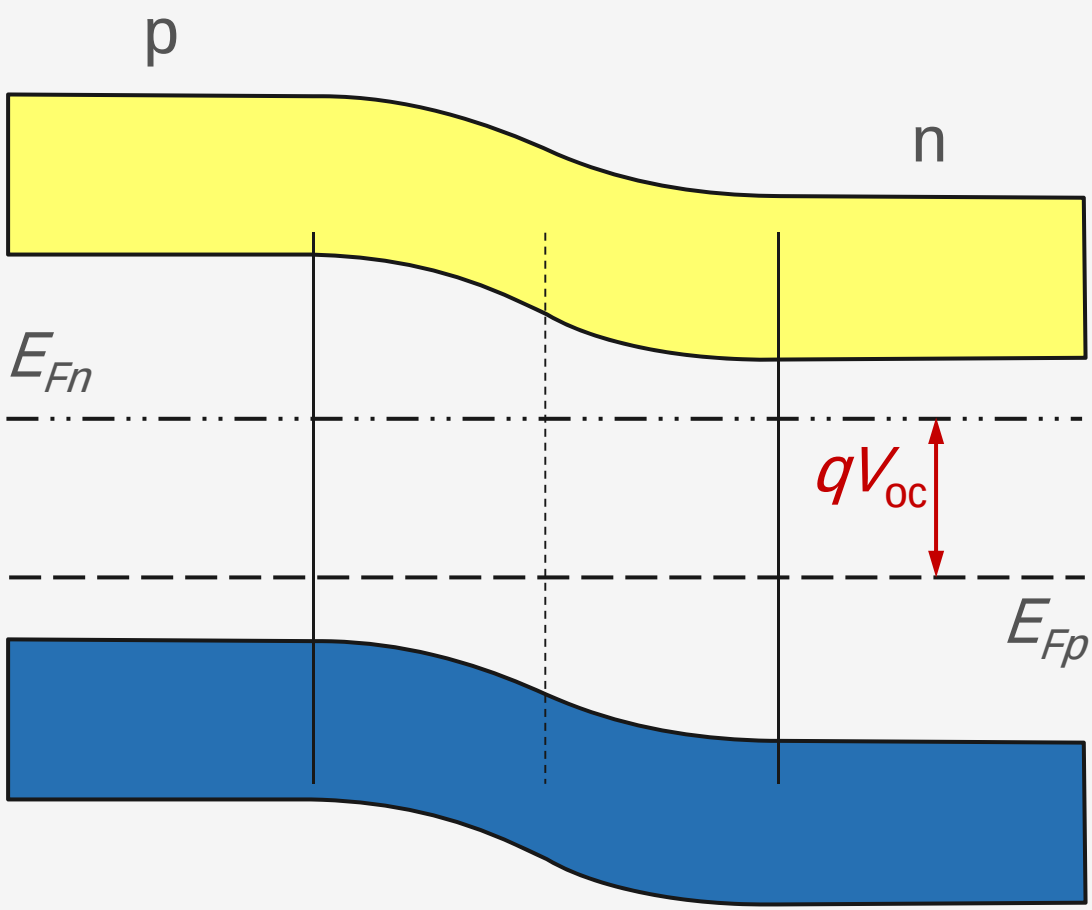
$$L_h = \sqrt{D_h \tau_h} < L_e$$

# Minority carrier diffusion length



# Relation between diffusion length and typical thickness of solar cells




p
n
$E_{Fn}$
$qV_{oc}$
$E_{Fp}$