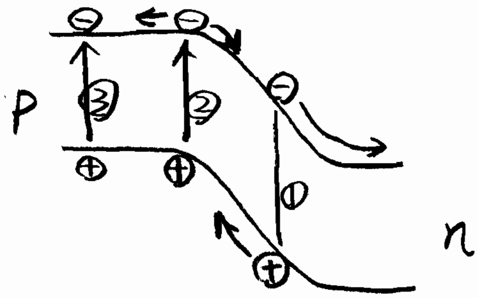
P-i-n Photodiode

Reverse-biased p-n junction.



Photon absorbed in

① depletion region. electrons and holes are separated and collected

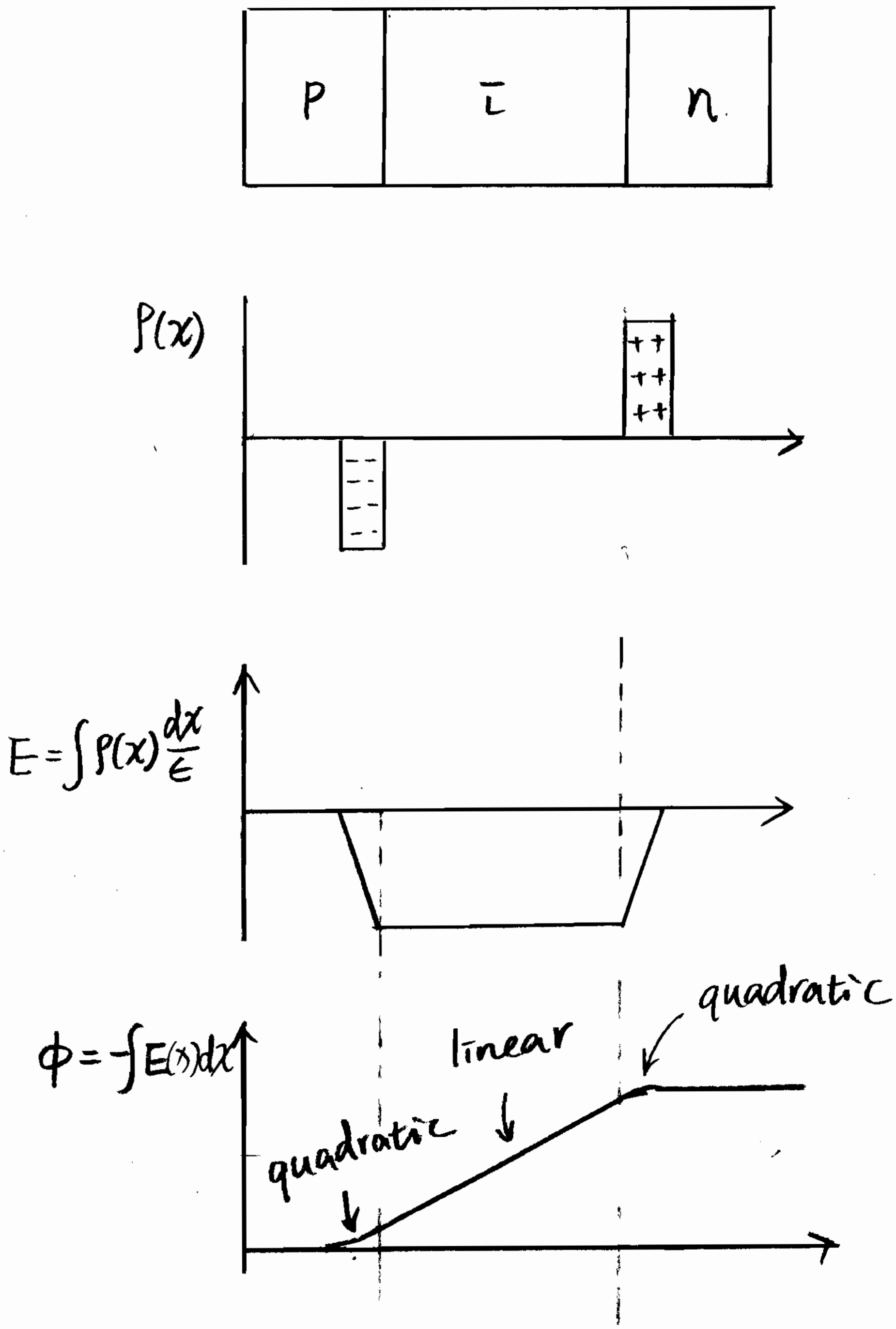
② depletion (e.g. on p-side): electron will diffuse to depletion region, and produce photocurrent

③ neutral region: recombine without generating i_{ph}.

① most desirable

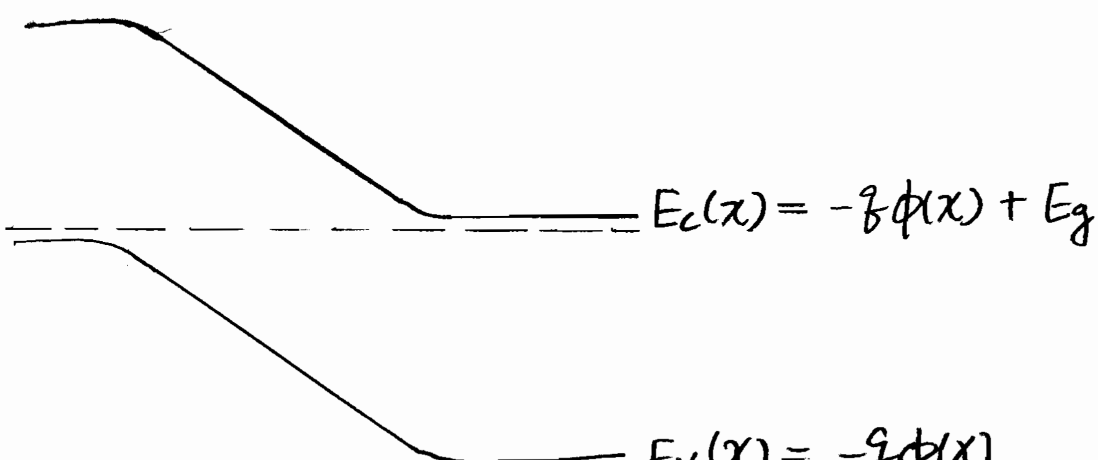
② may have long tail in temporal response (diffusion tail)

To widen depletion region. ⇒ p-i-n



P and n region can be large-E_g material to minimize absorption

$\Rightarrow$ P-i-N

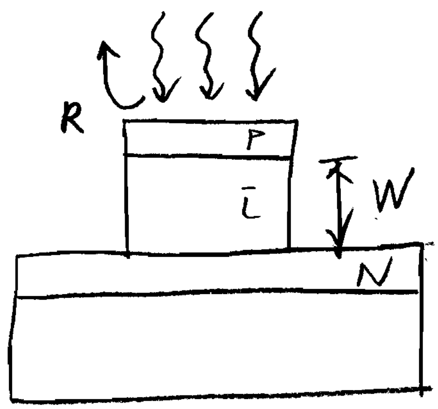


Additional benefits of P-i-N

- Smaller capacitance ⇒ smaller RC, higher speed
- Longer absorption ⇒ higher efficiency
- But longer transit time ⇒ lower speed.

Quantum Efficiency

① Surface-illuminated p-i-n



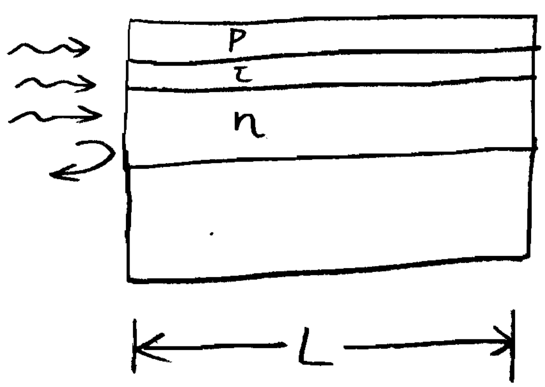
Neglect diffusion current

$$\eta = \eta_i \cdot (1-R)(1-e^{-\alpha W})$$

α = absorption coef

$\alpha \sim 10^4\ cm^{-1}$ for direct bandgap

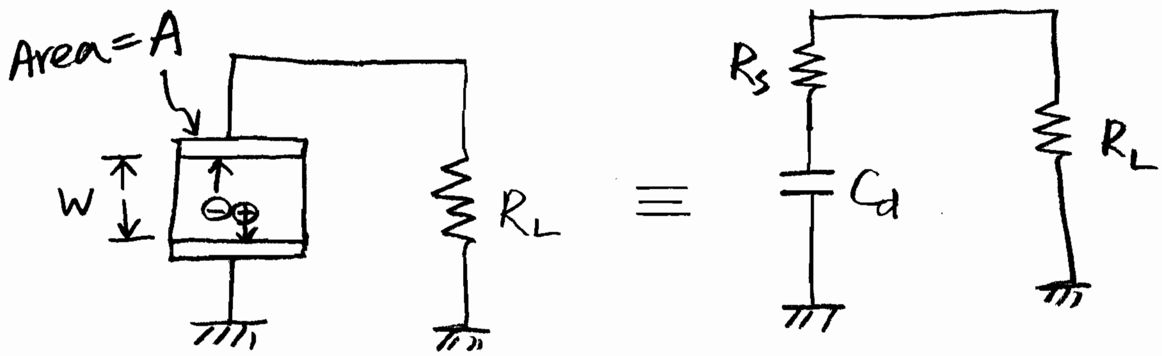
② Waveguide p-i-n



$$\eta = \eta_i (1-R)(1-e^{-\alpha \Gamma \cdot L})$$

Γ = confinement factor

Frequency Response



① RC charging
② Transit time

<u>RC</u>: $R = R_s + R_L$ ← input impedance of the following stage

↑ (R_s): contact resistance + resistance of P and N region.

$$C_d = \frac{\epsilon A}{W}$$

$$\omega_{RC} = \frac{1}{RC_d}$$

<u>Transit time</u>: