3.5 Quantum Efficiency & LED Power

- The **internal quantum efficiency** (η_{int}) is defined as the ratio of radiative recombination rate to the total recombination rate.

$$\eta_{int} = \frac{R_r}{R_r + R_{nr}}$$

where,

R_r is radiative recombination rate.

R_{nr} is non-radiative recombination rate.

- If n are the excess carriers, then radiative life time, $\tau_r = \frac{n}{R_n}$ and non-radiative life time, $\tau_{nr} = \frac{n}{R_{nr}}$
- The internal quantum efficiency is given as -

$$\eta_{int} = \frac{1}{1 + \frac{R_{nr}}{R_r}}$$

$$\eta_{int} = \frac{1}{1 + \frac{\tau_r}{\tau_{nr}}}$$

- The recombination time of carriers in active region is T. It is also known as bulk recombination life time.

$$\frac{1}{\tau} = \frac{1}{\tau_r} + \frac{1}{\tau_{nr}}$$

- Therefore internal quantum efficiency is given as

$$\eta_{int} = \frac{\tau}{\tau_r}$$

- The interval quantum efficiency in the active region is a fraction of electron-hole pairs that recombine radiatively.
- If the current injected into the LED is I and q is electron charge then total number of recombination's per second is

$$R_r = \eta_{int} \times \frac{I}{q}$$

- Optical power generated internally in LED is given as

$$P_{int} = \left(\eta_{int} \times \frac{I}{q}\right) \cdot h\nu$$

$$P_{int} = \left(\eta_{int} \times \frac{I}{q}\right) \cdot h\frac{c}{\lambda}$$

$$P_{int} = \eta_{int} \cdot \frac{hcI}{q\lambda}$$

- Not all internally generated photons will available from output of device. The external quantum efficiency is used to calculate the emitted power.
- The external quantum efficiency is defined as the ratio of photons emitted from LED to the number of photons generated internally. It is given by equation

The optical output power emitted from LED is given as

$$P = \frac{1}{n(n+1)^2} \cdot P_{int}$$