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1 Paper

2 Internal Fluorescence

Define the internal fluorescence as η_{if}. Then, the dark current is

$$F_{co} = \tag{2.1}$$

From `https://arxiv.org/pdf/1106.1603.pdf`

$$V_{oc} = V_{oc-ideal} - kT|\ln \eta_{ext}| \tag{2.2}$$

where η_{ext} is the external fluorescence efficiency. η_{ext} is less than or equal to one, and thus represents a lose in voltage due to poor light extraction.

$$R_{recomb} = \frac{1}{\eta_{ext}} R_{em} \tag{2.3}$$

If $\eta_{ext} = 1$, the internal recombination rate, R_{recomb} equals the external emission rate, R_{em}. This means, every carrier recombines radiatively, and every radiated photon successfully escapes.

If for example, $\eta_{ext} = 0.5$, $R_{recomb} = 2R_{em}$. This means, that only half of the carriers recombine and emit photons that make it out of the cell. The total recombination rate is twice the rate of external emission.

From `http://optoelectronics.eecs.berkeley.edu/ThesisOwenMiller.pdf`,

$$np = n_i^2 \exp\left[\mu/kT\right] \tag{2.4}$$

where μ is the Fermi energy. At quasi-equilibrium,

$$n = N_c e^{-(E_c - E_{Fn})} / kT \tag{2.5}$$

$$p = N_v e^{-(E_{Fp} - E_v)} / kT \tag{2.6}$$

So, at quasi-equilibrium,

$$\begin{align} np &= N_c e^{-(E_c - E_{Fn})/kT} N_v e^{-(E_{Fp} - E_v)/kT} \tag{2.7} \\ &= N_c N_v e^{-(E_c - E_v)/kT} e^{(E_{Fn} - E_{Fp})/kT} \tag{2.8} \\ &= n_i^2 e^{(E_{Fn} - E_{Fp})/kT} \tag{2.9} \\ &= n_i^2 e^{qV/kT} \tag{2.10} \\ &= n_i^2 e^{\mu/kT} \tag{2.11} \\ & \tag{2.12} \end{align}$$

The total photon emission rate is

$$R_{em} = e^{\mu/kT} \int \int A(E,\theta) b(E) \cos(\theta) dE d\Omega \tag{2.13}$$

$$R_{em} = q \int_0^\infty b_e(E, qV) - b_e(E, 0) dE \tag{2.14}$$

3 Step Function Absorber

The current-voltage is calculated from