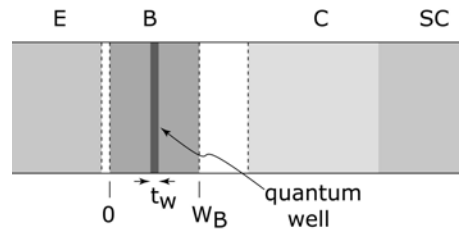

EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
Instructor: Debdeep Jena (djena@nd.edu, x8835)

2nd Mid-Term Exam

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Problem (20 Points)



You will not need your calculator for this question!

Consider the short base GaAs (intrinsic carrier density n_i) n-p-n bipolar transistor shown above. The depletion regions are depicted by dashed boxes. A quantum well (QW) of thickness t_w has been inserted in the middle of the quasi-neutral base layer of thickness W_B and doping N_{AB} . The composition and the thickness of the QW is designed such that the radiative recombination time of electron hole pairs inside the well is τ_{rad} , and the photons emitted from this recombination process falls in the red region of the electromagnetic spectrum. Outside the QW, the non-radiative recombination time (by Shockley-Read-Hall processes) is τ_{nr} . It is also given that $\tau_{rad} \ll \tau_{nr}$. Minority carrier diffusion constant in the base is D_{nB} . Denote the minority carrier density in the base at a point x by $n_p(x)$.

- Sketch the minority carrier distribution $n_p(x)$ in the base *with* and *without* the quantum well when the transistor is biased in the forward-active mode with BE bias V_{BE} .
- Assume that $t_w \ll W_B$, and hence minority carrier density across the QW is constant, equal to $n_p(W_B/2)$. What is the recombination current density that results in red emission? Call it J_{QW} , and express it in terms of $n_p(W_B/2)$ and other given parameters.
- Using the current continuity across the base region, find $n_p(W_B/2)$ in terms of all given parameters. Verify that $n_p(W_B/2)/n_p(0) = 1/2$ for $t_w = 0$. For the special case where $W_B = 0.1L_n$ (L_n is minority carrier diffusion length), $t_w = W_B/10$ and $\tau_{rad} = \tau_{nr}/2000$, find the fraction $n_p(W_B/2)/n_p(0)$.
- Assume that the reverse injection of holes from the base into the emitter is negligible. How is the gain affected by the QW? Explain *quantitatively* by calculating the base transport factor.
- Explain *qualitatively* how the base transit time is affected with and without the QW. Comment on how the introduction of the QW has affected the speed of the bipolar transistor. (Bonus: If you have time, can you give a quantitative estimation of the base transit time with the QW?).