EE566 Solid State Devices

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Assignment 8
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Collector transit times and Kirk effect

Problem 1: *Collector transit time in Bipolar Transistors*

In this problem, you will show that for a bipolar transistor, the collector transit time through a collector depletion width W_C is $\tau_C=W_C/2v_{sat}$, where v_{sat} is the saturation velocity of electrons in the collector. [Note that many textbooks erroneously give a $\tau_C=W_C/v_{sat}$ (Shur falls in that category, so you can't find the solution to this problem in the textbook!).] To derive the transit time, do the following (collector depletion region is $0<x<W_C$) –

a) Denoting the electron density at any x as $n(x)$, show that the *displacement current* [$J_D=\varepsilon_S(\partial F/\partial t)$, F is the electric field] for the BC capacitor associated with a sheet of charge located between x and $x+\Delta x$ is $\Delta J_D=qv_{sat}n(x)\Delta x/W_C$. What is the expression for the *TOTAL* displacement current?

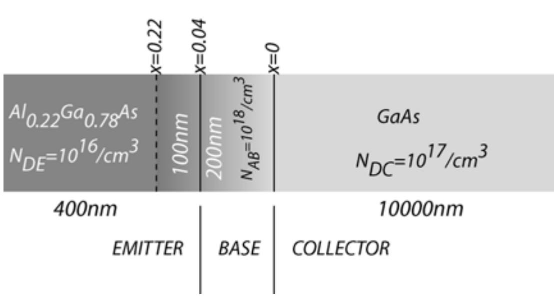
b) Now consider the electrons moving as a traveling wave with a speed equal to the electron saturation velocity v_{sat}. The carrier distribution may then be written as $n(x,t)=n_0 exp[i\omega(t-x/v_{sat})]$. Using the result from part (a), show that the displacement current *magnitude* can now be written as

$$|J_D(\omega)|=qn_0v_{sat}\frac{\sin(\omega\tau_C)}{\omega\tau_C},$$

where $\tau_C=W_C/2v_{sat}$. Thus, in reality, thought the actual time taken by *individual electrons* to move through the base is W_C/v_{sat}, the time delay associated with the current (or signal) is only half of it.

Problem 2: *Kirk effect at high Injection*

(Note that this HBT structure is the same as in Assignment 7.) Use constants for GaAs at 300K.



a) Calculate the current density for the onset of Kirk effect, J_{kirk}. Assume a collector-base reverse bias of $V_{BC}=4Volt$.

b) Plot the base-widening (in nm) as a function of the current density for $J_C>J_{kirk}$.

c) Comment on how Kirk effect harms the device performance, and how to deal with the problem.