Photonics, Spring 2023

Exercises to be returned via Google Classroom by **14:00 next Tuesday 21.3.** For each problem, ½ a point will be awarded for an honest effort and 1 point for a well worked solution. Exercise sessions are held on Tuesdays from 16:00 - 18:00 at Chemicum A121.

Exercise 8, 21.3.2023

This week's exercises have to do with some fundamental concepts relating to semiconductors, including electron energy levels and the accompanying statistics (**Optoelectronics and Photonics: Chapter 3**).

1. Fundamental concepts relating to semiconductor (4 points)

In the context of semiconductors, verbally define/describe the following:

a) Density of states (DOS) $g(E)$
b) Fermi-Dirac function $f(E)$
c) The product $g(E)f(E)$ and it's integral
d) Degenerate and nondegenerate semiconductors, and how Boltzmann statistics relates to the latter

2. Electrons in the CB of a nondegenerate semiconductor (4 points)

a) Consider the energy distribution of electrons $n_E(E)$ in the conduction band (CB) in a nondegenerate semiconductor. Assuming that the density of state $g_{CB}(E) \propto \sqrt{E - E_c}$ and using Boltzmann statistics $f(E) \approx \exp[-(E - E_F)/k_B T]$, show that the energy distribution of the electrons in the CB can be written as:

$$n_x(x) = C \exp(-x)$$

where $x = (E - E_c)/k_B T$ is the electron energy in terms of $k_B T$ measured from E_C, and C is a constant at a given temperature (independent of E).

Hint: Introduce an arbitrary constant based on the proportionality argument for $g_{CB}(E)$. Try then to arrive at the desired form by introducing multiplier terms in the form a/a.

b) Setting arbitrarily $C = 1$, plot $n(x)$. Where is the maximum and what is the FWHM of the curve?

c) Using numerical integration, show that the average electron energy in the CB is $\frac{3}{2}k_B T$ (above the bottom of the conduction band).

Hint: The approach is similar to what we have seen with time-averaged quantities. Now instead of time, the normalizing quantity is the electron concentration $n_E(E)$. Note that the total energy in a given state is $En_E(E)$. What should the integral expression for the average then look like? Try to then express it as a function of x, as in part (a).

d) Show that the maximum in the energy distribution is at $x = 1/2$ or at $E_{max} = \frac{1}{2}k_B T$.