

MIT OpenCourseWare  
<http://ocw.mit.edu>

## 3.23 Electrical, Optical, and Magnetic Properties of Materials

Fall 2007

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.

# Homework # 12

Nicolas Poilvert & Nicola Marzari

December 6, 2007

*Numerical answers with no derivation or justification will not be credited.*

## 1 Average lifetime of excited carriers.

Consider Figure 5.8 p. 102 of your book *Optical Properties of Solids* by Mark Fox. The photoluminescence spectrum is plotted at two different time delays after  $2 \times 10^{24} \text{ m}^{-3}$  carriers have been excited using an ultra-short laser pulse.

- a) Why is the photoluminescence spectrum time-dependent? What is the underlying physical phenomenon?
- b) If the effective carrier temperature was 0 K, calculate what the electron Fermi energy would be for the initial carrier density. Take  $m_e^* = 0.039m_0$ .
- c) Do the same for the hole Fermi energy. Assume that the densities of states from the light and heavy hole bands can just be added together. Take  $m_{hh}^* = 0.45m_0$  and  $m_{lh}^* = 0.05m_0$ .
- d) The effective carrier temperature for the 24 ps spectrum is 180 K. Are the carriers degenerate? Explain why.
- e) Propose a graphical method to find the electron Fermi energy 24 ps after the excitation. Is the value that you find consistent with the answer you gave in b)?
- f) Using the same idea as in e), find an estimate of the carrier density at 250 ps. Hence estimate the average lifetime of the carriers.

## 2 Laser oscillation.

- a) Explain briefly how a laser differs from a simple light emitting diode.

Consider a laser made up of a 10 cm long ruby rod (refractive index = 1.76).

- b) Calculate the reflectivity of the ruby-air interface.
- c) Calculate the frequency separation of the longitudinal modes.

d) Suppose the ruby rod is coated so that one end has a reflectivity of 95%. The other end is uncoated. Calculate the threshold gain coefficient for the laser if the scattering and other impurity losses are negligibly small.

### **3 Power efficiency.**

A laser diode emits at 800 nm when operating at an injection current of 90 mA.

a) Calculate the maximum possible power than can be emitted by the device.

b) Calculate the power conversion efficiency, if the actual power output is 45 mW and the operating voltage is 1.8 V.

c) The threshold current of the laser is 30 mA. What is the slope efficiency and the quantum efficiency?