S-104.3310 Optoelectronics **Exam** **15.12.2011**

You can answer either in english or in finnish!

1. We want to grow a GaN/InGaN multi quantum well structure to make a UV laser.

a) Calculate the lattice constant for $In_{0.1}Ga_{0.9}N$ (a(GaN)=3.19Å , a(InN)=3.55Å).

b) Calculate the bandgap energy for $In_{0.1}Ga_{0.9}N$ (E_g(GaN)=3.44eV, E_g(InN)=1.89eV, bowing factor C(InGaN) =1.7eV).

c) According to the Matthews & Blakeslee model, what is the critical thickness of $In_{0.1}Ga_{0.9}N$ on GaN? Is the InGaN layer compressive or tensile stressed and why?

2. Name three non-radiative recombination mechanisms and briefly explain them.

3. a) What material combinations would you use in a light-emitting diode (LED) at the blue and red areas of the visible spectrum, at the near-infrared (≈0.8–1 μm) and at the communication wavelengths 1.3 μm and 1.55 μm?

b) We want to connect our LED chip to an optical fiber. What type of LED structures or designs can be used for that purpose?

4. The operation of a semiconductor diode laser can be described with the rate equations

$$\frac{dn}{dt} = AI - \frac{n}{\tau} - \frac{Bn\varphi}{\tau}$$
$$\frac{d\varphi}{dt} = \frac{Bn\varphi}{\tau} - C\varphi \quad ,$$

Where φ is the photon density, n the injection density, τ the recombination time constant, I the current and A, B, C are parameters. Explain which processes are described by each of the terms in the equations. Has there been used any approximations in the equations? Calculate the photon and injection densities at the steady-state situation.

5. In solar cells a fill factor $FF = I_m V_m / I_{sc} V_{oc}$ is used to define the power extraction efficiency.

a) Draw an image of the solar cell's current-voltage characteristics. The image should indicate and explain each of the terms used in the above FF-equation.

b) How should one design the solar cell in order to maximize the output power?