S-104.3310 Optoelectronics **Exam** **25.5.2011**

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. a) Write the equation for Fermi-Dirac distribution. What does it describe?

b) How does one define the Fermi level E_F?

c) What is meant with Boltzmann approximation and when is it valid?

3. a) The internal quantum efficiency of some LEDs may approach 100%. Explain briefly why the external quantum efficiencies are considerably lower.

b) How can one increase light extraction from LEDs?

c) How can one produce white LEDs?

4. a) Name three semiconductor laser structures that enable monomode operation (lasing in one longitudinal mode). Describe briefly the principles of each structure.

b) 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?

5. a) Explain the idea and structure of a double heterostructure laser.

b) What are the advantages of quantum well lasers?