ELEC-E3210 Optoelectronics **Exam** **June 8, 2023**

Write your name, student number, degree programme, course code, and date of the exam in one of the answer papers. Write your name and student number in each of the answer papers.

1. Briefly explain the following terms: a) differential gain, b) optical confinement factor, c) Einstein coefficients, d) Pockels effect, e) background current in photodiodes, and f) fill factor.

2. a) Describe the different efficiencies used to characterize LEDs. b) Explain the layer structure and the energy band structure of a double heterostructure laser. What are the two main advantages of this laser type?

3. a) Compare the characteristics, e.g., output power, threshold current and mode structure of an edge-emitting stripe laser and a vertical-cavity surface emitting laser. b) Describe at least three diode laser component types capable of operating in a single longitudinal mode.

4. a) Explain, what processes are included in the RATE equations describing the dynamics of a semiconductor laser. Explain how each of these terms depends on the main variables. b) Describe the differences between a semiconductor laser diode and a semiconductor optical amplifier. Discuss also the linearity of a semiconductor optical amplifier.

5. Quantum efficiency of an InGaAsP/InP avalanche photodiode is 0.8 at the wavelength of 1.3 μm. When the input optical power is 1.0 μW, the output current from the detector is 20 μA. The thickness of the avalanche layer is 1.5 μm. a) What is the avalanche gain? b) Calculate the impact ionization coefficient if only the electrons cause multiplication.

Natural constants:

$m_e = 9,1091 \times 10^{-31}$ kg	$m_p = 1,6725 \times 10^{-27}$ kg	$m_n = 1,6748 \times 10^{-27}$ kg	amu $= 1,6605 \times 10^{-27}$ kg
$e = 1,6021 \times 10^{-19}$ C	$c = 2,9979 \times 10^{8}$ m/s	$h = 1,0545 \times 10^{-34}$ Js	$\mu_B = 9,2732 \times 10^{-24}$ JT^{-1}
$\varepsilon_0 = 8,8544 \times 10^{-12}$ C^{2}N^{-1}m^{-2}	$K_e = 1 / 4\pi\varepsilon_0$	$\mu_0 = 1,2566 \times 10^{-6}$ mkgC^{-2}	$K_m = \mu_0 / 4\pi$
$\gamma = 6,670 \times 10^{-11}$ Nm^{2}kg^{-2}	$N_A = 6,0225 \times 10^{23}$ mol^{-1}	$R = 8,3143$ JK^{-1}mol^{-1}	$k = 1,3805 \times 10^{-23}$ JK^{-1}