Tampere University
FYS-5456 Applications of Laser Technologies
Exam, Tuesday 25.2.2020, 13:00 - 16:00
Examiner: Mircea Guina

Obs.: Only a non-programmable calculator is allowed. In order to receive the credit points please remember to give feedback about the course through the Kaiku-system!

1) **Answer shortly the following question (6p):**
   a) Name the three operation modes of pulsed lasers.
   b) Name three benefits of optical communication over other communication methods.
   c) Name the three main categories in which lasers are separated according to gain media.
   d) Explain the term "heat affected zone" (HAZ) in material processing.
   e) Explain the term "wavelength-division multiplexing" (WDM).
   f) Explain the abbreviation "LIDAR".

2) **Answer only two (2) out of the three (3) questions (6p):**
   a) What are the most important phenomena in laser-matter interactions? Give a short description and explain under which conditions they appear. (3p)
   b) Laser induced interaction mechanisms in tissue can be divided into five categories. Choose three of them and explain how they work, what are the typical laser exposure times and typically used lasers. In addition, mention at least one existing medical application for each chosen mechanism. (3p)
   c) Describe the principle of scanned-wavelength direct-absorption spectroscopy. (3p)

3) Calculate the M^2 value of the two lasers described below and comment on the transverse mode profile you would expect for each of them (6p).
   The following equations are given:

$$\mathrm{BPP} = \varphi \cdot w_0 = M^2 \cdot \frac{\lambda}{\pi} \qquad \mathrm{NA} = n \cdot \sin(\varphi)$$

   a) **Coherent DILAS** fibre coupled multi-diode laser module
      - NA = 0.22 (numerical aperture)
      - Fiber core diameter 200 µm (to be seen as the beam waist diameter)
      - λ = 640 nm
   b) **M-SQUARED Equinox CW** 532 nm laser
      - Half opening (divergence) angle φ = 0.013°
      - Beam waist radius w_0 = 14.3 µm
      - λ = 532 nm

4) A time-of-flight type LIDAR is using a pulsed laser at 905 nm having pulse length of 10 ns. Detection electronics is capable of recording the received signal at 1 GHz frequency. The time delay between the pulse emission and receiver pulse is 0.3 μs.

a) What is the distance of the scattering object from the lidar instrument?
b) What is the smallest distance of two small objects at approximately same direction from the lidar that the instrument can separate from each other, i.e. the spatial resolution in the distance measurement? **(6p)**

5) We want to perform Fourier-domain OCT imaging with the best possible axial resolution. You have the choice between a superluminescent diode (SLED) with central wavelength at 800 nm, 1100 nm, 1300 nm, or 1550 nm. The spectral bandwidth of the different SLEDs at 800 nm, 1100 nm, 1300 nm, and 1550 nm is 15, 25, 45, and 55 nm respectively. **(6p)**

a) Which SLED should be used to obtain the best possible axial resolution and what is the achieved resolution?
b) Using this SLED, what should be the numerical aperture of the lens used to focus light on a sample under test to obtain a lateral resolution of at least 5 μm?
c) What is the period of the spectral interference in nm corresponding to the surface of a sample displaced by 500 μm distance from the equal path position in the interferometer arms? Hint: convert the interference period to optical delay and then to optical path difference.

- The axial resolution of OCT is given by $0.44\ \lambda^2/\Delta\lambda$
- The lateral resolution of OCT is given by $0.64\lambda/NA$