**Exam Photonics January 6 2019**

**In answering the following questions:**

* **Be concise and to the point**
* **Explain everything as if the reader is an electrical engineer or a physicist who has NOT taken the Photonics course**
* **Write your name on every page**

**If a question is not fully clear, ask for clarification.**

**All questions have equal weight. The exam is open book.**

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1. Can a lens system consisting of two positive lenses (spaced by a certain distance) have an overall refractive power that is negative? Explain your answer.

Can a lens system consisting of two negative lenses (spaced by a certain distance) have an overall refractive power that is positive? Explain your answer.

1. You image the moon onto a sheet of paper by means of a simple lens with a focal distance of 2cm. Give an estimate of the size of the image for the following situations:
   1. The diameter of the lens is 1cm
   2. The diameter of the lens is 0.1mm

Assume the lens is free of aberrations.

First give an answer from a purely geometric optics point of view. After that adapt your answer by also considering diffraction effects (whereby you can use an approximate Gaussian beam approach).

Some data about the moon:

* [Distance to Earth](https://www.google.be/search?biw=1536&bih=663&q=moon+distance+to+earth&stick=H4sIAAAAAAAAAOPgE-LQz9U3MCkvi9cyyE620k8sLinKz8vPrdRPTs1JLS7JTMyJz0_KSk0usUrJLC5JzEtOVSjJV0hNLCrJAAC6vQDRPgAAAA&sa=X&ved=0ahUKEwilk9jytY3KAhXMWhoKHS3XCvIQ6BMIkQEoADAU): 384400 km
* [Radius](https://www.google.be/search?biw=1536&bih=663&q=moon+radius&stick=H4sIAAAAAAAAAOPgE-LQz9U3MCkvi9fSyk620k8sLinKz8vPrdRPTs1JLS7JTMyJz0_KSk0uscpNTcyLL0pMySwtBgCZJ6O1OAAAAA&sa=X&ved=0ahUKEwilk9jytY3KAhXMWhoKHS3XCvIQ6BMIlAEoADAV): 1737 km
* Average wavelength of moonlight: 550nm

1. A monochromatic TE-polarized plane wave is incident on a glass prism (with refractive index of 1.3) as shown below whereby the refracted plane wave hits the opposite glass wall under normal incidence (in other words: sin(θ)=1.3 sin(45)). Two of the three faces of the prism are coated such that they act as perfect 100% mirrors, as shown. In which directions is light leaving the prism? Make a qualitative drawing of the intensity of the output beams as a function of wavelength. What can you say about the maximum and the minimum transmission on these spectral plots? Is power conserved?

Note: assume that all beams are plane waves. In other words, neglect the finite beam size inside the prism and for the output light.

n=1.3

45°

45°

θ

Perfect

100%

mirror

L=10mm

L=10mm

1. Assume a fiber optic link that connects Brussels with Paris (300 km). At the transmitter end a laser beam with wavelength of 1.55 µm and a power of 10 mW is coupled into the fiber and is on-off modulated at 10Gb/s (on = a bit with value “one”; off = a bit with value “zero”) . The fiber has a loss of 0.15 dB/km and a group index of 1.5.

* How many bits are travelling in the fiber at any point in time.
* How many photons does a “one”-bit represent at the transmitter side.
* How many photons does a “one”-bit represent at the receiver side.

Note: neglect dispersion.

1. Explain why the population inversion in a laser is independent of the pump rate as soon as the laser operates at or above threshold. Plot how both the stimulated emission and spontaneous emission evolve as a function of pump rate (below and above threshold).
2. Waveguides can have a small or a large difference between the refractive index of the core and that of the cladding. Discuss the advantages and disadvantages of a small and a large difference. Why is the index difference chosen to be very small in optical fibers used for telecommunication?
3. Explain the trade-offs between responsivity and bandwidth in a surface illuminated semiconductor photodetector.
4. Which statement is more correct (and why):
   1. the lens in a CD-player needs to have a small focal distance
   2. the lens in a CD-player needs to have a large numerical aperture
5. A right-handed circularly polarized plane wave is hitting a perfect mirror under normal incidence. What is the polarization of the reflected wave?
6. A semiconductor laser with a length of 300 micron has facets formed between the semiconductor waveguide (n=3) and air. The scattering loss of the laser waveguide is 2/cm. The lasing wavelength is 1.55um. Make an estimate of the gain per unit length the lasing mode experiences. Express this value in 1/cm and dB/cm. Calculate the differential responsivity (in W/A) of this laser, assuming an injection efficiency of 100%.