PHYS-E0435 - Optical Physics Exam, 14.12.2021

PROBLEMS:

1. Short tasks on three different topics:

(a) Describe the difference between the microscopic and macroscopic Maxwell equations and the physical meaning of the polarization and magnetization densities. (2 p)

(b) A dot matrix printer prints closely spaced dots which cannot be resolved by a human eye. If the eye pupil has a diameter of 5 mm, what is the maximum distance between the dots such that they cannot be resolved from a distance of 50 cm? [Hint: Assume that the wavelength is 550 nm, at the center of the visible range] (2 p)

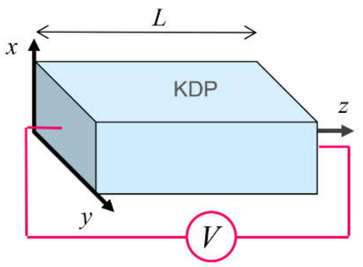
(c) Describe qualitatively how can the Lorentz oscillator model be used to calculate the refractive index of a resonant medium. (2 p)

2. A KDP crystal in a Pockels cell shown in the figure below is used as a phase retarder or a polarization modulator for an optical beam propagating along the z-axis.

(a) Describe how can the device be used as a phase retarder and calculate what voltage should be applied to the crystal to shift the phase of the beam by 30°. (2 p)

(b) Assume that the applied voltage is $V_\pi/2$ = 4376 V and find the output polarization of the beam if the incident beam is (1) linearly polarized along the x-axis, (2) linearly polarized at 45° to the x-axis, and (3) right circularly polarized. (2 p)

(c) Describe shortly two different methods to obtain an electro-optic intensity modulator based on this device. (2 p)



$$\bar{\bar{r}} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & r_{41} & 0 \\ 0 & 0 & r_{63} \end{bmatrix}$$

3. Calculate the Fraunhofer diffraction pattern of a transparency that modifies the phase on the incident plane wave by $\varphi(x) = A\sin(2\pi x/\Lambda)$, without changing its amplitude. The incident wave propagates in the z-direction normal to the transparency. Describe shortly how would you calculate the diffraction pattern, if the phase was changed along a line that makes an angle of 45° with the x-axis. [Hint: The following expression for the Bessel function of n^{th} order can be used: $J_n(x) = \frac{1}{2\pi}\int_{-\pi}^{\pi} e^{ix\sin(t) - int} dt$] (6 p)

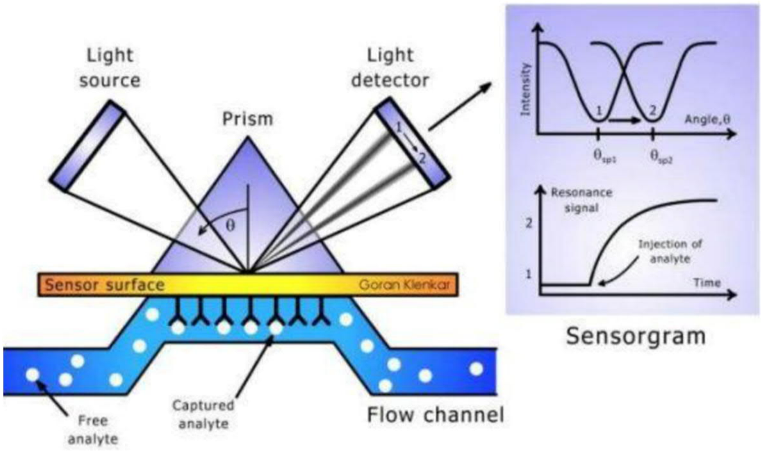
4. Consider a surface plasmon resonance sensor shown in the figure below. The prism is made of glass with refractive index $n_{\text{glass}} = 1.5$, and the flow channel contains a liquid with $n \approx 1.3$.

(a) Find an expression for the resonance angle (θ), at which the incident light couples to the surface plasmon mode. (1 p)

(b) Find an expression for the sensitivity of the sensor to the refractive index of the liquid ($d\theta/dn$). (3 p)

(c) What will be the resonance angle at λ = 600 nm, if the metal film is made of gold with refractive index $n_{\text{gold}} = 0.2487 + 3.075i$ at this wavelength. (1 p)

(d) If the minimum angle that the detector can resolve is 0.05°, what is the minimum change in the refractive index of the analyte that can be measured using this setup? (1 p)



5. A laser operating at λ = 633 nm has a confocal resonator, the mirrors of which has the same radii of curvature. The length of the resonator is 75 cm. The laser gain has a Gaussian spectrum with the width (FWHM) equal to 2 GHz and the peak value exceeding the loss level by a factor of 2.

(a) Assuming that the longitudinal modes of the resonator saturate the gain independently and that one of the modes coincides with the peak of the gain spectrum, calculate the number of the modes in the output beam. (2 p)

(b) What would you choose for a length of an intracavity Fabry-Perot filter to provide a single-longitudinal-mode operation for the laser? (2 p)

(c) An aperture of the radius equal to the beam radius of the fundamental transverse mode can be used to achieve a single-transverse-mode operation of the laser. Select a position inside the resonator for the aperture and calculate its radius. (2 p)