NTNU
Norwegian University of Science and Technology
Department of Physics

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TFY4200 Optikk VK (Optics – advanced course)

Examination May 19th, 2006, Time: 09.00 – 13.00

Allowed aid
Text: All kinds of text-books, supplementing written material, etc, are allowed.
Electronics: Calculator, portable computer (no equipment with internet access, wireless LAN, etc).

Grades to be announced before June 10th, 2006.

The examination problems (and correct solutions) have been reviewed by: Prof Ola Hunderi, May 10th, 2006

Prof. Ola Hunderi

Evaluation/grades
Total number of points of the written examination is 75. These together with lab-report (giving max 25 points) will constitute the basis for evaluation (totally max 100 points). The following table recommended by NTNU will be used for converting to A, B, C, …-scale.
A: better than 85 points
B: better than 75 points
C: better than 65 points
D: better than 55 points
E: better than 35 points
F: less than 35 points

Section A: Problems to which only answers shall be given (each max 5 points)

1: Using infrared (IR) wavelengths it is not trivial to get cheap and broadband polarization components. It is common to utilize an optically flat transparent “glass” plate to obtain a polarizer utilizing the Fresnel reflection equations. With glass we here mean some material transparent in the actual infrared, not necessarily ordinary glass. Germanium (Ge) is usually used for such purposes. The refractive index is approx. 4.0 and it is transparent in essentially the whole thermal IR. Show how to arrange such a Ge-plate if we want to produce linearly polarized light utilizing reflection phenomena. A) Draw a scheme indicating all relevant polarization components with respect to geometrical constraints (angles). B) Calculate the approximate polarization efficiency if un-polarized light is used as input.

2: In a lab-experiment a student makes a prism coupling experiment to examine the optical wave-guiding properties of a thin film of refractive index 1.7 using a red He-Ne laser and a high index prism. The glass substrate is of refractive index 1.5, and the thin film approximately 5 micrometer, so there is guaranteed “wave-guiding” occurring in the film for appropriate excitations using the prism coupling.

Let the axis perpendicular to the film be x, and z the propagation direction of guided modes in the film. Draw the approximate field distributions (as a function of x) of the relevant field components appropriate for the 0-th order wave-guiding mode, for both the A) TE-polarization and, B) TM-polarization.

3: Tellurium of symmetry group 32 may form optically uniaxial crystals. Specifically, $n_E > n_O$ and it is transparent in the range 3.5 – 36 μm, and therefore it is sometimes utilized to produce new laser frequencies in the infrared. The CO_2 laser is a useful and reliable source and one wants to produce 5.3 μm radiation from 10.6 μm using SHG. What is the A) phase-matching angle and B) the appropriate conversion scheme (i.e., oo → e or ee → o) for collinear phase-matching? Take the appropriate refractive indices to be:

10.6 μm: $n_E = 6.247$ and $n_O = 4.792$
5.3 μm: $n_E = 6.306$ and $n_O = 4.855$

4: A uniaxial crystal has the d-tensor as shown below. The optic axis is as usual along the z-direction. Kleinman symmetry applies. What is the "effective nonlinearity" (d_{eff}) for the SHG collinear phase matching condition ee → o ?

$$d_{iJ} = \begin{pmatrix} d_{11} & -d_{11} & 0 & d_{14} & 0 & 0 \\ 0 & 0 & 0 & 0 & -d_{14} & -d_{11} \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

5: The r-tensor describing the electro-optic effect in a crystal having a 3-fold axis of symmetry along the z-axis is given by:

$$r_{Ij} = \begin{pmatrix} r_{11} & -r_{22} & r_{13} \\ -r_{11} & -r_{22} & r_{13} \\ 0 & 0 & r_{33} \\ r_{41} & r_{51} & 0 \\ r_{51} & -r_{41} & 0 \\ -r_{22} & -r_{11} & 0 \end{pmatrix}$$

If in addition it is a two-fold rotation axis about the x-axis, what is the resulting r-tensor.

6: The r-tensor describing the electro-optic effect in a crystal is given below. The crystal is uniaxial with the optic axis along z. You would like to produce a polarization modulator. You are allowed to propagate light and apply a static field (compared to optical frequencies) along the crystallographic directions. How would you manage the simplest possible polarization rotator. Draw a scheme and briefly motivate your answer.

$$r_{Ij} = \begin{pmatrix} r_{11} & 0 & 0 \\ -r_{11} & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & -r_{41} & 0 \\ 0 & -r_{11} & 0 \end{pmatrix}$$

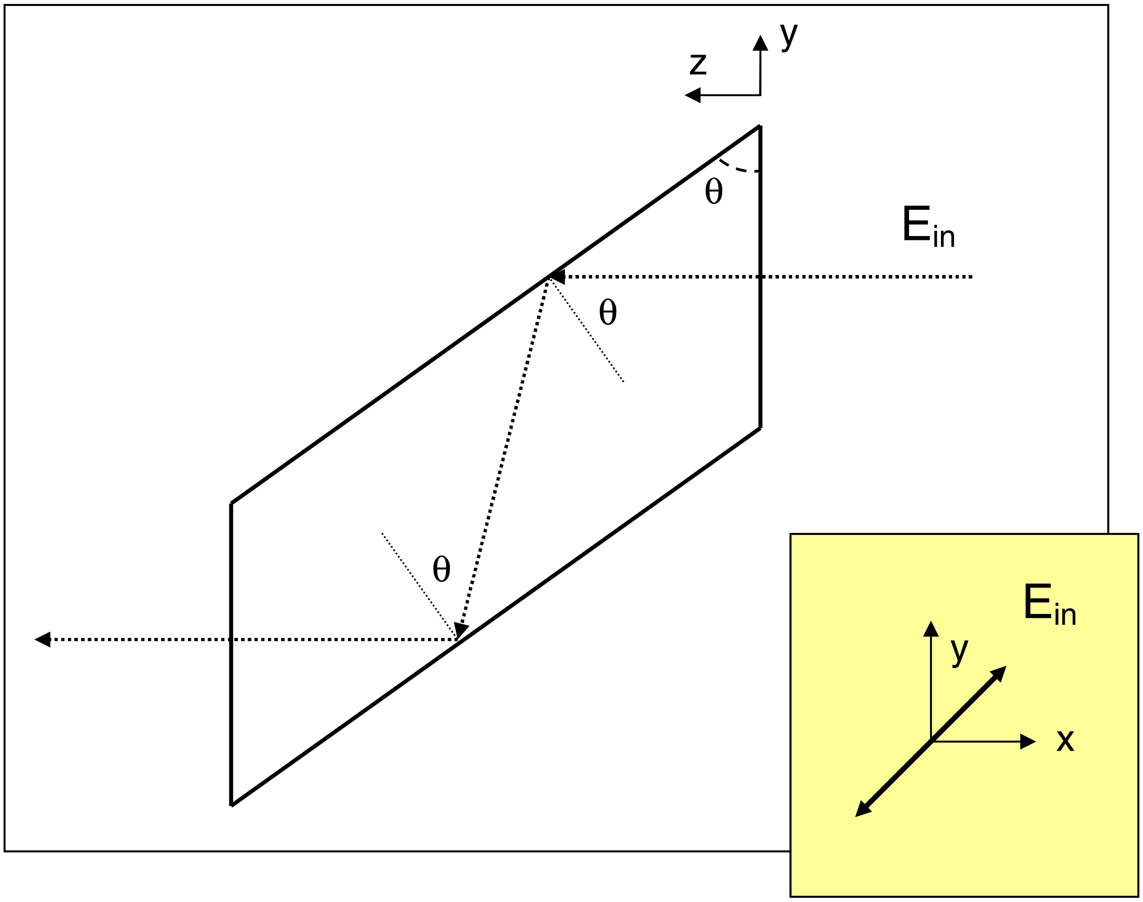
Section B: Problems to which also solutions must be handed in (each max 15 points)

7: One needs to know the polarization state of laser-light emitted from a scattering experiment. Since the scattering process might depolarized the light a Stoke's vector description is necessary. A lab-assistant carries out a series of experiment using a quarter-wave plate and a polarizer. These can both be regarded as "ideal" for the laser-wavelength used.
First she measures the intensity 0.25 i.u. (intensity units) using a vertical polarizer. Secondly, she measures the intensity 0.50 i.u. with the polarizer rotated 45^o. With the polarizer horizontal she obtains 0.75 i.u. Finally, keeping the polarizer horizontal she inserts a quarter wave plate with the fast axis vertical. She then measures 0.25 i.u..

Calculate the corresponding Stokes vector parameter for the scattered light and determine the degree of polarization. Finally, sketch the corresponding polarization ellipse and indicate the rotation of the electric field component with time (for some fixed plane in space along the scattered beam).

8: A planar distribution of point sources is located at a distance z_1 from a lens with focal length f. Using diffraction theory, show where we can find the Fourier transform of the distribution of point surces. (At what distance with respect to the point source distribution and the lens.) The paraxial approximation applies (sometimes also referred to as the small angle approximation or Fresnel approximation).

9: Polarized light (+45°) is incident on a rhomb made out of glass of refractive index 1.5, as shown below. The angle of the rhomb (θ in the Figure) is 53°.



A. Derive expressions of the phase-shift obtained at the two internal reflections.

B. What is the polarization of the light exiting the rhomb.

You may neglect the influence of the reflection in the planar input surface and the planar exit surface.