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TFY4200 Optikk VK (Optics – advanced course)

Examination May 26th, 2008, 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 20th, 2008.

The problems were reviewed by Ass. Prof. Morten Kildemo May 15, 2008.

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: 100-90 points
B: 89-80 points
C: 79-60 points
D: 59-50 points
E: 49-40 points
F: 39-0 points

Section A: Problems to which only answers shall be given (each max 6 points)

1: A long slit of width 0.25 mm, tilted 30° from the vertical axis, is used to examine diffraction phenomena using a coherent parallel laser-beam of an Nd:YAG laser (λ = 1064 nm). One wants to study the Fraunhofer diffraction pattern using a lens with f = 50 cm.

A) Where to put the lens, and where is the diffraction pattern observed? (make a sketch) [1p]

B) Sketch the shape of the observed diffraction pattern in relation to the extension/width of the slit. [2p]

B) Determine the distance between the first minima located on each side of the main spot. You may assume that the extension of the slit is "unlimited". [3p]

2: A student equipped with a photo-detector is investigating the optical properties of Rignes' Pils (a kind of weak beer). She fills a glass of diameter 7 cm with transparent walls, with cold water. Using a laser pointer (green light: 532.5 nm) she measures the transmitted intensity. Replacing the water with beer, the transmitted intensity is reduced with 50%.

What is the absorption coefficient of beer? [6p]

3: The d-matrix for three-wave interactions under Kleinman symmetry in crystals of point group $4mm$ or $6mm$ is indicated below.

$$d = \begin{pmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{15} & 0 & 0 \\ d_{15} & d_{15} & d_{33} & 0 & 0 & 0 \end{pmatrix}$$

What is the effective nonlinearity expressions for the $o+o \Rightarrow e$ and $e+e \Rightarrow o$ SHG interactions, i.e. d_{eff}^{ooe} and d_{eff}^{eeo}, respectively?

Section A, cont: Problems to which only answers shall be given (each max 6 points)

4: Pair the expressions A, B, C with the expressions 1, 2, 3 (answer like A1, C3, etc). [6p]

A: $(\bar{b}\times\bar{c})\cdot\bar{a}-\bar{c}\cdot(\bar{a}\times\bar{b})$

B: $(\bar{c}\times\bar{a})\times\bar{b}$

C: $\bar{c}\times(\bar{a}\times\bar{b})$

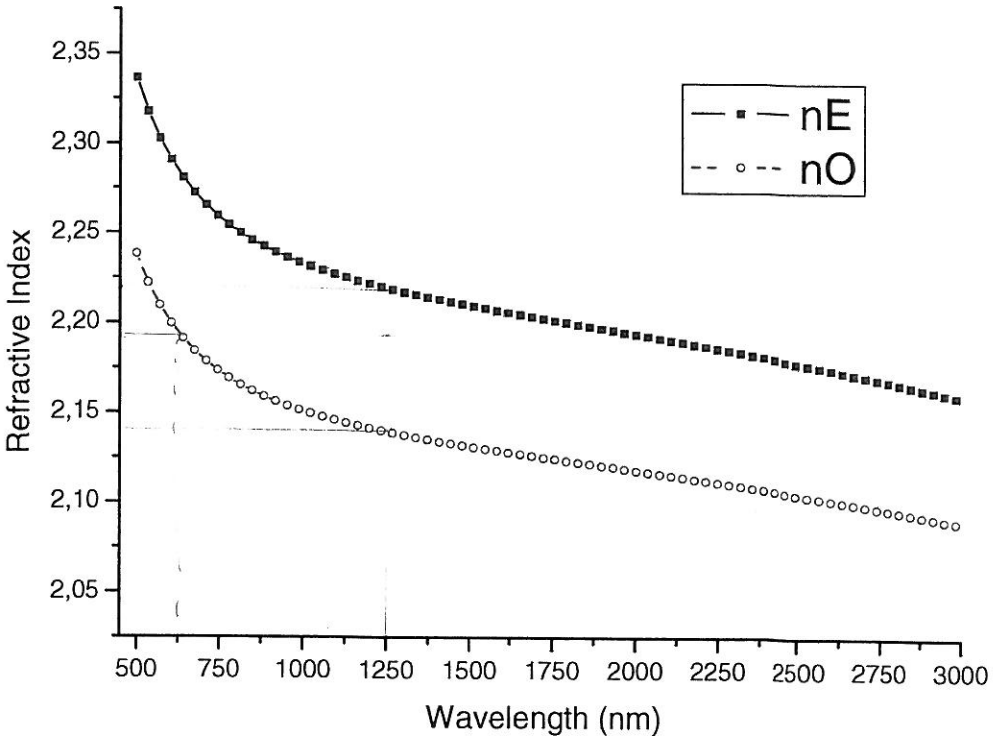
1: $\varepsilon_{rsi}a_j b_k c_s \varepsilon_{ijk}$

2: $a_r b_s \varepsilon_{rsi} c_i - a_i \varepsilon_{kij} b_j c_k$

3: $(\delta_{sj}\delta_{rk}-\delta_{sk}\delta_{rj})c_j a_k b_s$

4 2

5: Congruently grown $LiNbO_3$ doped with 5-mol % MgO forms uniaxial crystals with extraordinary and ordinary refractive index as in the Figure below.



A) What are the possible ways of forming phase-matched SHG, i.e., what kind of polarization for the pump beam and the generated SHG? [2p]

B) What is the phase-matching angle for generating SHG at 625 nm using an infrared pump-beam. [4p]

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

6: You should design a phase modulator for vertically polarized light ($\lambda = 633$ nm). You are allowed to propagate light and apply a low frequency static field (compared to optical frequencies) along the crystallographic directions. There are two kinds of crystals available:

Crystal I: ZnSe. This crystal is isotropic with refractive index n = 2.60, r41 = 2.0 pm/V; and with the following r-tensor,

$$r_{ij} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & r_{41} & 0 \\ 0 & 0 & r_{41} \end{pmatrix}$$

Crystal II: $KNbO_3$. This crystal is biaxial with refractive indices: $n_1 = 2.279$, $n_2 = 2.329$, $n_3 = 2.167$ and electrooptic coefficients: $r_{13} = 28$, $r_{23} = 1.3$, $r_{33} = 64$, $r_{42} = 480$, $r_{51} = 105$ pm/V.

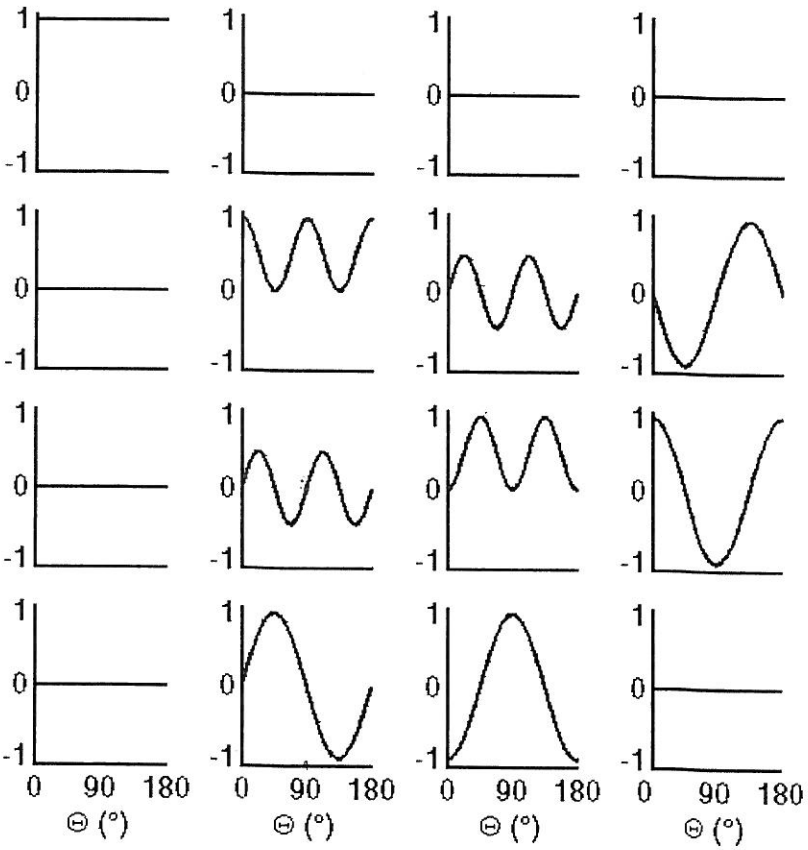
$$r_{ij} = \begin{pmatrix} 0 & 0 & r_{13} \\ 0 & 0 & r_{23} \\ 0 & 0 & r_{33} \\ 0 & r_{42} & 0 \\ r_{51} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

A) Chose one of the crystals and arrange a simple phase modulator. Draw a scheme and briefly explain how it works with reference to the applied electric field, polarized laser beam, crystal symmetry and electrooptic tensor, etc [10p].

B) Calculate the corresponding half-wave voltage [5p].

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

7: A PhD student in applied physics constructed a Mueller matrix ellipsometer and used it to analyse a bunch of unknown flat optical components he found in a closet. The transmitted light was aligned to be perpendicular with respect to the flat surface. He rotated the component about an axis parallel to the transmitted light (rotation angle Θ). The resulting Mueller matrix elements (arranged as a Mueller matrix) as a function of rotation angle are displayed below:

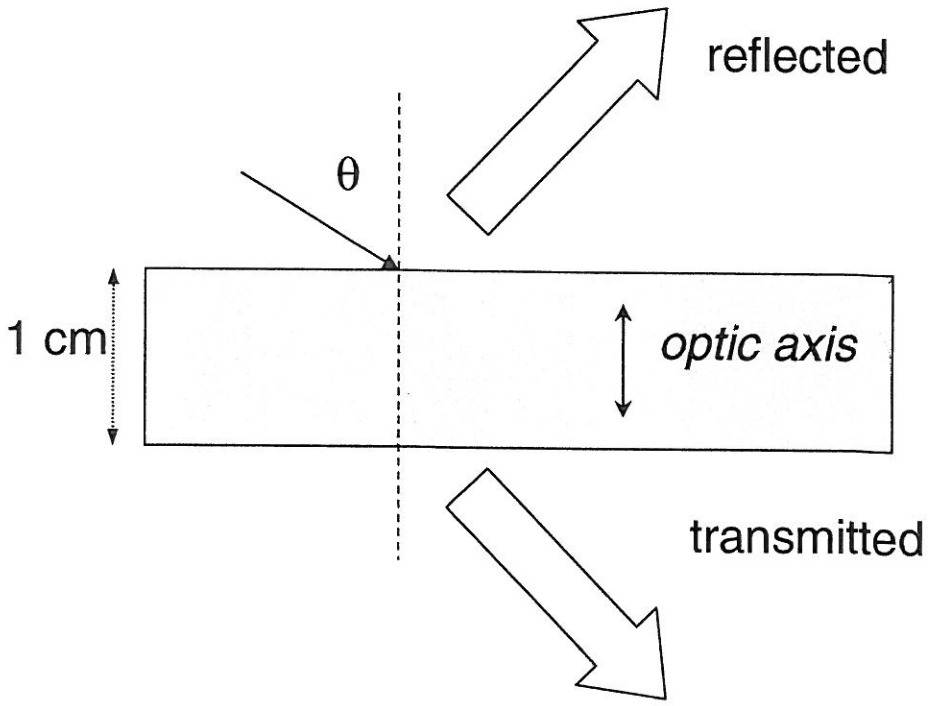


A) What kind of optical component was measured? [8p]

B) Using light specified by the Stokes' vector (2, -1, 1, 0), determine the Stokes' vector of transmitted light with the optical component oriented at angles 45 ° and 90°. Explain in words the result in each case. [7p]

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

8: A thin parallel laser beam of circularly polarized light (left) is incident from air on a flat 1 cm thick uniaxial crystal. The angle of incidence is 55.7°. The crystal is characterized by refractive index $n_o = 1.50$; $n_e = 1.40$ and the optic axis is oriented perpendicular to the surfaces (see figure below).



A) Trace and draw the ray transmitted through the crystal to the other side as well as the reflected ray. Indicate the polarization state of all rays. Specify and calculate the necessary angles and distances. Ignore multiple reflections. [8p]

B) Assume 10 mW of incident power. Calculate the power of each ray. (Again, ignore multiple reflections.) [7p]