PHYS 408, 2023W2

Problem Set 3: Polarization Optics

Posted: Wed, February 14 $\longrightarrow$ *Due*: Fri, March 1.

1. In Lecture 9, we derived Fresnel's equations for the reflection and transmission coefficients. We then discussed the phenomenon of Total Internal Reflection (TIR). Analyze what happens to the reflection coefficients at *and above* the critical angle θ_c. Prove that $|r_\perp|^2 = |r_\parallel|^2 = 1$.

2. In Lecture 11, we discussed the degree of polarization as the ratio between the intensity of the polarized part of the light wave and its total intensity. Imagine a beam of unpolarized light reflecting from an air-glass interface at $\theta_i = 30°$. What is the degree of polarization of the reflected light?

3. Consider a Pockels cell (introduced in Lecture 10), made out of the KDP crystal, described in the Example 21.2-2 of the Saleh & Teich textbook. To create a fast intensity switch (or modulator), one often sandwiches such Pockels cell between two crossed linear polarizers. The intensity of the transmitted light is controlled by applying an external voltage along the direction of the crystal's optical axis (so-called "longitudinal" geometry, illustrated in the figure below).

(a) Without the applied voltage, KDP is a uniaxial crystal. However, when subjected to the external electrical field, it becomes biaxial, as illustrated in Fig. 21.2-4 of the textbook. How would you orient the two transverse axes of the KDP crystal (x_1 and x_2) with respect to the input polarizer? Explain your choice.

(b) Assuming that the input light beam is polarized along the input polarizer and has the intensity I_{in}, write down the expression for the intensity of the output beam I_{out} (after the output polarizer) as a function of the applied voltage V.

(c) What voltage would you need to apply for "opening the switch", i.e. passing trough as much light as possible. Use the following parameters for the KDP crystal: $n_0 = 1.51$, $r_{63} = 10.6 \times 10^{-12}$ m/V, and assume the wavelength of 800 nm.

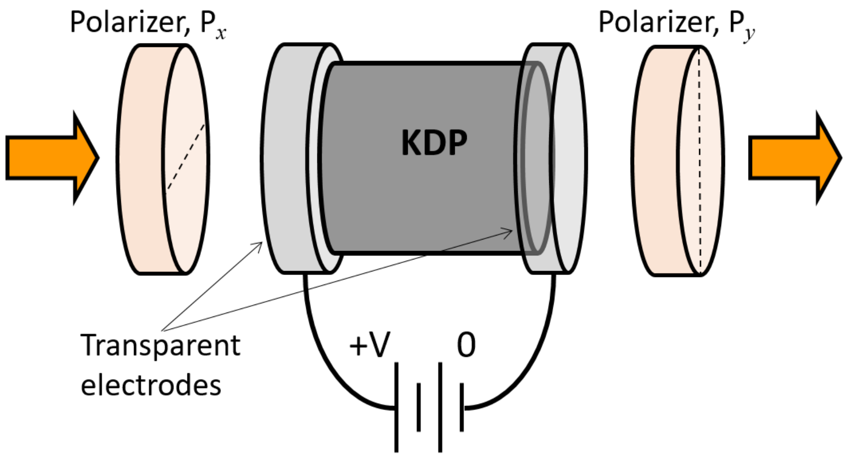

Figure 1: Fast light switch: a Pockels cell sandwiched between crossed polarizers.

4. Show that circularly polarized light changes handedness (right becomes left, and *vice versa*) upon reflection from a mirror.

5. One important optical polarization system is the optical isolator, which prevents laser light from being reflected back into the laser (which could cause instability or even damage). An optical isolator typically consists of a polarizer (say, along x), followed by a 45° polarization rotator, followed by a polarizer at 45°.

(a) Derive the Jones matrices for forward and backward propagation through the isolator. Assume ideal polarizers and note that the rotator produces the same rotation independent of the light's direction. Show that x-polarized light passes forward through the system unattenuated, but that any light traveling backwards through the isolator will be completely extinguished. (Realistic isolators attenuate the reverse beam by about 40 dB.)

(b) A cheaper isolator is a polarizer (say, along x) followed by a quarter-wave retarder oriented at 45°. Show that if a laser passes through this isolator, the isolator will block any light returning from a direct mirror reflection, but will not block arbitrary return polarizations.