Exercise 03

1 Polarization Optics

1.1 Anisotropic Materials

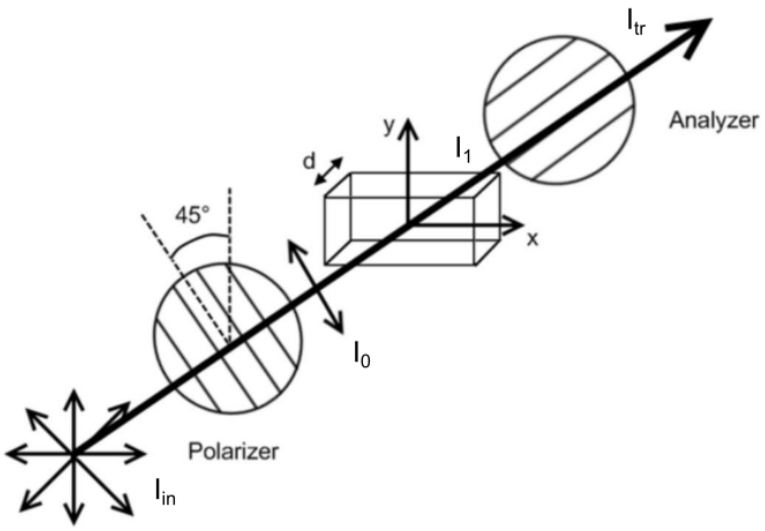

Figure 1: Schematic of a polarizer-analyzer setup.

In the setup shown in Figure 1 unpolarized light I_{in} with $\lambda = 500\,\text{nm}$ is transmitted through a pair of polarizers called Polarizer-Analyser pair (PAP), which are fixed perpendicular to each other. Between the PAP the setup allows for placing a material of interest. Calculate the intensities of the light in each section (I_0, I_1, I_{tr}) as a function of the incoming light I_{in} for the following configurations:

(a) Isotropic material with refraction index $n_0 = 1.5$ and thickness $d = 5\,\mu\text{m}$ placed inside the PAP

(b) Birefringent material with refractive index $n_x = 1.4$, $n_y = 1.5$ and thickness $d = 1250\,\text{nm}$ placed inside the PAP

(c) Same as (b) but thickness $d = 22.5\,\mu\text{m}$

(d) Same as (b) but thickness $d = 10\,\mu\text{m}$

2 Polarization Microscopy

2.1 Bright-field vs. Polarization Microscopy

Figure 2 shows images of a histological sample of thin mesentery that was stained with red *picrosirius*, *orcein* and *hematoxylin*, and was then observed with bright-field and polarizing microscopy.

(a) Find the image taken with bright-field and polarizing microscopy.

(b) Find the histological components shown in both images.

(c) Compare the two images taken from an identical specimen, what can you say about the optical properties of the sample and background? Reason in short sentences.

Hints:

1. *Picrosirius* stains collagen fibers red
2. *Orcein* stains elastic fibers dark brown – purplish red
3. *Hematoxylin* stains cell nuclei blue or violet
4. The two images were possibly not taken in the same position of the specimen.

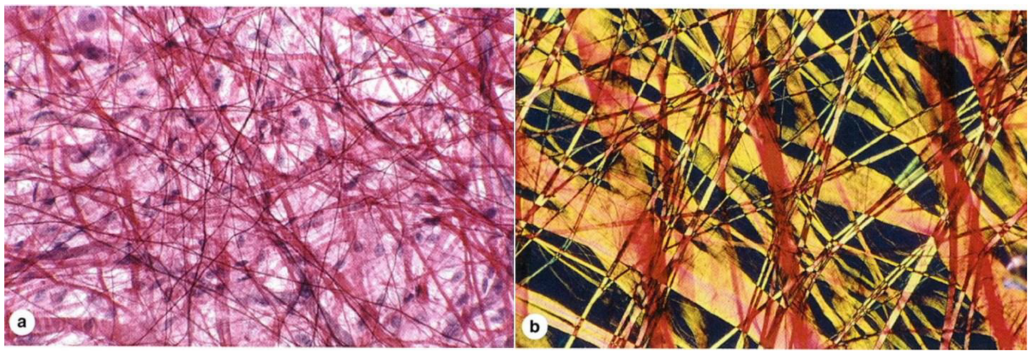

Figure 2: Microscope images of a histological sample taken with different microscopy techniques.

2.2 Polarization Microscopy Setup

A simplified optical setup of polarization microscopy is shown in Figure 3. The axis of the polarizer and the analyzer are perpendicular to each other. An anisotropic birefringent tetragonal crystal specimen with an optical axis oriented parallel to the long axis of the crystal is placed on the rotating stage (see Figure 3b). The axes of the polarizer and analyzer are indicated by P and A, respectively. Light entering the crystal from the polarizer travels perpendicular to the optical (long) axis of the crystal.

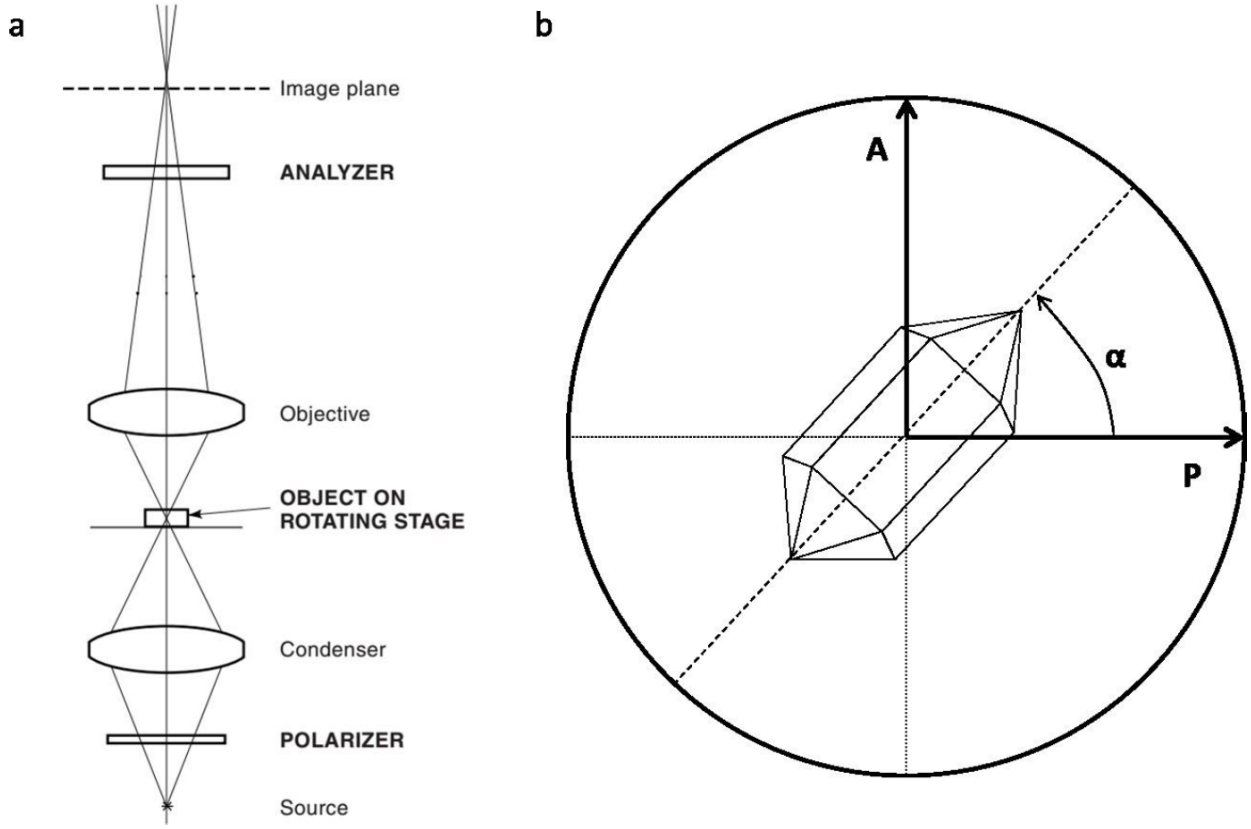

Figure 3: Simplified schematic of an polarization microscope.

Assume that polarization of the extraordinary ray is parallel to the optical axis. Consider the incident wavelength λ and thickness of the crystal d that fulfil the half-wave condition (additional phase shift between ordinary and extraordinary waves while passing through the crystal is $\Delta\phi = (2m+1)\pi$, where $m \in Z$). The optical axis of the crystal is positioned at an angle of α with respect to the polarizer. Find the angle α when:

(a) The crystal becomes invisible in the image plane

(b) The image of the crystal shows maximum brightness

3 Differential Interference Contrast (DIC) Microscope

3.1 Building a DIC Microscope

You have different optical components and a sample shown below in Figure 4. Choose and place the optical component(s) between an collimated light source and a CCD detector such that the completed setup acts as an DIC microscope. You can use the same component multiple times. Do not forget to place the sample.

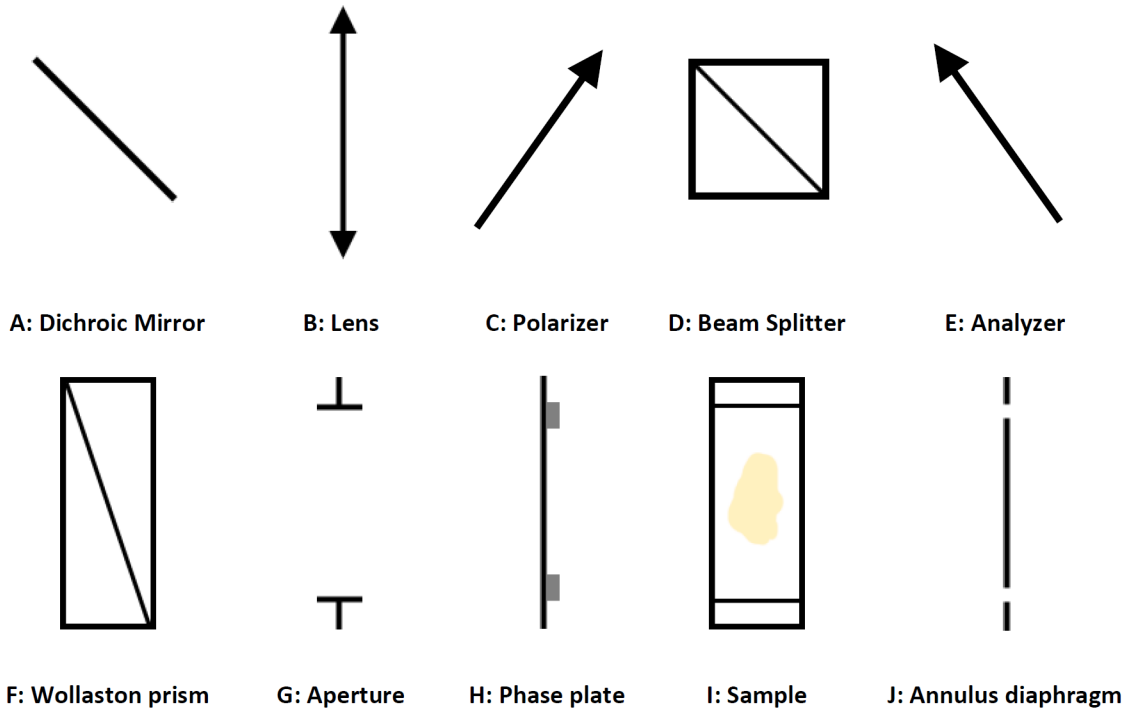

Figure 4: Optical components and sample *e.g.* for constructing a DIC microscope.