Exercise 03 - Solutions

1 Polarization Optics

1.1 Anisotropic Materials

Independent of the material placed between the polorizer-analyser pair, the intensity $I_0 = \frac{1}{2} I_{\text{in}}$ as discussed in the last exercise sheet. Similarly, the sample is considered non-absorptive, so the intensity $I_1 = I_0$ for all cases. Therefore, the following solutions will only state I_{tr} with respect to I_0.

(a) The isotropic material will induce a phase shift, but the polarization of the light will be the same. As the polarizer and analyzer are orthogonal with each other, the transmitted light after the sample cannot transmit through the analyzer thus $I_{\text{tr}} = 0$.

(b) The birefringent material will induce a relative phase shift between the x- and y-components of the incident light, as can be calculated with the following formula:

$$\Delta\varphi = \frac{2\pi}{\lambda}(n_x - n_y)d = \frac{2\pi}{500\,\text{nm}}\,(1.5 - 1.4) \times 1250\,\text{nm} = \frac{\pi}{2} \tag{1}$$

As the incident light onto the sample is linearly polarized, this phase shift between the x and y component will result in circularly polarized light. At the analyzer, the circularly polarized light can be split up in two linear components according to the reference frame of the analyzer, one that is transmitted completely, and another that is absorbed completely. They each correspond to half of the original intensity. Thus, the transmitted intensity $I_{\text{tr}} = \frac{1}{2} I_0$.

(c) Reusing Equation 1 we get a phaseshift of $\Delta\varphi = 9\pi$:

$$\Delta\varphi = \frac{2\pi}{\lambda}(n_x - n_y)d = \frac{2\pi}{500\,\text{nm}}\,(1.5 - 1.4) \times 22\,500\,\text{nm} = 9\pi$$

This is equivalent to a phase shift of π, now one component is in anti-phase with the other, resulting in a polarization perpendicular to its prior polarization. The light is now oriented parallel to the axis of analyzer such that it will be transmitted completely by the analyzer. Therefore $I_{\text{tr}} = I_0$.

(d) Reusing Equation 1 again we get a phaseshift of $\Delta\varphi = 4\pi$. This is equivalent to no phase shift. The transmitted light is still oriented parallel to the axis of polarizer such that it will be blocked completely by the analyzer, thus $I_{\text{tr}} = 0$.

2 Polarization Microscopy

2.1 Bright-field vs. Polarization Microscopy

Figure 1 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) Figure 2a is taken with bright-field and Figure 2b with polarization microscopy.

(b) In Figure 2a, collagen fibers were stained red with *picosirius*, cell nuclei were stained darkblue/violet with *hematoxylin* while elastic fibers were stained dark brown-purplish red with *orcein*. However, in Figure 2b, only collagen fibers were visible. A labeled version of Figure 2a is shown in Figure 1

(c) Under routine bright-field microscopy all the three stained components were visible, while only collagen fibers were visible under polarization microscopy, indicating collagen fibers changed the polarization of the light and exhibit intense birefringence. Elastic fibers and nuclei as well as the background lack oriented macromolecular structure, which did not alter the polarization of the incident light, hence became invisible.

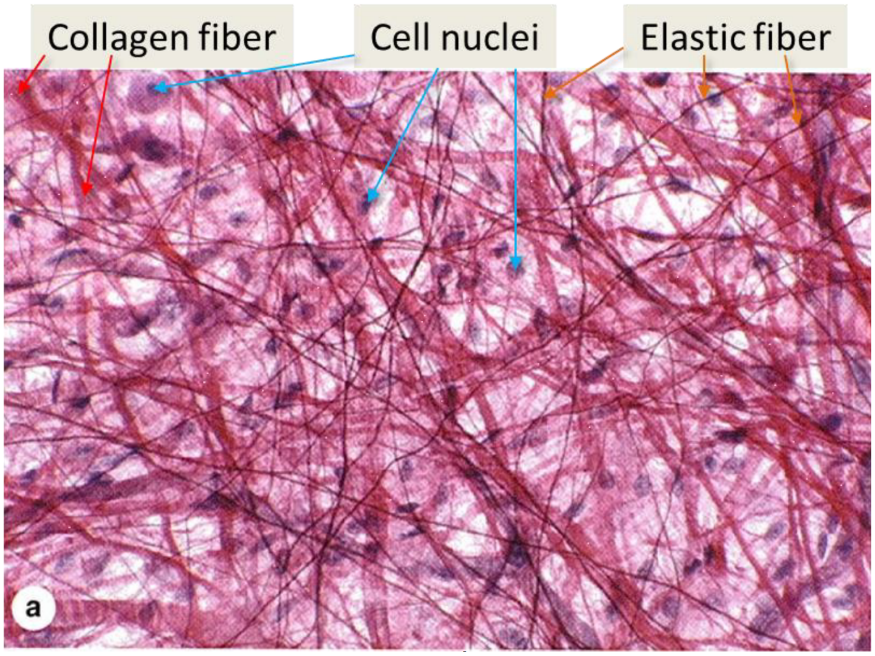

Figure 1: Bright-field microscope image of a histological sample.

2.2 Polarization Microscopy Setup

Since the experiment configuration fulfils the half-wave condition (the same as in halfwave plate), the output polarization would be rotated by $\gamma = 2\alpha$ angle.

(a) For crystal to become invisible the output polarization should be perpendicular to the analyzer transmission axis. This means that rotation of the polarization is $\gamma = m\pi$, where $m \in Z$. The resulting crystal axis angle is then $\alpha = \gamma/2 = \frac{m}{2}\pi$.

(b) In order to get the maximum brightness the output polarization should be aligned with analyzer axis, hence rotation angle equals to $\gamma = \frac{\pi}{2}(2m+1)$, where $m \in Z$ and the resulting crystal axis should be $\alpha = \gamma/2 = \frac{\pi}{4}(2m+1)$, where $m \in Z$.

3 Differential Interference Contrast (DIC) Microscope

3.1 Building a DIC Microscope

A typical optical setup for DIC microscopy is shown in Figure 2. From the light source, the setup is composed of polarizer, Wollaston prism I, condenser lens, specimen, objective lens, Wollaston prism II and analyzer. Thus the choice for the components and the correct order is: **C - F - B - I - B - F - E**.

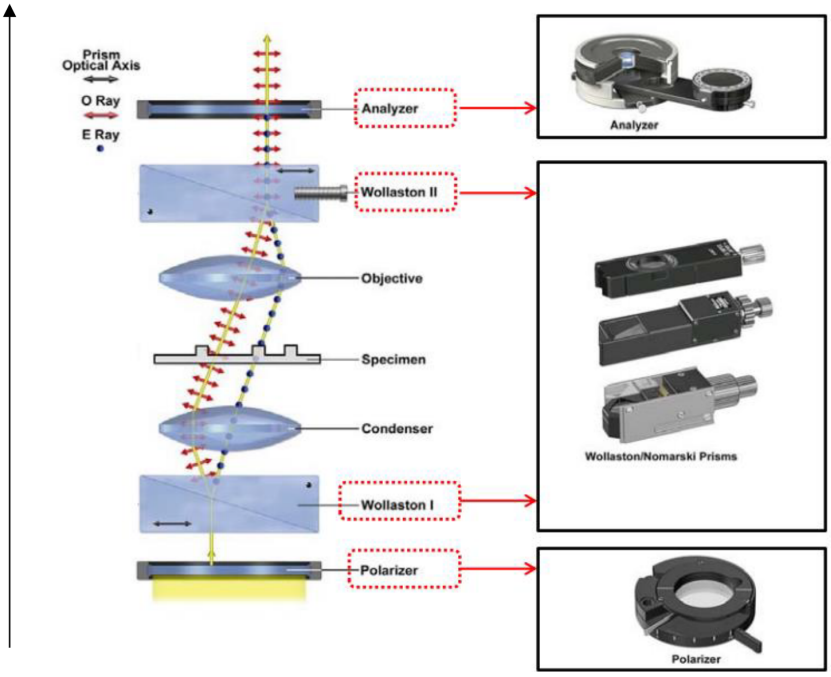

Figure 2: Schematic of a typical DIC setup.