Al-Mustaqbal University

Biomedical Engineering Department

Class: 4th

Subject: Biomedical Instrumentation Design I

Lecturer: Mr. Mahir Rahman Al-Hajaj

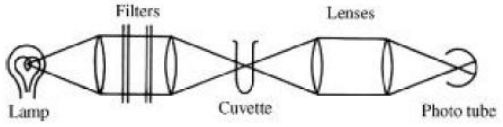
1st term – Lect. 7: Geometrical and Fiber Optics.

Email: mahir.rahman@uomus.edu.iq

Geometrical and fiber optics

Geometrical optics

- There are a number of geometric factors that modify the power transmitted between the source and the detector.



- The lamp emits radiation in all directions. The first lens should have as small as f number (ratio of focal length to diameter) as practical to collect the largest practical solid angle of radiation from the lamp.
- The first lens is with one focal length away from the lamp in order to collect and collimate the radiation. Thus, the second lens can be placed at any distance without losing any radiation. Also, some interference filters operate best in collimated rays.
- The second lens focuses the radiation on a small area of sample in the cuvette. Because the radiation now diverges, 3rd and 4th lenses are used to collect all the radiation and focus it on a detector.

- *Fiber optics* are an efficient way of transmitting radiation from one point to another. Transparent glass or plastic fiber with a refractive index n_1 is coated or surrounded by a second material of a lower refractive index n_2. By Snell's law,

$n_2 \sin\theta_2 = n_1 \sin\theta_1$

Θ: angle of incidence

An example of the use of Snell's Law in biomedical engineering is in the design and application of **optical coherence tomography (OCT)**. OCT is a non-invasive imaging technique used to obtain high-resolution cross-sectional images of biological tissues, such as the retina in ophthalmology.

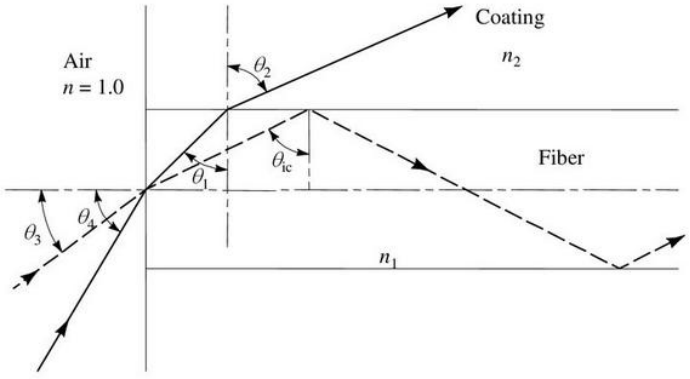


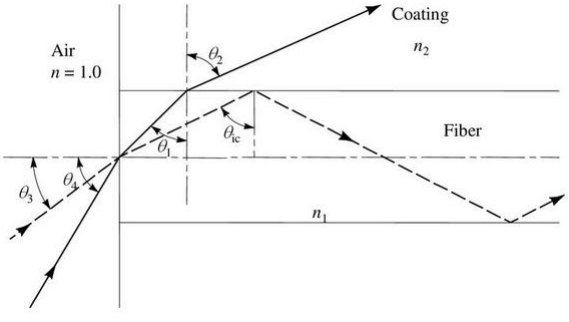
Figure (2) Fiber optics. The solid line shows reflection of rays that escape through the wall of the fiber. The dashed line shows total internal reflection within the fiber.

- *The critical angle* for reflection (θ_{ic}) is found by setting $\sin\theta_2 = 1.0$, which gives:

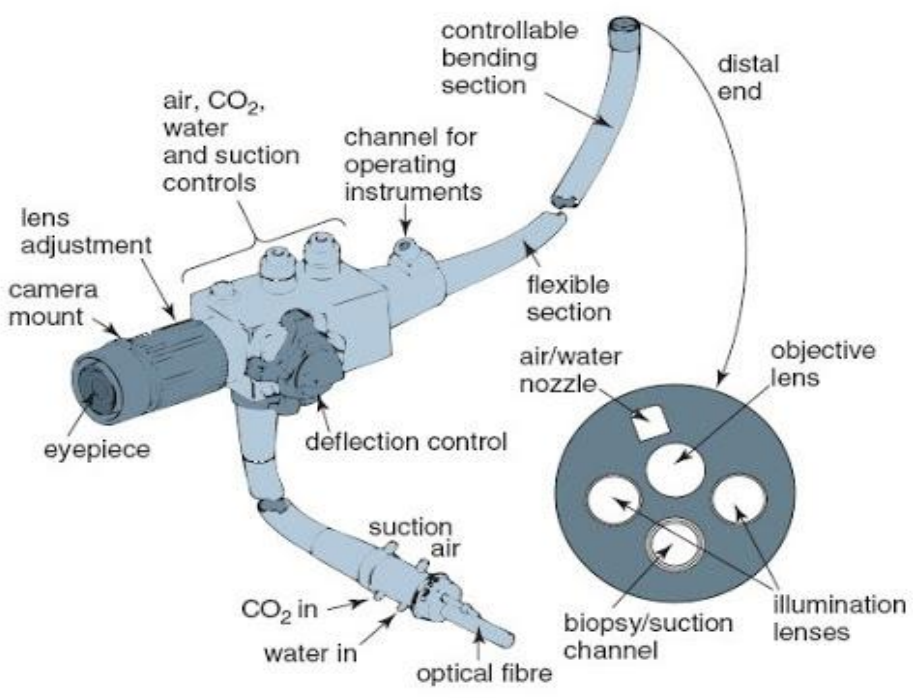
$\sin\theta_{ic} = n_2/n_1$ … … (2)

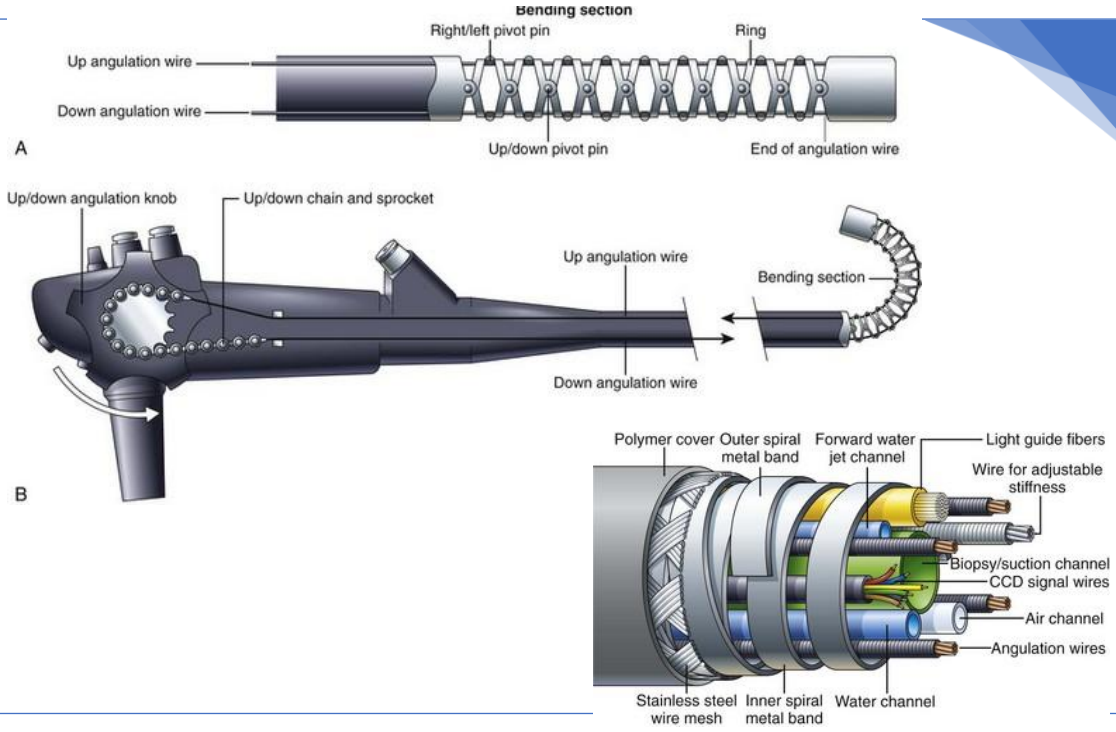
- A ray is internally reflected for all angles of incidence greater than θ_{ic}. Because rays entering the end of a fiber are usually refracted from air (n = 1.0) into glass (e.g. n = 1.62), a larger cone of radiation (θ_3) is accepted by a fiber than that indicated by calculations using 90°- θ_{ic}.

- Rays entering the end of the fiber at larger angles (θ_4) are not transmitted down the fiber; they escape through the walls.

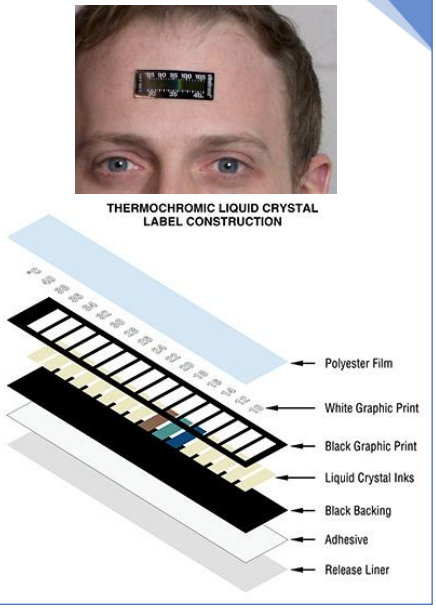


- *Fiber-optic (FO) sensors* are chemically inert and have freedom from electromagnetic interference.
- The most important medical application of optical fibers is in the endoscope.
- A typical endoscope is 1m long and 1cm in diameter and may be used for viewing the lining of the stomach, intestines, and so forth.
- A small lens focuses the image of the lining onto the end of a coherent bundle, which transmits the image in such a way that it may be viewed or photographed.
- External levers make it possible to steer the internal end of the optical-fiber device over a 360° range so that the examining physician can look at cavity walls and around corners.

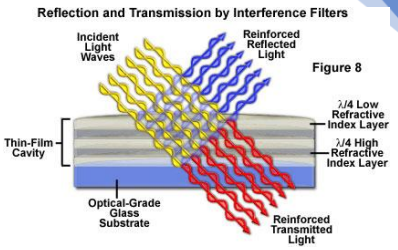




- *Liquid crystals* change their state in such a way that they modify passive scattering or absorption of light.
- As the crystals melt, the three-dimensional order becomes a two-dimensional or one-dimensional order. Layers or strands form that can be seen as a clarification of the previously turbid melt.
- Liquid crystals are also used, in disposable thermometers, in the measurement of oral temperatures.

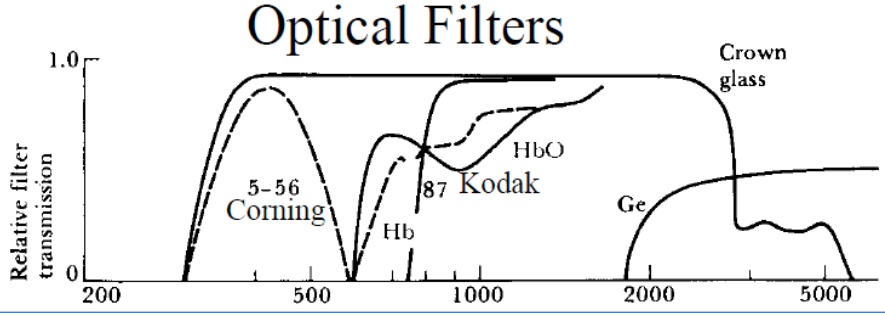


- *Optical Filters* are frequently inserted in the optical system to control the distribution of radiant power or wavelength. To reduce radiant power only, neutral-density filters are used.
- When glass is partially silvered, most of the power is reflected, and the desired fraction of the power is transmitted.
- When carbon particles are suspended in plastic, most of the power is absorbed and the desired fraction of the power is transmitted.
- Two Polaroid filters may also be used to attenuate the light. Each filter transmits only that portion of the light that is in a particular state of polarization. As one is rotated with respect to the other, the optical transmission of the combination varies.

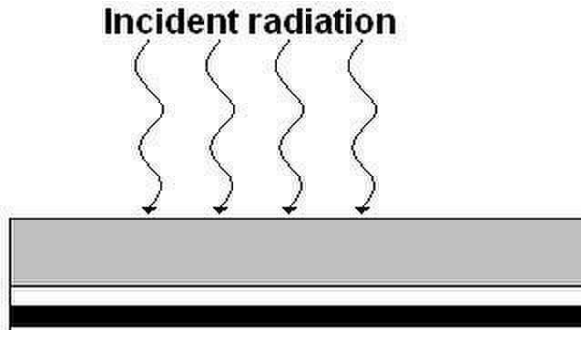


The pulse oximeter typically employs two light-emitting diodes (LEDs) that emit light at different wavelengths (usually red and infrared). The optical sensor detects the light that passes through the tissue and calculates the ratio of absorbed light, allowing it to determine the oxygen saturation level.

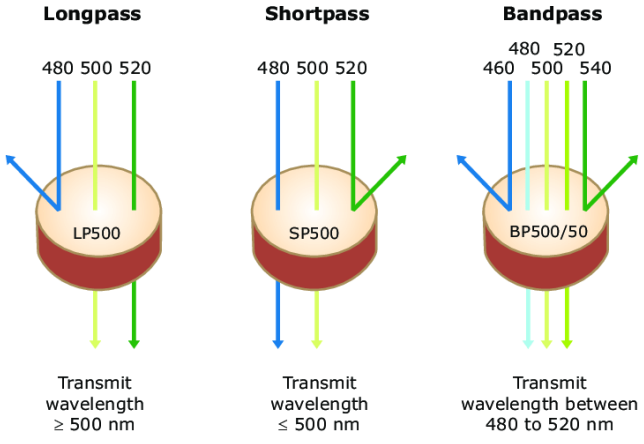
- *Color filters* transmit specific wavelengths and reject others.
- Gelatin filters are the most common type of absorption filters. An organic dye is dissolved in an aqueous gelatin solution, and a thin film is dried on a glass substrate, like the Kodak 87 Wratten filter.
- Glass filters, made by combining additives with the glass itself in its molten state, are extensively used. They provide rather broad passbands, as illustrated by the blue Coming 5-56 filter shown in Figure 3.



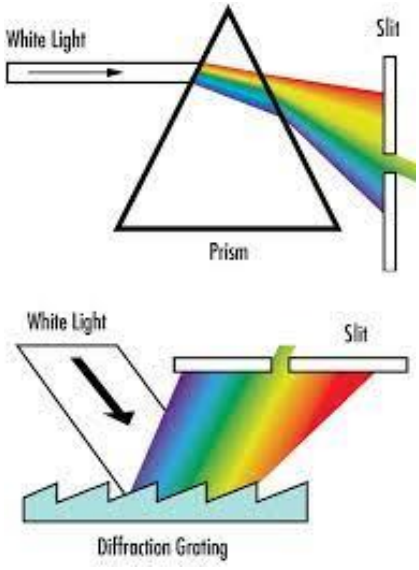
- *Interference filters* are formed by depositing a reflective stack of layers on both sides of a thicker spacer layer.
- This sandwich construction provides multiple reflection and interference effects that yield sharp-edge high, low, and bandpass filters with bandwidths from 0.5 to 200 nm.
- Interference filters are generally used with collimated radiation and cost more than those just mentioned.



- *Interference filters*
- Interference coatings are used on dichroic mirrors (cold mirrors), which reflect visible radiation from projection lamps. The non-useful infrared radiation is transmitted through the coating and mirror to the outside of the optical system. *This reduces heat within the optical system without sacrificing the useful light.*

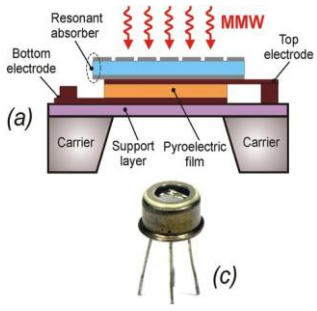


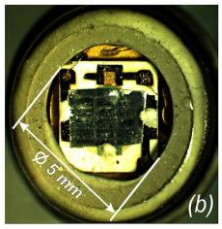
- *Diffraction gratings* are widely employed to produce a wavelength spectrum in the spectrometer.
- Plane gratings are formed by cutting thousands of closely spaced parallel grooves in a material.
- The grating is overcoated with aluminum, which reflects and disperses white light into a diffraction spectrum.
- A narrow slit selects a narrow band of wavelength for use.



- *The thertmal sensor* absorbs radiation and transforms it into heat, thus causing a rise in temperature in the sensors.
- Typical thermal sensors are the thermistor and the thermocouple.
- The sensitivity of such a sensor does not change with (is flat with) wavelength and the sensor has slow response.

- *The pyroelectric sensor* absorbs radiation and converts it into heat. The resulting rise in temperature changes the polarization of the crystals, which produces a current proportional to the rate of change of temperature.
- *The quantum sensors* absorb energy from individual photons and use it to release electrons from the sensor material. Typical quantum sensors are the eye, the phototube, the photodiode, and photographic emulsion.
- Such sensors are sensitive over only a restricted band of wavelengths: most respond rapidly.





THANK YOU!