Homework III BME136/251 Engineering Optics for Medical Applications

Endoscopy

1. What dictates the resolution of a fiber bundle relay? Why?

Spacing of the individual fibers dictates your resolution because each fiber core represents a 'pixel' in the image which is then sampled by the image sensor.

2. What is the advantage of using a CCD sensor to directly receive images vs a fiber bundle relay in an endoscope? Name at least two

Doesn't require extra image processing to eliminate 'honeycomb'/'screen door' effect from fiber relay which pixilates the final image

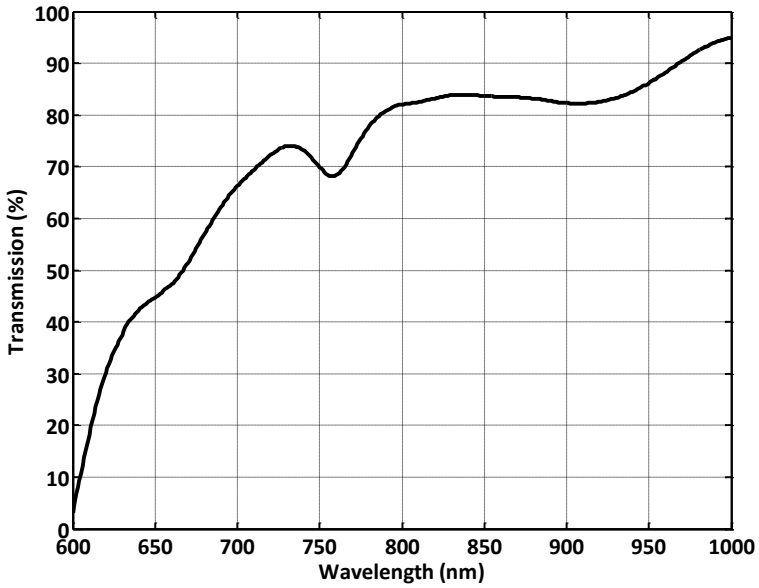
Capable of better resolution because there are more pixels in the detector than there are fibers in the fiber bundle

3. Why do endoscopes require a long working distance? Give at least two reasons

Need the long working distance to have a wider field of view and to have ample space to take biopsies, suction liquids, etc.

Spectroscopy

1. You take a measurement of pure 1mM deoxy-hemoglobin (HB) solution in a 1cm cuvette using a well-characterized broadband light source. You then calculate the percent transmission shown below.



a. You want to apply Beer-Lambert law to solve for the extinction coefficient of HB. First, explain the main assumption you would need to make.

Assume losses in optical power are purely due to absorption of the chromophore.

b. Solve for the extinction coefficient of HB at 750 nm.

From $100\frac{I}{I_0} = T = e^{-\varepsilon(\lambda)cx}$, $\varepsilon(750) = -\frac{ln\left(\frac{T}{100}\right)}{cx} = 0.357\,\frac{1}{cm*mM}$

c. Without performing any calculations, approximately what percent transmission would you expect oxy-hemoglobin (HBO2) to have if you use an 800 nm laser? What is special about 800 nm in the context of hemoglobin?

There is an "isosbestic" point around 800 nm for HBO2 and HB. This means the absorption coefficient is the same for both molecules, thus the transmission should around 82% for both.

Optical Coherence Tomography

1. Ophthalmic imaging and catheter/endoscopic imaging are applications for OCT with low numerical aperture. Explain how this limitation affects axial resolution, transverse resolution, and depth of field.

OCT can achieve fine axial resolution independent of the numerical aperture of the focusing. This feature is especially powerful for applications such as ophthalmic imaging or catheter/endoscope imaging, where numerical apertures are limited. However, low numerical aperture focusing also limits the transverse resolution because the focused spot sizes are large. There is a trade-off between transverse resolution and depth of field; decreasing the transverse resolution increases the depth of field.

2. Describe the main differences between time-domain OCT and spectral/Fourier-domain OCT. Outline the advantages of spectral/Fourier-domain OCT.

Please refer to the schematic of both approaches described in the lecture slides.

Spectral/Fourier domain detection (SD-OCT) has a powerful sensitivity advantage over time domain detection, since spectral/Fourier domain detection essentially measures all the echoes of light simultaneously. For most OCT systems, this corresponds to a sensitivity increase of 50–100 times, enabling a corresponding increase in imaging speeds.