BME 136/251 **Homework 5** **Due Date: Monday, March 5**

1. You are attempting to measure oxy- and deoxy-hemoglobin of the vastus lateralis (i.e. a muscle of the thigh) using a flat wearable, frequency-domain NIRS instrument as subjects undertake a lengthy marathon. However, as there is a thin layer of adipose tissue between skin and muscle, you want to set up your instrument in a way that you are confident your signal is coming from the tissue of interest.

a) Your instrument has two lasers with wavelengths: 690nm, and 830 nm. Explain one assumption concerning chromophores that you have to make in order to perform this measurement. *Hint: What must stay constant?*

b) In order to probe deeper into to the tissue and access the muscle beneath the adipose layer, you increase the source-detector (S-D) separation of your probe from 1.5 cm to 3 cm. Although the S-D separation is increased, you may assume that the overall size of your probe is unchanged. Explain why increasing the S-D separation effectively probes deeper into tissue, and the real-world disadvantage of doing this.

c) Besides increasing the S-D separation of your probe, list another way you can probe deeper into the tissue, and explain how it works.

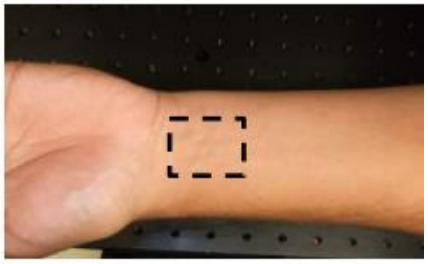
d) Your colleague suggests that since you are at 3 cm S-D separation, light from your source will arrive at your detector after 0.1 ns. He shows his work to you: $t = \frac{S-D}{c} = 0.1\ ns$, where t is time, S-D is the source-detector separation, and c is the speed of light. You explain to your colleague that this is not quite accurate, and that the light will actually arrive much, much later. From your knowledge of tissue optics, fully explain how this is possible.

2. Why is the sky blue in the daytime? Explain your reasoning

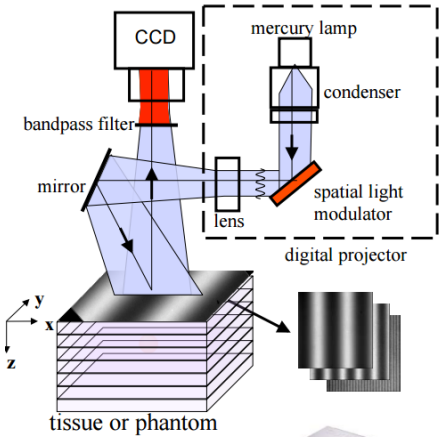
3. You are sent an 830 nm laser modulated at 200 MHz into a forearm and detect the light that comes out 2 cm away from the source, what do expect to observe for the output amplitude and phase in comparison to the input? Explain why

4. Compare and contrast frequency domain spectroscopy and broadband spectroscopy. Provide at least one advantage and one limitation for each modality.

5. Spatial frequency domain imaging (SFDI) is a noncontact wide-field imaging technique that uses spatially-modulated light to characterize multiply scattering media, such as biological tissue. SFDI separates the contributions of light scattering from absorption by measuring the frequency-dependent modulation transfer function of diffusively reflected light. This information is used to map and form images of tissue optical properties, absorption and reduced scattering. Absorption values at multiple wavelengths are then used to derive concentration maps of biochemical species, such as oxy- and deoxyhemoglobin. I did an arterial cuff occlusion experiment where I measure my forearm with our SFDI instrument in BLI. There are two data points in this experiment: before and after the occlusion.



Region of Interest

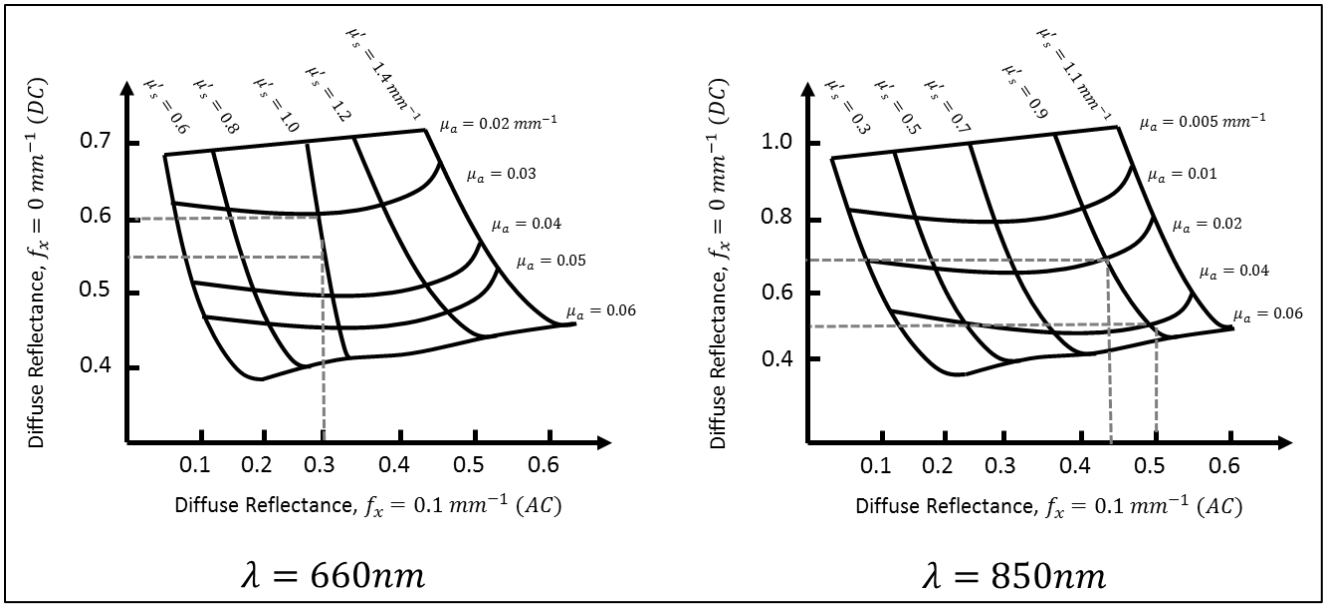


Schematic of SFDI Instrument

The following table shows calibrated diffuse reflectance ($R(f_x)$) values at two spatial frequencies on the selected region of interest.

Wavelength (λ)	660nm		850nm	
Spatial frequency (mm^{-1})	0	0.1	0	0.1
$R(f_x)$ before occlusion	0.55	0.3	0.5	0.5
$R(f_x)$ after occlusion	0.6	0.3	0.7	0.44

a) Use the following lookup table which was generated using a forward Monte Carlo simulation of light transport in turbid medium (Input: (μ_a ,μ'_s), Output: $R(f_x)$) to extract absorption and reduced scattering coefficients at each wavelength before and after the occlusion.



b) Calculate oxygen saturation (StO2) and total hemoglobin (Unit: mMol/Liter) values before and after the occlusion. How do you interpret your results?

The extinction coefficients of the chromophores are provided in the following table: *Hint: What's the relation between concertation, molar extinction coefficient, and absorption coefficient?*

molar extinction coefficient ε in **[cm^{-1}/(Moles/Liter)]**	660nm	850nm
HbH	3226.56	691.32
HbO2	319.6	1058