Lab 8
Hear Rate Monitoring by non-invasive Optical Reflection

I. Introduction

Objective - Assemble and test a non-invasive, in-situ optical system that measures the heart rate via reflection of laser light.

In brief, you will be measuring the diffuse reflection of red light from the skin. Skin is a turbid medium. This means that light is efficiently scattered in different directions within a short distance from the skin surface. The reflectivity of light from the skin depends on skin color, age, skin location, presence of blood, and other factors. In particular, the reflectivity depends on the amount of blood just under the top layers of skin. As the heart beats, the amount of blood in the skin changes resulting in a modulated reflectivity.

II. Procedure

You will use a He-Ne laser, fiber optic cables, a photodetector, amplifier and digitizing oscilloscope (see attached Figure). MAKE SURE you understand WHAT the different components are and HOW they work and WHY they are included as part of the optical system. For example, what is the function of the amplifier and filters? Why is red laser light used?

(a) Experimental Set-up and Testing using vibrating Membrane: Your first goal is to set up the equipment to measure the time varying reflectance from a vibrating rubber band. The time varying reflectance from the rubber band is a relatively large signal. If you can not get the optics/ electronics/ data analysis working together to make this measurement, measurements of the heart rate will not work.

- Couple the light into a fiber optic cable (1mm core size). At the end of the fiber where the light emerges, securely tape another fiber optic cable. One cable delivers the light to the sample. The other cable collects a portion of the reflected light.
- Detect the reflected light after it emerges from the fiber with a photodetector. Make sure that you use the large area photodetectors (round housing) and that the gain setting (small adjustable switch on back of the detector is turned to the HIGHEST gain setting - fully clockwise).
- Close to the ends of the two cables, mount a stretched rubber band.
- Pluck the rubber band so that it vibrates. The vibration will modulate the reflected light intensity to model the modulation of the reflected light due to the pulsing of blood in the fingertip.
- Use an oscilloscope to record the transient reflectivity as measured by the photodetector.
- Use the provided data acquisition program to save the oscilloscope trace to a Text data file.
- Plot the data using EXCEL, MATHCAD, etc. and determine the vibration frequency of the rubber band. NOTE: this frequency will depend on the tension force experienced by the rubber band. Remember since your goal is the measure the human heart rate, the vibration rate should be comparable to the human heart rate in order to use the rubber band as a reasonable test of the detection system.

(b) Measuring the Heart Rate: Now that you have demonstrated the detection of a time varying reflectivity, your goal is to measure the heart rate from a person.

- With the test subject in the sitting position, have the subject rest their hand, palm side up, on the optical table. Position your fiber optic detector just above the finger tip in a RIGID holder.
- Measure the detected reflectivity with the photodetector and the oscilloscope.
- Adjust the subject's hand location relative to the fiber ends, adjust the oscilloscope, etc. until you observe the heart beat on the oscilloscope. (A sample trace of what you are looking for will be given out in class).
- Use the data acquisition program to save the oscilloscope trace to a Text data file.
- Plot the data using EXCEL and determine the heart rate.

- Compare your measured heart rate with the rate as measured by taking the subject's pulse (the old fashioned way). For each student in your lab group, fill in the following table:

TABLE A

Subject	**Age (years)**	**Skin Tone**	**Sex**	**Measurement Location**	**"optical" Heart Rate**	**"Taking the Pulse" Heart Rate**	**Comments**
Male #1	20	Light brown	Male	Fingertip	20 Beats/min	21 beats/min	Optical heart rate easy to find
Male #2							
Female #1							

NOTE: To observe the heart rate will take some trial and error, patience and some experimental talent. If you have difficulty observing a signal, please ask for help. If the finger tip does not work well, try the earlobe or neck.

(c) Measuring Differences in Heart Rate: Conduct some simple tests to determine if you can measure differences in heart rates. Conduct the following experiments:

- Measure the heart rate when you are sitting, standing. Is there a difference? Medically, do you expect a difference? Compare your measured data to the standard "taking the pulse" and fill in the following table. You should have an entry for EACH member of your lab group.

Subject	**Poition**	**Measurement Location**	**"optical" Heart Rate**	**"Taking the Pulse" Heart Rate**	**Comments**
Male #1	Sitting	Fingertip	20 Beats/min	21 beats/min	Optical heart rate easy to find
Male #2	Standing				
Female #1	Sitting				
Female #1	Standing				

- Measure the heart rate before exercise and after exercise. Is there a difference? Why? How long does it take the heart rate to return to "Normal" after exercise. To answer this last question, you can have the subject run around the hallway for a few minutes and measure the heart rate 0,1,2,3,5,10 minutes after exercise. Compare your results to the standard "taking the pulse" and fill in the following table for at least ONE member of your lab group

Time after Exercise	**"optical" Heart Rate**	**"Taking the Pulse" Heart Rate**	**Comments**
Before exercise	20 Beats/min	21 beats/min	Optical heart rate easy to find
0 min			
1 min			
2 min			
3 min			
5 min			
10 min			

III. Data Analysis

Make sure that you record all of your data on a floppy for further analysis. The typical analysis should include the determination of the heart rate (and an explanation of HOW you extract the number). You can use EXCEL, MATHCAD, etc. to plot the data.

IV. Discussion

For your lab write up, make sure that the tables above are filled in. In addition, answer the following questions/ perform the following tasks.

1. Plot a trace from the oscilloscope of one of your lab group member's heart rate. Make sure that the axes are labeled correctly. From your plot, determine the heart rate in Beats per min. EXPLAIN and SHOW how you determined this number.
2. Notice in your plot that the measured reflected light intensity DESCREASES when the heart beats. Based on the following table of optical properties of skin with no blood and skin with 2% blood content, would expect the reflectivity to INCREASE when the heart beats or to DECREASE? Why?

Layer	μa [cm^{-1}]	μs [cm^{-1}]	g
Dermis (no blood)	2	180	0.89
Dermis (2% Blood)	2	182.4	0.8918

3. Plot the oscilloscope traces from each group member listed in Table A.
4. Did the optical heart rate monitor work for everyone in your lab group? Explain.
5. Based on your results of Table A, does the "optical" heart rate a good measure of the "taking the pulse" heart rate? Why or why not?
6. Based on your results of Table B, do you measure a difference in the heart rate depending upon whether the subject is standing or sitting? Do you expect there to be a difference? Why or Why not?
7. Based on your data for Table C, plot (on the same graph) the "optical" and "pulse" heart rate versus minutes after exercise. Include the "before exercise" data point. Does the heart rate change with exercise? Do you expect it to change? Why or why not.
8. Based on your data, how long does it take the heart rate to return to "normal".