Week #11 – Biophotonics Part 1

We will still randomly assign groups this week and next, but if you want to choose your group for the final project, then you need to let me know your chosen group members by the end of today (Monday, Week 11) so that I can post the final groups and they can start planning their final project ideas.

READ THIS CAREFULLY PLEASE!

These two weeks will allow you to: (1) learn a bit about biophotonics; (2) importantly, prepare for the final design project, which is worth a lot of points.

You have now gone through 10 weeks of lab and mastered all the basic tools in the lab, including absorbance measurements with the spectrometer. This week and next, your job will be to setup your own lab experiment procedures! I will give you lab topics, and some hints/clues for each lab.

By now you have seen how to setup a professional optical experiment and report on it. Now you will learn how to develop your own procedures and theoretical calculations. This will require as much work as a normal lab, at least, if you go to the level of detail needed! The experiments are a bit short/simpler, because you will spend more time setting up your procedure and theory. The experiments are also a bit 'messier' and open-ended, so that you can't simply look up an exact procedure or solution on-line. You will need to figure most of the procedures out! The results may not be as concrete or definitive either, which for many of you will be great preparation for your final projects.

You need to justify your work as much as possible using theoretical calculations or other defendable methods. Lack of proper details for your design, or lack of justification of your design, will cause a significant loss of points for this lab.

Lab report format is a recorded video! This is your report. So do a good job! Your team should share the presentation (each student pick a few slides to present). We will do video recordings, because (1) scheduling so many presentations is challenging; (2) it is a very effective way to quickly document your findings, and is a skill that is going to be needed more and more in the workplace.

You can use any recording device/software that allows recording of voice over powerpoint slides. I really like using a stylus and 'Explain Everything' on a tablet (Mac and Windows version available, only $3, there is also a 30 day free trial). Powerpoint also has audio/video record as well for your laptops. Use slide animations, on-screen mouse or some sort of pointer or mark-up tool to point to what you are talking about.

Again, I expect to hear from everyone in the group. You likely need to record it a few times to get it right (Explain Everything lets you conveniently redo just one slide). Please, export only to MP4 or MOV format (not AVI, etc.) and no more than 1024x768 pixels. No exceptions else you will receive a zero for your grade.

Also, adhere strictly to the time limits. Practice it, and redo the recording if needed. Getting your message across in a clear, CONCISE and fully informed manner, is a talent that will accelerate your careers more than you think. Your supervisors are busy, and when you present at large meetings there are many people there whose time is valuable. It is upon you to prepare, polish, and deliver concisely (but with all key information there, of course).

■ *Week 11 - Optical Biological Measurement*

Due date – the following Monday by noon, uploaded to blackboard.

You must cover ALL details that someone else would need if they were to EXACTLY reproduce your work. This means you need to cover details like distances between optical elements, optical powers used, etc. You will need to specify any and all parts you used. See "A note of warning" at the end of this document for common mistakes."

STUDENTS – OPTION B IS MUCH MORE USEFUL FOR YOUR CAREERS AND NOT THAT HARD.

Experiment Option A (choose only one, A or B)

Goal: using mainly parts in the lab demonstrate optical heart rate detection and determine what it would take to make a simple wearable device that measures a person's heart rate using optics.

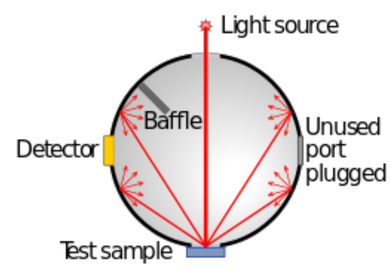
Using a light source, and the 'signal output' at the backside of the Newport power meters fed into an oscilloscope, determine how well light can be used to accurately measure heart rate. Right now, only three of the optical meters have an analog outputs. We have two oscilloscopes in the lab. Not all wavelengths/light sources will work well… You can use transmission or reflection based measurement, your decision! Include in your measurements a rough measurement of the optical-efficiency (power-loss) of your setup (what % of light you input, gets to the detector). To do this rough measurement, you could directly measure Pin/Pout and or measure absorbtion coefficient w/ the spectrometer.

***Mandatory Theoretical/Engineering Problem* -** Goal: you need to choose only ONE of these two options. Your choice!

> Apple Watch **-** Goal: do you best job to reverse engineer and understand the design of heart-rate measurement in the new Apple Watch (include your comment on everything from wavelengths/physics to design/layout). As stated by Apple: "*The wrist is a convenient area for collecting data about your physical activity, a task Apple Watch is designed to perform throughout the day. On the back of the case, a ceramic cover with sapphire lenses protects a specially designed sensor that uses infrared and visible-light LEDs and photodiodes to detect your heart rate.*"
>
> Or…
>
> *Vein Finder* **-** Goal: do you best job to reverse engineer this technology, and provide a system level diagram of how it works. You should include the optics/physics of seeing veins (how it actually works). *http://www.fastcodesign.com/3038035/fast-feed/this-gadget-reveals-exactly-where-veins-are-so-nurses-dont-stab-you-blindly*

This lab does not take a lot of time. The challenge is developing a good lab procedure, and performing critical thinking and calculations. Next week will be more challenging, and the final project, will of course be the most challenging of all.

Experiment Option B (again, choose only one, A or B)



Goal: using mainly parts in the lab demonstrate how to make an integrating sphere for high accuracy reflection measurements, such as skin reflectivity measurements. Optical skin reflectivity can be used to assess wound healing, long term skin deterioration such as too much sun, skin diseases, and even internal health like disorders (jaundice, bilirubin).

An integrating sphere basically is able to 'integrate' all the light angles that are inputted into it (key point: regardless of angle). Wikipedia has a great description: "The effects of the original direction of light are minimized." https://en.wikipedia.org/wiki/Integrating_sphere. This is very important for reflection measurements, because many surfaces like skin can have varying degrees of glossy/shiny reflection vs. diffuse reflection. If you just had a mirror surface, you could accurately reflect light from a light source, off the mirror surface, and to the detector the same way each time. If you don't have a mirror surface, it is no longer a reliable measurement (you don't know how much light is reflected toward the detector vs. how much light is scattered). For the integrating sphere shown at right, light is collected and detected regardless of the angles of light reflected off the test sample.

*Work: using a white light source and the spectrometer, record the **skin reflectivity**'s for all your group members **with and without an integrating sphere** and comment on the accuracy between the two methods. Also, with the integrating sphere, record the reflectivity spectrums for a **metal ruler and for the yellow and the red paper** in the lab **with and***

without an integrating sphere. *You will find the mirror-like ruler surface can give the most error (you will find depending on incidence and detector angle you can get >100% or <0% reflectivity, which is impossible! This is why you need an integrating sphere!*

For the case of no integrating sphere, just try something quickly. Spend most of your time on the integrating sphere test.

For the integrating sphere, a couple things that might help:

1. ***Foam coolers***, *you can take 1 (only 1 please) and modify it as you please to make a 'cheap' integrating sphere. There is a serrated knife in the blue bins. Clean up carefully! This can be messy!*
2. ***Think carefully before you start to cut holes in it***. *Don't worry about it not being a sphere… diffuse reflection does not care so much about the geometry. My idea for where to place the test sample is shown at right. You can use anything in the lab to help with your setup. Integrating spheres above cost $1000's of dollars. My research lab has one, but we have also used foam coolers like you are using in the past, which cost only about $4.*
3. *The* ***light source*** *should only hit the surface to be measured for reflectance. You can create a collimated white light source with lenses (not so easy to do, but possible https://www.newport.com/n/focusing-and-collimating), or maybe you could use the fiber optic prox cable to get the light source closer to the sample* **inside** *the integrating sphere, and maybe wrap the cable with Al foil so it absorbs less light. Or maybe you could put the white lamp inside close to where you put the test sample. You decide! There are bamboo skewers to help position things inside the cooler.*
4. ***Spectrometer.*** *It might be good if you put the ocean optics fiber behind one of the raised Styrofoam portions in the cooler, so there is no direct line of sight with the test sample or the light source (this improves data quality).*
5. *See the spectrometer guide for* ***calibration for reflectance***. *If you need to calibrate or confirm your 'dark state' of near 0% reflectance, maybe use black paper (over by the bins) or even better, just use an open hole and no room lights on. To calibrate your '100%' reflectance state just plug the test sample hole up with styrofoam that you removed. You may need to increase the spectrometer integration time. If you do so, here are some tips to minimize noise: http://oceanoptics.com/faq/can-reduce-noise-spectra/*
6. *Also, in your report explain why Styrofoam has such a very high reflectance that it can be used as an integrating sphere. The answer is simple, and is similar to why clean sand at a beach looks white even though each sand granule is actually just transparent SiO2.*

This may help, but may also be a bit more info than you need.

https://www.labsphere.com/site/assets/files/2551/a-guide-to-integrating-sphere-theory-and-applications.pdf

Mandatory Theoretical/Calculation Problem - Goal: design a LOW COST (using as few layers as possible) dichroic mirror used in biophotonics, that reflects green laser light (555 nm) at >98% and transmits red light from 610-630 nm with less than 25% reflection. You may choose any two thin film materials you wish (but they must be real materials, and ones which can be coated as thin films). Use the MATLAB photonic crystal simulator we used in previous week.

This lab does not take a lot of time. The challenge is developing a good lab procedure, and performing critical thinking and calculations. Next week will be more challenging, and the final project, will of course be the most challenging of all.

Presentation

Your 5-6 minute video-recorded presentation (if is more than 5-6 minutes, it will not be graded!) should use the slide templates and fonts we use for lectures in the class. You should have 5-6 slides, no more, which include:

(1) Title, group name, brief statement of project goal.
(2) Diagramed photo of experimental setup, listing of key procedures, and a solid but concise explanation of how it works theoretically with any equations or other parameters.
(3) Experimental results including signal achieved, optical efficiency of your setup, and, you should somehow validate that it matches blood flow change due to heart rate (you can determine the best way to do this… we have some pulse ox units in the bins).
(4) Discussion of your best-effort analysis for one of the two options listed below (see info below). Then at this point conclude the audio portion of your video.
(5) Then, as part of the same audio video time limit, have one last slide which has your answer to the theoretical problem that you chose.

A note of warning – based on previous video submissions:

This is from a past year. Please read it carefully. Don't make the same mistakes.

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Optics students,

I will start sending out the grades and comments for Week 11 videos.

Few comments:

1) Most groups did a very poor job following instructions, left out key calculations. Half of you did not even do a video, which was clearly stated in the requirements.

2) Most groups did not give adequate experimental details. Can someone really reproduce the results you show based on the info you give them? Think of all the variables at play. Think of how different results were from group to group. Your experiment details should let someone get the SAME results that you did, basically. That is the purpose, so in the future, someone can EXACTLY repeat your experiment and get the SAME results. If you don't give that level of detail, then a lab report (in industry is a technical report) is useless. Results, if not documented well, are of no value, if others cannot reproduce them (if you can't reproduce them, you can't use them). Hope you see the point I am trying to make....

3) Most groups needed a deeper theoretical explanation. Most presentations were the level you would present to non-engineers. Your audience is other engineers. You need to provide them with the theoretical tools they would need also to understand the fundamentals of the experiment.

4) Lastly, I am wondering about what would happen if I were to split the class such that half does week 11, half does week 12, then the next week, you switch and attempt the experiments based ONLY on the video provided from a group that previously did the experiment. Many of you would have that Eureka moment of "Oh, that's the purpose of lab reports and now I understand what is needed". Think about this as you create your video report, is your video report good enough such that another group could EXACTLY reproduce your results? If not, it is not good enough, and you will receive a poor grade.

Anyway, this is the warm-up. Next week, will expect improved video reports, and by the time of the final video report, they will all be good ;) This is why you get 2 times to practice before the final.

All the best,

-JCH

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