Group 7 - Lensless Digital Hologram Microscopy
Divide and Conquer

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Project Narrative

Premise:
A lensless microscope that will be viewed digitally. Either through a computer or a smartphone. The imaging will be constructed using back-propagation and shift-and-add pixel super resolution of in-line holograms captured on a CMOS Sensor, see figure 1 for example. This will be done using fiber optics and an LED array to slightly shift the attack angle of the incoming light onto a semi-transparent sample.

Possible uses include: Oil monitoring in Ocean Water (Tracking runoffs, seeking oil sources) Air health (Bioaerosols, Pollution, Mold Spores, Bacteria) Plant health (Cell burst, Cell Hyponatremia)

Motivation:
To create a simple, cost-effective, and portable digital lensless microscope that can be constructed at home or mass manufactured with smartphone compatibility. (Bluetooth or direct lens imaging)

We are working with the CPE and EE to create a microcontroller that will understand the optical formulas enough to create a visible hologram. Along with this, we are creating an iPhone app that will display the hologram on screen for easy access. In terms of the electrical components of this product, they should be rather low cost and low in weight, they shouldn't become too unwieldy to feel awkward to work with either in the field or in a lab setting, current concept in figure 2.

For the optical design of this project, rather than splitting into two separate optical designs, we will work together AND with the CPE and EE students to create a good blend between the optical side and the computer and coding side. We need to both design the physical device, and work the formulas out enough to be translated into usable code for our teammates. Our optical design will be something similar to the device shown to the right. We might change the device to be able to fit as an attachment on an iPhone, while still functioning well.

Project Requirements and Constraints

Programming Requirements	Justification
1. Should be able to implement phase retrieval with the use of deep learning	
2. Should have the ability to generate an in line hologram/ Gabor Hologram	the main ability to record and present information for the project. The ability to get the hologram allows for implementation method records the entire field information (i.e. amplitude and phase) not just the usual intensity
3. Should be able to create a focused image with the use of simple back propagation in order to create a focused and defocused image (two-image artifact)	this allows for no loss of resolution
4. Should implement the "shift-and-add" in order to take low-resolution holograms and up-sample, shift, and digitally add them in order to create a good image	in order to create an image with the highest resolution possible
5. Should be able to implement digital hologram reconstruction (digital back-propagation) with the method of angular spectrum method	The reason is that the image quality would be compromised by the use of twin image and self-interference related noise terms, thus it needs to be improved by phase retrieval techniques. This because the recorded hologram we get has only the amplitude information and it's phase is originally missing

Electronics Requirements	Justification
1. A source of power either on board or using the device it is mounted to for power	There is going to be a relatively low load requirement, due to the small list of electrical components, but since there could be an available phone I need to see if it is efficient and not too unwieldy to use the phone's battery. However an on board rechargeable battery might be implemented anyway
2. A sensor (the related material showed a specific CMOS sensor, there will be pro-con list between this sensor and all relevant substitutes)	This device will be needed a imaging sensor that supports color in some capacity, there is a lot of possible sensors on the market on of which will be needed to complete this device
3. A microcontroller (Anything as robust as a raspberry pi or simple embedded system that can send a bluetooth signal can be utilized)	Ideally the microcontroller should be performing as much as the computations as possible, so there will be a cost-benefit analysis in future papers about what each relevant microcontroller can contribute to this device. But the bare minimum is just send the Bluetooth signal and have the phone do the computations.
4. LEDs (> 20)	From an electrical point of view I just need to have them be powered, and connected separately for how the image process is intended to work.

Photonic Requirements	Justification
1. LEDs (>20)	Light source, what encodes the data into the CMOS sensor
2. Fiber	What guides the light and allows us to position the light in specific positions
3. CMOS Sensor	What will end up capturing the in-line hologram data and communicating it to the computer
4. Resolution Size 50 μm - 250 μm	Will be tested with desired field's subject matter, as well as micrometer beads in the design phase

Project Constraints:

Programming Constraints
understanding what language would be needing for coding with the microcontroller and sensor
the planning for the coding of the project understanding that the code software will have multiple iterations
time crunch with the coding and communication with fellow group mates to make the code work along with all other components. The ability to stay up to date and record the many project changes
resource constraints with the potential application of an phone application with the programming of the Bluetooth and the app itself
Electronic Constraints
Needs a sufficient power source that can provide enough energy for the microcontroller and the about 20 LEDs
The device is expected to be able to be used multiple times in a single session so the battery life must be able to do go for a couple of hours at least
The microcontroller needs to at least send the images via Bluetooth to the device for process, or hopefully be able to do as much computation on the embedded system as possible
Photonics Constraints
Optical Shadowing: Blur caused by anything not on imaging plane
Twin image artifacts: Unavoidable extraneous data, can be mitigated by spacing out twin image and image.
CMOS CCD Pixel Size restrictions: Limited by current hardware limits and finances.
Speckled Interference Pattern: Caused by monochromatic light, will be using partially chromatic light.
Multiple Reflection Interference: Can be mitigated using partially chromatic light.
Structure around 16 cm or less. (soft restriction)
Image subject must be semi-transparent

Figure 1: UCLA depiction of device

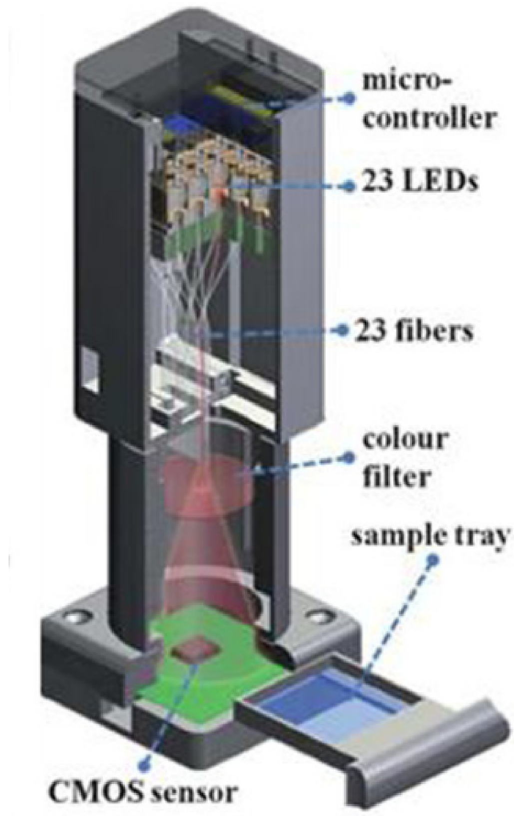
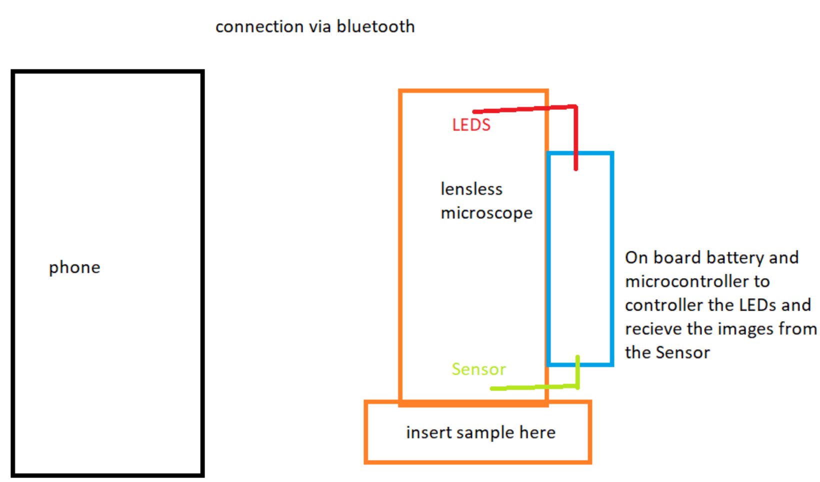


Figure 2: Simple Visual Representation (Idea 1: CMOS Sensor)



House of Quality:

In figure 3, we attempt to illustrate the various tradeoffs and benefits that we are trying to provide our customers, as well as show the correlation between our design concepts.

Figure 3 - House of Quality:

Correlation matrix

+ positive, supporting
- negative, tradeoff

Strong +	+2
+	+1
0	0
-	-1
Strong -	-2

Interrelationship matrix

Customer Requirements \ Product Requirements	COST (-)	POWER (-)	MICROCONTROLLER (+)	OPTICS (+)	APP (+)	SENSOR (+)
Cost (-)	+2	+2	+2	+1	0	+2
Accessible (+)	0	+1	+2	+1	+2	+1
User Interface (+)	0	0	-2	-2	+2	0
Precision (+)	-2	-1	+1	+2	+1	+2
Visibility (+)	-2	0	+1	+2	+2	+2

Block Diagram:

The General Design block diagram can be found in figure 4 and the Design Specifications will be in figure 5. The responsibility of each aspect is determined by the shape of the block, and the color will determine the current state of that feature. The responsibilities go towards our respective majors so both majoring in optics will share that load, but we do plan all help out where we can in others respective fields.

Figure 4: General Design Block Diagram:

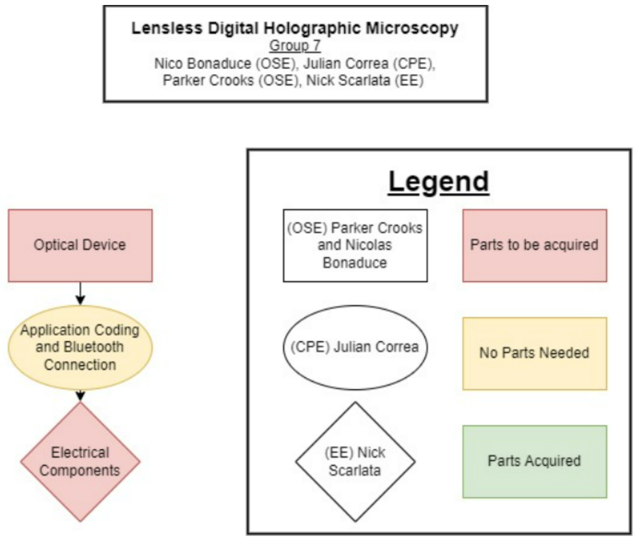
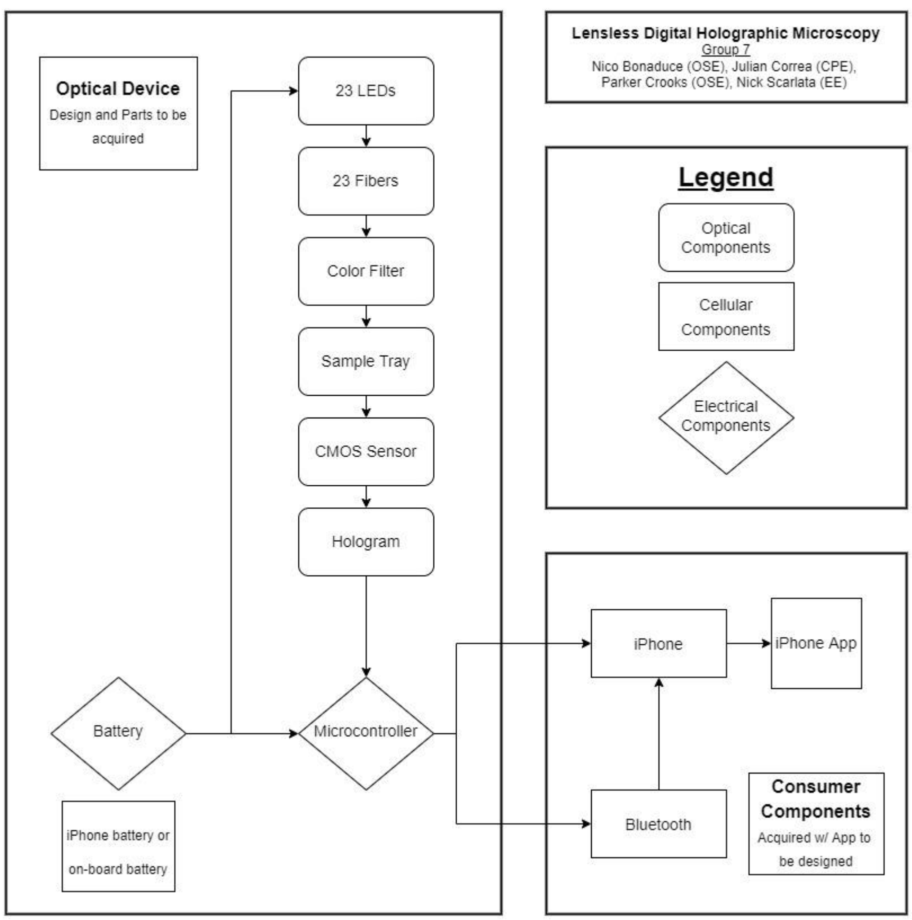


Figure 5: Design Specification Block Diagram:



Project Budgeting and Financials:

From a baseline cost analysis all the electrical components should cost at most $50 at market price

Glass beads - $45

Fiber - $100

LEDs - $7

CMOS Sensor - $8 - $25

Project Milestone:

Programming milestones:

In the midway point of the semester I want to have planned out the microcontroller coding ready for the working optical feature we need to have ready to present

- implementation
- Quality assurance testing
- Deployment
- Support
- Design analysis

From there I want to improve the code while keeping record of the code in order to show the growth of our project but to also show that the project on the software and programming side has improved by the next time we present the working optical feature again.

The goal for next semester is to research and code for expanding the application to phone application and the feature of Bluetooth applications for the lens less microscopy

Optical Milestones:

Working optical feature for demo by week 8.

Improvement upon optical feature to demo by week 14

Electrical Milestones:

By the end of this semester, I want to have the parts selected and purchased, with a full schematic ready to begin prototyping.

From there I would hope that it would only take about a month or two into the next semester to get the prototype completely working.

Then by the end of the next semester we should have a complete minimum viable product and would be adding in stretch goal features.

Goals:

Basic:

- The Device is able to turn on and power the LEDs in sequential order, via an from of power source (on board battery or plugged into a computer)
- The Device is able to take images from the CMOS sensor and store them in the Microcontroller (they will be basically incompresible but useful)
- The Device is able to send this images to the app (phone or computer) via either bluetooth or physical connection

Advanced:

- The Device is powered by an on board battery, and all the electrical components are stored on the device, as if it was a modern product
- The Device is able to process the images into a single usable image, and be able to send it to either the users phone or computer of choice
- The Device will be able to provide useful imagining of the desired goal at the practical magnification

Stretch Goals:

- In order to view different specific things a change is necessary both to the optics and the programming we’ve done for the imagining, therefore as a stretch goal we would want to work on other versions of this device that can effectively do the same thing but for other relevant subjects.
- To make our device more accessible we want to make the blueprint, design specifications, and code open source, so anyone with reasonable knowledge and equipment can replicate our work, with our bill of materials