Cheap Do-It-Yourself Small Volume UV Spectrometer for Nucleic Acid and Protein Quantitation

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Joseph received much training on electronics design and programming in his bachelor's degree. He will aim at designing the user interface and signal processing.

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Dushanth, worked as an optics technician for 2 years before coming to Cambridge. He will share his knowledge by building the optical unit of the spectrometer and the hardware enclosure.

Summary

Minimization of the use of valuable biological materials is a critical factor that affects the viability of any assay. Small volume UV spectrometry allows researchers to use minimal amounts of solution to check the purity and quantity of their DNA and protein samples. Unfortunately, currently available small volume UV spectrometers have a relatively high cost. This project aims at creating an open source small volume UV spectrometer as a cheap alternative to the pre-existing ones. By using LEDs as the UV light source, and cheap UV sensors that can be processed and analyzed via an Arduino system, this once expensive system can now be affordable for not well-funded labs, or potentially labs in resource poor countries. Additionally, we intend to use 3D printing to create the housing for the instrument, with the hope that the flexibility provided by this approach will allow future users to modify the spectrometer based on their research needs.

Proposal

i. Nucleic acids, such as DNA and RNA, and proteins are two very important materials in a wide array of synthetic biology work. Nucleic materials are used for diagnostics, data storage, and protein synthesis, while proteins have been used for electron harvesting in biofuel cells, DNA amplification, and antibody production. Despite the use of these materials, it is always very important to know the both quantity of DNA/Protein in use, as well as, the purity. Due to its simplicity, reliability, and speed, one technique used to obtain this information is spectrophotometric quantification. This is the same principle used in NanoDrops to quantitate DNA, and since this instrument requires a very small volume to operate, it is a very valuable research instrument. The downside of this instrument, however, is that it is very expensive meaning that labs in resource poor settings cannot afford this tremendously useful tool. We believe by making a cheap DIY small volume UV spectrometer, we can give these not well-funded labs access to a critically piece of scientific equipment and thus improve the development of science.

ii. Strictly speaking, this system does not use biological systems but could be applied to multiple biological applications. It can be used to analyze experiments that utilize biological systems such as E. Coli cultures. For example, protein production often involves first inducing the bacteria with a protein encoded plasmid, and after protein expression, the cells are lysed and the protein is purified. The instrument we would like to build could provide information on the amount of plasmid used for induction, as well as information on the purity and concentration of the produced protein. Furthermore, since this instrument requires a small quantity of solution, the user will only lose a minute amount of their precious sample for the assay. This is especially important in resource-restricted settings, where efficiency must be the top priority, since biological research is often costly, and as much of the sample must be retained for their desired experiments.

important in resource-restricted settings, where efficiency must be the top priority, since biological research is often costly, and as much of the sample must be retained for their desired experiments.

iii. The ultimate goal is to build a cheap and easily replicable UV spectrometer which is capable of performing photometric analysis on small volumes of nucleic acids and proteins. Design wise, the spectrometer should be compact and robust. The user-interface and data collection methods should be simple and intuitive. USB interface for data logging and collection. Some secondary design goals will include power consumption minimization, built-in memory for data logging, smartphone to instrument interface for mobile control and data collection. Finally, the tertiary goal for this project will be to incorporate a visible light spectrum for fluorescent tag based analysis and improve the flexibility and detection range of the device.

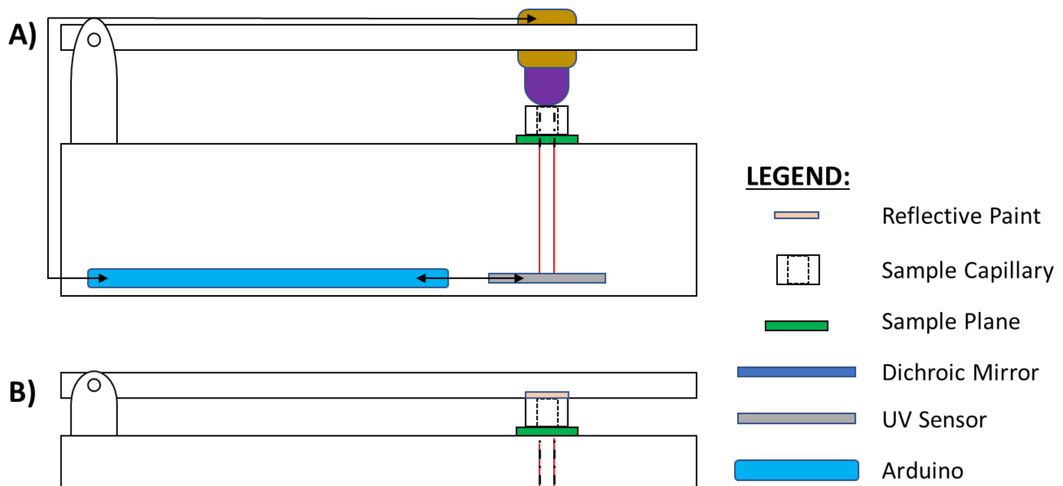
iiii. With regards to implementation, 3D printing will be used to build the housing and potential probes. This would allow for the structure of the instrument to be easily replicated, and housing will be designed in such a manner that the rest of the components will fit into place. Furthermore, the light source will be provided by cheap ball lens UV LEDs. This provides us with a cheap UV source with a small focal length, perfect for close range UV absorption tests while minimizing the cost. If the UV light needs to be reflected to obtain the right optical length, or to assist in keeping the equipment casing neat and compact, then UV reflective paint will be used to divert the light while keeping the cost low. Furthermore, if the same side design (seen in figure 1.B.) is utilized, then a dichroic mirror will be used to separate the absorption beam from the reflected beam. As for data acquisition, a cheap UV sensor will be used to convert the light into a voltage signal that will be processed by the Arduino and converted into both concentration and purity data.

v. To continue, the time management goals for this project have been separated into two categories; hardware design and software design. The preliminary emphasis will be on the optics and hardware control. As the components are assembled, the software aspects, such as signal processing and user-interface, will be developed alongside the hardware. Initially Dushanth will tackle the optics and Joseph will do the software. As the framework matures, we intend to interchange the roles to utilize the knowledge we gained from each other. To better understand the time frame of the project, a Gantt chart highlighting the key objectives is displayed in figure 2.

vi. The major outcome of the open source project will be creating a cheap and useful UV spectrometer alternative for resource-restricted labs to enhance their synthetic biology research. Being an open source device, the future plan is to increase the variability of probes. Switchable probes can facilitate users' personal needs where each probe is designed to perform spectrophotometry at different wavelengths and signals are picked up by a wide spectrum sensor. Furthermore, being an open source spectrometer, this device may go beyond the lab setting and even benefit households. One potential usage will be for water cleanliness detection. Rather than using the UV setup, households could use the red or infrared setup to test how clean their water is. Lastly, the final product should have a simple and friendly interface that can be properly utilized by both professional and amateur tinkerers.

Estimate the components and budget that you need to complete the project

We have estimated a total cost of 650GBP for the entire project. This includes the starter kit, optics, and rough 3D printing costs. A more detailed breakdown of the cost estimate is shown in table 1.



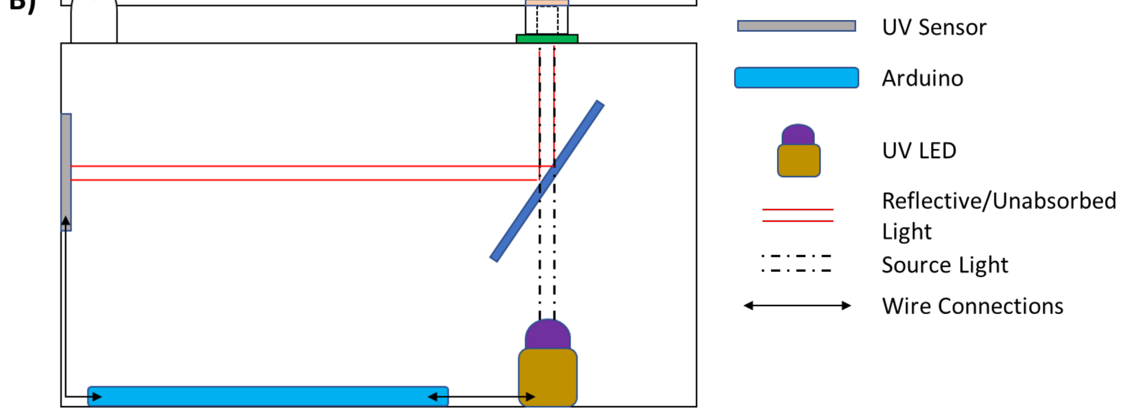


Figure 1: 2D Design Schematics where A) Contains a LED on the detachable probe and B) The enclosure contains both the LED and Sensor.

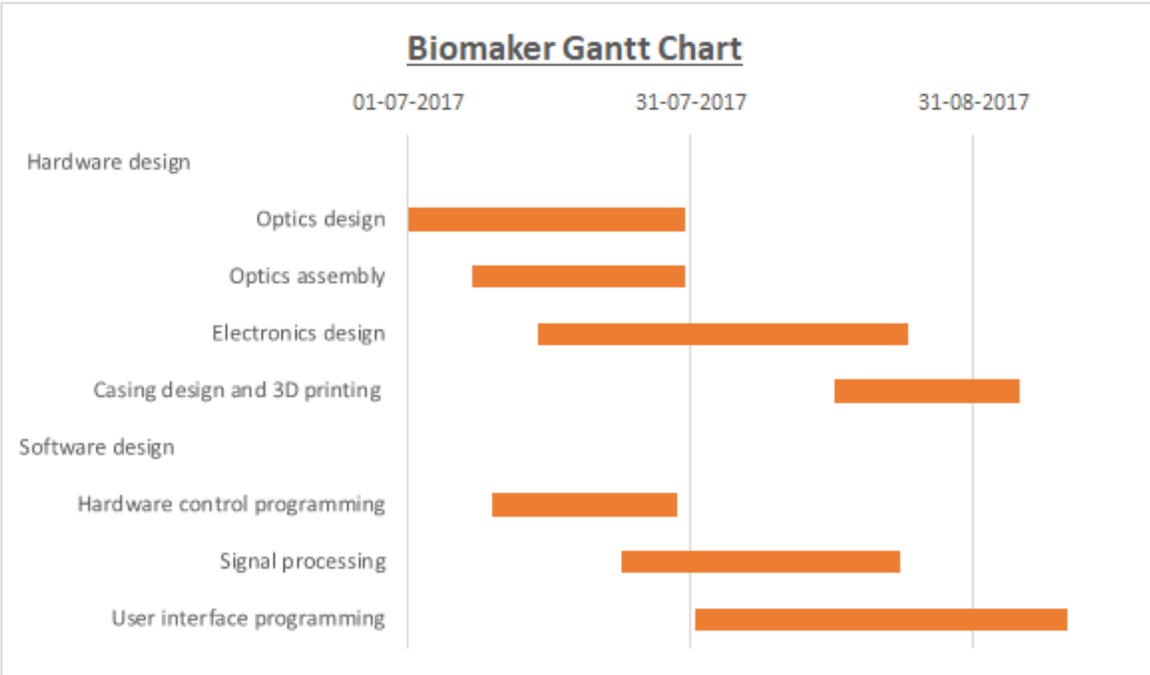


Figure 2: Gantt Chart highlighting the timeframe for all the major objectives.

Component	Quantity	Cost (GBP)
Biomaker Starter Kit	1	250
TO-39 Ball Lens	4	240
UV Sensor	2	20
Reflective Material	1	20
Dichroic Mirror	1	60
3D Printing	2	40
Other Materials	N/A	20
	Total:	**650**

Table 1: Estimated Cost for BioMaker Project