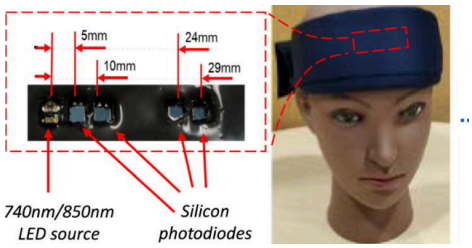
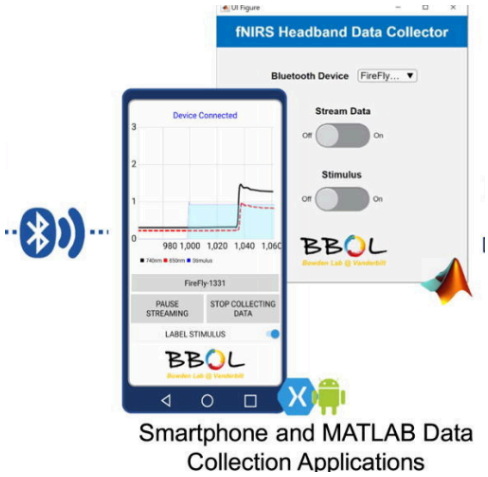
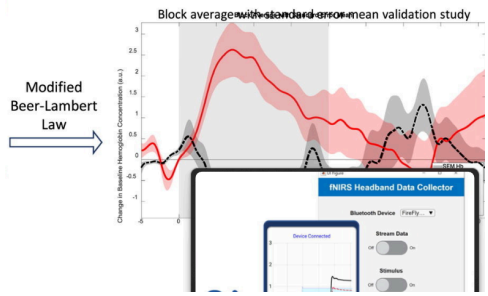
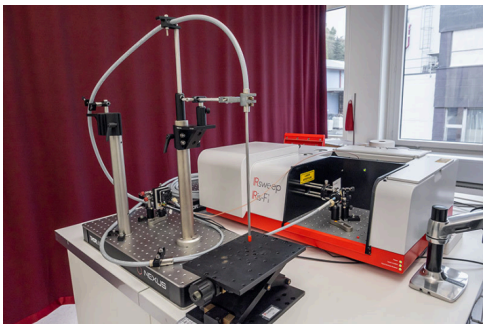
Background & Market Research

Device:	Limitations:	How will we improve:
Name: Do-it-yourself functional near-infrared spectroscopy (DIY-fNIRS) headband Link to article  *Figure 1: Image of the headband device and it's outer appearance*  *Figure 2: The connected applications that process the data*  *Figure 3: How device was validated through a breath holder test*	The device presented in this article has a single-channel system, This is a limitation to the effectiveness of the device because it only measures brain activity at one specific spot. This stops it from getting a better picture of the complex activity in the brain regions. Having that single-channel system also can be troubling as not enough information can be collected to help draw conclusions. Another limitation of this device is the location of it. Because this device is located on someone's head, their movements can disrupt the fNIRS signal, which can lead to skewed data. This may only be more prevalent in longer studies, but to be translated for other purposes, it wouldn't be ideal for the device to be in the form of a headband. The cost is significantly less than other stationary devices but still relatively high.	We want to alter the shape and structure of the device; we don't need it for the same particular need, therefore it is unnecessary to have the technology in the form of a headband. Instead, we plan to build an attachment to a typical phone camera that will serve as further accessible and easy to use. This device will take pre-existing infrared light that already comes off phones and amplify the light so it can be used for the purpose of malaria detection. By having the device in a different form, we also eliminate the issue of having a single-channel system when examining our samples. Even if for a different purpose, that kind of system should be avoided for accurate data collection, so changing the shape so it's still portable but not in a headband form will remedy this issue. Our device aims to be on the cost-friendlier side so we will be improving on the price of the device as well, substituting materials for cost-efficient alternatives where we can.

	Electronic costs were $204, multi-use consumables were $9, and other equipment tallied up to $23,000.	
Name: nlir mid IR spectrometer, 2-5µm Link to product  *Figure 1 and 2: These images display the shape and relative size, as well as the overall appearance of this product*	The biggest limitation with this product is its limited spectral range. The product highlights its 2-5µm range which can pose a problem as typical mid IR devices range anywhere from 2.5-25µm. This lack of range can limit its analysis abilities. This means it can really only target specific functional groups. Important information can be lost because of that. On top of that, this technology uses upconverting light sources, and its smaller size can cause it to have a lower intensity than other typical devices, which directly impacts how well it can analyze specific components, like weakly absorbing materials, for example. Similar to the last product, while they don't directly mention the price, from the materials they use, it can be inferred the price is still relatively expensive.	Our device aims to use a wider range, by opting for a filter that will enhance the phone's preexisting infrared light to make sure it has a high enough intensity to accurately analyze the functional groups we need it to. Furthermore, the cost will be reduced by substituting expensive materials for cost-friendly alternatives, in a way that won't harm the success of the device. Even if our device is more portable, we want to avoid having that limit the success and function of our product, so the materials we use will ensure that the smaller size won't lead to worsened analysis of samples.
Name: Mid-IR PAT with 10 meter fiber probes	This divide uses custom-made probes,	Our device aims to simplify the process for users by

Link to device  *Figure 1: The MIR device with 10m probes*	which hints at a higher cost, reducing the target audience as the product becomes more expensive. Furthermore, the article briefly mentioned the need for an external detector. This means it needs multiple parts to function, and as it's already stationary, this proves to be a device that isn't portable and has to be stationary to function. Overall, just from the picture, it is clear that this is a bulkier device, with multiple parts, making it inaccessible for a lot of people. This could commonly be found in a lab setting, but harder for others to use due to its size and complexity.	designing a simpler, more portable product that can be used in different settings because of its easier accessibility. Not only that, but no external detector will be required in the sense that it will add a whole other part to the device. Everything will be compact and mobile. Without using custom made materials, the cost will be significantly reduced, while still maintaining strong function and usability. With the ultimate goal being a portable device that can enhance the phone's existing infrared lights, this device will serve as simpler, employable method of running MIR spectroscopy.

Malaria is a parasitic disease caused by certain mosquitoes. Those infected can experience fevers and chills and become fatal if not treated. Some severe symptoms include kidney failure, mental confusion, and seizures (CDC, 2023). In 2021 alone, there were approximately 241 million cases of Malaria, mostly coming from sub-Saharan Africa. Of these, 627,000 people died due to a lack of detection and treatment. Moreover, Malaria is slowly becoming more prevalent in communities as deaths increase by 10% from 2019 to 2020 (U.S. President's Malaria Initiative, 2023).

Evidently, Malaria has become a pressing issue for global health. Efficient and simple at-home malaria detection would not only allow early treatment, but it will provide detection resources to those in rural areas who may not be able to make the extensive commutes to their nearest healthcare provider. Additionally, it will reduce the mental and economic strain during the detection process.

Real-time virus detection presents solutions for the Malaria crisis. Current methods include Giemsa stained blood smears. However, these have al limit of less than 5 parasite per μL of blood and a need for well trained microscopists. Rapid diagnostic tests are simple and cost friendly, however they are sensitive and have a low specificity in detecting low parasitemia. Short for polymerase chain reaction has proven to be the most trust-worthy method, however it requires technical experts (Goh et al., 2021).

However, spectroscopy provides a promising solution for detection. Spectroscopy is a chemical field of study where molecules are excited via light to emit spectra, which is then recorded. Each element and molecule has its own unique spectra, allowing scientists to detect functional groups from the spectrometer graphs. In a spectrometer, a light is passed through a small hole or slit in a metal plate to isolate it. It is then bounced off of a grating to split the light, which is read by a detector (NASA, 2022). Particularly, mid-infrared spectroscopy has been seen in the area of malaria detection. Mid-infrared spectroscopy pushes light at different wavelengths and measures how much light is absorbed by the different bonds. It uses this information to plot the percent transmittance against the wavelength to then identify functional groups (Bennett et al.). Within the graph, 1500cm^-1 to about 4000 cm^-1 is the functional group region where significant functional groups like the OH band or C-C bond stretching can be seen.

Current methods of spectroscopy for viral and parasitic detection are often bulky, expensive, lack convenience. Therefore, mid-infrared spectroscopy is not easily accessible, and does not prove useful in places where it may be necessary for malaria detection. A small and portable device linked to a phone, may be able to solve this issue, and provide people with the resources they need to begin safe and easy malaria detection.

Prototype sketches -

https://scientistnobee.wordpress.com/2020/03/20/diy-smartphone-spectrometer-part-1/

https://www.youtube.com/watch?v=ORJkTW8sd0E

https://unterbahn.com/2019/12/01/papercraft-spectrometer/

http://www.upb.edu/en/contenido/smartphone-spectrometer

Potential datasets/diseases -

Using Infrared spectroscopy to detect antibodies with machine learning

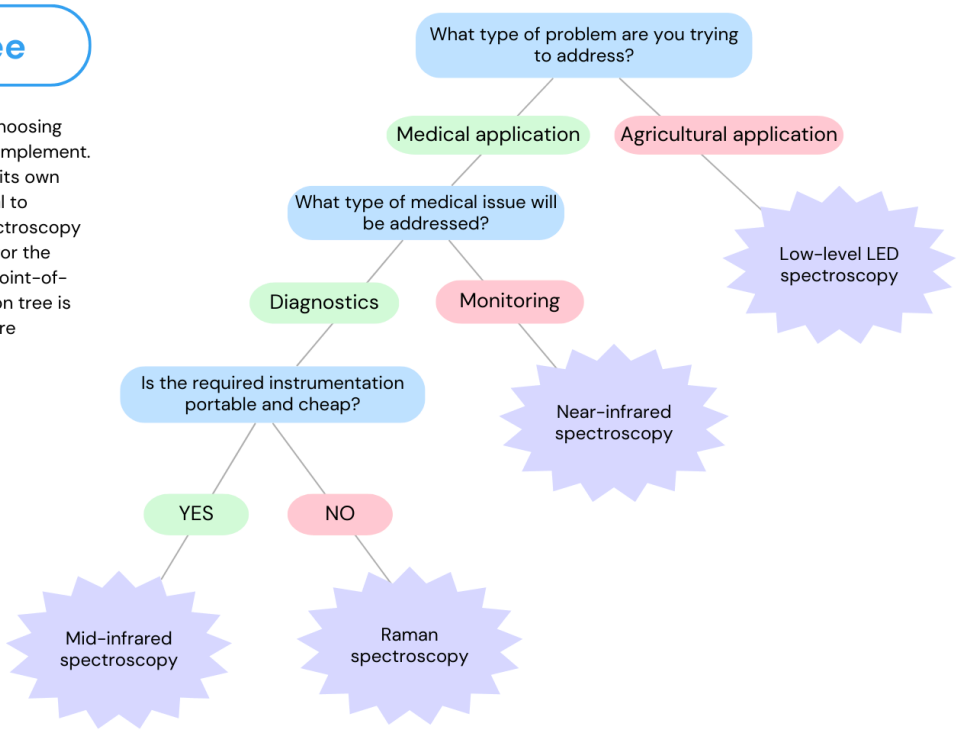
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8086480/#r72 - smartphone application

https://www.medrxiv.org/content/10.1101/19001206v1.full-text

Decision Tree

Decision Tree

There are multiple options for choosing which type of spectroscopy to implement. Each type of spectroscopy has its own pros and cons, and it is essential to choose the correct type of spectroscopy for the problem that is optimal for the problem we aim to help solve: point-of-care viral detection. This decision tree is based on the resources that were available to us,



Systems Diagram

Dried blood sample taken from the individual in a rural population

Mobile Mid-Infrared Spectrometry for the Easy Real-time Diagnosis of Malaria

implemented for accurate diagnosis because....

Portable

Description

Mid-infrared spectroscopy requires straightforward instrumentation, all of which can be attached to the mobile phone camera. Compared to large PCR machinery and assay instruments, MIR spectroscopy is much more feasible in field testing and can be transported easilly.

Key visual

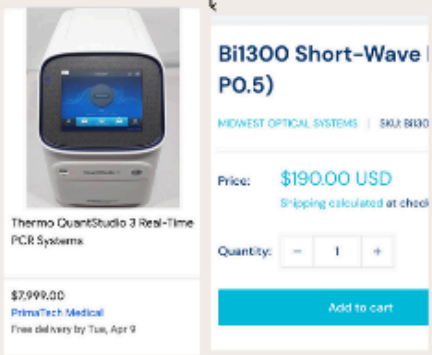
Mid-infrared technology can be applied directly on a mobile phone. Image taken from ScientistNobee.

Low-cost

Description

The technology required to implement mid-infrared technology for point-of-care virus detection is very cheap. The most expensive component of the MIR technology is $190.00 for the light filter. The PCR instrumentation, on the other hand, costs anywhere from $3,000-$15,00.

Key visual



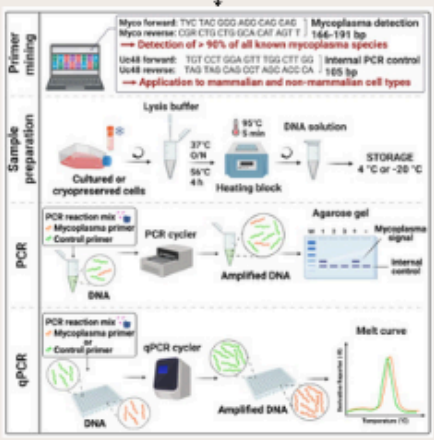
PCR machinery is much more expensive than a Mid-infrared lens! Picture on right from PrimaTech Medical. Picture on the left from Machine Vision Direct.

Easy to implement

Description

Using PCRs and assay technology requires extensive lab training. On the other hand, utilizing Mid-infrared technology is very simple, and the diagnostic process is completely autonomized through machine learning models.

Key visual



The PCR protocol is extensive and complicated! Image from "A PCR protocol to establish standards for routine mycoplasma testing that by design detects over ninety percent of all known mycoplasma species"

Patient receives early and accurate diagnosis, allowing for early treatment, avoidable suffering, and substantially decreased risk of death.

Requirements	**Weight**	**Papercraft Spectrometer (Sketch #1)**	**Smartphone Spectrometer (Sketch #2)**	**Grating Spectrometer (Sketch #3)**
Cost friendly materials: Doesn't require a lot of money to attain/produce the materials. *Justification: This product is a cost-friendly alternative that can serve those in low income communities who are at a financial disability.*	**7**	**8**	**6**	**7**
Accurate	**10**	**10**	**10**	**10**

display of results: The user is given clear and understandable results that are CORRECT. *Justification: The accuracy display is important because it gives the user a clear depiction of the results.*				
Convenient to use: Easy for the user to understand and operate and doesn't require a lot of work.	**7**	**7**	**8**	**8**

Justification: This product is meant to be used casually in a way that users can utilize on the spot. This is not meant to be advanced or a lengthy process.				
Portability: Easily transportable and can be carried. *Justification: Allows users to use this device anywhere and easily detect malaria wherever they*	**7**	**10**	**9**	**7**

go.				
Visually appealing: Comprehensive appearance that doesn't overwhelm the user. *Justification: Doesn't attract attention. Also a simple design that doesn't distract or confuse the user.*	**3**	**7**	**9**	**8**
Easy to DIY: Ability for users to create themselves. Doesn't require complicated machinery to	**6**	**10**	**7**	**5**

attain parts. Further works for this project could include on top of manufacturing this device, allowing users the ability to make it themselves by providing them with the basic materials and files. *Justification: Since we are targeting those in lower income communities, they may not have access to the equipment*				

that is needed to create the parts. Ex. 3D printer				
Ability to read samples: The spectrometer can accurately read and analyze the given samples. *Justification: The accuracy of the analysis and ability to read the samples is important because malaria is a serious disease that should be combated as much as possible. This*	**9**	**10**	**10**	**10**

starts with being able to accurately identify it.				
Prior reviews: The spectrometer model has positive feedback and approval/proof that it works for other customers. *Justification: This gives a general estimate on customer satisfaction and if this model has a history of working well.*	**5**	**7**	**8**	**7**
Durability: The	**6**	**5**	**8**	**7**

spectrometer is not easily breakable and can withstand some amounts of force. *Justification: The device should not break easily because that is very inconvenient for the users.*				
No prior spectroscopy knowledge: The spectrometer does not require extensive knowledge on spectroscopy to operate it. It can	**8**	**9**	**8**	**7**

be used without a former background in the area. *Justification: This device is for low income communities who might not have access to resources on spectroscopy or the educational background required to operate complex devices.*				
Total:		**583**	**572**	**531**

https://wpi0-my.sharepoint.com/:x:/g/personal/inagireddy_wpi_edu/EUwDh1Gs6xtAnjKhvuPxqFYBkwSt_hG2UWUSBgXsmHt_IQ?e=6ITj4T

Materials List

https://machinevisiondirect.com/products/midopt-bi1300-13_25?currency=USD&variant=43736243437826&utm_medium=cpc&utm_source=google&utm_campaign=Google%20Shopping&stkn=cc6434354364&srsltid=AfmBOooVHPix2sP9Qndh9TBwH6SwsjANaYEIhDnvDY6ao02N04rxgUqrycA

Papercraft Spectrometer - foldable-2.0.7.pdf

1. PDF of papercraft spectrometer design
2. Thick poster paper or equivalant
3. Pair of scissors
4. Butter knife/ballpoint pen
5. DVD fragment
6. 2 sheets of black paper
7. Smartphone
8. Mid-infrared lens filter

Smartphone spectrometer - https://scientistnobee.wordpress.com/tag/spectrophotometer/

1. 3D printed parts of the smartphone spectrometer (tube and cylinder outer component)
2. Small jewelry spectrometer
3. Small rechargeable LED light
4. Smartphone
5. Mid-infrared lens filter

Grating spectrometer -

1. 3D printed STL files
2. Mid-infrared filter
3. Smartphone
4. Mobile app for capturing spectra waves

References

Bennett, H., Markwick, A., & Turner, K. (n.d.). Infrared (IR) spectroscopy | Resource. RSC Education. Retrieved March 27, 2024, from https://edu.rsc.org/resources/infrared-ir-spectroscopy/4010243.article

CDC. (2023, August 18). Malaria. Centers for Disease Control and Prevention. Retrieved March 27, 2024, from https://www.cdc.gov/parasites/malaria/index.html

Goh, B., Ching, K., Soares Magalhães, R. J., Ciocchetta, S., Edstein, M. D., & Sikulu-Lord, M. T. (2021). The application of spectroscopy techniques for diagnosis of malaria parasites and arboviruses and surveillance of mosquito vectors: A systematic review and critical appraisal of evidence. PLoS Neglected Tropical Diseases, 15(4). https://doi.org/10.1371/journal.pntd.0009218

NASA. (2022, September 30). Spectroscopy: Reading the Rainbow. HubbleSite. Retrieved March 27, 2024, from https://hubblesite.org/contents/articles/spectroscopy-reading-the-rainbow

U.S. President's Malaria Initiative. (2023, April). Report to Congress. PMI. Retrieved March 27, 2024, from https://www.pmi.gov/ar17/