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NIR camera for early detection of diabetic ulcers

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A portable, low cost, near-infrared camera for self-monitoring of diabetic patients to manage inflammation of tissue at risk of ulceration

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Statement of Purpose: The purpose of this creative inquiry is to test whether near-infrared (NIR) imaging devices can detect areas of skin at risk for ulceration in diabetic patients. Venous blood accumulation, or high levels of deoxygenated blood within a tissue, can indicate poor blood circulation and increased risk of ulceration. Here we propose to detect venous blood in tissues using differences in optical spectra of oxygenated vs. deoxygenated blood in NIR region. We previously designed and built a prototype scanner with three integrated NIR light sources that is being tested at MUSC. Our current work is focused on testing of improved NIR illumination systems and improved NIR imaging device, and our second prototype that uses a more sensitive Raspberry Pi-controlled camera and advanced NIR light sources will provide significantly improved image quality. Upon success, the ultimate goal of this project is to manufacture a cheap, portable NIR camera for skin self-monitoring by diabetic patients.

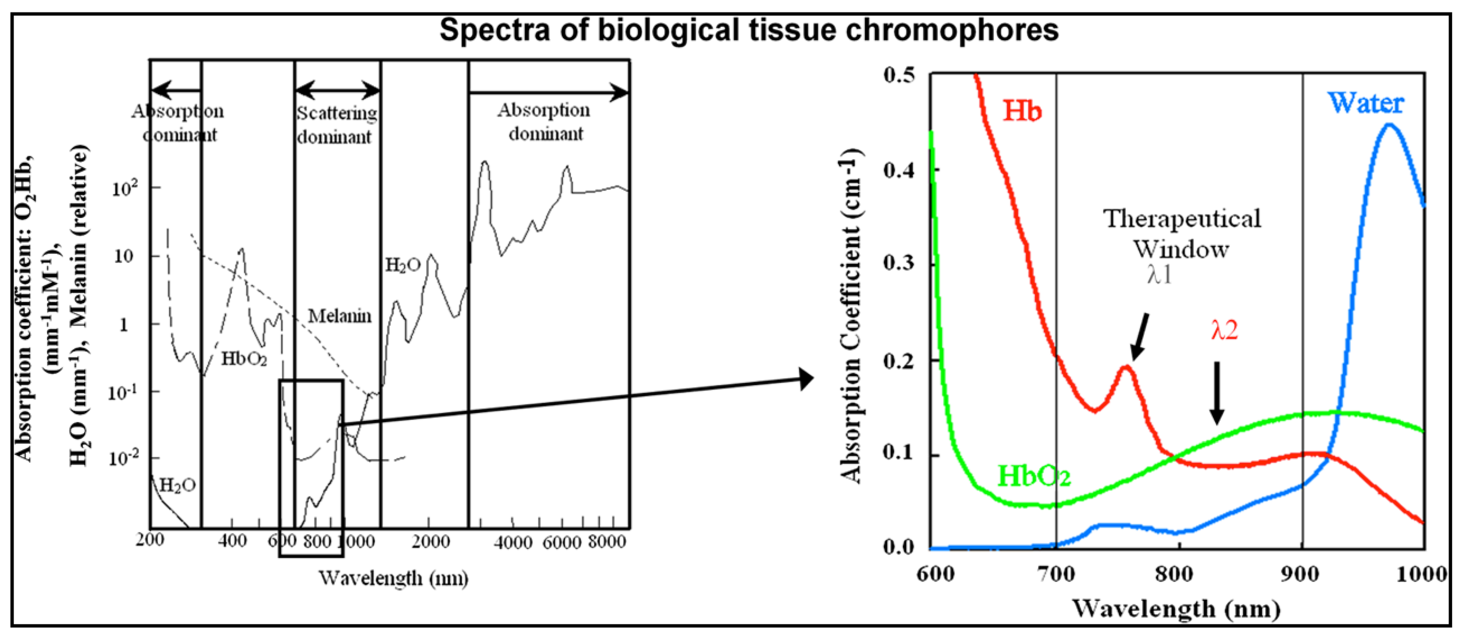

Figure 1. Absorption spectrum for oxygenated VS deoxygenated blood.

Methods: Our light source was designed using CadSoft EAGLE PCB Design Software. Photolithography was used to fabricate the circuit board used for our light source. LEDs were then soldered onto the PCB board. 5V regulators were installed to ensure a constant voltage supply to the LEDs from the alkaline battery power supply. Individual switches and rheostats, which control the intensity of the LED by varying current, for each set of LEDs were also installed. A Sony Cyber-shot digital camera was modified to increase sensitivity to NIR light and reduce sensitivity to visible light

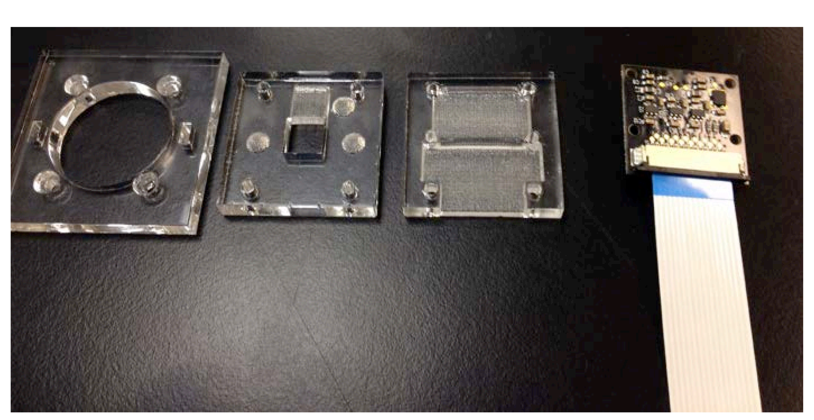

Figure 6. Acrylic case and filter holder assembly.

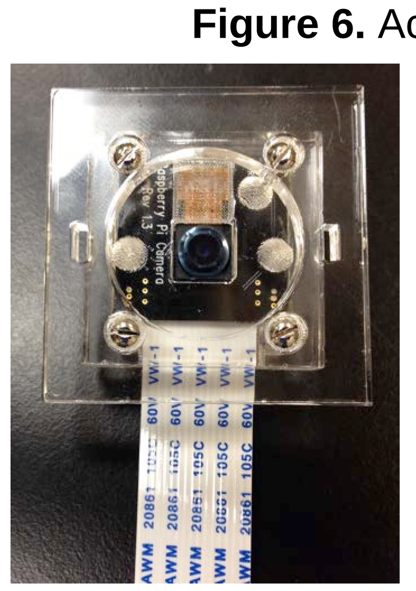

Figure 7. Front view.

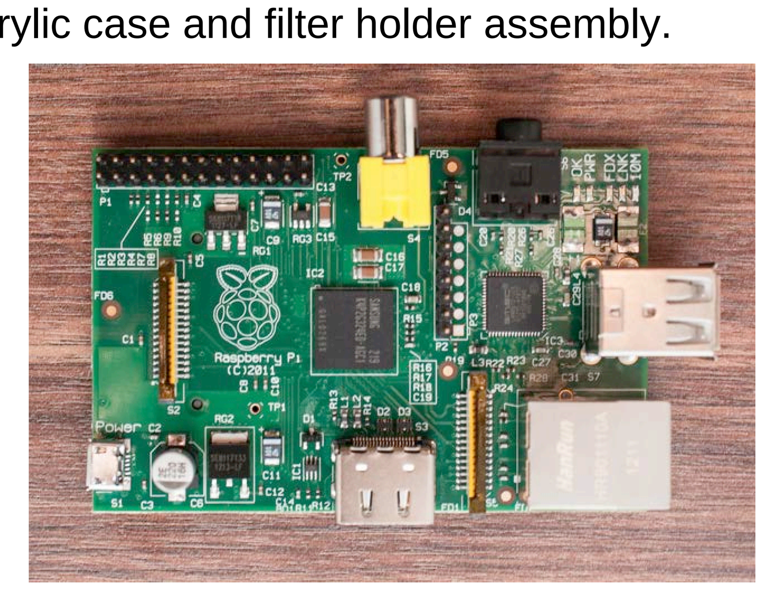

Figure 8. Raspberry Pi Computer.

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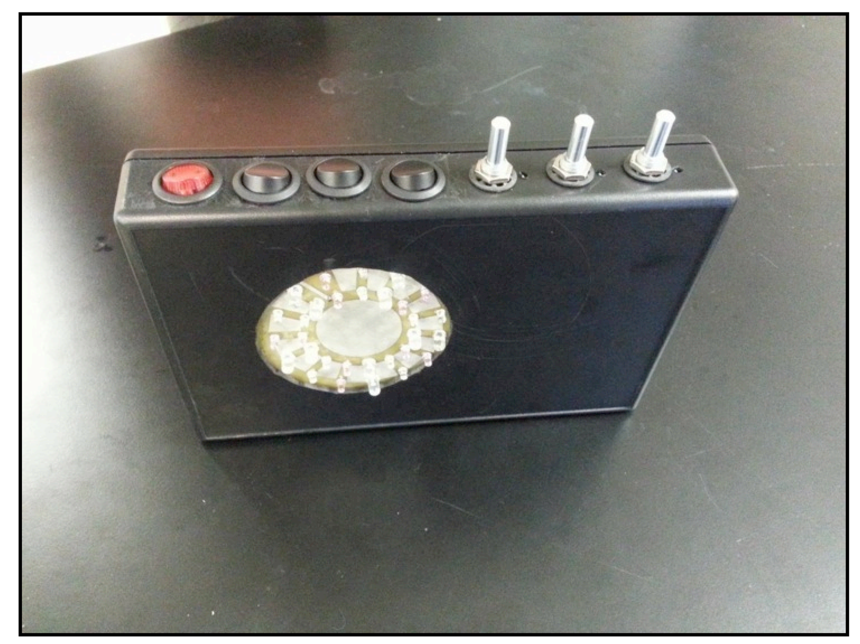

Figure 2. Previous prototype camera.

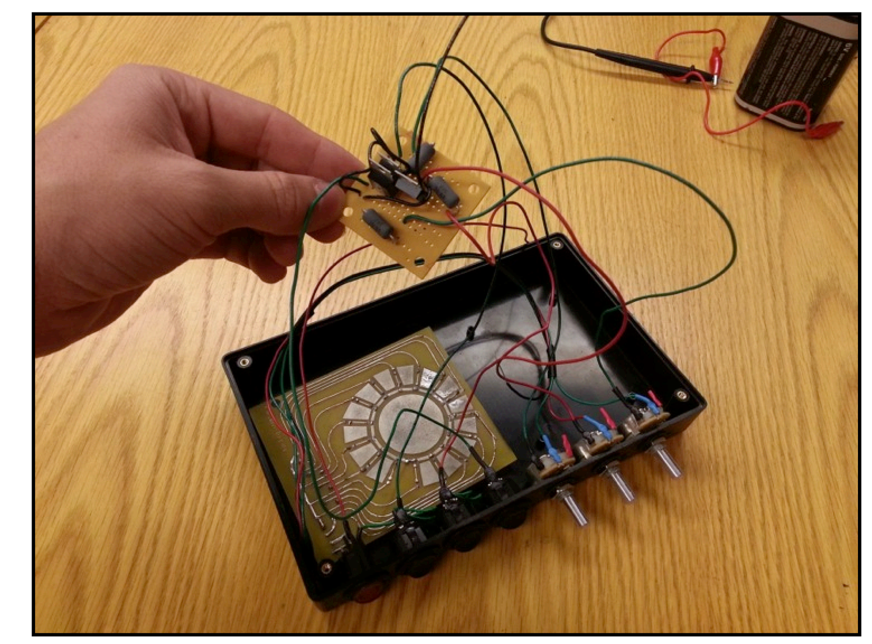

Figure 3. Inside the previous prototype device

Results:
- Upon the completion of our device, we were able to visualize the patients vasculature much more accurately compared to a non-modified camera
- We experienced a small difference in the amount of visualization between the two different NIR wavelengths (740nm, 880nm), even when the intensity of each set was varied using the rheostats
- The 640 nm light was not detected using our modified camera, due to being too far outside the NIR range (800nm), instead it provided low intensity red light which allowed dark room imaging.
- Modifications of camera have been made to make it more portable and more efficient.

We found that for better imaging we need a camera with better sensitivity in NIR region and, probably, another combination of light source and NIR-passing filters, so:
- A second prototype has been developed using a Raspberry Pi NoIR camera (Figures 5-7, 11).
- New set of narrow-band LEDs and matching NIR filters were used to increase signal-to-noise ratio and acquire better images allowing us to obtain more vasculature information.
- The second prototype is being tested now to figure out the optimal combination of LEDs and filters for better vasculature imaging.

Conclusions: Successful vascular imaging using our device gives us the confidence to further pursue the development of our low cost, portable NIR camera. Further improvements of our prototypes can include addition of diffusers and pulse-wave modulated light to improve the ability to visualize areas of interest at a greater light intensity. We also plan to further test the device by imaging specifically for inflammation. Future projects could incorporate image analysis software to accurately measure amounts of inflammation and report the data to the patient via computer or cell phone application.

Figure 9. Imaging without modified camera.

Figure 10. Imaging the vasculature of the patient's foot with old prototype.

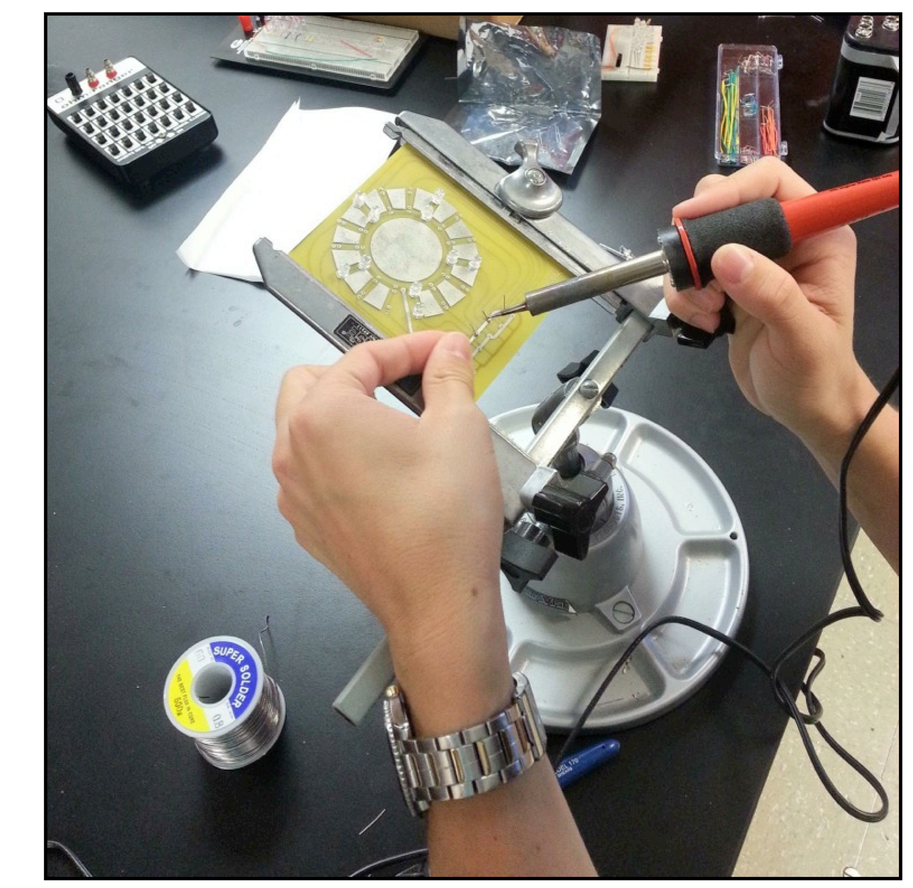

Figure 4. Assembly of the previous device.

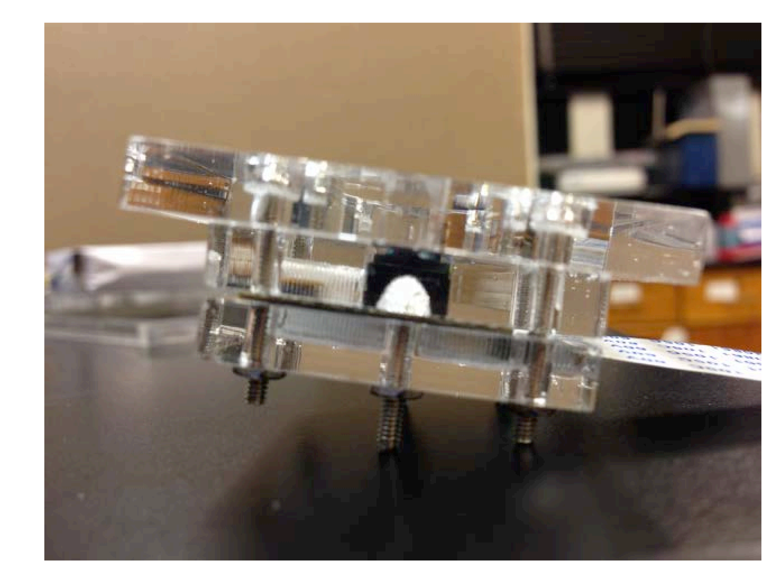

Figure 5. Side view of Raspberry Pi NoIR camera with acrylic filter holder.

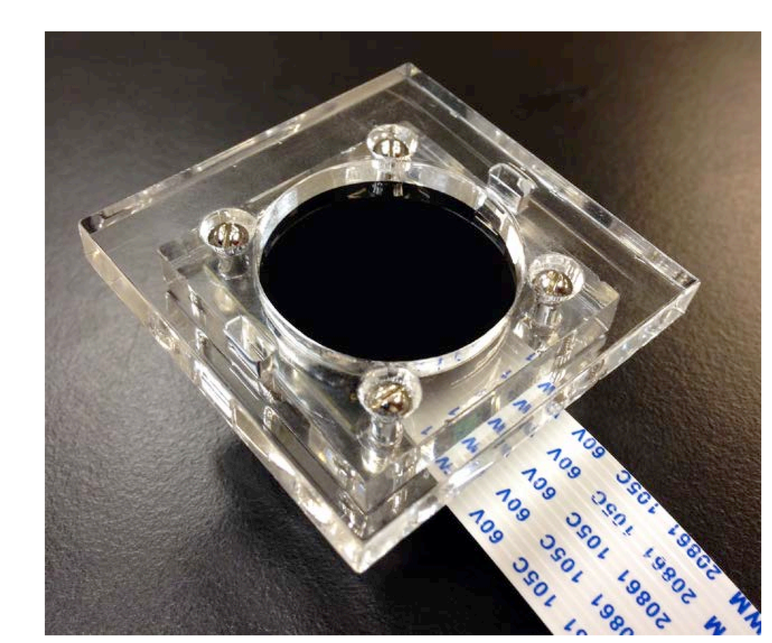

Figure 11. Raspberry Pi NoIR camera with filter in place.

References: [1] M. Meinke, I. Gersonde, M. Friebel, J. Helfmann, and G. Muller., *Chemometric Determination of Blood Parameters Using Visible–Near-Infrared Spectra,* Applied Spectroscopy, 2005,, Volume 59:6, 826-835