Mobile phone based mini-spectrometer for rapid screening of skin cancer

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ABSTRACT

We demonstrate a highly sensitive mobile phone based spectrometer that has potential to detect cancerous skin lesions in a rapid, non-invasive manner. Earlier reports of low cost spectrometers utilize the camera of the mobile phone to image the field after moving through a diffraction grating. These approaches are inherently limited by the closed nature of mobile phone image sensors and built in optical elements. The system presented uses a novel integrated grating and sensor that is compact, accurate and calibrated. Resolutions of about 10 nm can be achieved. Additionally, UV and visible LED excitation sources are built into the device. Data collection and analysis is simplified using the wireless interfaces and logical control on the smart phone. Furthermore, by utilizing an external sensor, the mobile phone camera can be used in conjunction with spectral measurements. We are exploring ways to use this device to measure endogenous fluorescence of skin in order to distinguish cancerous from non-cancerous lesions with a mobile phone based dermatoscope.

Keywords: UV-VIS Spectroscopy, imaging, smartphone spectroscopy, skin imaging, fluorescence

1. INTRODUCTION

Portable spectroscopy is emerging as an important tool for onsite chemical sensing, food analysis and color detection. Fiber coupled charge coupled device (CCD) spectrometers are commercially available with wavelength resolution in the range of 0.1-10 nm. However, these spectrometers are expensive and generally used for research applications. Mobile phone based spectrometers on the other hand, have become popular following significant improvements in the imaging capability of mobile phones. Typically a mobile phone based spectrometer comprises of a dispersive element like a grating, a few slits and the mobile phone [1]. The camera of the mobile phone acts like a linear CCD sensor and an app is sometimes available to carry out plotting operations. But most of these demonstrations have been very basic in nature and often suffer from low accuracy and resolution. Often a section of a compact disc is used to disperse light on to a cell phone screen. There has been some innovation in the grating technology with demonstrations of a G-Fresnel spectrometer [2]. There are other proprietary spectrometers from companies like SpectroClick, SCiO, iSPEX among others patents [3]. The Public Lab Store offers some low cost mobile phone spectrometers which can be used for educational purposes but not sensitive enough for research based applications.

In this report, we have integrated a MEMS based spectrometer with the mobile phone. The entire device is compact with the spectrometer weighing only 9 g. The spectrometer connects to the mobile phone through a Bluetooth connection making it a standalone device without the need of an external computer. We have also explored coupling the spectrometer to a dermatoscope in order to carry out visual as well spectral examination of the skin. There have been reports that endogenous fluorescence from skin can be used to distinguish between cancerous and non-cancerous lesions [4, 5] and also provide markers for aging [6]. We attempt to use the spectrometer-dermatoscope combination to rapidly screen for skin cancer.

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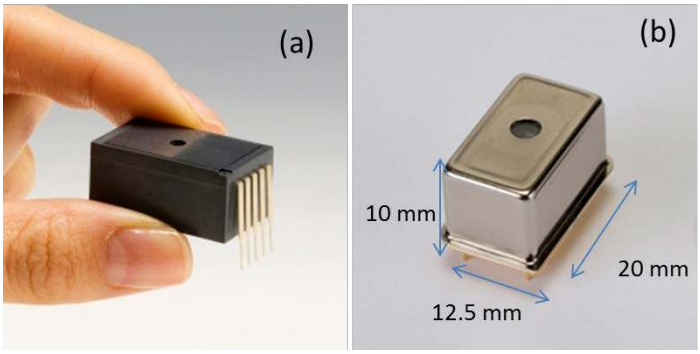

Figure 1: Photograph of Hamamatsu (a) Minispectrometer and (b) Microspectrometer

2. METHODS

2.1 Spectrometer integration with mobile phone

The mini/microspectrometer modules have been developed by Hamamatsu Photonics using MEMS technology. A grating fabricated by nano-imprint lithography is used as the dispersive element. The entire spectrometer assembly including the image sensor, lenses and slits is enclosed with 20 mm x 12.5 mm x 10 mm and weighs about 9 g as shown in Figure 1. The spectrometers have a spectral resolution of about 10 nm in the wavelength range of 340-780 nm. The spectrometer was connected to an Arduino Uno microcontroller board that carried out the A/D conversion and at the same time provided the necessary clock pulses to trigger the circuit. The spectrometer was powered through the Arduino board which was in turn powered by either a computer or a USB power bank. A Bluetooth module connected to the Arduino board was used to integrate with the mobile phone. An app was developed that was capable of receiving data from the Arduino Bluetooth module through the phone's Bluetooth connection. Figure 2 shows a schematic of the spectrometer interface with the mobile phone. Data was collected either using the mobile phone or a computer using the Processing software.

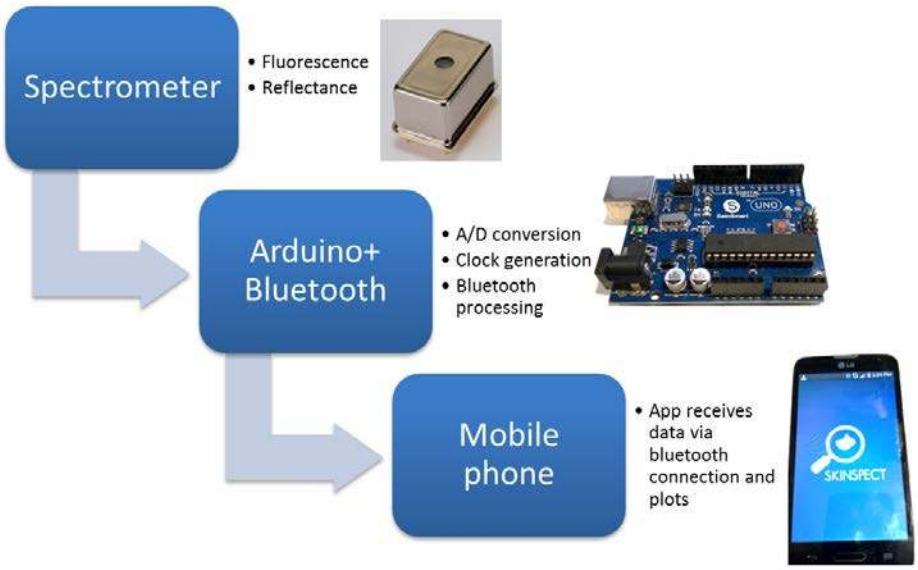

Figure 2: Schematic of spectrometer integration with the mobile phone.

2.2 Spectrometer integration with Dermatoscope

A dermatoscope was setup using a 8x telephoto lens system as the magnifier as shown in Fig. 3. A set of crossed polarizers were introduced to minimize surface reflections from the skin surface. A beam splitter (50:50) was used to split the reflected light and channel a fraction to the spectrometer. The rest of the light was coupled to the camera of the mobile phone to yield an image of the skin. Since endogenous fluorescence is of interest in detecting skin cancer, the device was equipped with UV (365 nm) LEDs along with white LEDs. White LEDs are used for general examination whereas the UV LEDs are utilized to excite flourophores like enzymes, amino acids and lipids (4). A schematic of the lighting control is shown in Fig. 4(a). Figure 4(b) shows an integrated dermatoscope-spectrometer that is coupled to a mobile phone.

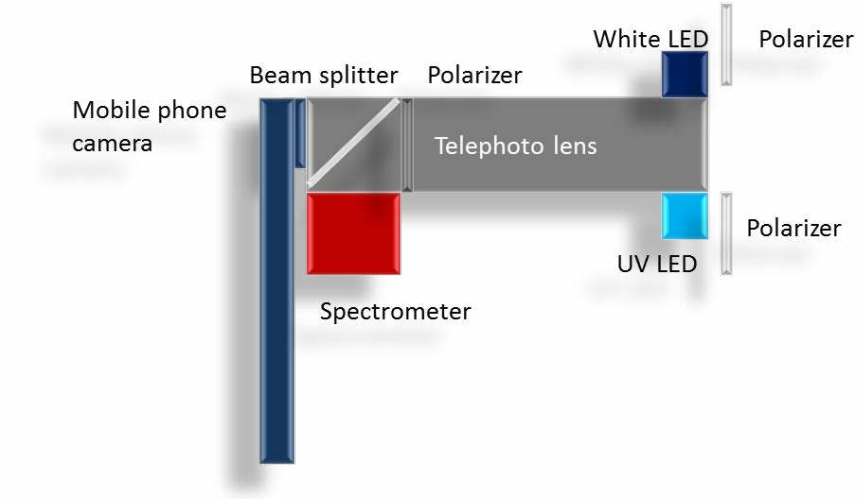

Figure 3: Schematic of the dermatoscope integration with spectrometer

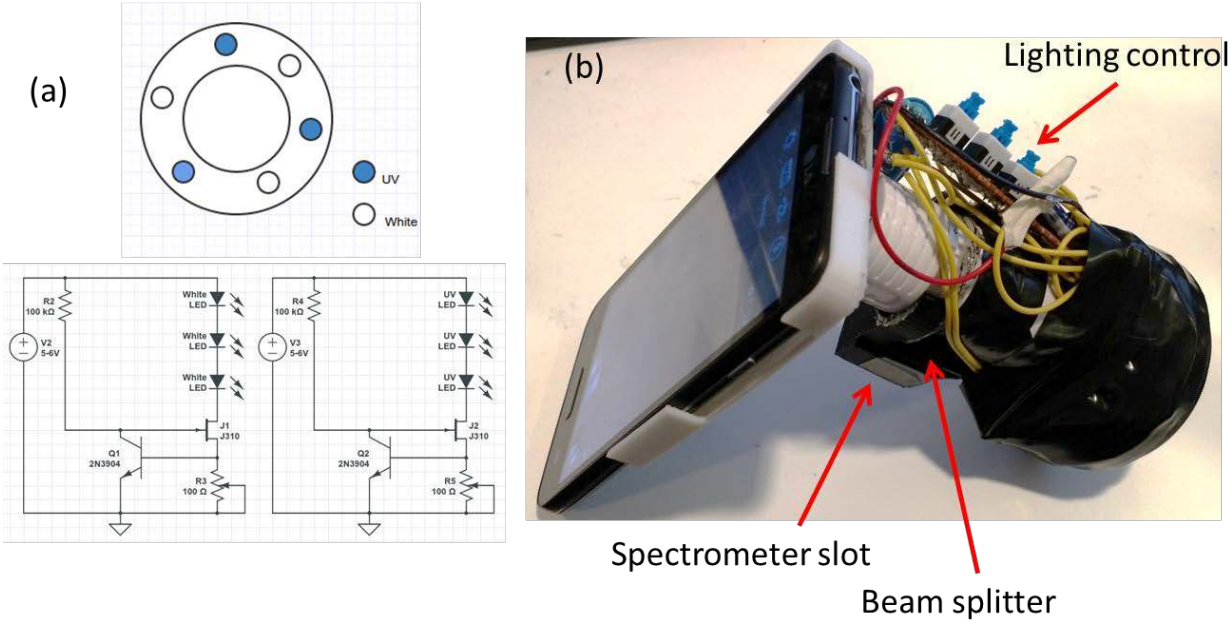

Figure 4: (a) Lighting control for the dermatoscope. UV (365 nm) and white LEDs are integrated into the dermatoscope as shown in (b).

3. RESULTS

The spectrum obtained from a white light test source is shown in Fig. 5(a). As can be seen in the figure, the spectrometer is connected to the mobile phone in a wireless manner. Figure 5(b) shows initial skin spectra obtained from a test subject. As can be ascertained in the figure, there are noticeable changes in the reflection spectra of a lesion from the normal skin. However, with our current setup endogenous fluorescence has not been detected due to optical losses in the system.

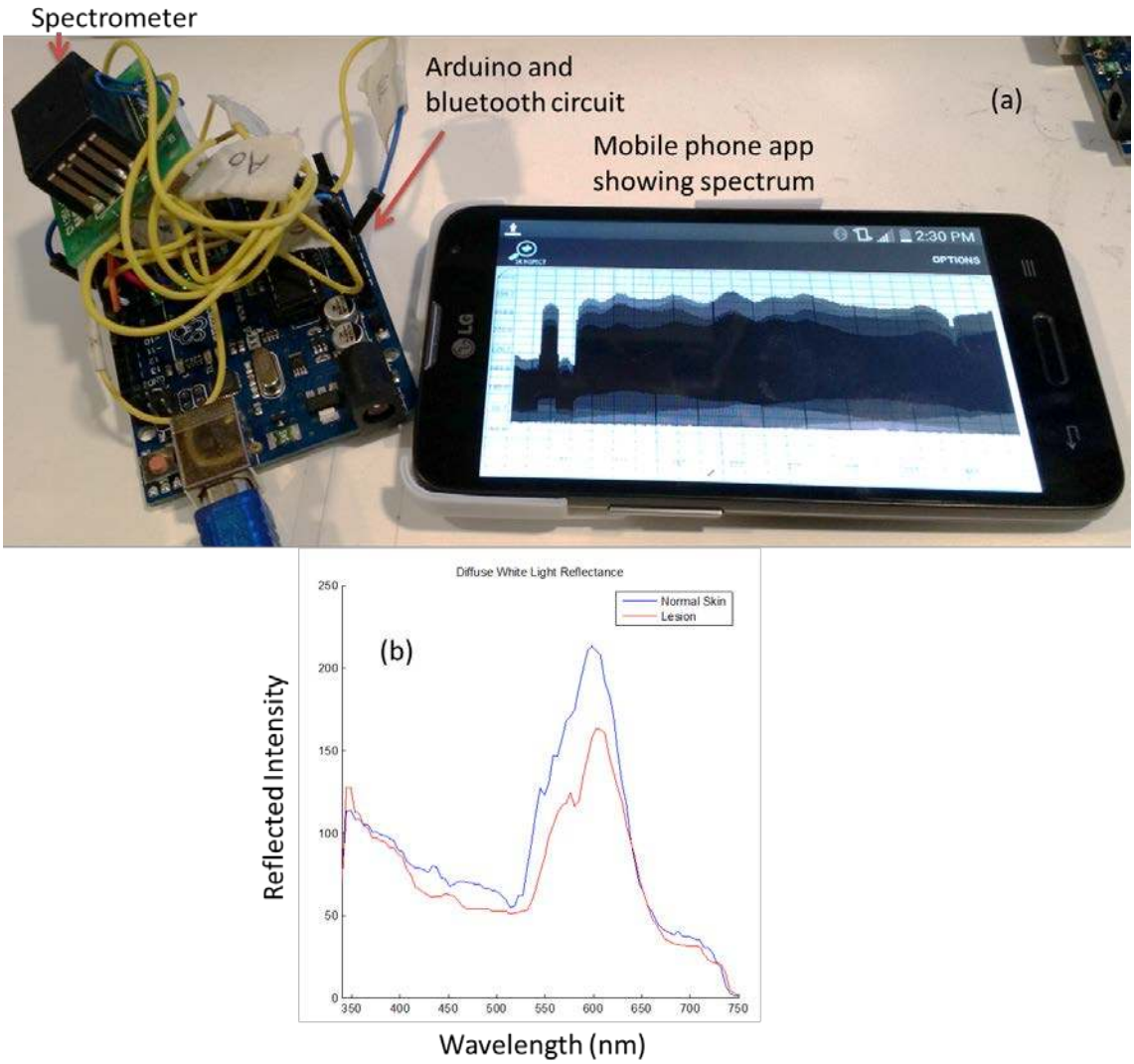

Figure 5: (a) Mobile phone app displaying the spectrum of a test white light source. (b) Reflected spectrum from a lesion and normal skin.

4. DISCUSSION

Our current device needs improvement on the detection arrangement. A suitable beam splitter with 10:90 splitting ratio can help in maximizing the signal. We are also exploring high brightness LEDs and increasing the number of illumination sources. The use of an optical fiber coupling system may also improve fluorescence detection. Once these

modifications are incorporated, the device should be able to gather endogenous fluorescence that is beneficial in skin cancer screening.

5. CONCLUSION

A fully functional mobile phone spectrometer prototype was demonstrated with a resolution of 10 nm. The device could connect to the mobile phone in a wireless configuration and operated as a stand-alone device. The device was also coupled to dermatoscope with potential in detecting endogenous fluorescence to differentiate between cancerous and non-cancerous lesions.

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REFERENCES

[1] Z. J. Smith et al., "Cell-Phone-Based Platform for Biomedical Device Development and Education Applications," *PLoS ONE* **6**(3), e17150 (2011).

[2] C. Yang et al., "Proposal and demonstration of a spectrometer using a diffractive optical element with dual dispersion and focusing functionality," *Opt. Lett.* **36**(11), 2023-2025 (2011).

[3] S. X. Wang, and X. J. Zhou, "Spectroscopic sensor on mobile phone," Google Patents (2008).

[4] E. G. Borisova, L. P. Angelova, and E. P. Pavlova, "Endogenous and Exogenous Fluorescence Skin Cancer Diagnostics for Clinical Applications," *Selected Topics in Quantum Electronics, IEEE Journal of* **20**(2), 211-222 (2014).

[5] E. Borisova et al., "Light-induced autofluorescence and diffuse reflectance spectroscopy in clinical diagnosis of skin cancer," 91291O-91291O-91298 (2014).

[6] N. Kollias et al., "Endogenous Skin Fluorescence Includes Bands that may Serve as Quantitative Markers of Aging and Photoaging," *J Investig Dermatol* **111**(5), 776-780 (1998).