A system for full-body dermoscopic spectral imaging at visible and near-infrared wavelengths

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ABSTRACT

A prototype device for full-body skin dermatoscopy at three visible wavelengths — 450 nm, 520 nm, and 638 nm — was developed and clinically validated in 2024. Now it has been complemented with spectral imaging channel in the near-infrared range (850 nm), aiming to identify the deeper skin inclusions including tumors. A brief description of the additional elements is provided, along with the first obtained infrared images of skin nevi.

1. INTRODUCTION

Full-body imaging systems have gained attention in dermatology for their efficiency in melanoma detection and monitoring. Unlike traditional dermoscopy methods that focus on a single lesion, these systems capture multiple high-resolution images of the entire body, enabling the detection of multiple lesions in a single session and allowing for their comparisons to identify malignant changes.

Several advanced but still costly full-body imaging systems are commercially available [1-3]. They capture skin images under broadband white light illumination and analyze the obtained color (RGB) images using specific algorithms. To the best of our knowledge, there are no spectrally selective full-body imaging devices on the market so far, and the commercial systems do not utilize the NIR spectral band, limiting their ability to detect malformations that penetrate in deeper skin layers, e.g. melanoma.

For research purposes, Kottner et al. detailed an application that integrates full-body multispectral imaging with 3D scanning technology, incorporating ultraviolet and near-infrared light sources [4]. Korotkov et al. proposed an automatic algorithm system for early melanoma diagnosis [5], while Ahmedt-Aristizabal et al. developed the "3DSkin-mapper", an AI-driven tool that tracks skin lesions over time using deep learning [6].

Spectral imaging with visible triple-laser line illumination has been used to map skin chromophores in malformations [7]. Recently, we demonstrated abilities of this approach for full-body spectral line imaging at the wavelengths 450 nm, 520 nm and 638 nm [8]. This study builds on the previous research by extending the spectral imaging capabilities to the near-infrared spectral range at 850 nm wavelength. The current system combines illumination by visible and NIR spectral lines to enhance lesion identification, enable deep-layer analysis, and track tumor changes over time. It improves the potential for dermatological diagnostics through simultaneous multispectral imaging, providing comprehensive analysis for both clinical and research applications, including early melanoma screening and long-term monitoring.

2. MATERIALS AND METHODS

The developed prototype device, shown in Figure 1, features a 60 m spiral-shaped side-emitting optical fiber (600-micron silica core) coupled to a 3W RGB laser (HangZhou NaKu Technology Co., Ltd), emitting three spectral lines (450 nm, 520 nm, and 638 nm) at approximately 1W each, along with a near-infrared laser (850 nm, 4W, HangZhou NaKu Technology Co., Ltd). The side-emitting optical fiber is SMA-connected to both lasers through a Y-shaped optical fiber coupler (Light Guide Optics International, LV). A micro-reflector mounted at the distal end of fiber ensures uniform side-emission intensity, so enabling even illumination of large skin areas with all four used laser wavelengths simultaneously or separately.

A 61-megapixel RGB camera (Sony a7R IVA with a Sony SEL2470GM F2.8 G full-frame standard zoom lens) is positioned inside the fiber spiral. To accommodate near-infrared imaging, the infrared filter in front of camera's CMOS sensor blocking all wavelengths above 700 nm has been replaced by a transparent glass window. A short-pass filter transmitting wavelengths up to 860 nm and a long-pass filter cutting-off the wavelengths shorter than 830 nm can be placed on camera lens to select the desired wavelengths. The illuminator - camera system is mounted on a motorized platform that moves vertically between two fixed heights (0.5 m and 1.5 m) using a linear actuator with a screw drive, ensuring high movement precision and allowing optimal height adjustments for capturing upper and lower body images. To prevent ambient light interference, the system and patient are enclosed in a light-shielding tent, which also serves as a dressing cabin. The system operates remotely via Wi-Fi, with full-body imaging requiring six to ten fixed body positions which, takes approximately 2–5 minutes.

Unlike commercial systems that use broadband white light for illumination (e.g., FotoFinder), this prototype provides high spectral selectivity of imaging. The laser lines used for illumination have full width at half maximum (FWHM) linewidth < 0.1 nm, which corresponds to the spectral imaging bandwidth after appropriate processing of camera RGB image data [7,8]. Standard RGB cameras under broadband illumination produce only R-, G-, and B-images with significantly lower spectral resolution (FWHM ~80–100 nm).

The Matlab programming environment is used for image processing. Images captured in ARW (uncompressed) format are loaded into a data array, from which R-G-B and NIR images are extracted. These images are then intensity-normalized to enhance the visibility of skin formations of interest [8].

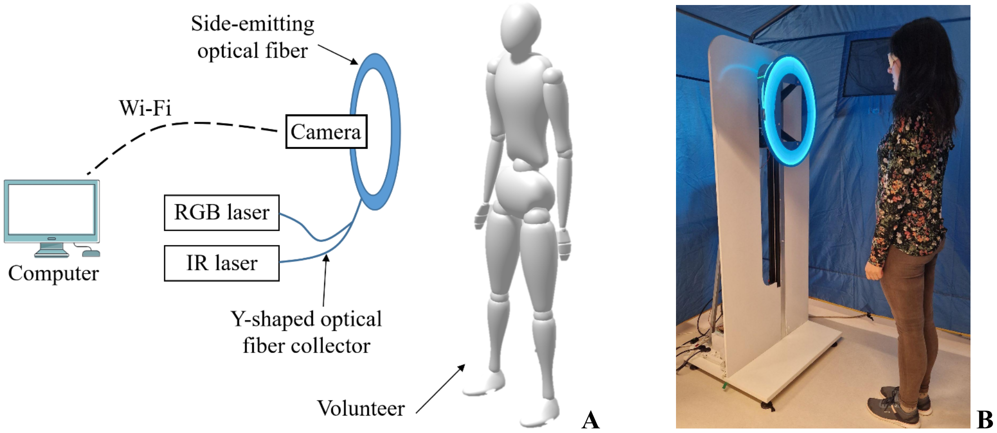

Figure 1. A - setup scheme; B - general view of the prototype device.

3. RESULTS

In Figure 2, the top left image displays the upper body at RGB laser radiation used for illumination. The top and second row presents a magnified view of a nevus from the mid-abdomen at each wavelength in the corresponding CMOS camera channels (with the red channel used for the 850 nm wavelength).

Under 450 nm wavelength illumination, the nevus absorbs significantly more light compared to 638 nm and 850 nm wavelengths. This suggests that the nevus is located in the upper skin layers rather than in the deeper layers, as 850 nm wavelength light penetrates much deeper into the skin than blue and green spectrum light.

Additionally, monochromatic image ratio calculations were performed and are visualized in the third row of the image. In the 520 nm to 450 nm wavelength ratio, the intensity of the formation is almost the same as that of the surrounding healthy skin. In contrast, the 850 nm to 520 nm wavelength ratio shows the most distinct contrast between the formation and healthy skin, making the nevus boundaries clearly visible. As the wavelength increases, light penetrates deeper into the tissue, revealing deeper structures while making the outer skin layer less visible. During calibration under 850nm illumination, we found that the B and G channel sensors were affected by near-IR light by 68% and 35% comparing with R channel (100%), respectively. This explains why the RGB image under NIR light appears magenta.

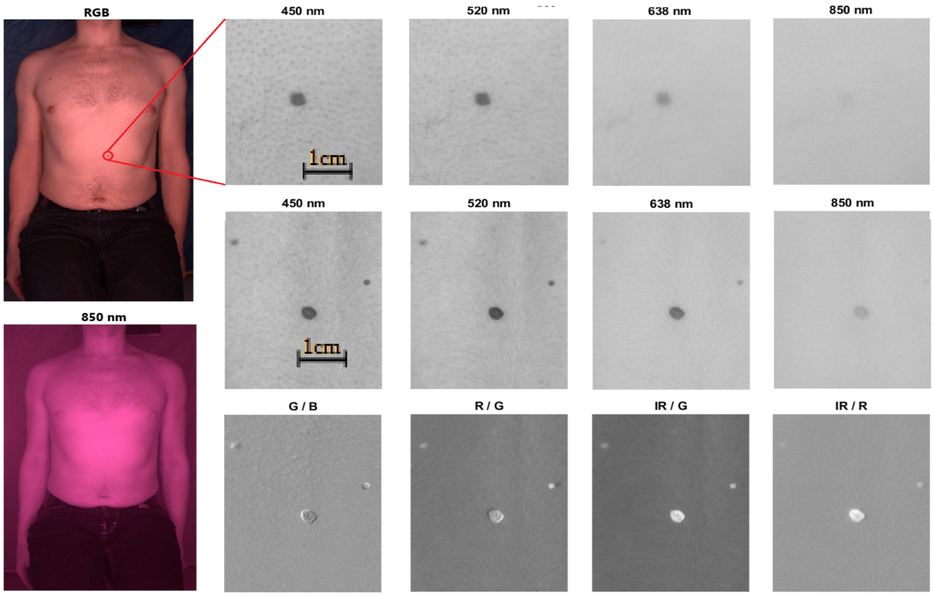

Figure 2. Full body images under RGB and NIR illumination (left), spectral images of the nevus (right).

4. CONCLUSIONS

The prototype device for multi-spectral whole-body skin imaging, using wavelengths of 450 nm, 520 nm, 638 nm, and 850 nm, has been developed and experimentally tested. It captures high quality images across four spectral bands, enabling both surface and deep-layer analysis of skin nevi. The first results show that nevi absorb more light at 450 nm, suggesting they are in the upper skin layers, while in the infrared spectrum, they "fade". Clinical trials at the Latvian Oncology Center will validate its effectiveness for early detection and monitoring of skin conditions.

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