Optimization of Tissue-specific Illumination for Medical Applications

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Medical illumination can support a surgeon to discriminate between different biological tissues or tissue conditions. To find the optimal illumination, the specific tissues to be illuminated should be considered. Therefore, we propose a method to measure angular- and wavelength-dependent tissue reflectance and optimize color difference taking into account CRI and CCT as constraints.

1 Introduction

Nowadays, surgeons can control color temperature or filter specific regions of the visible spectrum to better distinguish between different tissues or tissue conditions [1]. However, LED-Technology provides far more opportunities, e.g. to fully control illumination and realize a tissue-specific optimization for medical applications. Wang et al. (2015) showed that human color perception and color difference can be optimized using appropriate spectral powers distributions (SPD) considering the reflection properties of biological tissues [2]. In fact, full sets of optical tissue properties, angular and wavelength-dependent, are not available in literature. Therefore, we propose a method to measure bidirectional reflectance distribution functions (BRDF) of biological tissues and perform a tissue-specific optimization of color difference (ΔE) with color temperature (CCT) and general color rendering index (CRI) as constraints.

2 Methods

BRDF of biological tissues are measured using a developed device that is added on the goniometer and orientates the light source with regard to the tissue sample.

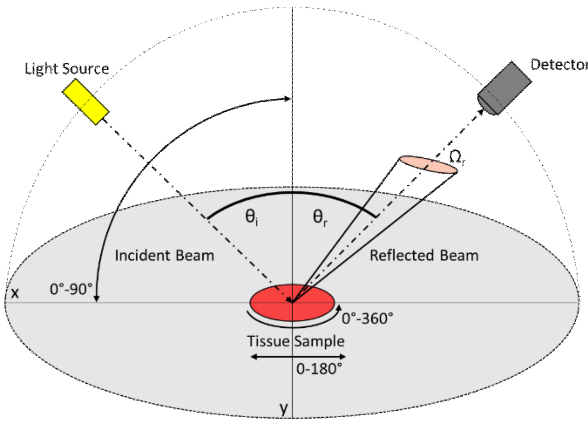

Fig. 1 *Measurement system used to measure bidirectional reflection distribution functions (BRDF).*

Figure 1 demonstrates the method BRDF are measured. The tissue sample is centrally aligned and tiltable between 0°-180° with 360° rotation, whereas the light source is movable from 0°-90°. The detector of the goniometer is used for the measurement and is therefore fixed. The light source used for the BRDF measurement is a Sunlike high-power LED from Seoul Semiconductor (see Figure 2).

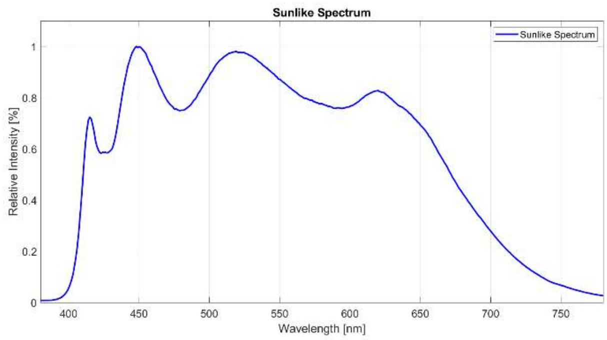

Fig. 2 *Seoul Semiconductor: Sunlike LED normalized spectral distribution.*

An ultra-narrow TIR-lens is additionally put on the LED to shape the angular light distribution from Lambertian to a half cone angle of approximately 8°. The Sunlike LED clearly provides a SPD S(Λ) including maxima and minima. However, to measure reflection spectra, the reference spectrum is ought to be constant over wavelength. Therefore, the reference measurement R(Λ) is carried out by locating a mirror M(Λ) (Alanod MIRO-SILVER® 2, highgloss surface with low diffuseness: <5 %) at the position where the sample will be placed.

$$R(\Lambda) = M(\Lambda)/S(\Lambda) \quad (1)$$

The reflectance spectrum acquired with the mirror M(Λ) is then divided by the initial Sunlike spectrum S(Λ) to obtain the reference spectrum R(Λ).

$$TR(\Lambda) = T(\Lambda)/R(\Lambda) \quad (2)$$

The final tissue reflectance TR(Λ) is then calculated by dividing the reflectance spectrum T(Λ) of the biological tissue sample for the reference spectrum

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R(λ). Of course, the preparation of the tissue sample influences the results; we already discussed this in another work [1].

3 Results

We measured the reflection spectrum of Alanod MIRO-SILVER® 2 to verify our system and compared the reference measurement (blue) to the manufacturer's reflection specifications (green).

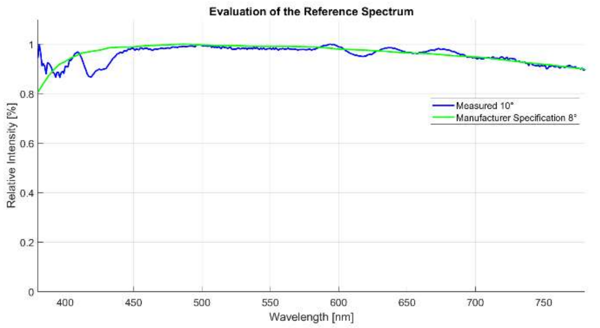

***Fig. 3** Reference Measurement Alanod MIRO-SILVER® 2 (b) compared to the manufacturer's specifications (g).*

Figure 3 demonstrates that the reflection spectrum we measured approximates the specifications given by the manufacturer except the region below 400 nm and between 420-440 nm. The graph is almost constant in a range between 400-750 nm and has a slight intensity decrease towards the red parts of the visible spectrum. Based on the BRDF information obtained, the SPD can then be optimized taking into account the color perception of a human observer. The goal of our optimization process is to maximize color difference ΔE under the constraints CRI≥85 and CCT 3000-6000 K given in IEC 60601-2-41 that describes the performance characteristics of surgical lights [3]. To create any given SPD, either a broadband light source with filters or multiple narrow-band LEDs are needed.

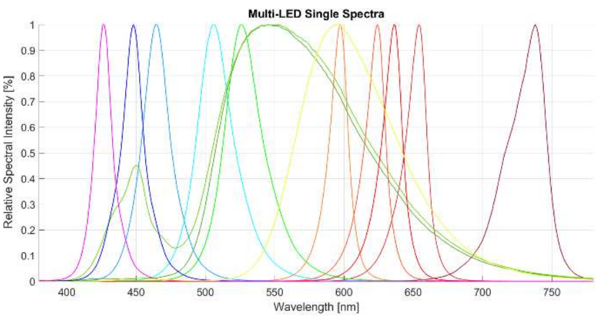

***Fig. 4** Multi-LED unit normalized SPD.*

Therefore, we developed a Multi-LED unit with 13 monochromatic high-power LEDs (Lumileds Luxeon C Color Line) toroidally arranged on a circuit board. Figure 4 shows the normalized SPD of the Multi-LED unit. Each high-power LED is individually controllable using pulse width modulation technique via an Arduino board.

4 Conclusion

The Sunlike LED used here as reference light source provides power in the range between 410-750 nm. Clearly, the visible range of a human observer covers wavelengths between 380-780 nm. Therefore, additional LEDs can be implemented at the boundaries of the visible spectrum to measure reflection spectra. However, one has to consider that the optimization takes into account the color perception of a human observer. With regard to the spectral sensitivity of rods and cones in the human eye, the parts of the spectrum below 410 nm and above 650 nm have a minor contribution to the entire color vision (see Figure 5).

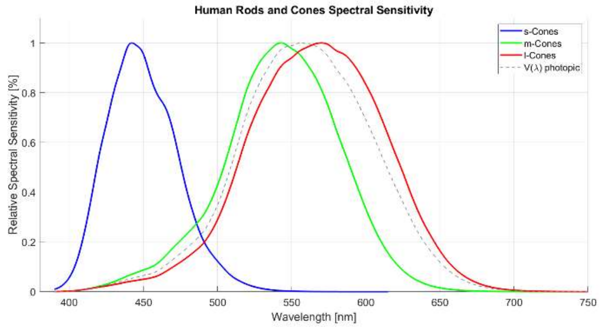

***Fig. 5** Human rods and cones spectral sensitivity [4,5].*

Thus, the Sunlike LED can be considered as a suitable reference light source to measure wavelength dependent BRDF of tissues and other materials.

In our next work, we will focus on classifying and selecting the suitable tissue samples and how their preparation influences the measurement results.

References

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