Spatially resolved reflectance (SRR) measurement

C. Reble, J. Helfmann, Laser- und Medizin-Technologie GmbH, Berlin, Germany (April 2015)

Application Note

The determination of the optical properties (absorption, scattering) of tissue such as skin is of fundamental importance for many applications in the fields of optical diagnostics or laser therapy.

Light is absorbed, for example by hemoglobin or melanin, and is scattered by different tissue components such as nucleus, cell membrane, muscle fibers, etc. When light passes through tissue, both absorption and scattering determine how far the light penetrates into the tissue and which portion leaves the tissue. The light leaving the tissue on its surface can be detected as diffuse reflection. The intensity of the reflectance decreases with the distance from the illumination spot. This distance-dependent decrease together with an appropriate model for the propagation of light (e.g. diffusion approximation, Monte Carlo simulations) allows the determination of absorption and scattering coefficients.

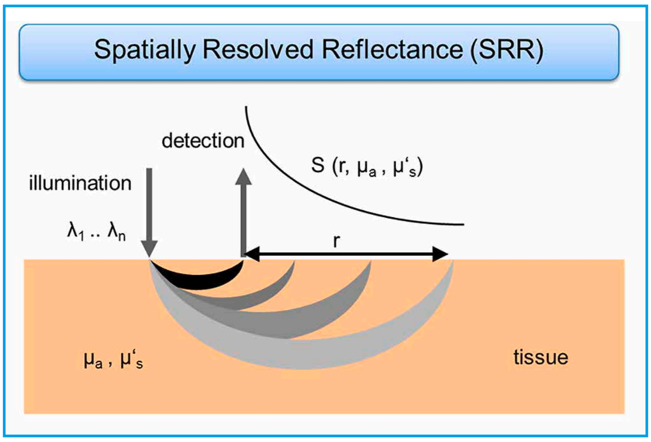

Figure 1: The principle of a spatially resolved reflectance measurement. Absorption (μa) and reduced scattering coefficient (μ's) both influence the measured light distribution.

This measurement principle is often referred to as "spatially resolved reflectance (SRR)", see Fig. 1. Basically a number of light sources (e.g. white light LEDs) and detectors (spectrometers or photodiodes) can be used. The setup shown below uses an ozone-free xenon short arc lamp (150 W) from LOT-Quantum Design GmbH as the light source, see Figure 2.

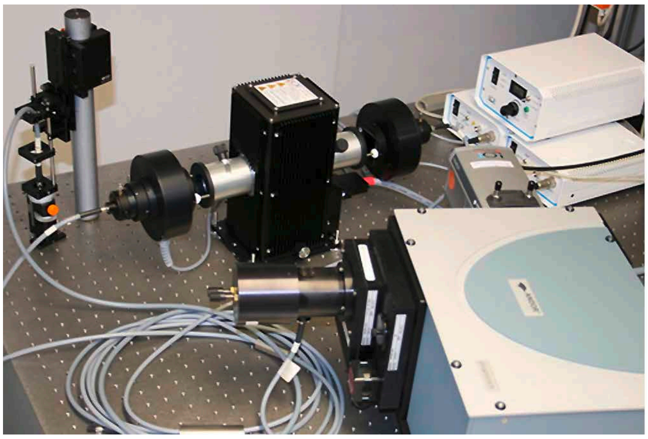

Figure 2: Setup of the xenon light source with two fiber optic outputs including shutters, the Shamrock SR-303i-A-SIL spectrograph with a Newton DU920P-OE CCD detector from Andor Technology.

A typical SRR arrangement further includes a fiber bundle with a central illumination fiber and around which there are several annularly or hexagonally arranged detection fibers, such as the example shown in figure 3. Each ring and the central fiber can be connected to the light source or a detector by separate SMA connectors.

The simultaneous spectrally resolved detection of multiple detection fiber rings requires a complex multichannel detection, for example, with an imaging spectrograph. The Shamrock 303i spectrograph used here together with the Newton 920 CCD detector is such an imaging spectrograph. An image is captured of a fiber stack made up of individual fibers with light originating from different detection rings. This setup allows both the spectrally and spatially resolved determination of the optical properties of tissue. This is particularly advantageous when the optical properties of tissue change are subject to rapid change, e.g. due to pulse beat. If the vertical (spatial) resolution of the CCD is only partially required or not at all, the signal-to-noise ratio can be improved by binning.

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Figure 3: Fiber bundle for measuring the backscattered light (reflectance) dependent on the distance from the illumination.

Illumination and detection can also be interchanged (inverse SRR). Using the two lamp outputs described above, it is possible to open a shutter on each side and without having to switch between the fibers sequentially, to illuminate at two different distances from the detection.

Figure 4 shows the decrease in the reflectance of a tissue phantom sample with increasing distance from the illumination spot. Figure 4a displays the normalized spectrally resolved data for two distances and in figure 4b you see the decrease in reflectance with distance, whereby the signal is integrated over a specific spectral range.

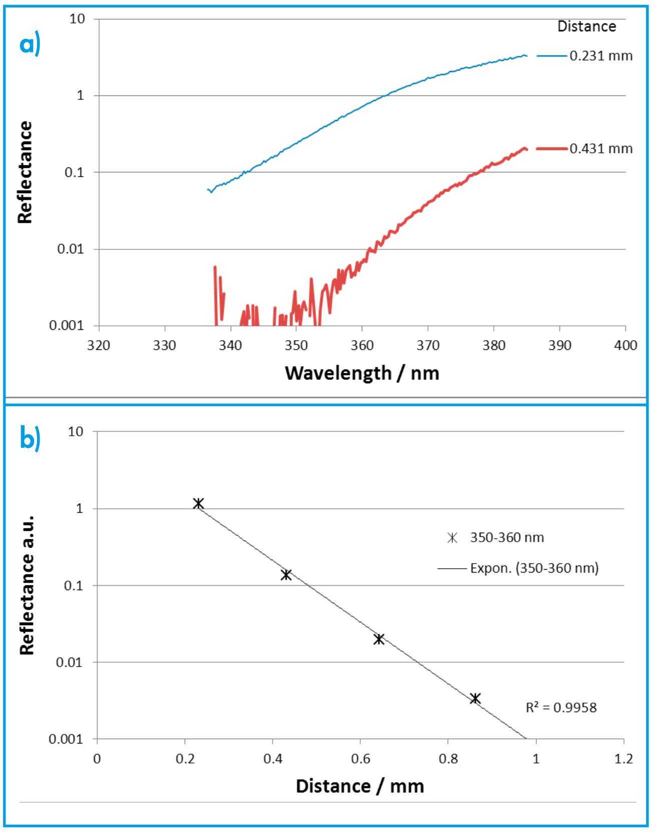

Figure 4a: Distance-dependent reflectance signal of a tissue phantom.
a) Normalized reflectance spectra,
b) Distance-dependent signal integrated over a spectral range.

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Contact
Dr. Jürgen Helfmann
Laser- und Medizin-Technologie GmbH, Berlin
phone: +49(0)30 844 923 - 32
mail: J.Helfmann@LMTB.de
web http://www.lmtb.de/