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Implementation of double-integration-sphere system for measurement of optical properties

Jaqueline R. Sousa[1*], Luciano Bachmann[1]
[1]Departamento de Física, FFCLRP – USP, Ribeirão Preto, Brasil
**jaqueline.ramos.sousa@usp.br*

Background, Motivation and Objective. Due to the high applicability of optical radiation in medicine (diagnosis, therapy and surgery) it is necessary the study of light propagation in biological tissues and precise determination of its optical properties. A highly scattering medium such as the biologic tissue has its optical properties characterized by determining the absorption coefficient μ_a, scattering coefficient μ_s and the anisotropy coefficient *g*. There is a variety of methodologies that can be employed to determine such properties. To evaluate these methods, optical phantoms are employed. One method employs measurements with two integrating spheres associated and an algorithm named Inverse adding-doubling (IAD) that calculates the values of μ_a, μ_s and *g* from the measured values of reflectance and transmittance. The aim of this work is to implement a double integrating sphere. The optical coefficients of polyurethane phantoms with different concentrations of absorbing and scattering materials will be measured using that system. The optical proprieties of these phantoms in 632 nm were previously reported in the literature.

Methods. In Figure 1 we have the experimental setup to measure the reflection and transmission. The two integrating spheres model UMBB-150 (Gigahertz Optik, Türkenfeld, Germany) have an internal diameter of 150 mm, an entrance aperture of 25.4 mm and coupling aperture of 37.7 mm, with internal coating of barium sulphate (~ 97% reflectance). The second sphere has an aperture to measure the scattered transmittance when it is closed and the collimated transmittance when it is opened. We employ a He-Ne laser (632 nm) to obtain the μ_a, μ_s and *g*. Signal detection was performed by silicon and germanium photodiode, (LM-2 VIS, Coherent, Wilsonville, USA) that was measured by power meter (FielMaxII-TOP, Coherent, Wilsonville, USA). The experimental measurements are the diffuse reflectance, diffuse transmittance, collimated transmittance, refractive index and sample thickness. These values and others sphere parameters are input to the IAD algorithm, which returns the coefficient value. The Inverse adding-doubling (IAD) algorithm is a numerical method that solves the photon transport equation. This method was developed by Prahl and elaborated for highly scattering media, especially for biological tissues (PRAHL, VAN GEMERT, & WELCH, 1993).

Results. The values of μ_a and μ_s of the polyurethane phantom developed by Prahl et al (1993) were reported by them as 9,5 m^{-1} and 48,0 m^{-1}, respectively. The first results obtained with this method showed a maximum variation of 75% for μ_a and 7% for μ_s with mean and standard deviation of (5,1 ± 4,2) m^{-1} and (73,0 ± 3,0) m^{-1}, respectively. Due to the high variation, we simulate possible changes in experimental measurements to verify how the coefficients changes with small changes in input values. We observe in Figure 2 results from this simulation over a transmittance (T) range and reflectance (R) range, also together with measure values.

Discussion and Conclusions. Considering these first results it is notable that an optimization is required in the execution of the experimental procedure and acquisition of the values of transmission and reflection of the samples, since a variation of 10% in these values generated a variation of 75% in the absorption coefficient (Figure 2). In this sense, a new set of detectors is being provided to acquire all the measurements simultaneously, as well as a detector that will monitor fluctuations in the intensity of the input beam, in order to make compensations in the other measures given the need. Although not conclusive results from an experimental view, it is worth mentioning that our system is still in the implementation phase and we are already taking the necessary steps to get around the problems and to achieve at more accurate results.

Figures and Tables.

Figure 1. Experimental setup. R and T correspond to spheres that measure the reflection and transmission of the sample (S) respectively. D_R (D_T) P_R and (P_T) are detector and power meter of the spheres. T_c corresponds to collimated transmitted component that is used in the calculation of the coefficients.

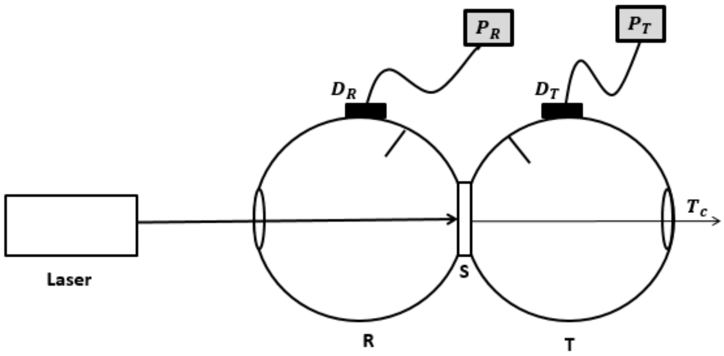
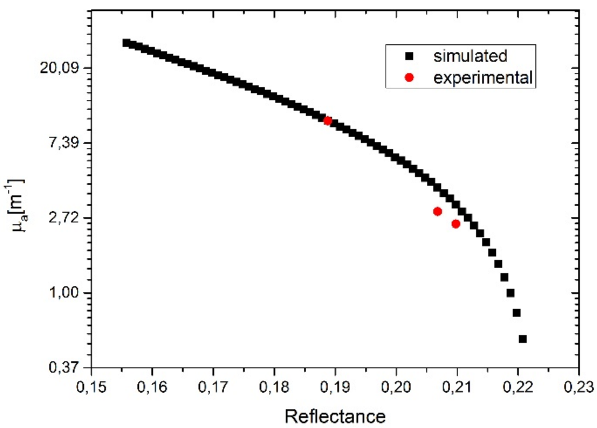


Figure 2. Absorption coefficient resulted from simulated T and R values (squares) and resulted



from experimental values of T and R (circule).

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Keywords. Optical properties; double-integration-sphere; Inverse adding-doubling (IAD).