Optical clearing of skin by 40%-glucose solution

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The mechanism of optical clearing:
The immersion liquid (or optical clearing agent (OCA)) diffuses into a tissue. The OCA has index of refraction greater than the interstitial liquid has. The immersion solution partly replaces the interstitial liquid. As a result there is established the matching of refractive indices of scatterers and environmental substance and light scattering decreases.

Estimation of glucose diffusion coefficient

Penetration of glucose in skin tissue was described in the framework of the free diffusion model

$$\frac{C\ x,t}{C} \quad D\frac{^2C\ x,t}{x^2} \qquad \textit{Diffusion equation}$$

$$C\ 0,t \quad C_0 \text{ and } \frac{C\ l,t}{x} \quad 0 \qquad \textit{Boundary conditions}$$

$$C\ x,0 \quad 0 \qquad \textit{Initial condition}$$

Solution of the diffusion equation for slab with thickness l at moment t with the boundary and the initial conditions has the form

$$C\ t \quad C_0\ 1 \ \frac{8}{^2} \ _{i\ 0} \frac{1}{2i\ 1^{\ 2}} \exp \quad 2i\ 1^{\ 2} t \frac{^2}{4} D \Big/ l^2$$

C(t) is the volume-averaged concentration within tissue sample, g/ml; D is diffusion coefficient, cm^2/sec

Dependence of average parameter of refraction and an interstitial liquid on time:

$$n_I\ t \quad n_{I0}\ 1\ C\ t \quad n_{osm} C\ t$$

Scattering coefficient of a sample skin:

$$_s\ t \quad N \frac{^2 a x_t^{\ 3}}{8}\ m_t^{\ 2}\ 1^{\ 2}\ 1 \ \frac{2}{m_t^{\ 2}\ 1^{\ 2}}$$

$$x_t \quad 2\ a n_I\ t \ / \qquad m_t \quad n_c / n_I\ t$$

Collimated transmittance

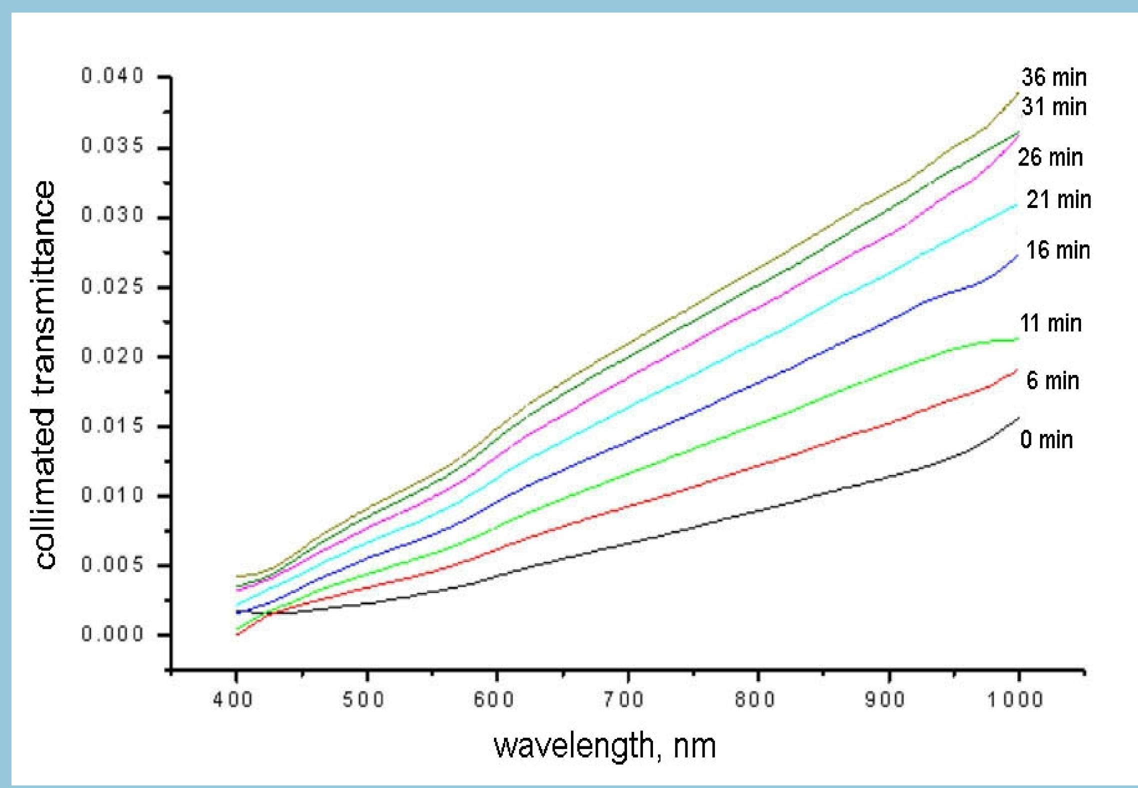
$$T_c(t) = (1 - r_s)^2 e^{-(m_a + m_s(t))l}$$

The reconstruction of the diffusion coefficient of OCA in tissue can be carried out on the basis of measurement of the temporal evolution of the collimated transmittance

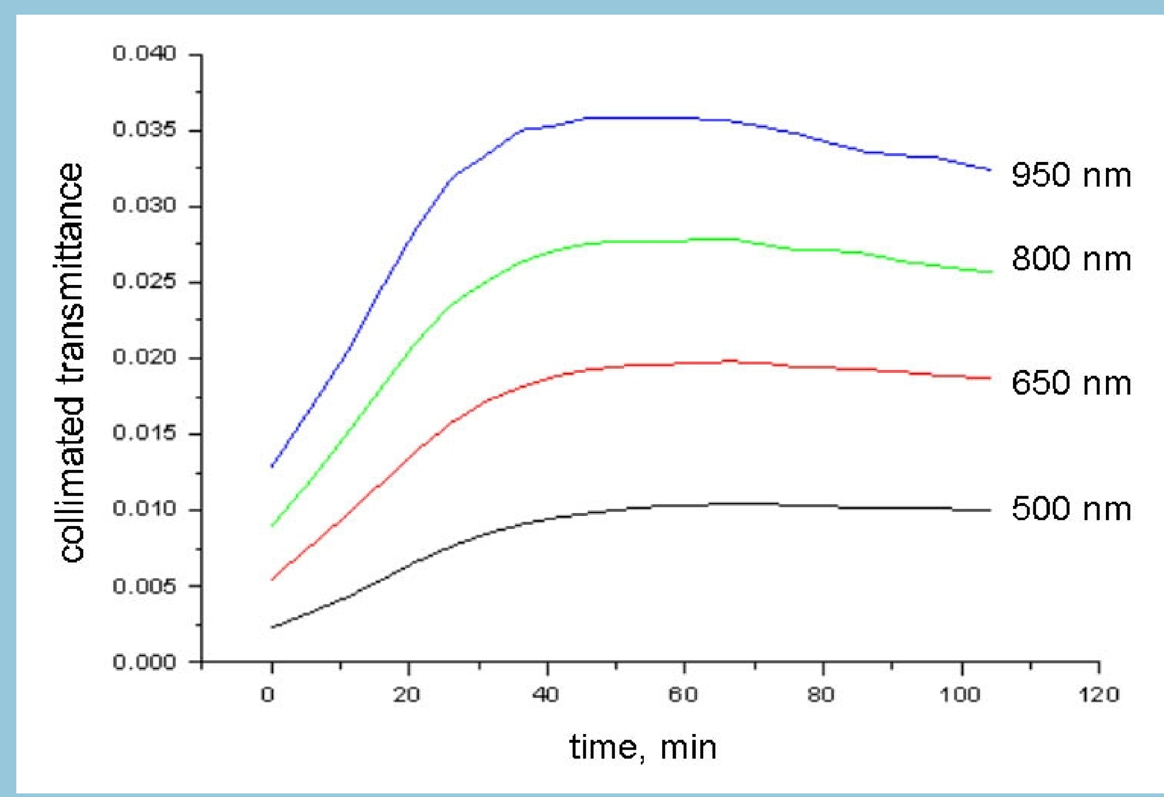
The solution of the inverse problem can be obtained by minimization of the target function:

$$F(D) \quad \sum_{i\ 1}^{N_t} T_c\ D,t_i \quad T_c^*\ t_i \ ^2$$

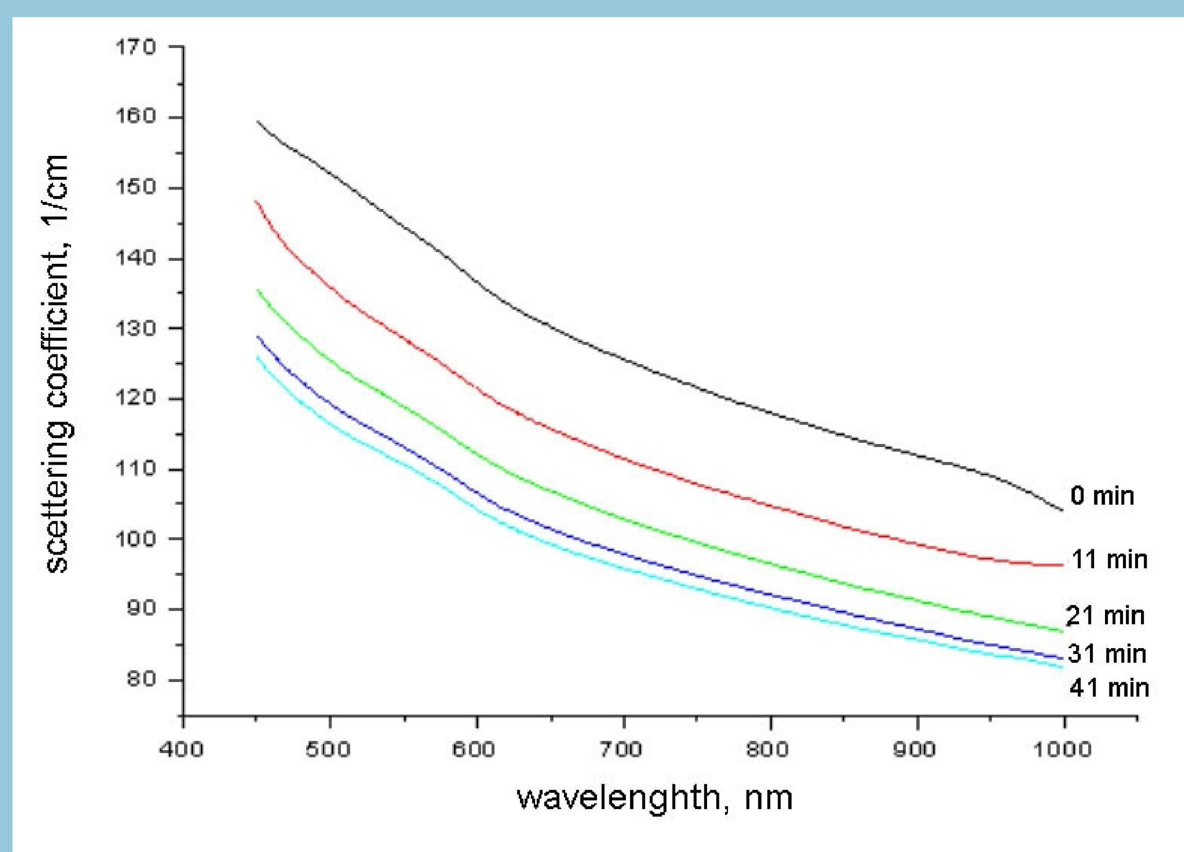
where $T_c(D,t)$ and $T_c^*(t)$ are the calculated and experimental values of the time-dependent collimated transmittance, respectively, and N_t is the number of time points obtained at registration of the temporal dynamics of the collimated transmittance



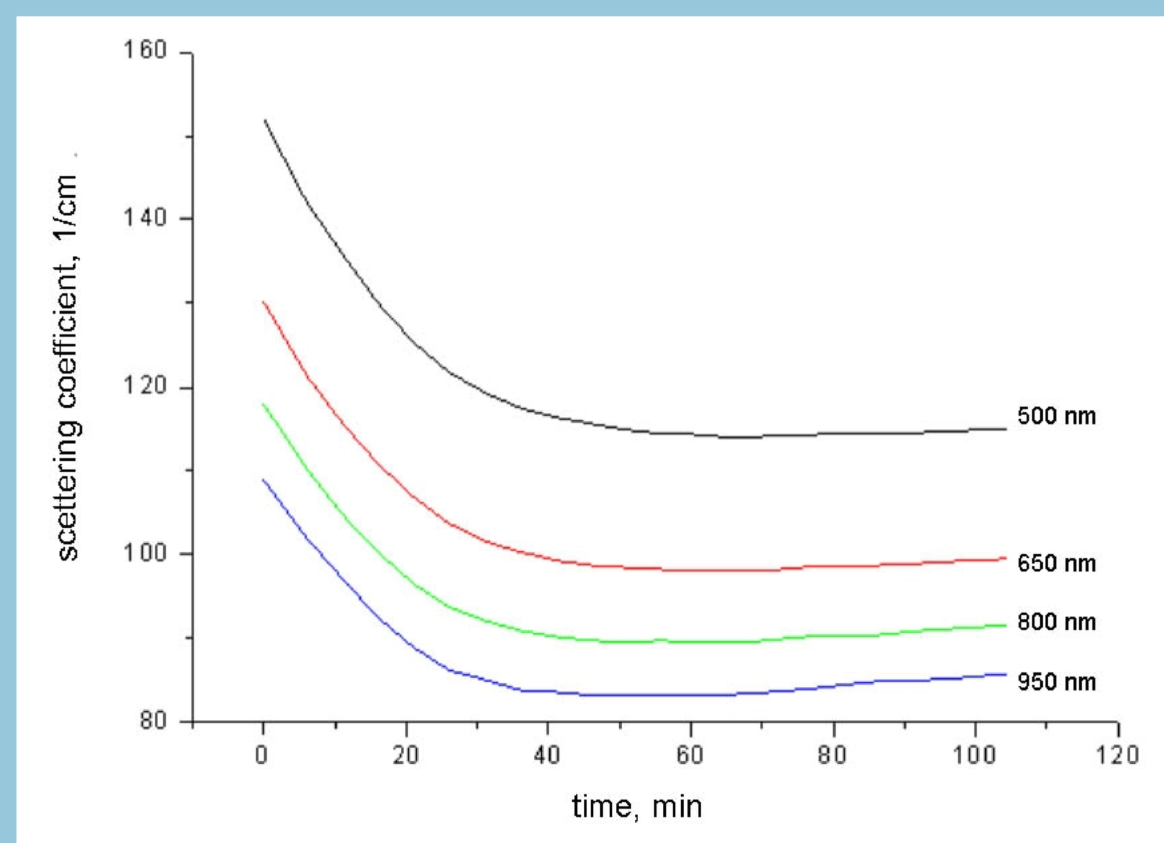
Spectra of collimated transmittance of the rat skin sample placed in 40%-glucose measured at different time moments



Kinetics of collimated transmittance of the rat skin sample placed in 40%-glucose

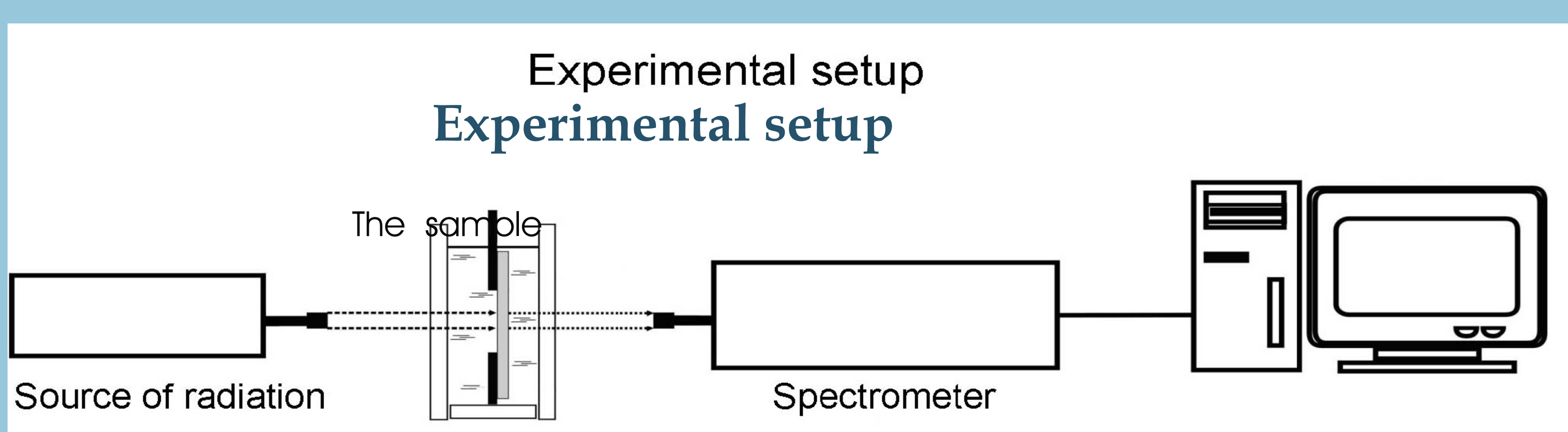


Spectra of scattering coefficient of the rat skin sample placed in 40%-glucose at different time moments



Kinetics of scattering coefficient of the rat skin sample placed in 40%-glucose

Source of radiation is a halogen lamp HL-2000,
Spectrometer is USB-4000 Ocean Optics



Glucose diffusion coefficient in skin

Sample	Diffusion coefficient, cm^2/sec	Sample	Diffusion coefficient, cm^2/sec
1	$(3.63\pm0.21)\times10^{-7}$	6	$(7.03\pm0.67)\times10^{-7}$
2	$(5.2\pm0.55)\times10^{-7}$	7	$(1.74\pm0.19)\times10^{-6}$
3	$(1.16\pm0.15)\times10^{-6}$	8	$(2.3\pm0.24)\times10^{-7}$
4	$(5.78\pm0.73)\times10^{-6}$	9	$(1.16\pm0.34)\times10^{-6}$
5	$(1.31\pm0.09)\times10^{-6}$	10	$(2.2\pm0.15)\times10^{-6}$
Average value: $(1.52\pm1.62)\times10^{-6}$ cm^2/sec			

The results show that usage of glucose solution as a clearing agent allows one to increas the penetration depth of optical radiation into a tissue.
Also, this method allows one to estimate the diffusion coefficient of glucose within a tissue.

Thus, it is shown that glucose effectively impacts on skin dermis as a fibrous tissue and allows one to control tissue optical properties.
This method is important for optical diagnostics and treatment.

Acknowledgments: The research has been made possible by grants: 224014 Photonics4life-FP7-ICT-2007-2; and Governmental contracts 02.740.11.0484, 02.740.11.0770, and 02.740.11.0879.