Biomedical Optics

General Introduction

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Biomedical optics at UT (1)

Laser-Doppler Velocimetry of Blood Perfusion (LDV)

- European (Clinical) Standardisation Project
- Probed depth and pathlength discrimination
- Fully integrated chip-probe for LDV in/on tissue
- Sheet tissue phantom material
- Dynamics of blood cells under shear stress
- Motility of human sperm cells
- Laser-Doppler Perfusion Imager
- Development of optical low-coherence techniques
- Brain perfusion of at-risk neonates (see PATS)
- Self-mixing Glass-fiber Laser-Doppler Velocimeter for intra-arterial use.

(Doppler) Monte-Carlo simulations

- Multilayers / Vessels and Inhomogeneities / Multi-detectors
- Reflection / Absorption / Transmission
- Layers / Tubes / Spheres / …
- Photon tracking.

PATS: Photoacoustic Tissue Scanning: Photoacoustics of Blood Vessels in Tissue
Non-invasive Compound Determination in Tissue

Biomedical optics at UT (2)

Laser-Doppler Velocimetry of Blood Perfusion (LDV)
(Doppler) Monte-Carlo simulations

PATS: Photoacoustic Tissue Scanning: Photoacoustics of Blood Vessels in Tissue

- 3D-Imaging of (micro)vascular capillaries, vessels and hairs
- Combined probe for NIRS, LDV and PATS
- Brain perfusion of at-risk neonates (see LDV)
- Congenital vascular malformations with neonates
- (Array-) detector design and Image Retrieval procedures
- Photoacoustic chip

Non-invasive Compound Determination in Tissue

- Effects of chemicals and drugs in tissue on optical characteristics
- Procedures for extracting data on concentrations
- High-frequency (MHz-GHz) modulated light transport in tissue

Biomedical Optics

Contents

1. - General Introduction
   - Overview of existing techniques

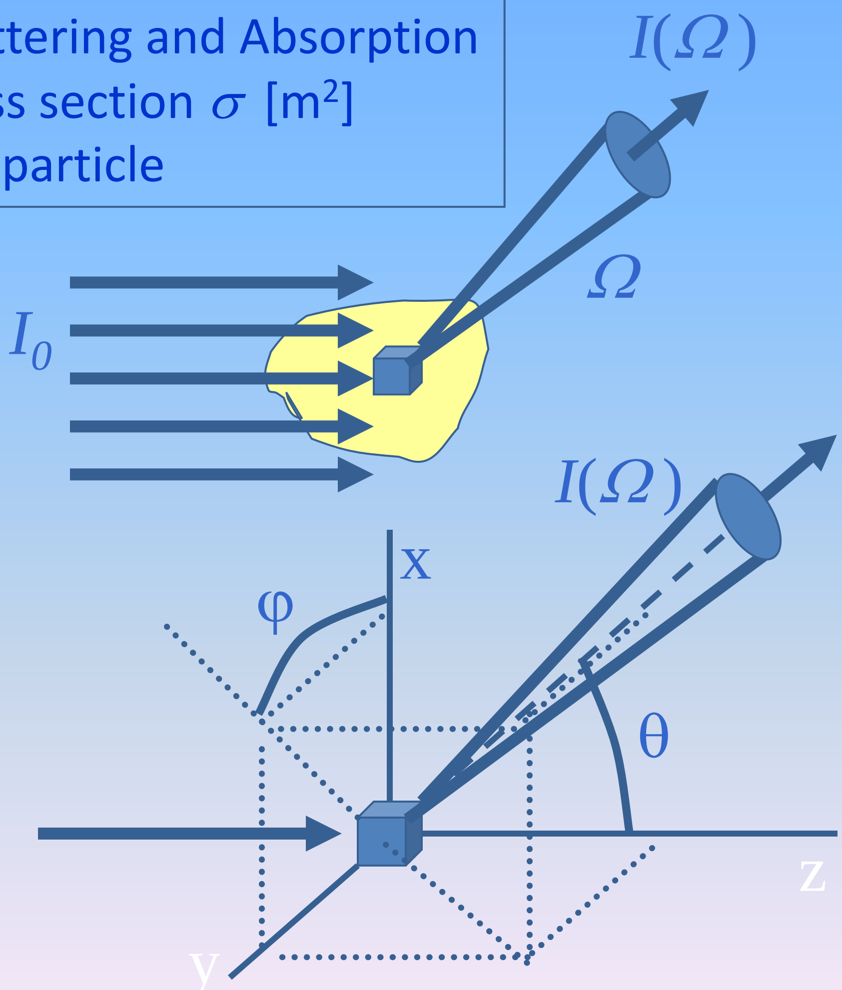
2. - Light scattering,
   - theoretical background,
   - Monte-Carlo + numerical assignment
   - Photoacoustics

3. Experimental: focus on some techniques:
   - Laser-Doppler perfusion
   - Self-mixing velocimetry
   - Speckles

Gen. Intro. (1) : Scattering

Scattered intensity

Scattering and Absorption cross section σ [m^2] per particle



$$I(\Omega) = \frac{d\sigma}{d\Omega} I_0$$

$$\left[\frac{W}{sr}\right] = \left[\frac{m^2}{sr}\right]\left[\frac{W}{m^2}\right]$$

$$\sigma = \iint_{\Omega} \left(\frac{\partial\sigma}{\partial\Omega}\right) d\Omega$$

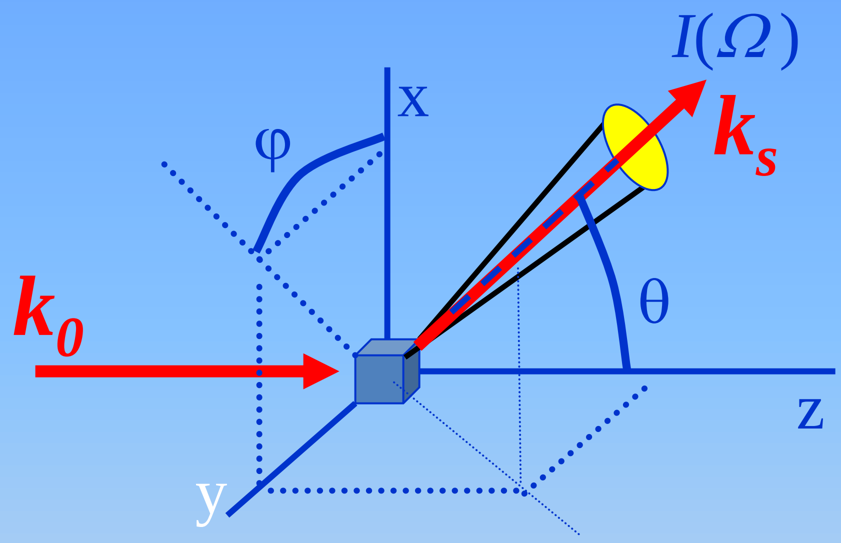
Scattering function:
p(θ,φ)

$$I(\Omega) = I(\theta,\varphi)$$

$$I(\theta,\varphi) = p(\theta,\varphi) I_0$$

$$\int_0^{\pi}\int_0^{2\pi} p(\theta,\varphi).\sin\theta.d\theta d\varphi = 1$$

Gen. Intro. (2) : Coefficients



Wavevectors: $\boldsymbol{k_0}$ and $\boldsymbol{k_s}$

$$k = \frac{2\pi}{\lambda} \quad ; \quad \lambda_{medium} = \frac{\lambda_{vacuum}}{n}$$

Scattering / Absorption coefficients: μ [m^{-1}]

$\mu = N\ \sigma$

[m^{-1}] = [m^{-3}] [m^2]

Beam attenuation coefficients:

- scattering: μ_s [mm^{-1}]
- absorption: μ_a
- total: $\mu_t = \mu_s + \mu_a$

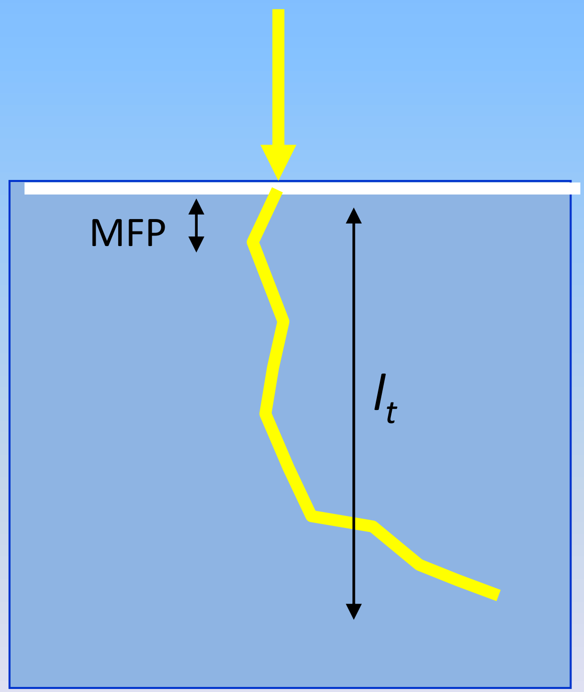
$$I(z) = I_0.exp(-\mu z)$$

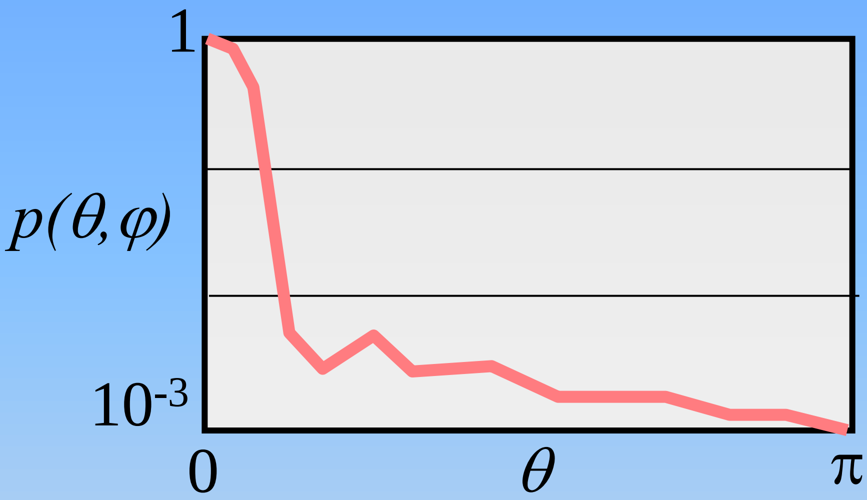
Mean-free-path (MFP):

$MFP = \mu_t^{-1}$

Gen. Intro. (3) : Forward Scattering

Scattering in tissue is predominantly forward:





Reduced scattering coefficient:

$\mu_s' = (1 - g)\,\mu_s \quad \ll \mu_s$

$g = \langle \cos\theta \rangle$

Transport mean-free-path:

$l_t = 1 / [\mu_s' + \mu_a] \gg \text{MFP} = 1 / \mu_t$

Gen. Intro. (6) : Diffusion

Diffusion Equation: $$D.\left(\nabla^2 - \mu_{eff}{}^2\right)U(\vec{\mathbf{r}}) = -q(\vec{\mathbf{r}})$$

q = source (nr. Photons injected in dV at ***r***) [$m^{-3}s^{-1}$]

U = radiant energy fluence rate at ***r*** [W/m^2]

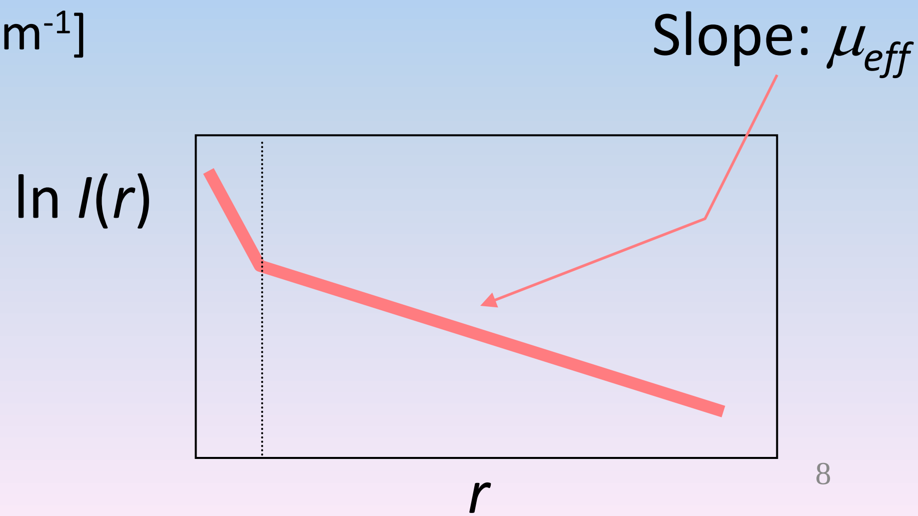
$\nabla^2 U$ = light scattering out of dV at ***r*** [W/m^4] = $\{\partial^2/\partial x^2 + \ldots\}\, U$

D = diffusion coefficient [m]

μ_{eff} = effective scattering coefficient [m^{-1}]

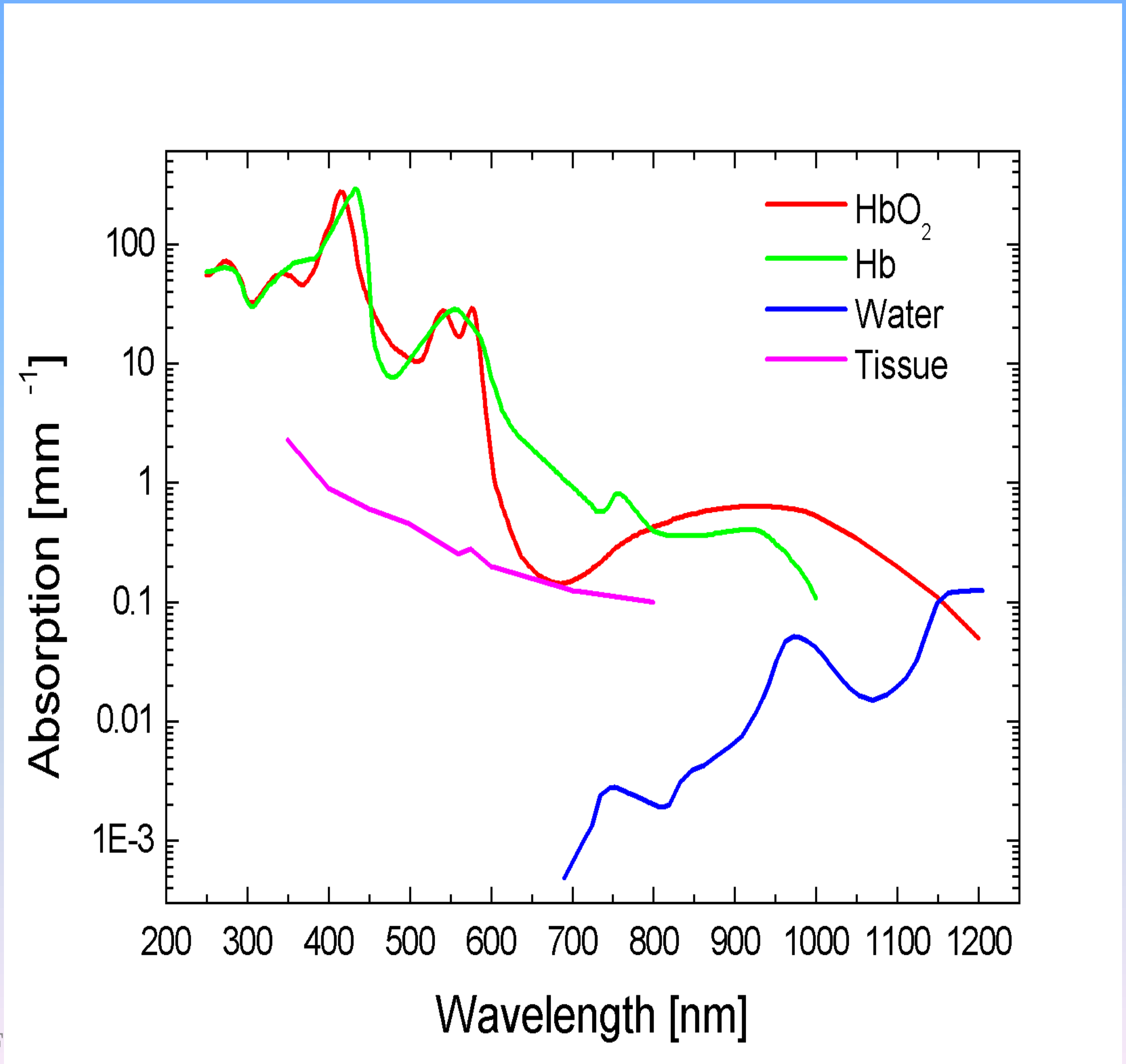
$$\mu_{eff} = \sqrt{3\mu_a\left(\mu_a + \mu_s'\right)}$$

$$D = \frac{1}{3\left(\mu_a + \mu_s'\right)}$$



Gen. Intro. (6) : Tissue, properties

Optical properties of tissue and blood



(Reduced) Scattering coefficient:

- λ = 580 nm:

  Dermis: 3 mm^{-1}

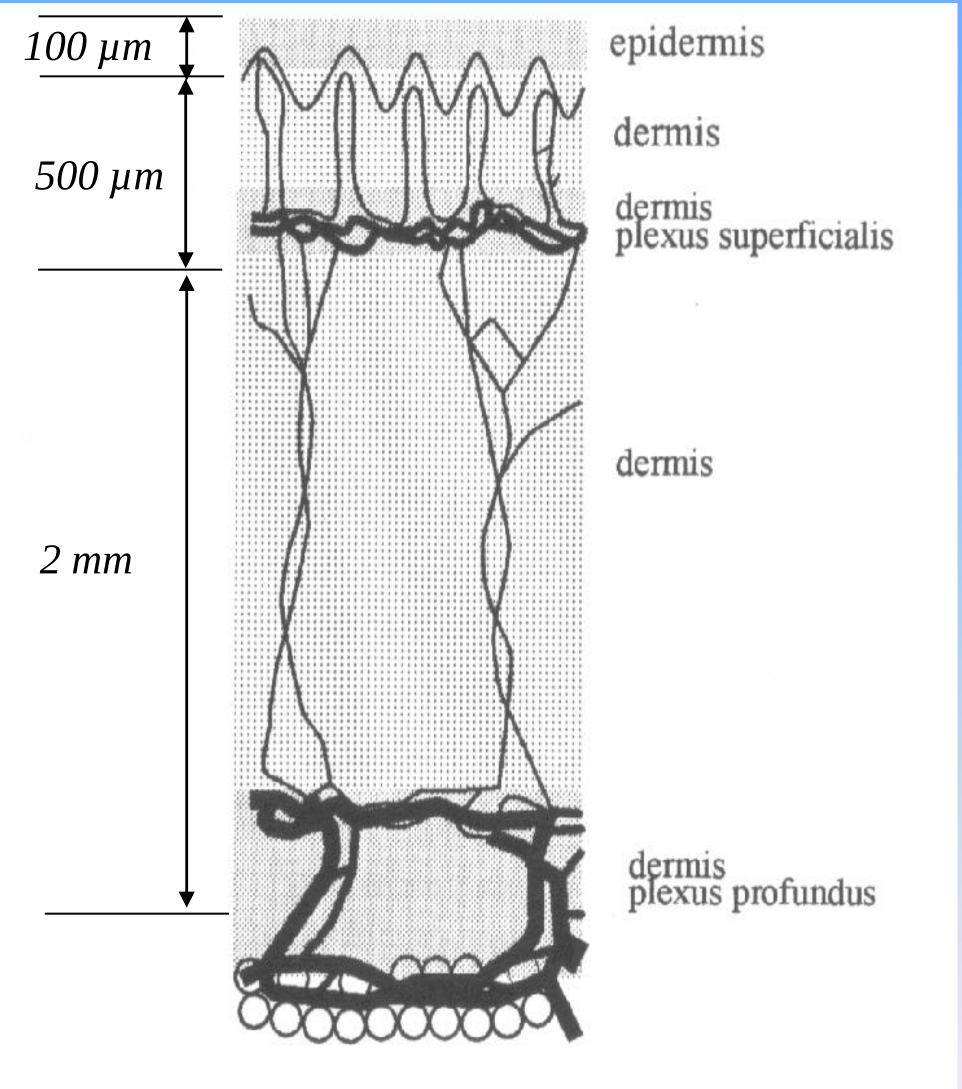
  Blood: 1 …

- λ = 850 nm:

  Dermis: 1 …

  Blood: 0.5 …

Gen. Intro. (7) : Human Skin

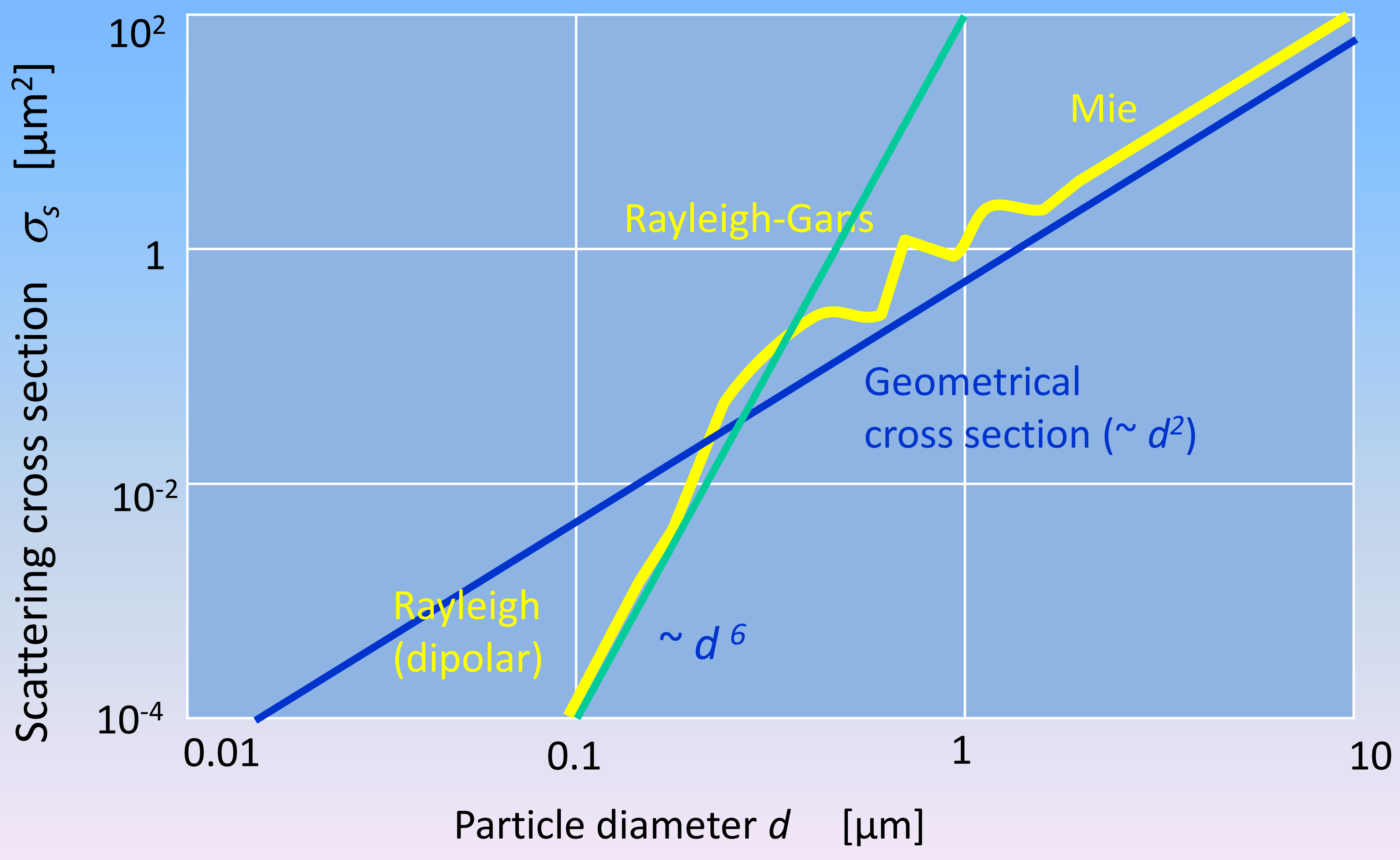


Model of human skin

With typical layer thicknesses

Gen. Intro. (8) : Scattering Overview

Scattering cross section, for λ = 500 nm and n = 1.5



General Introduction (9)

The end.