

# Biomedical Optics

Polarization

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Amplitude scattering matrix

$$\begin{bmatrix} E_{\parallel} \\ E_{\perp} \end{bmatrix} = \frac{\exp(ik(r-z))}{ikr} \begin{bmatrix} S_2 & S_3 \\ S_4 & S_1 \end{bmatrix} \begin{bmatrix} E_{\parallel,0} \\ E_{\perp,0} \end{bmatrix}$$

## Scattering matrix

$$\begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = \frac{1}{k^2 r^2} \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} \begin{bmatrix} I_0 \\ Q_0 \\ U_0 \\ V_0 \end{bmatrix}$$

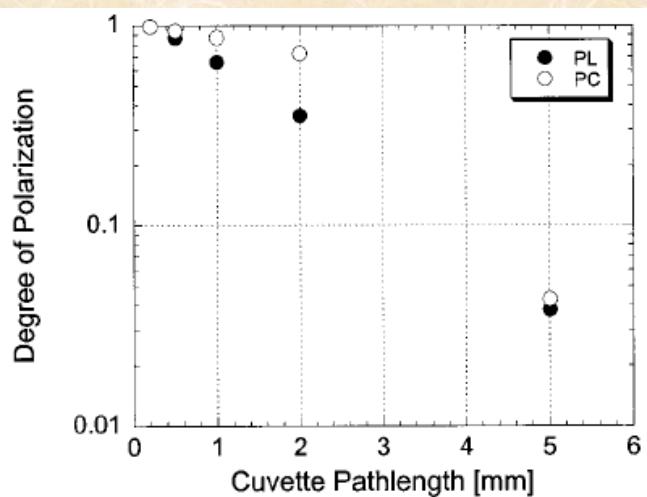
## Degree of polarization

$$p_L = \frac{\sqrt{Q^2 + U^2}}{I}$$

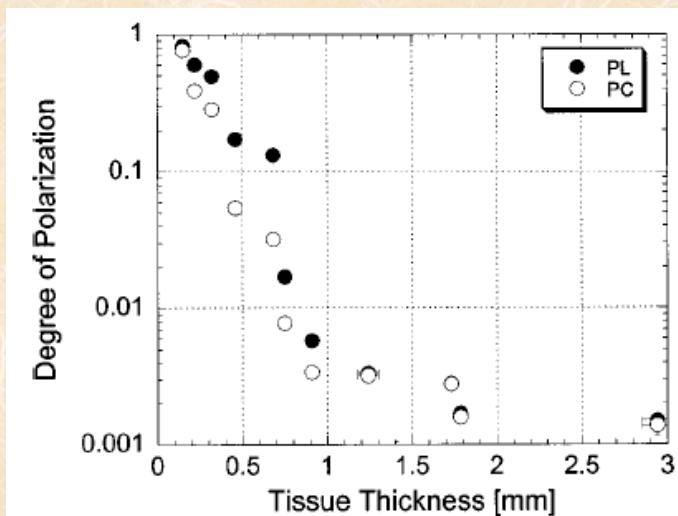
$$p_C = \frac{\sqrt{V^2}}{I}$$

$$p_T = \frac{\sqrt{Q^2 + U^2 + V^2}}{I}$$

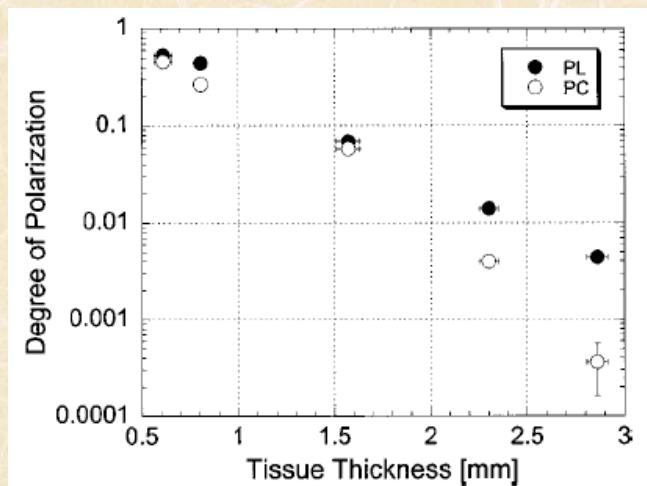
## Porcine whole blood



## Porcine adipose tissue



## Porcine myocardial tissue



$$p_L > p_C$$

Rayleigh limit scattering

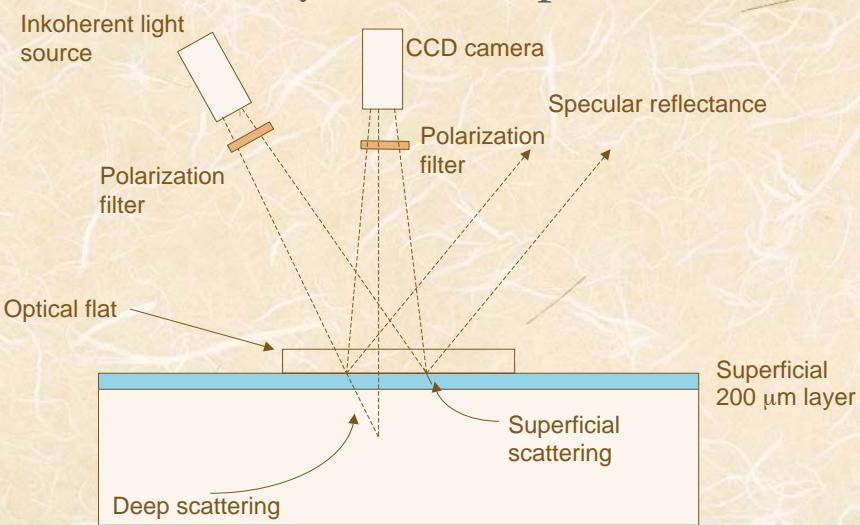
$$p_L < p_C$$

Mie scattering

$$p_L \approx p_C$$

Rayleigh-Mie transition regime

## System setup



## Polarization image

$$Pol = \frac{I_{par} - I_{per}}{I_{par} + I_{per}}$$

$$I_{par} = I_0 T_{mel} \left( R_s + \frac{1}{2} R_d \right)$$

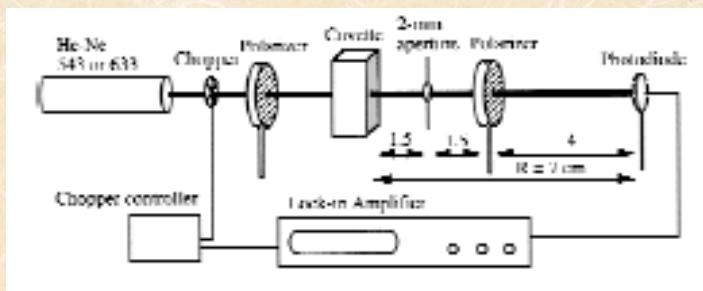
$$I_{per} = I_0 T_{mel} \frac{1}{2} R_d$$

continue

$$Pol = \frac{I_{par} - I_{per}}{I_{par} + I_{per}} = \frac{I_0 T_{mel} \left( R_s + \frac{1}{2} R_d \right) - I_0 T_{mel} \frac{1}{2} R_d}{I_0 T_{mel} \left( R_s + \frac{1}{2} R_d \right) + I_0 T_{mel} \frac{1}{2} R_d} = \frac{R_s}{R_s + R_d}$$

Prerequisites

- Glare is about 4% from surface (specular)
- 45% of incident light escapes as random pol
- Melanin act as absorber
- Oriented  $I_{par}$  and  $I_{per}$  is 3% and 0% of incident light
- Random  $I_{par}$  and  $I_{per}$  is 22,5% and 22,5% of incident light



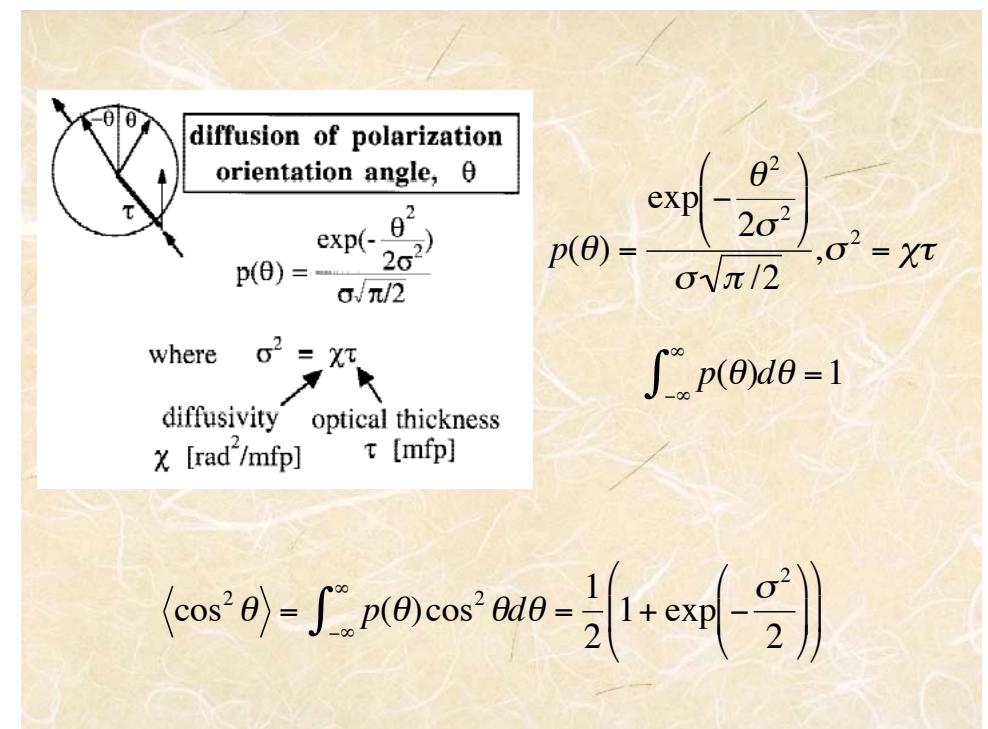
$$I_{par} = I_0 \exp(-\mu_s L) + f I_{parscatt}$$

$$I_{per} = f I_{perscatt}$$

## Degree of polarisation

$$Pol = \frac{I_0 \exp(-\mu_s L) + f I_0 (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 + \exp\left(-\frac{\chi\tau}{2}\right) \right) - f I_0 (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 - \exp\left(-\frac{\chi\tau}{2}\right) \right)}{I_0 \exp(-\mu_s L) + f I_0 (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 + \exp\left(-\frac{\chi\tau}{2}\right) \right) + f I_0 (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 - \exp\left(-\frac{\chi\tau}{2}\right) \right)}$$

$$Pol = \frac{\exp(-\mu_s L) + f (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 + \exp\left(-\frac{\chi\tau}{2}\right) \right) - f (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 - \exp\left(-\frac{\chi\tau}{2}\right) \right)}{\exp(-\mu_s L) + f (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 + \exp\left(-\frac{\chi\tau}{2}\right) \right) + f (1 - \exp(-\tau)) f \exp(-\mu_{atm} L) \frac{1}{2} \left( 1 - \exp\left(-\frac{\chi\tau}{2}\right) \right)}$$



## Pol dependence of $I_{par}$ , $I_{per}$

