Formulário / *formulary*

24 de Março de 2015

Conteúdo

1 Óptica / *Optics*

- formação de imagem / *image formation*
  - interface esférica
$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$$
  - lentes finas / *thin lenses*
$$\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$$
$$\frac{1}{f} = \frac{n_2 - n_1}{n_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = P$$
  - lentes espessas / *thick lenses*
$$\frac{1}{f} = (n_l - 1)\left(\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n_l - 1)\,d}{n_l R_1 R_2}\right) = P$$
$$h_1 = -\frac{f\,(n_l - 1)\,d}{R_2 n_l}$$
$$h_2 = -\frac{f\,(n_l - 1)\,d}{R_1 n_l}$$
  - combinação de lentes / *lens combination*
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$
- número-f / *f number*
$$f/\# = \frac{f}{D}$$
- difracção / *diffraction*
  - 1 abertura de largura b / *one aperture of width b*
$$I(\theta) = 4I_0 \frac{\sin^2(k\,b\,\theta/2)}{(k\,b\,\theta/2)^2}$$
  - 2 aberturas verticais / 2 *vertical apertures*
$$I = 2I_0 \frac{\sin^2(k\,b\,\theta/2)}{(k\,b\,\theta/2)^2}\left[1 + \cos(k\,\Delta + k\,d\,\theta)\right]$$
- disco de Airy / *Airy disk*
$$r_{Airy} = 1.22\,\lambda \times \left(\frac{f}{D}\right)$$

- Equações de Fresnel / *Fresnel equations*

$$(s \equiv \perp) \quad r_\perp = \frac{n_1 \cos\theta_1 - n_2 \cos\theta_2}{n_1 \cos\theta_1 + n_2 \cos\theta_2} \qquad t_\perp = \frac{2n_1 \cos\theta_1}{n_1 \cos\theta_1 + n_2 \cos\theta_2}$$

$$(p \equiv \parallel) \quad r_\parallel = \frac{n_2 \cos\theta_1 - n_1 \cos\theta_2}{n_1 \cos\theta_2 + n_2 \cos\theta_1} \qquad t_\parallel = \frac{2n_1 \cos\theta_1}{n_1 \cos\theta_2 + n_2 \cos\theta_1}$$

$$T_{\perp/\parallel} = \frac{n_2}{n_1} \frac{\cos\theta_2}{\cos\theta_1} t^2_{\perp/\parallel}$$

- Fluxo de Energia, Intensidade (W/m^2) / *energy flux*

$$I_0 = \frac{1}{2}\epsilon_0 c E_0^2$$

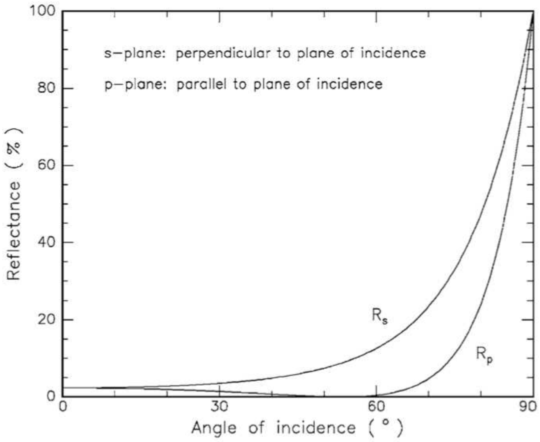


Fig. 2.3. Reflectances in s- and p-plane for water ($n = 1.33$)

- Doppler

$$f = f_0 + \Delta f$$
$$f = f_0 \frac{\mathrm{v} \pm v_{obs}}{\mathrm{v} \mp v_{fonte}}$$

2 Lasers e guias de onda / *lasers and waveguides*

- feixe Gaussiano (CW) / *gaussian beam*

$$I(r) = I_0 \exp\left(-\frac{2r^2}{w_0^2}\right)$$

- feixe Gaussiano (pulsado, duração τ) / *pulsed gaussian beam, duration* τ

$$I(r) = I_0 \exp\left(-\frac{2r^2}{w_0^2}\right) \exp\left(-\frac{8\,t^2}{\tau^2}\right)$$

- feixe / *beam top-hat*

$$I(r) = \frac{1}{1 + \left|\frac{r}{w}\right|^M} \qquad (M \gg 2)$$

- divergência de feixe α / *beam divergence*

$$\alpha = \frac{\Delta w}{\Delta z} = \frac{\lambda}{\pi \omega_0}$$

$$z_R = \frac{\pi\,\omega_0^2}{\lambda}$$

$$w^2 = w_0^2 \left(1 + \left(\frac{z}{z_R}\right)^2\right)$$

$$D.O.F. = 2 \times \left(\frac{4\lambda}{\pi}\right) \left(\frac{f}{D}\right)^2$$

- campo evanescente / *evansecent wave*

$$E_z = E_0 e^{-\frac{z}{d_p}}$$

$$d_{\mathrm{p}} = \frac{\lambda}{2\pi n_1 \sqrt{\sin^2\theta - \left(\frac{n_2}{n_1}\right)^2}}$$

3 Interacção Luz-Tecidos / *light-tissue interaction*

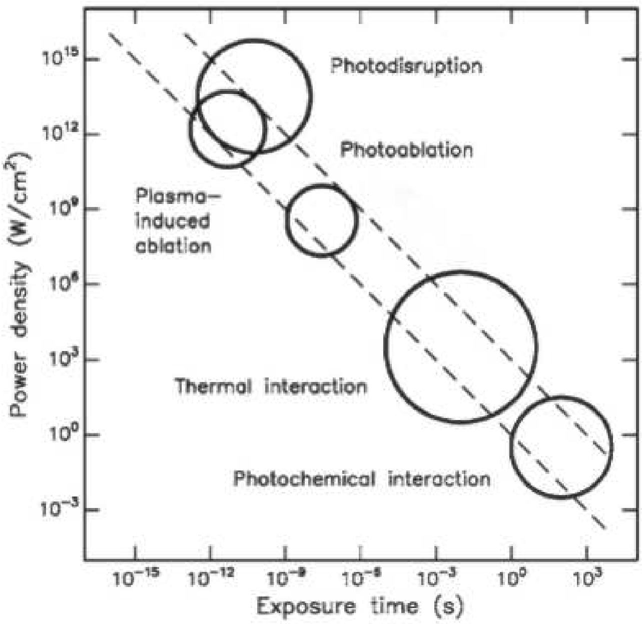
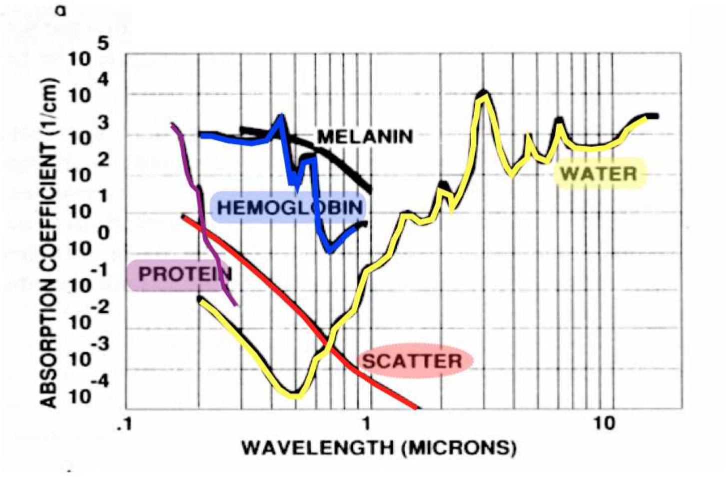


Fig. 3.1. Map of laser–tissue interactions. The circles give only a rough estimate of the associated laser parameters. Modified from Boulnois (1986)



3.1 Difusão/*Scattering*

- Rayleigh (δ, despolarização da luz)

$$\sigma_r(\lambda) = \frac{128\pi^5\alpha^2}{3\,\lambda^4}\frac{6+3\delta}{6-7\delta} \qquad \alpha = \frac{n-1}{2\pi N_0} \sim \frac{\left(n^2-1\right)}{4\pi N_0}$$

$$\sigma_r(\lambda) \overset{n\to 1}{=} \frac{8\pi^3}{3}\frac{\left(n^2-1\right)^2}{\lambda^4 N_0^2}$$

- funções de fase / *phase functions*

$$\text{Henyey-Greenstein} \qquad p(\theta) = \frac{1}{4\pi}\left[\beta + (1-\beta)\frac{1-g^2}{\left(1+g^2-2g\cos\theta\right)^{3/2}}\right]$$

$$\delta\text{-Eddington} \qquad p(\theta) = \frac{1}{4\pi}\left\{2f\times\delta(1-\cos\theta) + (1-f)\left[1+3g\cos\theta\right]\right\}$$

- factor geométrico / *geometric factor*

$$g = \langle\cos\theta\rangle = \int p(\theta)\cos\theta dw$$

- livre percurso médio / *mean free path*

$$mfp = \frac{1}{\alpha+\alpha_s}$$

- coeficiente de atenuação reduzido / *reduced extinction coefficient*

$$\alpha_t' = \alpha + (1-g)\,\alpha_s$$

- coeficiente de extinçao efectivo / *effective extinction coefficient*

$$\alpha_{eff} = \sqrt{3\alpha\,\alpha_t'}$$

- comprimento de difusão effectivo / *effective diffusion length*

$$L_{eff} = \frac{1}{\sqrt{3\alpha\alpha_t'}}$$

- difusão de 1ª ordem

$$I\left(z\right) = I_0 \exp\left[-\left(\alpha + \alpha_s\right) z\right]$$

- difusão /*diffusion aproximation*

$$I = I_c + I_d = Ae^{-\alpha_t z} + Be^{-\alpha_{eff} z}, \qquad A + B = I_0$$

3.2 características do olho humano / *human eye main characteristics*

- cornea,
  - $e \sim 0.5\,mm$
  - $n = 1.377$
- câmara anterior / *anterior chamber*
  - $e \sim 3.04\,mm$
  - $n = 1.336$
- cristalino / *lens*, $n \sim 1.4$
- vítreo / *vitreous*, $n \sim 1.336$

3.3 propriedades características térmicas e ópticas de tecidos biológicos / *thermal and optical characteristic properties of biological tissues*

- similaridade com água / *water similitude*: $n \sim n_{água}$
- Bausch&Lomb:

$$W = \frac{m_{H_2O}}{m_{total}} \qquad n_{632.8nm} = 1.53 - 0.2W$$

- Tabela com variabilidade a $T = T_{ref} \times \bar{T}$, $\rho = \rho_{ref} \times \bar{\rho}$, e $\lambda = \lambda_{ref} \times \bar{\lambda}$

$\rho_{ref} = 1000$ kg/m^3	$a_0 =$ 0,244257733
$T_{ref} = 273,1$ K	$a_1 =$ 9,74634476E − 3
$\lambda_{ref} = 0.589$ μm	$a_2 =$ 3,73234996E − 3
	$a_3 =$ 2,68678472E − 4
$\bar{\lambda}_{UV} = 0.2292020$	$a_4 =$ 1,58920570E − 3
$\bar{\lambda}_{IR} = 5.432937$	$a_5 =$ 2,45934259E − 3
	$a_6 =$ 0,900704920
	$a_7 =$ −1,66626219E − 2

$$\frac{n^2-1}{n^2+2}\frac{1}{\bar{\rho}} = a_0 + a_1\bar{\rho} + a_2\bar{T} + a_3\bar{\lambda}^2\bar{T} + \frac{a_4}{\bar{\lambda}^2} + \frac{a_5}{\bar{\lambda}^2 - \bar{\lambda}_{UV}^2} + \frac{a_6}{\bar{\lambda}^2 - \bar{\lambda}_{IR}^2} + a_7\bar{\rho}^2$$

- capacidade calorífica específica / *specific thermal capacity* @ 37 °C, c (kJ kg^{-1} K^{-1})

$$c \approx \left(1,55 + 2,8\frac{\rho_w}{\rho}\right)$$

- condutividade calorífica / *thermal conductivity* @ 37 °C, k (W m^{-1} K^{-1})

$$k \approx \left(0,06 + 0,57\frac{\rho_w}{\rho}\right)$$

- difusão térmica / *temperature conductivity or diffusion* @ 37 °C, $\mathbf{k}$ (m^2 s^{-1})

$$\mathbf{k} \approx \frac{k}{\rho c}$$

$\mathbf{k} = 1.4 \times 10^{-7}$ m s^{-2} (maioria dos tecidos biológicos (*most biological tissues*) a 37 °C)

3.4 propriedades da água / *water properties*

- índice de refracção: $n = 1.330$
- densidade: $\rho_{40^\circ C} \sim 0.992$ g/cm^3
- viscosidade: $\eta_{20^\circ C} = 0.001$ Pa.s
-

	0ºC, 1atm	25ºC, 1atm	37ºC, 1atm
capacidade calorífica [J/(g.K)]	∼ 4.2176	∼ 4.1814	∼ 4.1785

-

	37ºC	100ºC
$\lambda^{vap}_{100^\circ C}$, calor latente de vaporização[kJ/(mol)]	∼ 43.5	∼ 40.657

3.5 plasma e efeitos mecânicos / *plasma and mechanical effects*

- frequência plasma

$$\omega_{pl}^2 = \frac{N\,e^2}{\epsilon_0 m_e}$$

- absorção plasma

$$\alpha_{pl} = \frac{\nu_{ei}}{nc}\left(\frac{\omega_{pl}}{\omega}\right)^2$$

- ondas de choque / *shock waves*

$$\begin{array}{ll} p_1(r) & = p_0(r) + \frac{\rho_0 c_1}{b}\frac{1}{r^2} \\ E_S & \simeq (p_1 - p_0)\,A_s\,\Delta r \end{array}$$

- cavitação / *cavitation*

$$r_{max} = \frac{t_c}{0.916\sqrt{\frac{\rho}{p_{estat} - p_{vapor}}}}$$

4 Transporte / *transport*

- calor / *heat*

$$\frac{\partial T}{\partial t} = \mathbf{k}\nabla^2 T + \frac{S}{\rho c}$$

  - solução homogénea:

$$T\,(r,z,t) = T_0 + \frac{A}{(4\pi\mathbf{k}t)^{3/2}} e^{-\frac{r^2+z^2}{4\mathbf{k}t}}$$

  - solução impulsional:

$$T\,(z - z_0, t - t_0) = G\,(z - z_0, t - t_0) = \frac{1}{\sqrt{4\pi\mathbf{k}\,(t - t_0)}}\,e^{-\frac{z^2}{4\mathbf{k}(t-t_0)}}$$

  - solução equação não homogénea

$$T\,(z,t) = \frac{1}{\rho c}\int_0^t \int_{-\infty}^{+\infty} S\,(z',t')\,G\,(z - z', t - t')\,dz'dt'$$

  - extensão espacial

$$z_{therm}(t) = \sqrt{4\mathbf{k}t}$$

- Difusão

$$\vec{j}^N = -D\,\nabla n$$

$$\nabla \cdot \vec{j}^N + \frac{\partial n}{\partial t} = 0$$

$$x_D \approx \sqrt{4Dt}$$

5 Danos e Segurança / *safety and damages*

- equação Arrhenius

$$\ln c(t) - \ln c_0 = -A \int_0^t e^{-\frac{\Delta E}{RT(t')}} dt' \equiv -\Omega$$

$$A \simeq \frac{KT}{h} e^{\frac{\Delta S}{R}}$$

- grau de dano / *damage degree*

$$D_d = \frac{c_0 - c(t)}{c_0} = 1 - e^{-\Omega}$$

- densidade óptica / *optical density*

$$OD(\lambda) = \log \frac{H_0}{MPE}$$

- MPE_olho / *eye*

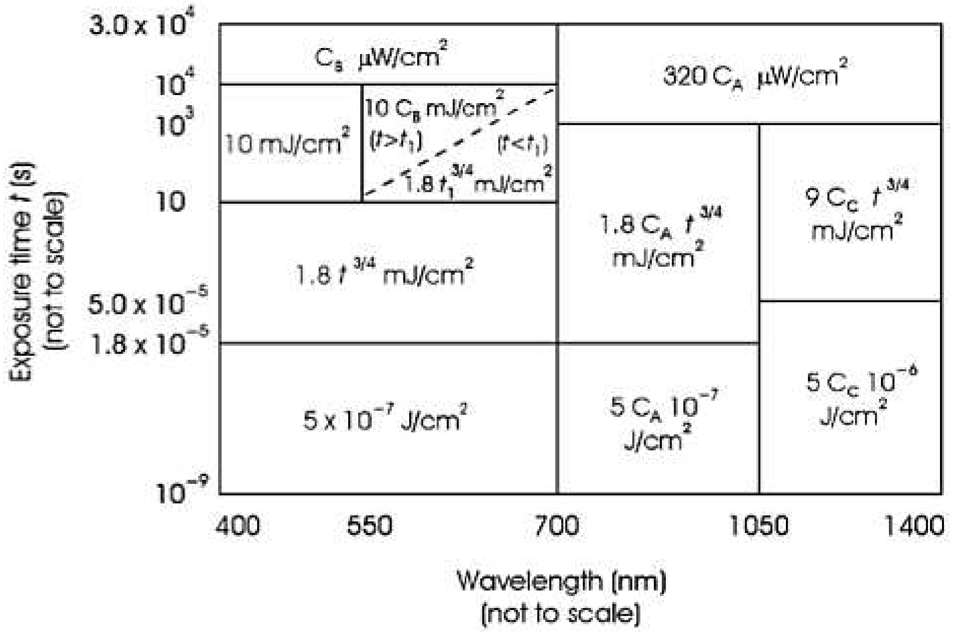


Fig. 5.2. Visible and near-IR MPE values for direct ocular exposure. Note that the correction factors (C) vary by wavelength. $C_A = 10^{2(\lambda-0.700)}$ for 0.700–1.050 μm. $C_A = 5$ for 1.050–1.400 μm. $C_B = 1$ for 0.400–0.550 μm. $C_B = 10^{15(\lambda-0.550)}$ for 0.550–0.700 μm. $t_1 = 10 \times 10^{20(\lambda-0.550)}$ for 0.550–0.700 μm. $C_C = 1$ for 1.050–1.150 μm. $C_C = 10^{18(\lambda-1.150)}$ for 1.150–1.200 μm. $C_C = 8$ for 1.200–1.400 μm

- protecção ocular - lasers pulsados

Table 5.3. Simplified method for selecting laser eye protection intrabeam viewing for wavelengths between 400 nm and 1400 nm. Data from American National Standards Institute's (ANSI) Z136.1 (1993)

Q-switched lasers (1 ns to 0.1 ms)		Non-Q-switched lasers (0.4 ms to 10 ms)		Attenuation	
Maximum output energy (J)	Maximum radiant exposure (J/cm^2)	Maximum output energy (J)	Maximum radiant exposure (J/cm^2)	Attenuation factor	OD
10	20	100	200	10^8	8
1	2	10	20	10^7	7
10^{-1}	2×10^{-1}	1	2	10^6	6
10^{-2}	2×10^{-2}	10^{-1}	2×10^{-1}	10^5	5
10^{-3}	2×10^{-3}	10^{-2}	2×10^{-2}	10^4	4
10^{-4}	2×10^{-4}	10^{-3}	2×10^{-3}	10^3	3
10^{-5}	2×10^{-5}	10^{-4}	2×10^{-4}	10^2	2
10^{-6}	2×10^{-6}	10^{-5}	2×10^{-5}	10^1	1

- protecção ocular/ *eye proteccion* - lasers CW

CW lasers momentary (0.25 s to 10 s)		CW lasers long-term staring (greater than 3 hours)		Attenuation	
Maximum output power (W)	Maximum irradiance (W/cm^2)	Maximum output power (W)	Maximum irradiance (W/cm^2)	Attenuation factor	OD
NR	NR	NR	NR	NR	NR
NR	NR	NR	NR	NR	NR
NR	NR	1	2	10^6	6
NR	NR	10^{-1}	2×10^{-1}	10^5	5
10	20	10^{-2}	2×10^{-2}	10^4	4
1	2	10^{-3}	2×10^{-3}	10^3	3
10^{-1}	2×10^{-1}	10^{-4}	2×10^{-4}	10^2	2
10^{-2}	2×10^{-2}	10^{-5}	2×10^{-5}	10^1	1

OD: optical density.
NR: not recommended.