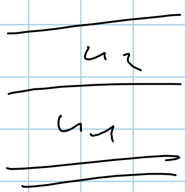
Aufgabe 6 F08

6.1.1



$$NA = \sqrt{n_1^2 - n_2^2} = 0{,}192$$

6.1.2)

a) $n_0 = 1$

$$n_0 \sin\alpha_1 = NA \Rightarrow \alpha_1 = 9{,}9°$$

b) $n_1 = 4$ $\quad n_1 \sin\alpha_2 = NA$

$$\Rightarrow \alpha_2 = 2{,}46°$$

6.1.3)

$\lambda \approx 1550\,nm$ (1530–1580 nm)

→ geringe Dämpfung

6.2.1)

$$\alpha_{A1} \cdot L \overset{!}{=} G_1$$

$$L = \frac{G_1}{\alpha_{A1}} = \frac{30\,dB}{0{,}25\,\frac{dB}{km}} = 120\,km$$

6.2.2)

$$G_2 = \alpha_{A2} \cdot L = 0{,}2\,\frac{dB}{km} \cdot 120\,km = 24\,dB$$

6.2.3)

$$V < 2{,}405$$

$$V = k_0 a\, NA = 0{,}8 \cdot 0{,}2405 = 1{,}924$$

$$a = \frac{1{,}924}{k_0 NA} = \frac{1{,}924}{\frac{2\pi}{\lambda_0}\cdot NA} = 2{,}33\,\mu m$$

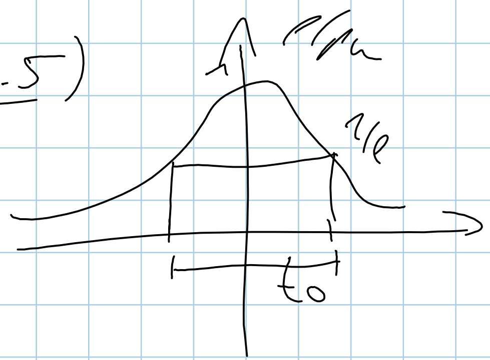
$$d = 2a = 4{,}66\,\mu m$$

6.2.4) Seite 86

$$t_{opt1} = \sqrt{4L\,\frac{D\lambda_1}{\omega c_0}} = \sqrt{4L\,\frac{D\lambda_1}{2\pi c_0^2}\lambda_1} = 372{,}8\,ps$$

$$t_{opt2} = \sqrt{4L\,\frac{D\lambda_2}{2\pi c_0^2}\lambda_2} = 229{,}4\,ps$$

6.2.5)



$$E(\omega) = E_0\sqrt{\frac{\pi}{2}}\,t_0\,e^{-\frac{(\omega-\omega_T)^2 t_0^2}{8}}$$

Abfall auf $\frac{1}{\sqrt{e}}$ $\Rightarrow$ $e^{-\frac{(\omega-\omega_T)^2 t_0^2}{8}}$

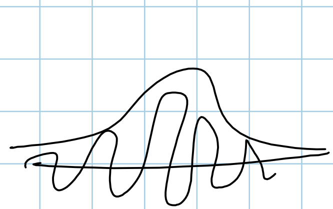
$$= e^{-\frac{1}{2}}$$

$$\left(\frac{\omega-\omega_T}{4}\right)^2 t_0^2 = 1 \qquad (f_{1,2} - f_T) = \pm\frac{1}{\pi t_0}$$

$$\Delta f = |f_1 - f_2| = \frac{2}{\pi t_0}$$

$t_{opt1} \Rightarrow \Delta f_1 = 1{,}7\,GHz$

$t_{opt2} \Rightarrow \Delta f_2 = 2{,}775\,GHz$



6.3.1) $t_{opt} = \sqrt{4L\,\frac{D}{\omega c_0}} = \sqrt{\frac{4}{2\pi c_0^2}\,L D \lambda}$

$(LD)_{gesamt} = L \cdot D_A + L_B D_B$

Damit bei beiden Wellenlängen das gleiche t_{opt} erreicht wird muss:

$$(L D_{A1} + L_B D_{B1}) \stackrel{!}{=} (L D_{A2} + L_B D_{B2}) \lambda_2 \quad (\circledast)$$

$L \cdot D_{A1} = 15\,km \qquad L D_{A2} = 4{,}8\,km$

$(\circledast) \Rightarrow \quad L_B = 15\,km$

6.3.2) $\Delta f = \frac{2}{\pi t_0}$ mit $t_0 = \sqrt{\frac{4}{2\pi c_0^2} L_1 D_1 \lambda_1}$

$L_i D_i \lambda_i = L D_{A1} \lambda_1 + L_B D_{B1} \lambda_1 = 3{,}93 \cdot 10^{-3}$

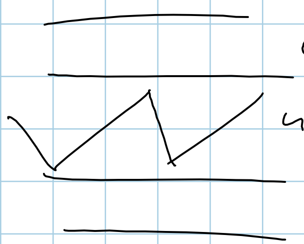
$\Rightarrow t_{opt} = 166{,}83\,ps$

$$\Delta f = \frac{2}{\pi t_0} = 3{,}82\ GHz$$

6.3.3) $g \stackrel{\wedge}{=} L_B \cdot \alpha_B = 15\,km \cdot 0{,}4\,\frac{dB}{km} = 6\,dB$

Aufgabe 6 H05

6.1.1)



Ursachen: OH^- Absorption im Bereich $\lambda = 1380\,nm$

Ursachen: OH Absorption $\lambda = 1380\,nm$

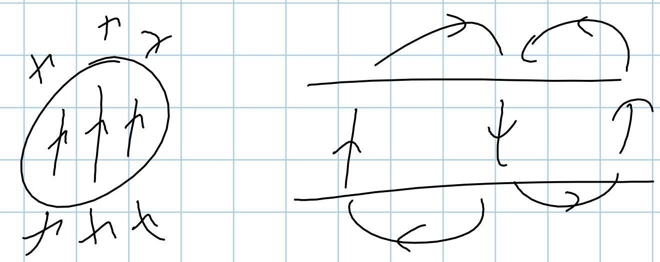
Rayleigh-Streuung $\lambda \leq 1650\,nm$

IR-Absorption $\lambda \geq 1650\,nm$

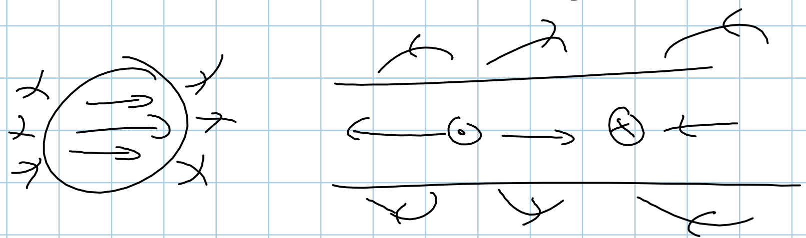
6.1.2)

LP_{01}

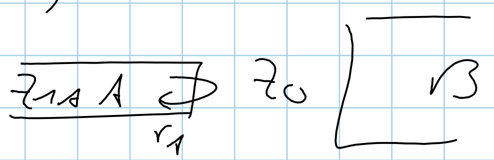
$\vec{E}$



$\vec{H}$ analog um 90° gedreht



6.2.1)



$$r = \frac{Z_0 - Z_{1A}}{Z_0 + Z_{1A}} = \frac{n_{1A} - 1}{n_{1A} + 1} = \frac{0,49}{2,49} = 0,1968$$

$$\frac{Z_0}{Z_{1A}} = \frac{Z_0}{\sqrt{\frac{1}{\varepsilon_A}}\, Z_0} = \sqrt{\varepsilon_A} = n_{1A}$$

6.2.2)

$$NA_A = \sqrt{n_{1A}^2 - n_{2A}^2} = 0,27$$

$n_{1B} = \sqrt{NA_B^2 + n_{2B}^2} = 1{,}53$

<u>6.2.3)</u> Extremfälle:

1.) $d = n \cdot \frac{\lambda_0}{2} \Rightarrow r_{A1} = \frac{n_{1A} - n_{1B}}{n_{1A} + n_{1B}}$

$= -0{,}01324$

2.) $d = (2a - 1)\,\frac{\lambda_0}{4}$

$r_{A2} = \frac{Z_{1Bin} - Z_{1A}}{Z_{1Bin} + Z_{1A}} = \frac{n_{1A} n_{1B} - 1}{n_{1A} n_{1B} + 1} = 0{,}3902$

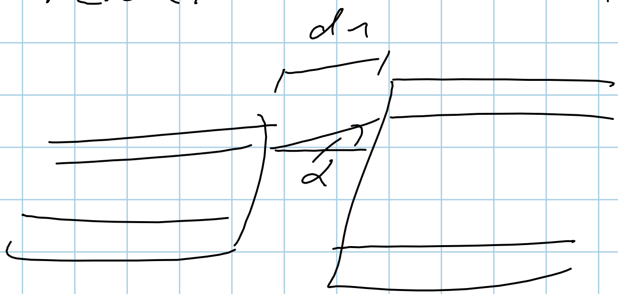
$P_{min} = P_{P\,Ende\,A} \cdot |r_{A1}|^2 = 0{,}11\,\mu W$

$P_{Ende\,A} = P_{p}|dB - \alpha_A L_A = -23 - 9 = -32\,|dB$

$= 6{,}3 \cdot 10^{-4}\,W$

$P_{max} = P_{P\,Ende\,A} \cdot |r_{A2}|^2 = 95{,}92\,\mu W$

<u>6.2.4)</u>



$\tan\alpha = \frac{\frac{d_B - d_A}{2}}{d_1} \qquad \sin\alpha = NA$

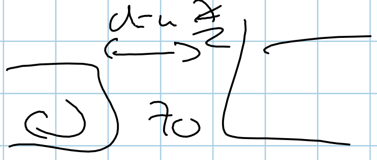
$d_1 = \frac{d_B - d_A}{2\tan\alpha} = \frac{d_B - d_A}{2\tan(\arcsin(NA_A))} = 89{,}15\,\mu m$

<u>6.3.1)</u>

6.3.1)

Für Abstand $d = n \cdot \frac{\lambda_0}{2}$ ist stets

$P_r \leq 1\mu W$



$$d = (2n-1)\frac{\lambda_0}{4}$$

$$P_r = P_{P\,Ende\,A} \left| \frac{\frac{Z_i^2}{Z_{1B}} - Z_{1A}}{\frac{Z_i^2}{Z_{1B}} + Z_{1A}} \right|^2 \leq 1\mu W$$

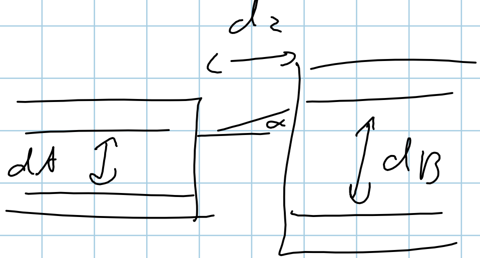
$$\left| \frac{n_{1A} n_{1B} - n_i^2}{n_{1A} n_{1B} + n_i^2} \right| \leq \frac{1\mu W}{6{,}3 \cdot 10^{-4} W} = 1{,}58 \cdot 10^{-3}$$

↳ 6.2.3

$$n_i^2 \geq \frac{1 - \sqrt{1{,}58 \cdot 10^{-3}}}{1 + \sqrt{1{,}58 \cdot 10^{-3}}} \cdot n_{1A} n_{1B}$$

$1{,}45 \leq n_i$ oder $n_i \leq -1{,}45$

6.3.2)



$$\frac{d_B - d_A}{2 d_2} = \tan \alpha_i \qquad n_n \sin \alpha_i = NA_A = 0{,}27$$

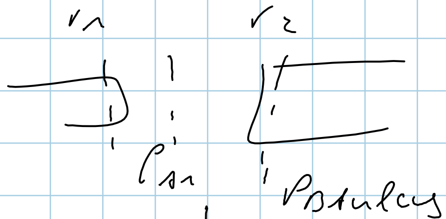
$n_i = 1{,}45$

$d_2 = \quad d_B - d_A$

$$d_2 = \frac{d_B - d_A}{2\tan\left(\arcsin\left(\frac{0{,}27}{n_i}\right)\right)} \overset{n_i = 1{,}45}{=} 132\,\mu m$$

$$\boxed{d_2 \approx 132\,\mu m}$$

6.3-3)



$$a = -10 \log \left| \frac{P_{B\,Anfang}}{P_{A1\,Ende}} \right| = -10 \log \left(1-|r_1|^2\right)\left(1-|r_2|^2\right)$$

$$P_{B\,Anfang} = P_{A1}\left(1-|r_2|^2\right) = P_{A\,Ende}\left(1-|r_1|^2\right)\left(1-|r_2|^2\right)$$

$$P_{A1} = P_{A\,Ende}\left(1-|r_1|^2\right)$$

$$|r_1| = \left| \frac{n_{1A} - n_i}{n_{1A} + n_i} \right| = 0{,}0133$$

$$|r_2| = \left| \frac{n_i - n_{1B}}{n_i + n_{1B}} \right| = 0{,}0265$$

$$\Rightarrow a = 0{,}00382\,dB$$

6.3.4

$$P_{B\,Ende} = P_A \cdot 10^{-\frac{\alpha_A L_A}{10}} \cdot 10^{-\frac{\alpha_B L_B}{10}} \cdot \underbrace{10^{-a}}_{=1}$$

$$= 50\,\mu W$$