第七次作业

6.1 (a)

$$n = N_c \exp\left(-\frac{E_c - E_f}{k_B T}\right) \quad (15.1\text{-}9a)$$

$$p = N_v \exp\left(-\frac{E_f - E_v}{k_B T}\right) \quad (15.1\text{-}9b)$$

$$np = N_c N_v \exp\left(-\frac{E_g}{k_B T}\right), \quad (15.1\text{-}10a)$$

由上述有$E_f = k_B T \ln\frac{n}{N_c} + E_c$且$E_f = -k_B T \ln\frac{p}{N_v} + E_v$

$$E_f = \frac{E_c + E_v}{2} + \frac{1}{2} k_B T \ln\frac{nN_v}{N_c p}$$

对于本征半导体，n=p，所以

$$E_f = \frac{E_c + E_v}{2} + \frac{1}{2} k_B T \ln\frac{N_v}{N_c}$$

同时有 $N_c = 2(2\pi m_c k_B T/h^2)^{3/2}$ and $N_v = 2(2\pi m_v k_B T/h^2)^{3/2}$

若m_c=m_v则

$$E_f = \frac{E_c + E_v}{2}$$

6.1 (b) $E_f = \frac{E_c + E_v}{2} + \frac{1}{2} k_B T \ln \frac{n N_v}{N_c p}$

将 $N_v = 2(2\pi m_v k_B T/h^2)^{3/2}$ $N_c = 2(2\pi m_c k_B T/h^2)^{3/2}$ 代入上式，得

$$E_{f1} = \frac{E_c + E_v}{2} + \frac{1}{2} k_B T \ln \frac{n_1 N_v}{N_c p_1} = \frac{E_c + E_v}{2} + \frac{1}{2} k_B T \ln \frac{n m_v^{3/2}}{p m_c^{3/2}} = \frac{E_c + E_v}{2} + \frac{3}{4} k_B T \ln \frac{m_v}{m_c}$$

对于N型半导体：$n_1 \approx N_D$，$p_1 = \frac{n_i^2}{N_D}$，$n_i^2 = np$，故$\frac{n_1}{p_1} = \frac{N_D^2}{n_i^2}$，

$$E_{f1} = \frac{E_c + E_v}{2} + \frac{3}{4} k_B T \ln \frac{n m_v}{p m_c} = E_f + \frac{3}{2} k_B T \ln \frac{N_D}{n_i}$$

对于P型半导体：

$$E_{f2} = E_f + \frac{3}{2} k_B T \ln \frac{N_A}{n_i}$$

6.2　电子空穴注入时时：

$$R = \frac{\Delta n}{\tau}$$

$$\frac{d(\Delta n)}{dt} = R - \frac{\Delta n}{\tau}$$

强注入时：

$$\tau = \frac{1}{r\Delta n}$$

得：

$$\frac{d(\Delta n)}{dt} = \begin{cases} R - \frac{\Delta n}{\tau}, 0 < t < t_0 \\ -\frac{\Delta n}{\tau}, \quad t > t_0 \end{cases} = \begin{cases} 0 \quad , \quad 0 < t < t_0 \\ -r\Delta n^2, \quad t > t_0 \end{cases}$$

所以：

$$\Delta n(t) = \begin{cases} \Delta n_0 \quad , \quad 0 < t < t_0 \\ [r(t - t_0) + \frac{1}{\Delta n_0}]^{-1}, \quad t > t_0 \end{cases}$$

故△n(t)是幂函数

6.4 频率间隔：$\nu_F = \frac{c}{2dn} = \frac{3\times10^8 m/s}{2\times250\times10^{-6}\times3.5} = 1.71\times10^{11}Hz$

频率光子需要满足：$\frac{E_g}{h} < \upsilon < \frac{E_{fc}-E_{f\upsilon}}{h}$,

=> $\frac{0.91\times1.6\times10^{-19}J}{6.63\times10^{-35}J\cdot s} = \frac{E_g}{h} < \upsilon < \frac{E_{fc}-E_{f\upsilon}}{h} = \frac{0.96\times1.6\times10^{-19}J}{6.63\times10^{-35}J\cdot s}$

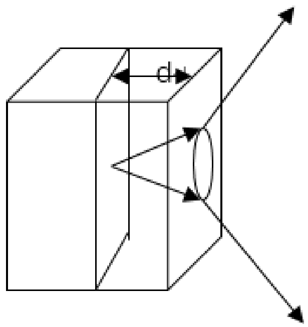
=> $2.196\times10^{15}Hz < \upsilon < 2.317\times10^{15}Hz$

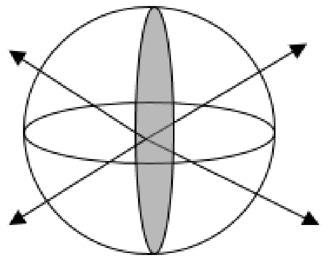
=> $1284.2 < \frac{\upsilon}{\nu_F} < 1354.9$

=> $N = 70$

第八次作业

7.2





$$r_x = \frac{n_1 \cos\theta_1 - n_2 \cos\theta_2}{n_1 \cos\theta_1 + n_2 \cos\theta_2} \quad (6.2\text{-}4)$$

$$t_x = 1 + r_x \quad (6.2\text{-}5)$$

Fresnel Equations (TE Polarization)

$$r_y = \frac{n_2 \cos\theta_1 - n_1 \cos\theta_2}{n_2 \cos\theta_1 + n_1 \cos\theta_2} \quad (6.2\text{-}6)$$

$$t_y = \frac{n_1}{n_2}(1 + r_y). \quad (6.2\text{-}7)$$

Fresnel Equations (TM Polarization)

(1)光波到达界面前损耗 $\eta_1 = \exp(-\alpha l_1)$

对于任意角度 $\eta_1 = \exp\left(-\alpha \frac{d}{\cos\theta_1}\right)$

(2)对于特定角θ_1(<θ_c)边界损失:

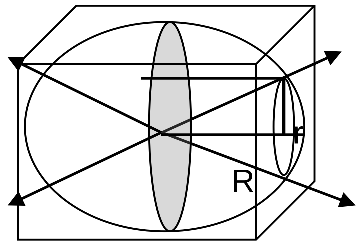
$$\mathscr{R} = |r|^2.$$

$$\mathscr{T} = 1 - \mathscr{R}.$$

$$\eta_2 = \frac{1}{2}\left[1 - \left(\frac{\cos\theta_1 - n\cos\theta_2}{\cos\theta_1 + n\cos\theta_2}\right)^2 + 1 - \left(\frac{n\cos\theta_1 - \cos\theta_2}{n\cos\theta_1 + \cos\theta_2}\right)^2\right]$$

7.2

(3)LED发光对称，设界面处光场面的发光总通量为$\Phi = 4\pi r^2$，即光强设为1.
球冠面积微圆环面积为$dS = 2\pi r * Rd\theta_1$

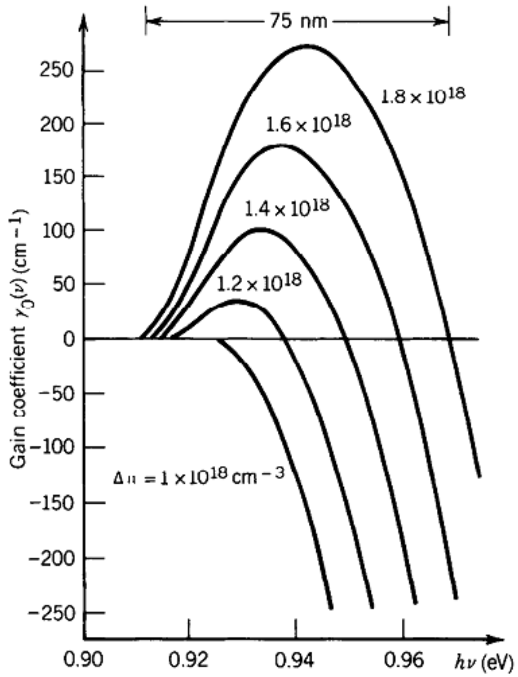


$$\eta_e = \frac{\int_0^{\theta_c} \eta_1 \eta_2 2\pi r R d\Theta_1}{\Phi}$$

$$\eta_e = \int_0^{\theta_c} \sin\theta_1 \exp\left(-\alpha \frac{d}{\cos\theta_1}\right) n\cos\theta_1 \cos\theta_2 [\frac{1}{(\cos\theta_1 + n\cos\theta_2)^2} + \frac{1}{(n\cos\theta_1 + \cos\theta_2)^2}]\, d\theta_1$$

其中：$\theta_c = \arcsin\frac{1}{n}$，$\sin\theta_2 = n\sin\theta_1$

7.4



(a)

由图得：

$\Delta n(1\times10^{18}cm^{-3})$	1	1.2	1.4	1.6	1.8
$h\Delta\nu$	0	0.023	0.035	0.047	0.060
$\Delta\nu$(THz)	0	6.031	8.444	11.339	14.475

由最小二乘法：

$$设\phi(a_0,a_1)=\sum_i(\Delta\gamma_i-a_0-a_1\Delta n)^2则$$

$$令\ \frac{\partial\phi}{\partial a_0}=-2\sum_i(\Delta\gamma_i-a_0-a_1\Delta n)=0,\ \frac{\partial\phi}{\partial a_1}$$

$$=-2\sum_i(\Delta\gamma_i-a_0-a_1\Delta n)K\cdot\Delta n=0$$

解得：$a_0=-11.099$，$a_1=14.114$

7.11 正入射时菲涅尔反射率: $\mathscr{R} = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$

=> R=0.309

$$\alpha_m = \alpha_{m1} + \alpha_{m2} = \frac{1}{2d}\ln\frac{1}{R^2} = 23.51\mathrm{cm}^{-1}$$

$$\gamma_{min} = \alpha_m = 23.51\mathrm{cm}^{-1}$$

第九次作业

8.1 $V_\pi = \frac{d}{L}\frac{\lambda_o}{\tau n^3}$

$$V_\pi = \frac{1.3 \times 10^{-6}\mathrm{m}}{1.6 \times 10^{-12}\mathrm{m/V} \times (3.6)^3} = 1.74 \times 10^4\mathrm{V}$$

$$T = \frac{L}{V} = \frac{3 \times 10^{-2}\mathrm{m}}{\frac{3 \times 10^8\mathrm{m/s}}{3.6}} = 3.6 \times 10^{-10}\mathrm{s}$$

$$C = \varepsilon\frac{S}{d} = \left(\frac{\varepsilon}{\varepsilon_0}\right)\cdot\varepsilon_0\cdot\frac{S}{d} = 13.5 \times 8.85 \times \frac{10^{-12}\mathrm{F}}{\mathrm{m}} \times \frac{1 \times 10^{-4}\mathrm{m}^2}{3 \times 10^{-2}\mathrm{m}} = 3.98 \times 10^{-13}\mathrm{F}$$

$$\tau = RC = 50\Omega \times 3.98 \times 10^{-13}\mathrm{F} = 1.99 \times 10^{-11}\mathrm{s}$$

$$T > \tau$$

由光通过晶体的时间决定器件速度

8.2 $\mathscr{T}(V)=\cos^2\left(\frac{\varphi_0}{2}-\frac{\pi}{2}\frac{V}{V_\pi}\right)$

对上式求导得：

$$\frac{dT}{dV}=2\cos\left(\frac{\varphi_0}{2}-\frac{\pi V}{2V_\pi}\right)\cdot\left[-\sin\left(\frac{\varphi_0}{2}-\frac{\pi V}{2V_\pi}\right)\right]\cdot(-\frac{\pi}{2V_\pi})$$

$$\frac{dT}{dV}=\frac{\pi}{2V_\pi}\sin(\varphi_0-\frac{\pi V}{V_\pi})$$

作为线性调制器满足

$$(1)\ \varphi_0=\frac{\pi}{2}\quad(2)V\ll V_\pi$$

所以：

$$\frac{dT}{dV}=\frac{\pi}{20}\sin(\frac{\pi}{2}-\frac{\pi V}{10})\approx\frac{\pi}{20}$$

8.4 $n_1(\mathrm{E}) = n_0 - \frac{1}{2} n_0^3 \gamma_{63} E$

$n_2(\mathrm{E}) = n_0 + \frac{1}{2} n_0^3 \gamma_{63} E$

$n_3(\mathrm{E}) = n_e$

纵向应用：

$$V_\pi = \frac{\lambda_0}{2\gamma_{63} n_0} = 8.4 \times 10^3 V$$

8.5 相邻KDP晶体间所加的电场方向相反，若要使其相位调制最大，需让相邻KDP间快慢轴一致，主轴旋转90度

$$\phi = \sum_{i=1}^{9} \phi_i = 9\,\phi_1 = 9 \cdot k \cdot \left(n_y - n_x\right) \cdot L = 9 \cdot \frac{2\pi}{\lambda_0} \cdot n_0^3 \cdot \gamma_{63} \cdot \frac{VL}{d}$$

L=d，令$\phi = \pi$ $\quad V_\pi' = \frac{1}{9} \cdot \frac{\lambda_0}{2 n_0^3 \gamma_{63}} = \frac{1}{9} V_\pi = 9.34 \times 10^2 \mathrm{V}$