第一章 几何光学

1.基本规律

光程 $\boxed{l=ns,\left(V=\frac{c}{n}\right).}$

费马原理

$\boxed{\delta l=0,l\text{取极大、极小或常数}\Rightarrow i=-i',n_1\sin\theta_1=n_2\sin\theta_2.}$

2. 成像

①单球面折射

$$\frac{s^2}{n^2(s+r)^2}-\frac{s'^2}{n'^2(s'-r')^2}=-4r\sin^2\left(\frac{\varphi}{2}\right)\left[\frac{1}{n^2(s+r)}+\frac{1}{n'^2(s'-r')}\right]$$

保持同心性物像点：

$$\frac{s^2}{n^2(s+r)^2}-\frac{s'^2}{n'^2(s'-r')^2}=0,\frac{1}{n^2(s+r)}+\frac{1}{n'^2(s'-r')}=0.$$

榜轴条件：

$$\boxed{\frac{n'}{s'}+\frac{n}{s}=\frac{n'-n}{r}.}$$

$$\boxed{f=\frac{nr}{n'-n},f'=\frac{n'r}{n'-n}}$$

$$\boxed{\frac{f'}{s'}+\frac{f}{s}=1.}$$

$$\boxed{V=\frac{y'}{y}=-\frac{ns'}{n's}.}$$

②球面镜成像 $\boxed{n'=-n.}$

$$\boxed{\frac{1}{s'}+\frac{1}{s}=-\frac{2}{r}},\ \boxed{f=f'=-\frac{r}{2}.V=-\frac{s'}{s}}$$

③薄透镜

$$\boxed{\frac{f'}{s'}+\frac{f}{s}=1.}$$

$$f=\frac{n}{\frac{n_L-n}{r_1}+\frac{n'-n_L}{r_2}},\ f'=\frac{n'}{\frac{n_L-n}{r_1}+\frac{n'-n_L}{r_2}}.$$

$$\boxed{n'=n,\ f'=f,\ \frac{1}{s'}+\frac{1}{s}=\frac{1}{f}.}$$

$$\boxed{\begin{array}{l} s=x+f,\ s'=x'+f', \\ xx'=ff',V=-\frac{f}{x}=-\frac{x'}{f'}. \end{array}}$$

④密接透镜组

$$\boxed{s_2=-s_1',\ \frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{f}.}$$

$$\boxed{P=\frac{1}{f},\ P=P_1+P_2.}$$

⑤望远镜 $M\equiv-\frac{f_o}{f_E}$

第二章 光的干涉

一.光波基本描述

1.$\boxed{v=\frac{c}{n}}$ $c=\frac{1}{\sqrt{\varepsilon_0\mu_0}}=3.0\times10^8\,m/s$，$n=\sqrt{\varepsilon_r\mu_r}$.

$$\boxed{\lambda=\frac{v}{\nu}=\frac{c}{n\nu}=\frac{\lambda_0}{n},\lambda_0=\frac{c}{\nu}}$$

2.单色波

①电场 $\vec{E}=\vec{E}_0(p)\cos(\omega t-\varphi(p))$

磁场 $\vec{B}=\vec{B}_0(p)\cos(\omega t-\varphi(p))$

②单色平面波

$\boxed{\vec{E}=\vec{E}_0\cos[\omega t-\vec{k}\cdot\vec{z}+\varphi_0]}$, $\boxed{\tilde{E}(p,t)=E_0\exp[-i(\omega t-\vec{k}\cdot\vec{r}+\varphi_0)]}$

波数$\boxed{k=\frac{2\pi}{\lambda},}$波矢$\boxed{\vec{k}=\frac{2\pi}{\lambda}=k\vec{k}_0,}$$\vec{k}_0$为传播方向的单位方向矢量。

波的相位$\boxed{\omega t-\vec{k}\cdot\vec{r}+\varphi_0=\omega t-\mathrm{R}\frac{2\pi}{\lambda}+\varphi_0}$, 其中 R 为$\vec{r}$在$\vec{k}_0$方向上的投影.

复振幅$\boxed{\tilde{E}(p)\equiv E_0\exp(i\varphi(p)).}$

③单色球面波

$$\boxed{E=\frac{A_0}{r}\cos[\omega t-kr+\varphi_0]}$$

$$\boxed{\tilde{E}(p,t)=\frac{A_0}{r}\exp[-i(\omega t-kr+\varphi_0)]}$$

复振幅为$\boxed{\tilde{E}(p)=\frac{A_0}{r}\exp[i(kr-\varphi_0)]}$.

3.光强度

光强$\boxed{I=\langle\bar{s}\rangle=E_0^2=\tilde{E}^*(p)\tilde{E}(p).}$ $\bar{s}$是电磁波能流密度.

谱密度$i(\lambda)=\frac{dI_\lambda}{d\lambda}$, ($dI_\lambda$是$\lambda\sim\lambda+d\lambda$之间光强).

$$I=\int_0^\infty dI_\lambda=\int_0^\infty i(\lambda)d\lambda$$

4. 反衬度$\boxed{\gamma\equiv\frac{I_M-I_m}{I_M+I_m}}$

二、线性叠加原理(弱光情况下成立):

1.$\boxed{\vec{E}(p,t)=\vec{E}_1(p,t)+\vec{E}_2(p,t)+\cdots.}$

同方向光振动叠加：

$$\boxed{E(p,t)=E_1(p,t)+E_2(p,t)+\cdots.}$$

2.同频率、同振向波的叠加

$$E_1(p,t)=E_{10}(p)cos(\omega t-\varphi_1(p)),$$

$$E_2(p,t)=E_{20}(p)cos(\omega t-\varphi_2(p))$$

$$E(p,t)=E_0(p)cos(\omega t-\varphi).$$

$$E_0^2(p)=E_{01}^2(p)+2E_{10}(p)E_{02}(p)cos[\varphi_1(p)-\varphi_1(p)]+E_{02}^2(p)$$

$$tg\varphi(p)=\frac{E_{10}(p)sin\varphi_1(p)+E_{20}(p)sin\varphi_2(p)}{E_{10}(p)cos\varphi_1(p)+E_{20}(p)cos\varphi_2(p)}.$$

$$\boxed{I(p)=I_1(p)+I_2(p)+2\sqrt{I_1(p)I_2(p)}cos\delta.}$$

$$\boxed{I=I_0(1+\gamma cos\delta),I_0=I_1+I_2.}$$

三、光的干涉和相干条件

1. 相干条件

①位相差判据

当$\boxed{\delta=2\pi m,\ (m=0,\pm1,\pm2,\cdots)}$(同位相),

$\boxed{I_M=(E_{01}+E_{02})^2}$,称为干涉极大,对应亮纹；

当$\boxed{\delta=(2m+1)\pi,\ (m=0,\pm1,\pm2,\cdots)}$(反位相),

$\boxed{I_m=(E_{01}-E_{02})^2}$, 称为干涉极小,对应暗纹.

②光程差判据

位相差$\boxed{\delta(p)=k(r_2-r_1)}\boxed{=\frac{2\pi}{\lambda_0}\Delta l(p),}$

其中$\boxed{\Delta l(p)=n_1r_1-n_2r_2}$.

干涉极大$\boxed{\Delta l(p)=m\lambda_0}$.

干涉极小$\boxed{\Delta l(p)=\left(m+\frac{1}{2}\right)\lambda_0}$.

四、杨氏实验

1.光程差$\boxed{\Delta l=r_1-r_2\approx d\sin\theta.\ \Delta l\approx d\frac{x}{D}}$.

2.极大位置$\boxed{x=\frac{m\lambda_0 D}{d}\quad(m=0,\pm1,\pm2,\cdots)}$.

极小位置$\boxed{x=\frac{(m+1/2)\lambda_0 D}{d}\quad(m=0,\pm1,\pm2,\cdots)}$.

3.条纹宽度$\boxed{\Delta x=\frac{\lambda_0 D}{d}}$.

4.光强分布

$$\boxed{\delta(p)=\frac{2\pi}{\lambda_0}\Delta l(p)=\frac{2\pi}{\lambda_0}d\frac{x}{D}}.$$

实验中，$I_1\approx I_2=I_0$，$\boxed{I=2I_0\left(1+\cos\frac{2\pi}{\lambda_0}d\frac{x}{D}\right)=4I_0\cos^2\left(\frac{\pi d}{D\lambda_0}x\right)}$.

5.最大光程差$\boxed{\Delta l_M=m'\lambda_0=\frac{\lambda_0^2}{\Delta\lambda_0}}$.

6.光源 S 沿 x 方向移动δs,干涉条纹的移动$\boxed{\delta x\approx-\frac{D}{l}\delta s}$.

7.扩展光源

●临界宽度$\boxed{b_c=\frac{l\lambda}{d}}$.

干涉口径角$\boxed{\beta \equiv \frac{d}{l},}$扩展光源干涉条件为$\boxed{b < \frac{\lambda}{\beta}.}$

●横向相干宽度$\boxed{d_c \equiv \frac{l\lambda}{b}.}$

●光场的空间相干性：$\boxed{d < d_c,}$即$\boxed{\beta < \beta_c = \frac{d_c}{l}}$内两点源都是相干点源.

●$\boxed{b\beta_c = \lambda.}$

五、薄膜干涉

1.光程差

$$\boxed{\Delta L = 2nt\cos\theta_r + \frac{\lambda}{2} = 2nt\sqrt{n^2 - n_1^2\sin^2\theta_i} + \frac{\lambda}{2}.}$$

2.等倾干涉

从中心向外数第 N 个亮环附近相邻两亮环间的角距离为

$(\Delta N = 1)\,\Delta\theta_N = \frac{1}{n'}\sqrt{\frac{n\lambda}{t}}\,\frac{\Delta N}{2\sqrt{N}}.$

第 N 个亮环半径$r_N \approx \theta_N f = \frac{f}{n'}\sqrt{\frac{nN\lambda}{t}}.$

相邻两亮环间的径向距离为$\Delta r_N \approx \Delta\theta_N f = \frac{n\lambda f}{2n'^2 t\theta_N}.$

3.等厚干涉

①楔形

相邻条纹的高度差$\boxed{\Delta t = t_{m+1} - t_m = \frac{\lambda}{2n}.}$

相邻条纹的间隔$\boxed{\Delta l = \frac{\Delta t}{\sin\alpha} = \frac{\lambda}{2n\sin\alpha}.}$

②牛顿环

光程差$\boxed{\theta_i = 0, \Delta L = 2t - \frac{\lambda}{2}.}$

m 级亮纹半径为$\boxed{r_m = \sqrt{\left(m + \frac{1}{2}\right)\lambda R}.}$

m 级暗纹半径为：$\boxed{r'_m = \sqrt{m\lambda R}.}$

$$\boxed{R = \frac{r'^2_{m+N} - r'^2_m}{N\lambda}.}$$

4.透射光

$\boxed{\Delta L = 2nt\cos\theta_r.}$ $\boxed{(I_0 = I_r + I_t)}$

5.薄膜厚度要求

$$\boxed{\Delta L = 2nt\cos\theta < \Delta L_M = m'\lambda = \frac{\lambda^2}{\Delta\lambda}.}$$

6.增透膜$\boxed{2nt = \left(m + \frac{1}{2}\right)\lambda, m = 0,1,2,\cdots}$

7.迈克尔逊干涉仪 $\boxed{\Delta t = \pm N\frac{\lambda}{2}.}$

六、光场的时间相干性：$\boxed{t < \tau_0.}$

光波的相干长度$\boxed{L_c = \Delta L_{max} = \frac{\bar{\lambda}^2}{\Delta\lambda},}$相干时间$\boxed{\tau_0 \equiv \frac{L_c}{c}.}$

第三章 光的衍射

一、惠更斯-菲涅耳原理

$$\tilde{E}(P)=k\iint_{(\Sigma)}\tilde{E}_0(Q)F(\theta_0,\theta)\frac{e^{ikr}}{r}d\Sigma.$$

基尔霍夫公式 $\tilde{E}(P)=\frac{-i}{\lambda}\iint_{(\Sigma_0)}\frac{(\cos\theta_0+\cos\theta)}{2}\tilde{E}_0(Q)\frac{e^{ikr}}{r}d\Sigma.$

傍轴条件下,即 $\theta_0\approx\theta\approx 0, r\approx r_0$

$$\tilde{E}(P)=\frac{-i}{\lambda r_0}\iint_{(\Sigma_0)}\tilde{E}_0(Q)e^{ikr}d\Sigma.$$

二、巴俾涅原理

几何像点之外，

$$\because \tilde{E}_a(P)+\tilde{E}_b(P)=\tilde{E}_0(P)=0,$$

$$\boxed{\therefore \left|\tilde{E}_a(P)\right|=\left|\tilde{E}_b(P)\right|,\Rightarrow I_a(P)=I_a(P).}$$

三、菲涅耳圆孔衍射和圆屏衍射

1. $\boxed{E_0(P)=\frac{1}{2}\Delta E_{10}+(-1)^{n+1}\frac{1}{2}\Delta E_{n0}.}$

2. $\boxed{k=\frac{\rho^2}{\lambda}\left(\frac{1}{R}+\frac{1}{r}\right).}$

平行光入射圆孔,则 $\boxed{R\to\infty}$， $\boxed{k=\frac{\rho^2}{\lambda R}.}$

3.自由传播 $\boxed{E_0(P)=\frac{1}{2}\Delta E_{10}.}$

4.圆屏衍射 $\boxed{E_0(P)=\frac{1}{2}\Delta E_{k+10}(P)\neq 0}$

5.波带片

• 遮住偶数带，轴上 P 点的振幅为

$$\boxed{E_0(P)=\Delta E_{10}(P)+\Delta E_{30}(P)+\Delta E_{50}(P)\cdots+\Delta E_{2n+10}(P).}$$

• 遮住奇数带，轴上 P 点的振幅为

$$\boxed{E_0(P)=-\left(\Delta E_{20}(P)+\Delta E_{40}(P)+\Delta E_{60}(P)\cdots+\Delta E_{2n0}(P)\right).}$$

●半波带半径

$$\boxed{\rho=\sqrt{k}\rho_1,\rho_1=\sqrt{\frac{Rb\lambda}{R+b}}.}$$

●透镜作用：$\boxed{\left(\frac{1}{R}+\frac{1}{b}\right)=\frac{k\lambda}{\rho_k^2}.}$

四、夫琅禾费衍射

1. 单缝

①光强

$$\boxed{\tilde{E}_0(P_\theta)=\tilde{E}_0(P_0)\frac{\sin(\alpha)}{\alpha}.}\boxed{I_\theta=I_0\left(\frac{\sin(\alpha)}{\alpha}\right)^2,}$$

其中 I_0 为衍射场中心光强度,

$\boxed{\left(\frac{\sin(\alpha)}{\alpha}\right)^2}$为单缝衍射因子.

②次极强 $\sin\theta=\pm1.43\frac{\lambda}{a},\pm2.46\frac{\lambda}{a},\pm3.67\frac{\lambda}{a},\cdots$

③暗纹位置 $\boxed{\sin\theta=m\frac{\lambda}{a},(m=\pm1,\pm2,\pm3,\cdots)}$

④零级亮斑的半角宽度 $\boxed{\Delta\theta\approx\frac{\lambda}{a}.}$

2. 圆孔

中心角半径：$\boxed{\theta=0.610\frac{\lambda}{a}\approx1.22\frac{\lambda}{D},D=2a.}$

最小分辨角 $\boxed{\delta\theta_m=\Delta\theta=1.22\frac{\lambda}{D}.}$

3.光栅

①光强

$$\bullet I(P_\theta)=A_0^2(P_0)\left(\frac{\sin(\alpha)}{\alpha}\right)^2\left(\frac{\sin(N\delta/2)}{\sin(\delta/2)}\right)^2.$$

●主极大：$\boxed{d\sin\theta=k\lambda,k=0,\pm1,\pm2,\pm3,\cdots}$

$$\boxed{I_{MAX}=N^2A_0^2\left(\frac{\sin(\alpha)}{\alpha}\right)^2}.\boxed{k_{MAX}=\frac{d}{\lambda}}.$$

●极小：$\sin\theta=\left(k+\frac{m}{N}\right)\frac{\lambda}{d}.m=1,2,\cdots N-1.(m\neq0,N)$

●主极大的半角宽度$\boxed{\Delta\theta=\frac{\lambda}{Nd\cos\theta_k}}$.

●主极大缺级：

主极大$\boxed{d\sin\theta=k\lambda,k=0,\pm1,\pm2,\pm3,\cdots}$

单缝极小$\boxed{a\sin\theta=n\lambda,n=\pm1,\pm2,\pm3,\cdots}$

当$\sin\theta=\frac{k\lambda}{d}=\frac{n\lambda}{a}$时,即$\boxed{k=\frac{dn}{a}}$缺级.

②光谱

●色散本领定义为$\boxed{D_\theta=\frac{\delta\theta_k}{\delta\lambda}=\frac{k}{d\cos\theta_k}}$.

●瑞利判据 ：最小分辨角$\delta\theta'$等于光谱线的半角宽度, 即$\boxed{\delta\theta'=\Delta\theta}$.

●色分辨本领$\boxed{R=\frac{\lambda}{\delta\lambda}=kN}$.

③闪耀光栅 $\boxed{d\sin2\theta_B=k\lambda_B^k}$, k 级最亮.

同时,$a \approx d$, $a\sin(2\theta_B) = k\lambda_B^k$ 也成立，即

其它干涉级均成为缺级.

④布拉格条件 $\boxed{2d\sin\theta = k\lambda.}$.

第五章 光的电磁性

一、偏振

1. 偏振度: $\boxed{P = \dfrac{I_{max} - I_{max}}{I_{max} + I_{max}}, 0 \le P \le 1.}$

2.马吕斯定律 $\boxed{I_2 = I_1 cos^2\alpha.}$

3.布儒斯特角 θ_B $\boxed{tg\theta_B = \dfrac{n_2}{n_1}}$.

4.e 光主折射率 $\boxed{n_e = c / V_e = \dfrac{sin\theta_i}{sin\theta_r^e}.}$

5. 波晶片

若 $\boxed{(n_0 - n_e)d = \pm\dfrac{\lambda}{4} + m\lambda, m}$ 为整数, $\boxed{\varphi_{o-e} = \pm\dfrac{\pi}{2}}$,则称波晶片为 $\dfrac{\lambda}{4}$ 片.

若 $\boxed{(n_0 - n_e)d = \pm\dfrac{\lambda}{2} + m\lambda, \varphi_{o-e} = \pm\pi, 2\pi}$,则称波晶片为 $\dfrac{\lambda}{2}$ 片.

6. 椭圆偏振光 $\vec{E} = \vec{E}_x + \vec{E}_y$.

其中 $E_x = E_{x0} cos\left(\omega t - \dfrac{2\pi}{\lambda}z\right), E_y = E_{y0} cos\left(\omega t - \dfrac{2\pi}{\lambda}z - \delta\right).$

二、光的吸收、色散和散射

1. 光的吸收 $\boxed{I = I_0 e^{-\alpha l}.}$

2. 色散

●柯西公式：$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}.$

●色散率 $\frac{dn}{d\lambda} < 0$, 正常色散; $\frac{dn}{d\lambda} > 0$, 反常色散.

3.瑞利散射：$I_s(\lambda) \propto \frac{f(\lambda)}{\lambda^4}, a < \lambda.$

第六章 光的量子性

1.普朗克能量子 $\boxed{\varepsilon_0 = h\nu}$

2.光电效应

●$\boxed{\frac{1}{2} m v_m^2 = eV_0 = eK(\nu - \nu_0).}$

●$\boxed{E = h\nu.}$

●$\boxed{\frac{1}{2} m v_m^2 = h\nu - A,}$

●$\boxed{\nu_0 = \frac{A}{h}.}$

3.康普顿散射

$$\boxed{\Delta\lambda = 2\lambda_c \sin^2\frac{\theta}{2}, \lambda_c = \frac{h}{m_0 c} = 0.0243 \overset{0}{A}}$$

4．光的波粒二象性 $\boxed{E = h\nu, p = \frac{h\nu}{c} = \frac{h}{\lambda}.}$

第七章 激光

自发辐射：$\frac{dN_{21}}{dt} = A_{21} N_2,$

受激辐射：$\dfrac{dN'_{21}}{dt}=B_{21}\rho(\nu)N_2$,

受激吸收：$\dfrac{dN_{12}}{dt}=B_{12}\rho(\nu)N_1$,

谐振腔纵模$\nu_j=j\dfrac{c}{2nL}, j=1,2,\cdots$ 间隔$\Delta\nu=\dfrac{c}{2nL}$.

说明：打黑框的公式必须理解，并且记住！不打黑框的公式要求理解其物理意义。