忘れたときに見返す用です.

- 波長板
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- 1. 波長板
- 1. 1. HWP

$$J_{HWP(heta)} = egin{bmatrix} -\sin^2 heta + \cos^2 heta & 2\sin heta\cos heta \ 2\sin heta\cos heta & \sin^2 heta - \cos^2 heta \end{bmatrix} \ \therefore J_{HWP(heta)} = egin{bmatrix} \cos2 heta & \sin2 heta \ \sin2 heta & -\cos2 heta \end{bmatrix}$$

1. 2. QWP

$$egin{aligned} J_{QWP(heta)} &= egin{aligned} e^{irac{\pi}{2}}\sin^2 heta + \cos^2 heta & \sin heta\cos heta(1-e^{irac{\pi}{2}}) \ \sin heta\cos heta(1-e^{irac{\pi}{2}}) & \sin^2 heta + e^{irac{\pi}{2}}\cos^2 heta \end{aligned} \ &= egin{aligned} i\sin heta\cos heta(1-e^{irac{\pi}{2}}) & \sin^2 heta + e^{irac{\pi}{2}}\cos^2 heta \end{aligned} \ &= egin{aligned} i\sin heta\cos heta(1-e^{irac{\pi}{2}}) & \sin^2 heta + e^{irac{\pi}{2}}\cos^2 heta \end{aligned} \ &= egin{aligned} i\sin heta\cos heta(1-i) & \sin^2 heta + i\cos^2 heta \end{aligned} \ &\therefore J_{QWP(heta)} &= egin{aligned} 1-i\cos2 heta & -i\sin2 heta \\ -i\sin2 heta & 1+i\cos2 heta \end{aligned} \ &J_{QWP(\pi- heta)} &= egin{aligned} 1-i\cos2 heta & i\sin2 heta \\ i\sin2 heta & 1+i\cos2 heta \end{aligned}$$

1. 3. LP

$$\begin{split} J_{LP(\theta)} &= \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \\ &= \begin{bmatrix} \cos \theta & 0 \\ \sin \theta & 0 \end{bmatrix} \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \\ \therefore J_{LP(\theta)} &= \begin{bmatrix} \cos^2 \theta & \sin \theta \cos \theta \\ \sin \theta \cos \theta & \sin^2 \theta \end{bmatrix} \end{split}$$

1. 4. SLM(反射型)

$$egin{bmatrix} -e^{i\delta} & 0 \ 0 & 1 \end{bmatrix}$$

1. 5. 表→裏

1. 5. 0. HWP

$$J_{HWP} = \begin{bmatrix} \cos 2(\pi - \theta) & \sin 2(\pi - \theta) \\ \sin 2(\pi - \theta) & -\cos 2(\pi - \theta) \end{bmatrix} \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{bmatrix}$$

$$= \begin{bmatrix} -\cos 2\theta & -\sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{bmatrix} \begin{bmatrix} \cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{bmatrix}$$

$$= \begin{bmatrix} -\cos^2 2\theta - \sin^2 2\theta & 0 \\ 0 & \sin^2 2\theta + \cos^2 2\theta \end{bmatrix}$$

$$\therefore J_{HWP} = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$

1. 5. 0. QWP

$$\begin{split} J_{QWP(\theta)} &= \begin{bmatrix} 1-i\cos 2(\pi-\theta) & -i\sin 2(\pi-\theta) \\ -i\sin 2(\pi-\theta) & 1+i\cos 2(\pi-\theta) \end{bmatrix} \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1-i\cos 2\theta & -i\sin 2\theta \\ -i\sin 2\theta & 1+i\cos 2\theta \end{bmatrix} \\ &= \begin{bmatrix} -1+i\cos 2\theta & i\sin 2\theta \\ -i\sin 2\theta & 1+i\cos 2\theta \end{bmatrix} \begin{bmatrix} 1-i\cos 2\theta & -i\sin 2\theta \\ -i\sin 2\theta & 1+i\cos 2\theta \end{bmatrix} \\ &= \begin{bmatrix} \cos^2 2\theta - 1 + 2i\cos 2\theta + \sin^2 2\theta & i\sin 2\theta + \sin 2\theta\cos 2\theta - \sin 2\theta\cos 2\theta \\ -i\sin 2\theta - \sin 2\theta\cos 2\theta - i\sin 2\theta + \sin 2\theta\cos 2\theta & -\sin^2 2\theta + 1 + 2i\cos 2\theta\cos^2 2\theta \end{bmatrix} \\ \therefore J_{QWP(\theta)} &= 2i \begin{bmatrix} \cos 2\theta & \sin 2\theta \\ -\sin 2\theta & \cos 2\theta \end{bmatrix} \end{split}$$

2. ベクトルビームの作り方(SLMに1回反射)



サンプル画像

この光学系で得られるジョーンズベクトル

$$J = J_{QWP(\theta_2)} J_{SLM} J_{HWP(\theta_1)} J_{PBS} \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

$$J = \begin{bmatrix} 1 - i\cos 2\theta_2 & -i\sin 2\theta_2 \\ -i\sin 2\theta_2 & 1 + i\cos 2\theta_2 \end{bmatrix} \begin{bmatrix} -e^{i\delta} & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 2\theta_1 & \sin 2\theta_1 \\ \sin 2\theta_1 & -\cos 2\theta_1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$$

$$= \begin{bmatrix} 1 - i\cos 2\theta_2 & -i\sin 2\theta_2 \\ -i\sin 2\theta_2 & 1 + i\cos 2\theta_2 \end{bmatrix} \begin{bmatrix} -e^{i\delta} & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 2\theta_2 & \sin 2\theta_2 \\ \sin 2\theta_2 & -\cos 2\theta_2 \end{bmatrix} \begin{bmatrix} \alpha \\ 0 \end{bmatrix}$$

$$\propto \begin{bmatrix} 1 - i\cos 2\theta_2 & -i\sin 2\theta_2 \\ -i\sin 2\theta_2 & 1 + i\cos 2\theta_2 \end{bmatrix} \begin{bmatrix} -e^{i\delta} & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 2\theta_1 \\ \sin 2\theta_1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 - i\cos 2\theta_2 & -i\sin 2\theta_2 \\ -i\sin 2\theta_2 & 1 + i\cos 2\theta_2 \end{bmatrix} \begin{bmatrix} -e^{i\delta}\cos 2\theta_1 \\ \sin 2\theta_1 \end{bmatrix}$$

$$\therefore J \propto \begin{bmatrix} -e^{i\delta}\cos 2\theta_1(1 - i\cos 2\theta_2) - i\sin 2\theta_1\sin 2\theta_2 \\ -ie^{i\delta}\cos 2\theta_1\sin 2\theta_2 - \sin 2\theta_1(1 + \cos 2\theta_2) \end{bmatrix}$$

(1)
$$heta_1=rac{\pi}{8}, heta_2=rac{\pi}{4}$$

$$\begin{split} J &\propto \begin{bmatrix} -e^{i\delta} - i \\ -ie^{i\delta} - 1 \end{bmatrix} \\ &= e^{\frac{\delta}{2}} \begin{bmatrix} -e^{i\frac{\delta}{2}} - ie^{-i\frac{\delta}{2}} \\ -ie^{i\frac{\delta}{2}} - e^{-i\frac{\delta}{2}} \end{bmatrix} \\ &= e^{\frac{\delta}{2}} \begin{bmatrix} -\cos\frac{\delta}{2} - i\sin\frac{\delta}{2} - i\cos\frac{\delta}{2} - \sin\frac{\delta}{2} \\ -i\cos\frac{\delta}{2} + \sin\frac{\delta}{2} - \cos\frac{\delta}{2} + i\sin\frac{\delta}{2} \end{bmatrix} \\ &= -e^{\frac{\delta}{2}} (1+i) \begin{bmatrix} \sin\frac{\delta}{2} + \cos\frac{\delta}{2} \\ \sin\frac{\delta}{2} - \cos\frac{\delta}{2} \end{bmatrix} \\ \therefore J &= e^{i\frac{\delta}{2}} e^{i\frac{5}{4}\pi} \begin{bmatrix} \sin\left(\frac{\delta}{2} + \frac{\pi}{4}\right) \\ \sin\left(\frac{\delta}{2} - \frac{\pi}{4}\right) \end{bmatrix} \end{split}$$

(1-1)

$$\delta = 2(arphi + rac{\pi}{4})$$

$$e^{i\varphi}e^{i\frac{3\pi}{2}}\Big(e^{i\varphi}\begin{bmatrix}1\\-i\end{bmatrix}+e^{-i\varphi}\begin{bmatrix}1\\i\end{bmatrix}\Big)\leftrightarrow e^{i\varphi}e^{-i\frac{\pi}{2}}\Big(e^{i\varphi}\begin{bmatrix}1\\-i\end{bmatrix}+e^{-i\varphi}\begin{bmatrix}1\\i\end{bmatrix}\Big)$$

$$m_1=2, m_2=0, \Delta arphi=-rac{\pi}{2}$$

(1-2)

$$\delta = 2(arphi - rac{\pi}{4})$$

$$e^{i\varphi}e^{i\frac{3\pi}{2}}\Big(-e^{i\varphi}\begin{bmatrix}1\\-i\end{bmatrix}+e^{-i\varphi}\begin{bmatrix}1\\i\end{bmatrix}\Big) \leftrightarrow e^{i\varphi}e^{-i\frac{\pi}{2}}\Big(-e^{i\varphi}\begin{bmatrix}1\\-i\end{bmatrix}+e^{-i\varphi}\begin{bmatrix}1\\i\end{bmatrix}\Big)$$

$$m_1=2, m_2=0, \Delta arphi=-rac{\pi}{2}$$

(1-3)

$$\delta = -2(arphi + rac{\pi}{4})$$

$$e^{-i\varphi}e^{i\frac{3\pi}{2}}\Big(-e^{i\varphi}\begin{bmatrix}1\\-i\end{bmatrix}+e^{-i\varphi}\begin{bmatrix}1\\i\end{bmatrix}\Big) \leftrightarrow e^{-i\varphi}e^{-i\frac{\pi}{2}}\Big(-e^{i\varphi}\begin{bmatrix}1\\-i\end{bmatrix}+e^{-i\varphi}\begin{bmatrix}1\\i\end{bmatrix}\Big)$$

$$m_1=0, m_2=2, \Delta arphi=-rac{\pi}{2}$$

(1-4)

$$\delta = -2(arphi - rac{\pi}{4})$$

$$e^{-iarphi}e^{irac{3\pi}{2}}\Big(e^{iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{-iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)\leftrightarrow e^{-iarphi}e^{-irac{\pi}{2}}\Big(e^{iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{-iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)$$

$$m_1=0, m_2=2, \Delta arphi=-rac{\pi}{2}$$

(2)
$$\theta_1 = \frac{\pi}{8}, \theta_2 = -\frac{\pi}{4}$$

$$egin{aligned} J & \propto egin{bmatrix} -e^{i\delta} + i \ ie^{i\delta} - 1 \end{bmatrix} \ & = e^{rac{\delta}{2}} egin{bmatrix} -e^{irac{\delta}{2}} + ie^{-irac{\delta}{2}} \ ie^{irac{\delta}{2}} - e^{-irac{\delta}{2}} \end{bmatrix} \ & = e^{rac{\delta}{2}} egin{bmatrix} -\cosrac{\delta}{2} + ie^{irac{\delta}{2}} \ i\cosrac{\delta}{2} - i\sinrac{\delta}{2} + i\cosrac{\delta}{2} + \sinrac{\delta}{2} \end{bmatrix} \ & = e^{rac{\delta}{2}} egin{bmatrix} -\cosrac{\delta}{2} - i\sinrac{\delta}{2} - \cosrac{\delta}{2} + i\sinrac{\delta}{2} \end{bmatrix} \ & = -e^{rac{\delta}{2}} (1-i) egin{bmatrix} \cosrac{\delta}{2} - \sinrac{\delta}{2} \ \cosrac{\delta}{2} + \sinrac{\delta}{2} \end{bmatrix} \ & \therefore J = e^{rac{\delta}{2}e^{rac{3}{4}\pi}} egin{bmatrix} -\cos\left(rac{\delta}{2} + rac{\pi}{4}
ight) \ \cos\left(rac{\delta}{2} - rac{\pi}{4}
ight) \end{bmatrix} \propto e^{rac{\delta}{2}e^{-rac{\pi}{4}}} egin{bmatrix} -\cos\left(rac{\delta}{2} + rac{\pi}{4}
ight) \ \cos\left(rac{\delta}{2} - rac{\pi}{4}
ight) \end{bmatrix} \end{aligned}$$

(2-1)

$$\delta = 2(\varphi + \frac{\pi}{4})$$

$$e^{iarphi}e^{irac{3\pi}{2}}\Big(e^{-iarphi}egin{bmatrix}1\-i\end{bmatrix}-e^{iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)\leftrightarrow e^{iarphi}e^{-irac{\pi}{2}}\Big(e^{-iarphi}egin{bmatrix}1\-i\end{bmatrix}-e^{iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)$$

$$m_1=2, m_2=0, \Delta arphi=-rac{\pi}{2}$$

(2-2)

$$\delta = 2(arphi - rac{\pi}{4})$$

$$e^{iarphi}e^{irac{3\pi}{2}}\Big(e^{-iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)\leftrightarrow e^{iarphi}e^{-irac{\pi}{2}}\Big(e^{iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{-iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)$$

$$m_1=2, m_2=0, \Deltaarphi=-rac{\pi}{2}$$

(2-3)

$$\delta = -2(arphi + rac{\pi}{4})$$

$$e^{-iarphi}e^{irac{3\pi}{2}}\Big(e^{iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{-iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)\leftrightarrow e^{-iarphi}e^{-irac{\pi}{2}}\Big(e^{iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{-iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)$$

$$m_1=0, m_2=2, \Delta arphi=-rac{\pi}{2}$$

(2-4)

$$\delta = -2(arphi - rac{\pi}{4})$$

$$e^{-iarphi}e^{irac{3\pi}{2}}\Big(-e^{iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{-iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)\leftrightarrow e^{-iarphi}e^{-irac{\pi}{2}}\Big(-e^{iarphi}egin{bmatrix}1\-i\end{bmatrix}+e^{-iarphi}egin{bmatrix}1\i\end{bmatrix}\Big)$$

$$m_1=0, m_2=2, \Delta arphi=-rac{\pi}{2}$$

(3)
$$\theta_1=rac{\pi}{8}, \theta_2=rac{\pi}{4}+lpha$$

$$J \propto egin{bmatrix} -e^{i\delta}(1-i\cos2 heta_2) + i\sin2 heta_2 \ -ie^{i\delta}\sin2 heta_2 + (1+\cos2 heta_2) \end{bmatrix} \ \therefore J \propto egin{bmatrix} -e^{i\delta}(1+i\sin2lpha) + i\cos2lpha \ -ie^{i\delta}\cos2lpha + 1-\sin2lpha \end{bmatrix}$$

$$\delta = 2(\varphi + \frac{\pi}{4})$$

$$J \propto e^{i arphi} egin{bmatrix} -e^{i arphi} (1+i \sin 2 lpha) - i e^{-i arphi} \cos 2 lpha \ -i e^{i arphi} \cos 2 lpha + e^{i arphi} (\sin 2 lpha - 1) \end{bmatrix}$$

$$\alpha = \frac{\pi}{4}$$

$$J \propto e^{iarphi} egin{bmatrix} -e^{iarphi}(1+i) \ 0 \end{bmatrix}$$

$$lpha = -rac{\pi}{4}$$

$$J \propto e^{iarphi} egin{bmatrix} -e^{iarphi}(1-i) \ -2e^{iarphi} \end{bmatrix}$$

3. ダイナミック位相

$$egin{align*} e^{iarphi}egin{align*} 1 \ -i \end{bmatrix} + e^{-iarphi}egin{bmatrix} 1 \ i \end{bmatrix} &\leftrightarrow egin{bmatrix} \cosarphi \ \sinarphi \end{bmatrix} \ e^{iarphi}e^{irac{3\pi}{2}}igg(e^{iarphi}igg[rac{1}{-i} igg] + e^{-iarphi}igg[rac{1}{i} igg] igg) &\leftrightarrow e^{iarphi}e^{irac{3\pi}{2}}igg[\cosarphi \ \sinarphi \end{bmatrix} \ (m_1,-m_2) &= (+1,-1) \ (m_1,-m_2) &= (2,0) \ e^{irac{3\pi}{2}}igg(e^{i2arphi}igg[rac{1}{-i} igg] + igg[rac{1}{i} igg) &\leftrightarrow e^{iarphi}e^{irac{3\pi}{2}} igg[\cosarphi \ \sinarphi \end{bmatrix} \ e^{iarphi} &\to e^{i0.9arphi}, e^{i0.8arphi}, \cdots \ e^{irac{3\pi}{2}} &\to e^{-irac{3\pi}{2}}, e^{irac{\pi}{4}}
otin egin{bmatrix} arphi \ arphi \end{matrix} \ \dot{z} \ \dot{z$$

4. ベクトルビームの作り方(SLMに2回反射)

$$\begin{split} J &= \begin{bmatrix} 1 & -i \\ -i & 1 \end{bmatrix} \begin{bmatrix} -e^{i\delta_2} & 0 \\ 0 & 1 \end{bmatrix} e^{i\frac{\pi}{2}} \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} -e^{i\delta_1} & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} \\ &= \begin{bmatrix} 1 & -i \\ -i & 1 \end{bmatrix} \begin{bmatrix} -e^{i\delta_2} & 0 \\ 0 & 1 \end{bmatrix} e^{i\frac{\pi}{2}} \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} -e^{i\delta_1} \\ 1 \end{bmatrix} \\ &= \begin{bmatrix} 1 & -i \\ -i & 1 \end{bmatrix} \begin{bmatrix} -e^{i\delta_2} & 0 \\ 0 & 1 \end{bmatrix} e^{i\frac{\pi}{2}} \begin{bmatrix} 1 \\ e^{i\delta_1} \end{bmatrix} \\ &= e^{i\frac{\pi}{2}} \begin{bmatrix} 1 & -i \\ -i & 1 \end{bmatrix} \begin{bmatrix} -e^{i\delta_2} \\ e^{i\delta_1} \end{bmatrix} \\ \therefore J &= e^{i\frac{\pi}{2}} \begin{bmatrix} -ie^{i\delta_1} - e^{i\delta_2} \\ e^{i\delta_1} + ie^{i\delta_2} \end{bmatrix} = e^{i\pi} \left(e^{i\delta_1} \begin{bmatrix} 1 \\ i \end{bmatrix} + e^{i(\delta_2 + \frac{\pi}{2})} \begin{bmatrix} 1 \\ -i \end{bmatrix} \right) \end{split}$$