忘れたときに見返す用です.

1. 波長板

1. 1. HWP

$$
\begin{aligned}
J_{HWP(\theta)} &= \begin{bmatrix} -\sin^2\theta + \cos^2\theta & 2\sin\theta\cos\theta \\ 2\sin\theta\cos\theta & \sin^2\theta - \cos^2\theta \end{bmatrix} \\
\therefore J_{HWP(\theta)} &= \begin{bmatrix} \cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{bmatrix}
\end{aligned}
$$

1. 2. QWP

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

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

1. 3. LP

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

1. 4. SLM(反射型)

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

1. 5. 表→裏

1. 5. 0. HWP

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

1. 5. 0. QWP

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

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

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

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

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

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

(1-1)

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

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

$m_1 = 2, m_2 = 0, \Delta\varphi = -\frac{\pi}{2}$

(1-2)

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

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

$m_1 = 2, m_2 = 0, \Delta\varphi = -\frac{\pi}{2}$

(1-3)

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

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

$m_1 = 0, m_2 = 2, \Delta\varphi = -\frac{\pi}{2}$

(1-4)

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

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

$m_1 = 0, m_2 = 2, \Delta\varphi = -\frac{\pi}{2}$

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

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

(2-1)

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

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

$m_1 = 2, m_2 = 0, \Delta\varphi = -\frac{\pi}{2}$

(2-2)

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

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

$m_1 = 2, m_2 = 0, \Delta\varphi = -\frac{\pi}{2}$

(2-3)

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

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

$m_1 = 0, m_2 = 2, \Delta\varphi = -\frac{\pi}{2}$

(2-4)

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

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

$m_1 = 0, m_2 = 2, \Delta\varphi = -\frac{\pi}{2}$

(3) $\theta_1 = \frac{\pi}{8}, \theta_2 = \frac{\pi}{4} + \alpha$

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

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

$$J \propto e^{i\varphi} \begin{bmatrix} -e^{i\varphi}(1 + i\sin 2\alpha) - ie^{-i\varphi}\cos 2\alpha \\ -ie^{i\varphi}\cos 2\alpha + e^{i\varphi}(\sin 2\alpha - 1) \end{bmatrix}$$

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

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

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

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

3. ダイナミック位相

$$e^{i\varphi} \begin{bmatrix} 1 \\ -i \end{bmatrix} + e^{-i\varphi} \begin{bmatrix} 1 \\ i \end{bmatrix} \leftrightarrow \begin{bmatrix} \cos\varphi \\ \sin\varphi \end{bmatrix}$$

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

$$(m_1, -m_2) = (+1, -1)$$
$$(m_1, -m_2) = (2, 0)$$

$$e^{i\frac{3\pi}{2}} \left(e^{i2\varphi} \begin{bmatrix} 1 \\ -i \end{bmatrix} + \begin{bmatrix} 1 \\ i \end{bmatrix} \right) \leftrightarrow e^{i\varphi} e^{i\frac{3\pi}{2}} \begin{bmatrix} \cos\varphi \\ \sin\varphi \end{bmatrix}$$

$$e^{i\varphi} \to e^{i0.9\varphi}, e^{i0.8\varphi}, \cdots$$

$$e^{i\frac{3\pi}{2}} \to e^{-i\frac{3\pi}{2}}, e^{i\frac{\pi}{4}} \text{ など}$$

4. ベクトルビームの作り方(SLMに2回反射)

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