Supplemental Document

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Polarization-preserving image rotator: supplement

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1. UNIVERSALITY OF THE POLARIZATION-PRESERVING GEOMETRY

The geometry of placing HWPs before and after a image rotator and rotating them at half the rotator's angle is not specific to K-mirrors. In this section, we show that the proposed and demonstrated configuration is universal and works for any image rotator. The Jones matrix of the K-mirror in Eq. (1) of the main manuscript can be written as

$$t_{\mathrm{KM}}(\theta) = R(\theta)\, t_{\mathrm{KM}}(0)\, R^T(\theta), \tag{S1}$$

where $R(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$ is the rotation matrix and $t_{\mathrm{KM}}(0)$ is the Jones matrix of the K-mirror at $\theta = 0$. This form holds for any image rotator, including Dove prisms [1, 2], Delta prism [1], Pechan prism [1], and five-mirror image derotators [3], differing only in their Jones matrix elements at $\theta = 0$. For the configuration in which two HWPs are placed before and after a image rotator and rotated by $\alpha\theta$ when the rotator is rotated by θ, the Jones matrix of the full configuration is

$$t_{\mathrm{tot}}(\alpha, \theta) = \mathrm{HWP}(\alpha\theta)\, R(\theta)\, t(0)\, R^T(\theta)\, \mathrm{HWP}(\alpha\theta), \tag{S2}$$

where $\mathrm{HWP}(\alpha\theta) = \begin{bmatrix} \cos 2\alpha\theta & \sin 2\alpha\theta \\ \sin 2\alpha\theta & -\cos 2\alpha\theta \end{bmatrix}$ is obtained from Eq. (2) of the main manuscript with $\epsilon = 0$. We show that

$$\mathrm{HWP}(\alpha\theta)\, R(\theta) = R^T(\theta)\, \mathrm{HWP}(\alpha\theta) = \mathrm{HWP}\left(\frac{2\alpha - 1}{2}\theta\right). \tag{S3}$$

Substituting into Eq. (S2), we get

$$t_{\mathrm{tot}}(\alpha, \theta) = \mathrm{HWP}\left(\frac{2\alpha - 1}{2}\theta\right) t(0)\, \mathrm{HWP}\left(\frac{2\alpha - 1}{2}\theta\right). \tag{S4}$$

For $\alpha = 1/2$, this reduces to

$$t_{\mathrm{tot}}(1/2, \theta) = \mathrm{HWP}(0)\, t(0)\, \mathrm{HWP}(0), \tag{S5}$$

which is independent of θ. This holds for any $t(0)$, and therefore for any image rotator. We note that $\alpha = 1/2$ is the unique value for which t_{tot} becomes independent of θ. For this value, and $t(0)$ of the K-mirror, $t_{\mathrm{tot}}(1/2, \theta) = t_{\mathrm{PPIR}}(\theta)$, consistent with Eq. (4) of the main manuscript. This confirms that the polarization-preserving image rotator (PPIR) is a specific implementation of this universal polarization-preserving geometry.

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