TECHNICAL NOTE

Polarization aberration analysis of the advanced x-ray astrophysics facility telescope assembly: errata

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Reference 1 contains a serious error that renders most of the results inapplicable to grazing-incidence telescopes and creates an incorrect impression as to the polarization properties of grazing-incidence telescopes. The errors arise from an incorrect application of the sign convention for the Fresnel equations. The Fresnel equations are correct as stated in Eqs. (2) and (3) but are incorrectly assembled into the Jones matrix in Eq. (8), where the minus sign of a_p should be removed. This equation is at the heart of the technical development, causing errors in many of the remaining equations. The retardance is incorrectly calculated by Eq. (5) and is plotted incorrectly in Fig. 4. Near grazing incidence, the linear retardance associated with reflection from metals, approaches zero ($\delta \to 0$) as the angle approaches grazing incidence ($i \to 90°$). The paper incorrectly states that $\delta \to \pi$ rad. Thus a grazing-incidence mirror acts as a nonpolarizing element, not as a half-wave linear retarder.

The polarization aberration function for the primary mirror in Jones matrix form [Eq. (16)] should be

$$\mathbf{J}(\rho, \theta) \approx \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \tag{1}$$

not

$$\mathbf{J}(\rho, \theta) \approx j \begin{pmatrix} \cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{pmatrix}, \tag{2}$$

as stated in Ref. 1. Similarly the polarization aberration equation in Mueller matrix form [Eq. (17)] should be

$$\mathbf{M}(\rho, \theta) \approx \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \tag{3}$$

not

$$\mathbf{M}(\rho, \theta) \approx \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos 4\theta & \sin 4\theta & 0 \\ 0 & -\sin 4\theta & -\cos 4\theta & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}, \tag{4}$$

as stated in Ref. 1.

The polarization effects of the primary mirror are minor. The remainder of the analysis, which derives from Eqs. (16) and (17), therefore does not apply to radially symmetric grazing-incidence mirrors with annular apertures, such as the advanced x-ray astrophysics facility high-resolution mirror assembly and other similar telescopes. We therefore retract the conclusions in Ref. 1 regarding the polarization properties of grazing-incidence telescopes. The following remarks correct several statements in Ref. 1:

(1) The primary mirror does not act as a spatial depolarizer. For polarized illumination the exit pupil polarization state is nearly uniform and in the incident polarization state. Similarly the secondary mirror is essentially nonpolarizing.

(2) The point spread functions for the primary mirror are essentially those of scalar diffraction theory with a uniform polarization state as a function of the image coordinate.

(3) The in-focus point spread functions have a bright peak in the center, not a null.

(4) Accurate polarimetry is feasible at the focus of the primary mirror.

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The paper by Almeida and Pillet[2] in this issue contains an analysis of grazing-incidence telescopes that corrects the mistakes in Ref. 1 and predicts residual instrumental polarization below 10^{-3}.

As a final check we measured experimentally the grazing-incidence properties of an aluminum mirror to confirm the near-zero retardance approaching grazing incidence. The retardance of a grazing-incidence metal mirror should approach zero regardless of the complex refractive index. Thus this property can be confirmed by visible light measurements. With a Mueller matrix polarimeter at 632.8 nm, a set of measurements was acquired for a beam reflecting for angles of incidence from 80° to 87.5°. The results clearly showed the retardance to be approaching zero and that circular polarized light would maintain its helicity on reflection.

Optical systems with the polarization aberration function given in Eqs. (2) and (4) above are physically possible and will have the interesting properties described in Ref. 1. Such systems act as half-wave linear retarders oriented tangentially in an annular pupil (Fig. 5). For such systems with annular apertures, the main results of Ref. 1 do apply, with the exception of those in Section II, Angles of Incidence, and Section V, HRMA Polarization. Thus the transmitted polarization states, depolarization, diffraction image formation, and interference patterns as described are correct for those systems described by Eqs. (2) and (4) above.

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References

1. R. A. Chipman, D. M. Brown, and J. P. McGuire, Jr., "Polarization aberration analysis of the advanced x-ray astrophysics facility telescope assembly," Appl. Opt. **31**, 2301–2313 (1992).
2. J. Sánchez Almeida and V. Martínez Pillet, "Polarizing properties of grazing incidence x-ray mirrors," Appl. Opt. **32**, 4231–4235 (1993).