Aberration Theory at Work

The Schmidt system demonstrates tradeoffs in optical design.

Figure 1 When we locate the aperture stop at the center of curvature of a spherical mirror, the mirror is totally free of coma and astigmatism.

If we locate the aperture stop of a spherical mirror at the center of curvature, the mirror will be totally free of coma and astigmatism (see figure 1). This is because any oblique beam through the aperture stop is treated exactly the same as the axial beam. Because mirrors do not suffer from chromatic aberration, the monocentric system being described suffers only the spherical aberration of the mirror and the curvature of the image, which is on a sphere concentric with the mirror. We can correct these aberrations with the addition of refractive elements. The trick in designing any reflective/refractive (catadioptric) system is to use weak refractive elements to correct the relatively small aberrations of the mirrors without introducing any large refractive problems that might overwhelm the benefits of the mirror system.

A Schmidt system consists of a spherical mirror with a thin aspheric plate located at the aperture stop, configured to correct the spherical aberration of the mirror. If we confine our attention to the Seidel (third-order) aberrations, stop-shift theory tells us that an aspheric surface located at the aperture stop will affect only the spherical aberration. It will have no effect on the chromatic aberrations or on the other Seidel aberrations (coma, astigmatism, Petzval field curvature, and distortion). This is exactly what we need. A fourth-order surface deformation (which varies as $y^4$) on a thin plate located at the aperture stop will correct the third-order spherical aberration without affecting the other aberrations.

It is important to note that the refractive index $n$ of the corrector plate varies with wavelength. At short wavelengths, the refractive index is higher, causing the spherical aberration to be overcorrected; at longer wavelengths, the refractive index is lower, causing the spherical aberration to be undercorrected. Our system now suffers from spherochromatism, or variation of spherical aberration with wavelength.

Since our aspheric surface is relatively weak, however, the spherochromatic aberration is modest; we can balance it with a weak positive lens that will introduce undercorrected chromatic aberration. The additional power reduces the size of the spherochromatic blur in the image by a factor of three or four. We don’t have to introduce it using a separate element; we can simply add a little positive power to the aspheric surface of the corrector (see figure 2). Note that if the system is fast, the aspheric surface may need sixth- and eighth-order deformation terms to correct the spherical aberration fully.

Ultimately, the performance of the Schmidt system is limited by the aforementioned field curvature, which is correctible with a positive field-flattener lens or by curving the film/sensor; by the spherochromatism, which can be corrected by achromatizing the corrector plate; and by a fifth-order aberration called oblique spherical aberration, caused by the oblique passage of the beam through the corrector plate.

![Figure 2 An aspheric corrector plate with positive power can balance spherochromatism in a Schmidt system.](image)

References

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