teaching an old mirror new tricks

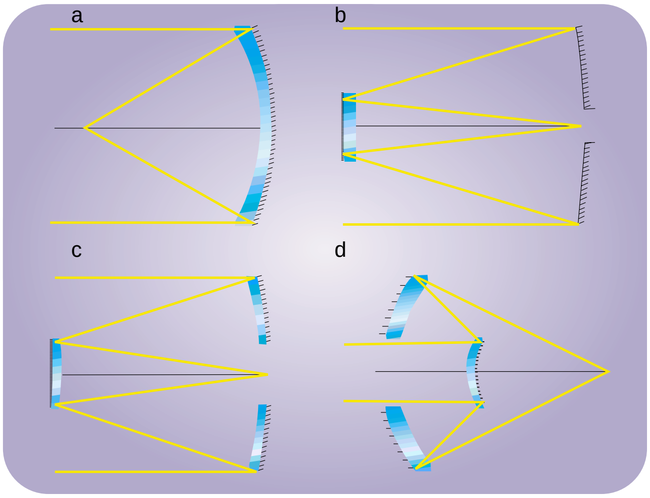
The Mangin mirror provides optical designers with a host of options for solving modern problems.

By Warren Smith, Kaiser Electro-Optics

Optical designers can branch out to the heights of innovation, but always their work is rooted in previous optical systems. In this way, knowledge of (optical) history comes in handy, as the following examples show.

Invented in 1876, the Mangin mirror consists of a meniscus negative lens with a mirrored convex second surface (see figure). The undercorrected spherical aberration of the mirror is offset by the overcorrected spherical aberration of the negative lens. Although bulky and heavy in large sizes, the Mangin enjoyed wide use in automotive headlights back in the days when the light source was an acetylene flame. More recently, it often shows up in fairly complex catadioptric systems as a simple, inexpensive substitute for an aspheric mirror.[1]

In 1960 we needed a quantity of 12-in.-diameter, near-IR systems to image, analyze, and identify the exhaust plumes of rockets. The required field of view was small, and the obvious solution was a Cassegrain system with one or two aspheric surfaces. Initially, we ruled out a Mangin primary mirror on the basis of the weight and cost of a 12-in.-diameter optical-quality glass blank. It turned out that a simple spherical primary mirror combined with a Mangin secondary worked out nicely, however. The large first-surface spherical primary mirror could be polished on a thin, low-quality, inexpensive Pyrex substrate. Thus, the only optical-quality glass needed was for the small secondary.



The basic Mangin mirror consists of a meniscus negative lens with a mirrored convex second surface (a). A near-IR Cassegrain system with Mangin secondary provides good performance with reasonable cost (b). A near-IR Cassegrain system with Mangin primary and secondary mirrors produces a system corrected for spherical aberration and coma (c). An achromatized UV Schwarzschild system features Mangin primary and secondary mirrors (d).

A few decades later, we needed a few hundred modestly sized (4 in.) Cassegrain systems to cover a significant field of view at a fairly high speed. The obvious solution was a Ritchey-Chretien Cassegrain with two hyperbolic surfaces, corrected for both coma and spherical aberration. Again, the fact that the system was near-IR and glass optics were acceptable allowed the Mangin to gallop to the rescue. Using Mangin mirrors as both primary and secondary, we could correct spherical aberration and coma with simple spherical surfaces, which yielded tremendous cost savings.

More recently, we needed a UV system operating around 0.3 µm that would cover a small field at a numerical aperture of 0.5. The system had to be achromatic and diffraction limited for two specific wavelengths spaced about 35 nm apart. A Schwarzschild system of two concentric spherical mirrors seemed a good solution—the necessary focal length was short, so the extremely large relative diameter of the concave mirror was not a problem. Unfortunately, a requirement for a long working distance ruled out the classical monocentric Schwarzschild arrangement with R_1=1.236F and R_2=3.236F, and it seemed that we would need one or two aspheric surfaces to get both the image quality and the working distance.[2]

Almost on a whim we tried two Mangins in the Schwarzschild arrangement and found that the system could be achromatized using only one material: fused quartz. The chromatic aberration, the secondary spectrum, and the spherical aberration could be corrected, and although the spherochromaticity was large, it was tolerable.

As can be seen, in addition to its incorporation into many quite complex systems, the simple Mangin mirror is sometimes capable on its own of satisfactorily substituting for an aspheric surface when the requirements of the application allow. **oe**

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