# Certification of a null corrector via a diamond turned asphere: design and implementation


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*Abstract*

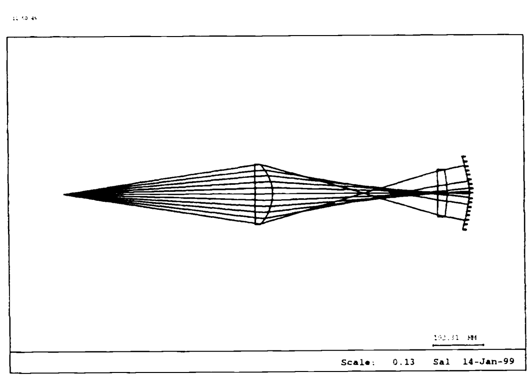
We discuss the design of diamond turned mirror to be used to certify a refractive null corrector to test a 6.5 meter, F/1.25 paraboloidal mirror. Practical details of the certification implementation will also be presented.


Summary

One well-known problem of null correctors used to test astronomical optics is the potential error that they can introduce in the surface under test. This error results from the fabrication or assembly errors of the null corrector itself. One solution to this problem is to certify the null corrector using a computer generated hologram. The holograms are manufactured with a circular laser writing machine, and have demonstrated accuracy of 0.01 waves rms for mirrors as fast as f/1.1. The holograms are designed and manufactured independent from the null correctors, so when the null corrector and the hologram agree, we are assured that both are correct.

After using holograms to certify over 10 null lenses for primary mirrors, we are considering a new philosophy in optical testing. We can build the null corrector at low cost if we do not require absolute accuracy from it, and we can adjust the null lens to match the hologram. However, this eliminates the redundancy in our process -- an error in the hologram would result in a mis-aligned null corrector which would cause the mirror to be made to the wrong shape.

A refractive null corrector and an aspheric certifying mirror.







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A mirror with a diamond turned aspheric surface can be used to provide the redundancy required to insure that the optical testing meets the telescope requirements. The added cost of a single diamond turned asphere is easily justified by the cost savings from making the null corrector to low tolerances.

Such certifying mirror is placed almost in contact to the null corrector and retro-reflects the light so that a null test condition is maintained. Every ray from the null corrector reaches the certifying mirror at normal incidence and is therefore reflected back on its incoming path. Provided that the certifying mirror is accurate then any error in the null corrector will be shown as an aberration at the ideal null test point.

We are using diamond-turning technology to manufacture the certifying mirror that we need to properly test a 6.5 meter diameter, F/1.25 paraboloidal mirror. We found that the standard aspheric surface provided in lens design programs cannot describe properly the surface of the certifying mirror even if many aspheric coefficients are used. The reason is that near the caustic produced by the normals of a paraboloidal mirror there is a strong non-linearity in the behavior of the rays. Therefore we had taken a different route to find the surface description of the certifying mirror. This involved setting a set of equations that fortunately we were able to solve in close form. These equations are:

$$z = \frac{1}{2}\left\{2P\cos(\theta) + \frac{R}{\cos^2(\theta)} - R\right\} - P \quad \text{and} \quad y = R\tan(\theta) - P\sin(\theta),$$

where $z$ is the sag of the certifying mirror, $y$ is the transverse coordinate, and $\theta$ is the angle of the normal intersecting the certifying mirror at coordinates $z$ and $y$. R is the vertex radius of the paraboloid, and P is the vertex-to-vertex distance between the paraboloid and the certifying mirror.

In these equations the trigonometric functions can be eliminated to obtain a relationship between $z$ and $y$ only. This is,

$$\begin{aligned}
&y^2\big(4P^4 - 4R^3z - 4P^3[3R + 4z] + 4y^2[y^2 + z^2] + R^2[y^2 + 32z^2] - \\
&4P[R^3 + 5Ry^2 - 16R^2z - 2y^2z + 12Rz^2] - \\
&4R[5y^2z + 4z^3] + 4P^2[3R^2 - 11Rz - 2[y^2 + z^2]]\big) \\
&+ 4z(2P + z)\big((P - R)^2 - 2Rz\big)^2 = 0
\end{aligned}$$

This closed form can be used in a ray-tracing program to user define the certifying mirror.