Wavefront Error and Point Spread Function: Through-focus Diagrams

M.Lampton
UCB SSL
28 Sept 2006

To better understand the connection between the Point Spread Function (PSF) as defined by geometrical ray tracing, and the WaveFront Error (WFE) as defined by geometrical ray tracing, I have undertaken the computation of both PSF and WFE for a typical optical telescope configuration TMA72 as computed by M.Sholl.

The basis of the computation is as follows:

1. Ray computations are involved throughout. There is no pupil diffraction. I chose three field points located 6, 10, and 14 milliradians off axis, corresponding approximately to the inner radius, mid radius, and slightly beyond the outer radius of our annular field. For each field point I used a 100 x 100 grid of equally spaced ray starts filling a 2x2 meter square. Of these 10000 ray starts, 6610 rays survive the ray traces. The lost rays lie in the corners of the square, in the central region, and along the three radial secondary support ribs.

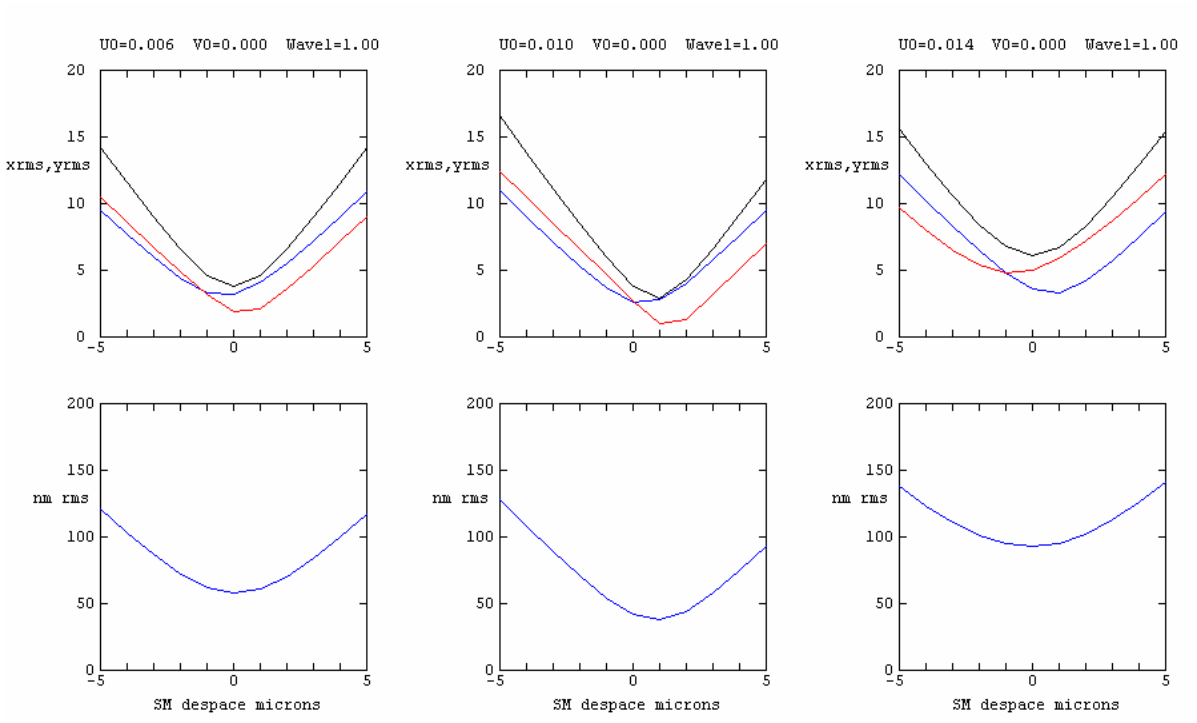
2. PSF size is calculated as the RMS deviation of the x-values and y-values of the ray intercepts with the final focal surface, measured from the centroid of the ray patch. The sum-of-squares Rrms is the root sum square of xrms and yrms.

3. The optical path RMS variation is determined by computing the telescope as a mapper of optical path from an input plane wave and an output spherical wave delivered to the focal plane. In the incident plane wave, each ray has been assigned a phase of zero. The OPD for each ray is computed as the sum of the optical path to the plane focal surface, plus a correction term that would extend this ray to a theoretical spherical surface minus the radius of that sphere...

```
Pcorrection =  (xbar-x)*u + (ybar-y)*v - (zbar-z)*w;
```

where (x,y,z) are the coordinates of the ray intercept with the planar focal plane, (xbar, ybar, zbar) are the coordinates of the centroid of the ray landing patch, and (u,v,w) are the direction cosines of each ray in the coordinate system of the focal plane.

Computed examples of the variation in PSF Xrms and Yrms (also Rrms = Root Sum Squares of these two combined, plotted in black) are shown in microns in the focal plane, for the upper three diagrams, computed for off axis angles of 6, 10, and 14 milliradians. In the lower three diagrams, the RMS optical path difference in nanometers is plotted. In all cases, the nominally perfect TMA72 is chosen for all optical parameters except the abscissa is the secondary mirror defocus position in microns. So these charts show the effects of secondary mirror defocus given an ideal TMA72 telescope.

I conclude that secondary mirror defocus of ±1 micron causes a noticeable but non fatal degradation in optical system performance: ~10% in Xrms, Yrms, or OPDrms. Evaluating TMAs other than TMA72 leads to the same conclusion.

A preliminary set of through-focus diagrams (psf only, not wfe) were published in the SNAP Telescope poster presented to the AAS January 2006 by Lampton et al.