Ghosts From Binospec Construction Design
102102AX Collimator and 100202AY Camera
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1 Introduction

This report summarizes a ZEMAX raytrace study of double-bounce ghosts of two types: (1) CCD detector to glass-air surface back to the CCD or (2) glass-air surface to glass-air surface back to the CCD. Since the reflectivity of the CCD is of order 10% and an air-glass-surface about 1%, the type (1) ghosts are down a factor of 1000 in intensity (7.5 magnitudes) and the type (2) ghosts down a factor of 10000 in intensity (10 magnitudes) before considering any dilution due to image size. When calculating dilution due to image size, we use a $1''$ diameter image as a reference, and compare this to the ghost image's RMS diameter or 50% encircled energy diameter. A $1''$ diameter image has a diameter of 0.061 mm at Binospec's final focus.

Ghost analysis then becomes a tedious exercise in creating the appropriate ZEMAX files using ZEMAX's built-in ghost focus generator. As of this writing, ZEMAX does not handle aspherics correctly in these automatically generated files, and the aspheric terms need to be entered in by hand, adding to the tedium. When a concentrated ghost is formed, it is important to add in these aspheric terms since they do affect the energy distribution.

All together, there are 16 air-glass surfaces in Binospec, a pair each from the filter, three lens groups in the collimator, and four lens groups in the camera (including the dewar window). In addition, there are possible ghosts from 10 air-glass surfaces in the f/5 wide-field corrector optics.

2 Summary

2.1 Internal Filter Reflections

The worst ghost image is due to reflections from the two filter faces. The image is defocussed only by a 10 mm path at f/5; the total image diameter at the telescope scale is 2 mm. After the Binospec's demagnification by a a factor of 2.72, the final image RMS diameter is about 0.3 mm. The image area gives a factor of 25 dilution compared with a $1''$ diameter image, or 3.5 magnitudes. This ghost is down by 13.5 magnitudes in total. The bad news is that it is very difficult to do anything about

this ghost (tilting the filter has no effect to first order. The good news is that if the filter is made to high tolerances (front and back surfaces parallel) this image will fall on top of the main image, where it can not be mistaken for a real object.

2.2 Other Filter Reflections

If the filter is located very close to the telescope's focus, ghost reflections from collimator lens 8 (the second collimator aspheric) and then the filter are troublesome, down only about 15 or 16 magnitudes. If the filter is moved closer to its actual position, closer to the first collimator element, this ghost can be made insignificant.

2.3 Other Noticeable Ghosts

The other ghosts that are down less than 20 magnitudes are listed in Table 1. Many of these ghosts vary in size with wavelength. The smallest ghost diameter (worst case) for wavelengths between 3900 and 9300 Å is used for Table 1.

Most Prominent Ghosts (Not Filter-Associated)

Magnitude Reduction	First Surface	Second Surface
17.1	CCD	Front of Col Lens 8
17.1	Rear of Dewar Window	Front of Camera Triplet
17.4	CCD	Front of Camera Triplet
17.9	CCD	Rear of Dewar Window
18.2	CCD	Front of Dewar Window
19.1	Rear of Dewar Window	Front of Dewar Window
19.3	Front of Col Lens 8	Rear of Col Lens 2
19.6	Rear of Camera Quad	Front of Camera Lens 1
20.0	CCD	Rear of Col Lens 2