Conceptual Design Phase Stray Light Analysis of the MOBIE Imaging Spectrograph for TMT

K. Scott Ellis[a], Rebecca A. Bernstein[b], Bruce C. Bigelow[c]

[a]Photon Engineering, LLC, 440 S. Williams Blvd., Suite 106, Tucson, AZ, USA 85711;

[b]UC Observatories, Astrophysics Dept, UC Santa Cruz, 1156 High St., Santa Cruz, CA, USA 95064;

[c]UC Observatories, CFAO 109, UC Santa Cruz, Santa Cruz, CA, USA 95064

INTRODUCTION

The Multi-Object Broadband Imaging Echellette (MOBIE) is the seeing-limited, optical spectrograph planned for the first generation of Thirty Meter Telescope (TMT) instruments[1]. The MOBIE instrument is currently in the conceptual design phase. This paper documents the progress to date on the stray light analysis of the imaging mode configuration. The goal of the stray light analysis at this phase of the project cycle is to provide a baseline estimate of the expected stray light background. To this end, four stray light calculations have been completed:

- Identification of critical objects;
- Estimated stray light background
- Off-axis rejection characteristics; and
- Ghost image formation.

The analyses are based on end-to-end ray traces of a complete, albeit reduced, system model that includes the Calotte-style dome, telescope optics and support structure, the MOBIE instrument optics and enclosure.

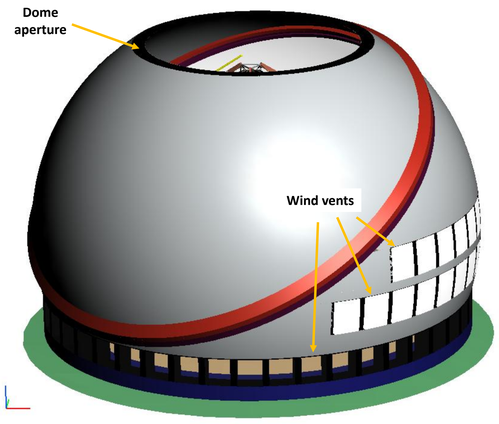

Figure 1. Complete TMT-MOBIE stray light analysis model

TMT-MOBIE GEOMETRY MODEL

The end-to-end system model is shown in Fig. 2 (the dome walls are hidden). The imaging mode configuration of the MOBIE instrument is shown in Fig. 3. A pair of atmospheric dispersion correction (ADC) prisms is located just prior to the field stop aperture. The field stop is a curved mask matching the curvature of the TMT focus surface and transmitting a 5.4±2.1 arc minute by ±4.8 arc minute rectangular field of view. The field stop is the principal stray light control mechanism inside the instrument. A reflective collimator (MC-1) follows the field stop. A dichroic beam splitter transmits and reflects light into the red and blue camera assemblies, respectively. It is subsequently folded into the refractive camera assemblies

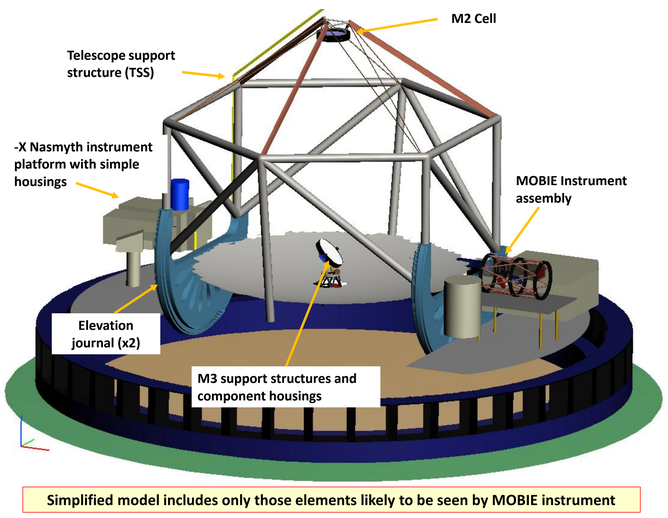

Figure 2. Dome interior

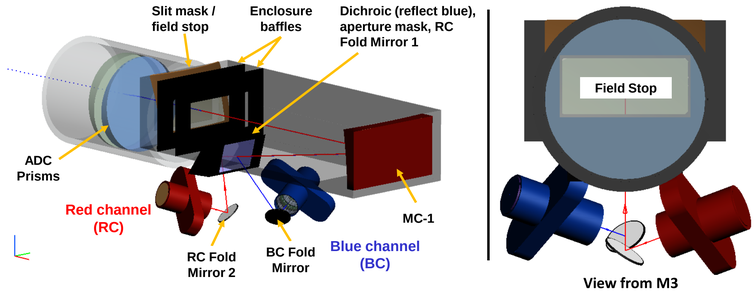

Figure 3. MOBIE instrument model

SURFACE PROPERTY ASSIGNMENTS

The mirror surfaces have a thin film aluminum coating, averaging 90% reflectivity across the instrument pass band. The lens surfaces have idealized anti-reflection coatings, reflecting 1% of the incident flux at each interface. The optical surfaces are assigned two scatter functions. A Harvey[2] BSDF simulates the scatter due to RMS micro-roughness[3]. A Mie scatter model using an IEST-STD-1246D particle size distribution function simulates the scatter due to particulate contamination[4,5]. Non-optical surface treatments vary from flat black paint to glossy white.

ANALYSIS RESULTS

The critical/illuminated object analysis showed that light entering from outside the field of view has no direct path to the cameras. The cameras see the telescope support structures in the vicinity of M2 and M3, the elevation journals, and the dome floor. All of these objects are illuminated by external sources, with light entering through the top of the dome or in through the wind vents arranged around the dome walls.

With a black dome interior, stray light accounts for 4.0% of the total flux reaching the blue camera detector plane. The blue camera sees a strong red ghost reflection from the dichroic beam splitter. Absent this contribution, the background is reduced to 3.2%. The scattered light background is 2.8%. Under the same conditions for the red camera, stray light accounts for 3.7% of the total flux reaching the detector plane. The scattered light background is 3.3% of the total. Most of the contribution originates from sources within the sensor field of view. A white dome interior adds 0.3% to the scattered light background in both camera paths.

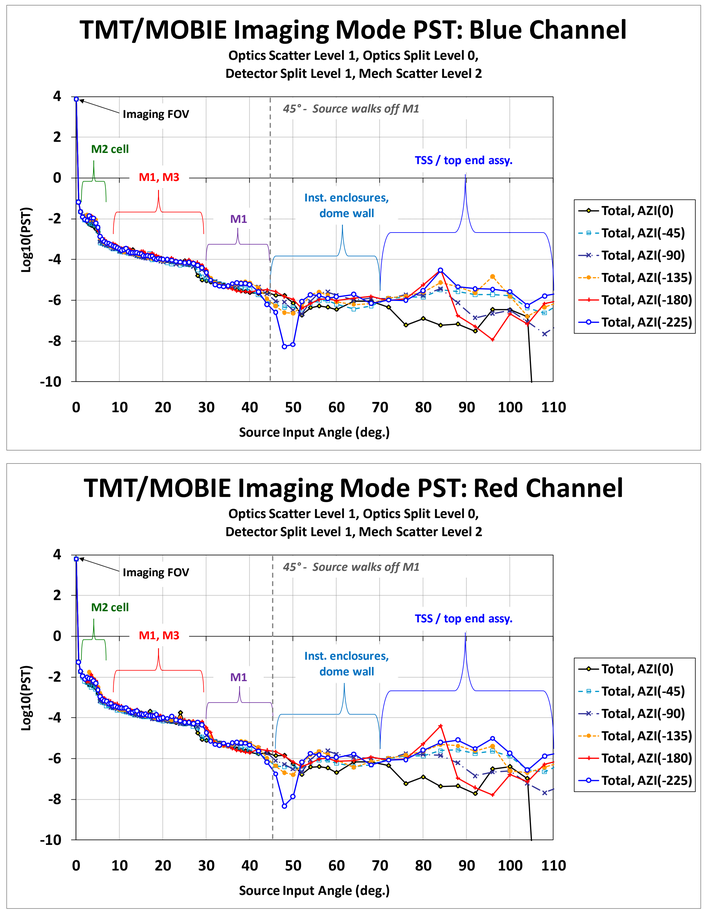

Figure 4. PST analysis results (blue – top; red – bottom)

Fig. 4 show the log space plots of the PST curves for the blue and red cameras, respectively. The PST analysis provides a way to quantify the out of field rejection characteristics of the telescope and instrument. The annotations on the plot indicate the most significant contributors to the stray light background over the range of angles indicated. The most important features to note are that there are no direct specular paths into the cameras from outside the instrument field of view and that scatter from the telescope optics and dome account for nearly all of the stray light background for objects outside the instrument field of view.

Fig. 5 shows log space ghost image irradiance plots at the camera sensor planes from source directions located inside the field of view. The ADC prisms produce image artifacts above and below the main image. The blue camera sees a strong red reflection from the dichroic beam splitter that overlays the direct image.

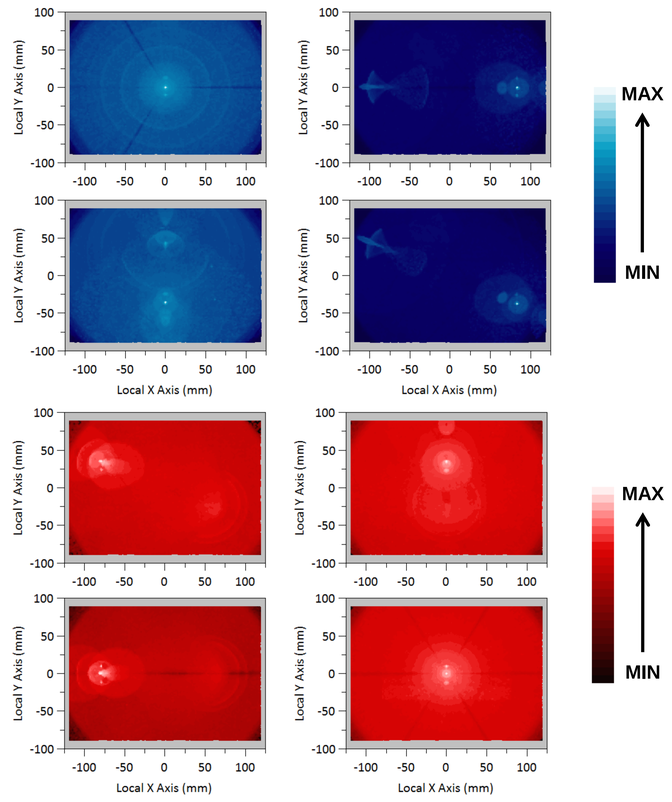

Figure 5. Ghost image irradiance (blue – top; red – bottom)

CONCLUSIONS

A preliminary stray light analysis of the imaging mode configuration of the TMT/MOBIE instrument has been completed. A complex opto-mechanical model containing key components of the dome, telescope, and instrument has been constructed. Analysis has shown the stray light background is dominated by the optical surface contributions, particularly from sources within the instrument field of view. The dome interior structures contribute to the stray light background at a comparatively low level.

Similar stray light analyses of the spectroscopic operating modes are planned for future work.

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