SMI Lens Design Number 330

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The SMI multi-band photometer takes center of the f/11 folded Cassegrain image of the Magellan telescope, collimates it, divides it into photometric bands by a series of dichroic beamsplitters, and then re-images the separated optical beams onto cooled 4K×4K CCD detectors. A schematic layout of the instrument is shown in figure 1. The series of lenses for SMI must meet the following requirements and design criteria:

1. The plate scale at the CCD should be as large as possible. Corner-to-corner, the CCD covers 6.24 arcminutes on the sky. This requires some reduction in effective focal length by the re-imaging system. The CCD is square, 60 mm on a side. At a pixel size of 15 μm square, each pixel subtends $0.066''$, which is highly oversampled. Excellent seeing of $0.3''$ corresponds to a spot size at the CCD of 4.5 pixels or 68μm diameter.

2. The angle of incidence of the beam at the dichroic reflectors must be minimized. Dichroics work best at zero angle of incidence, and fail badly near Brewster's angle (~ 56 deg).

3. The variation in angle of incidence at the dichroic reflectors must be minimized. The bandpass of dichroic filters varies with angle of incidence, causing bandpass variations across the field of view. This is undesirable and should be minimized.

4. There must be enough space between the collimating and re-imaging optics to insert two dichroic reflectors.

5. The collimated beam must not be too large—the practical size limit for manufacture of dichroic reflectors is about 150 mm.

6. The lenses must not be too large—lens manufacture becomes expensive as the lens dimensions approach 150 mm.

7. The use of aspheric surfaces is allowed but should be minimized to reduce cost.

8. The lenses should be easy to fabricate. The lens edges and centers should not be too thin. The spherical radius of the lens surfaces should be significantly larger than the radius of the lens itself.

9. The optical glasses should have relatively low coefficient of thermal expansion ($\sim 6 \times 10^{-6}$), and be well matched to each other, especially at glued surfaces. The coefficient of thermal expansion should also match the lens cell material.

10. The total passband of the system is 400 nm to 1150 nm. The lens glass must be transparent in this range, and the anti-reflection coatings must work in this range.

11. The optical glasses used in the design must be readily obtainable and relatively inexpensive.

12. Reflections are a problem. The total number of air-glass surfaces should be minimized. All air-glass surfaces should be antireflection coated.

13. The final lens in the system, just before the CCD, should be usable as a vacuum window for the cryogenic dewar that holds the CCD.

14. The system need not be telecentric, since the CCDs accept a wide range of angles of incidence.

15. The image at the CCD should have relatively low distortion ($< 5\%$).

16. Optical aberrations should not significantly degrade the image quality under good observing conditions. This means that 80% of the encircled energy should fall within a diameter of 90 μm or less.

This memo describes a series of lenses that meet these design criteria. One particular design is presented: `magellan330.zmx`. The design files can be found at `http://www.tonystark.org/pisco`.

This design is the latest in a long series. Some of these earlier designs have considerably smaller aberrations but more lenses and air-glass surfaces. Some of the earlier designs depend on aspheric surfaces, use exotic glasses, or have poorly matched coefficients of thermal expansion. The design presented here embodies numerous compromises and trade-offs in order to meet the design critera.

This lens design has four groups: a doublet, a triplet, a triplet, and a doublet. Approximate symmetry of the design around the center is a feature which helps cancel aberrations. The layout of `megellan330.zmx` is shown in figure 2. Spot diagrams and encircled energy plots for the two designs are shown in figures 3 through 6.

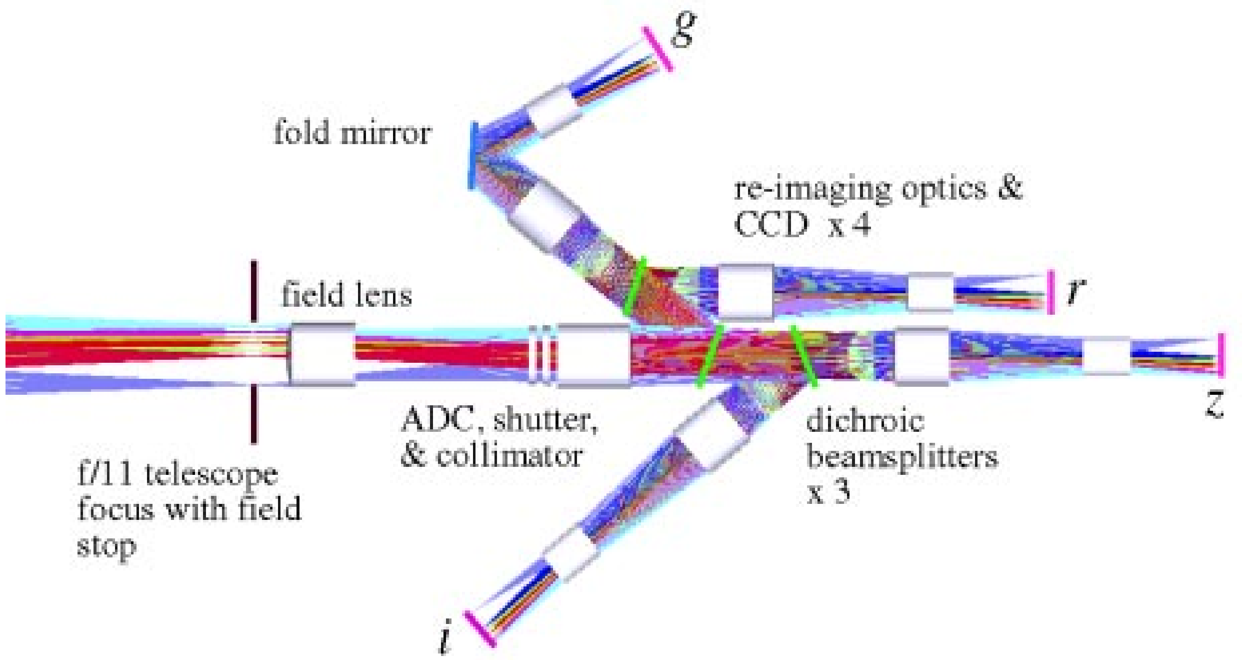

Fig. 1.— The schematic layout of SMI. The lenses shown here are an old design that have additional glass-air surfaces compared to the configurations discussed in this memo.

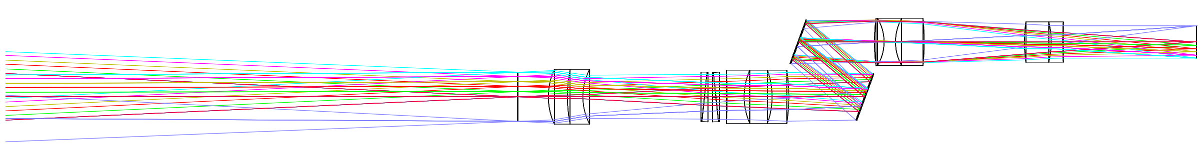

Fig. 2.— Layout of the `magellan330.zmx` design. Lenses are in four groups: a doublet, a triplet, a triplet and a doublet.

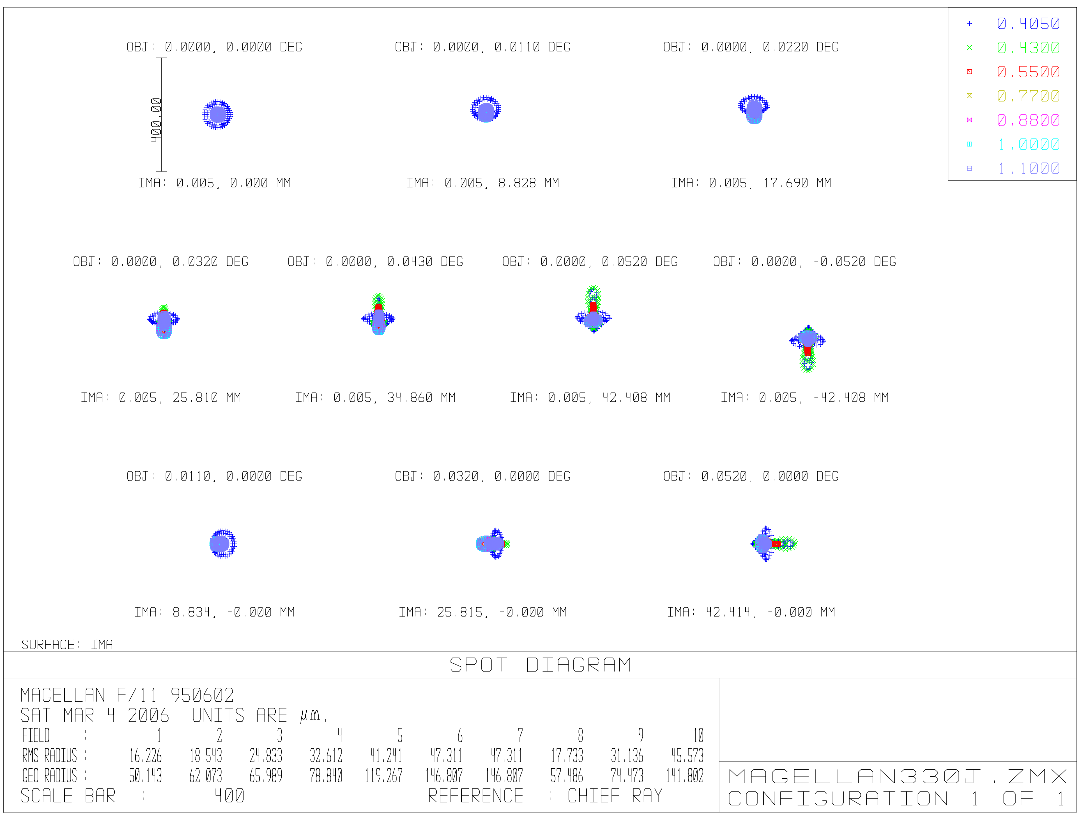

Fig. 3.— Spot diagram of the `magellan330.zmx` design.

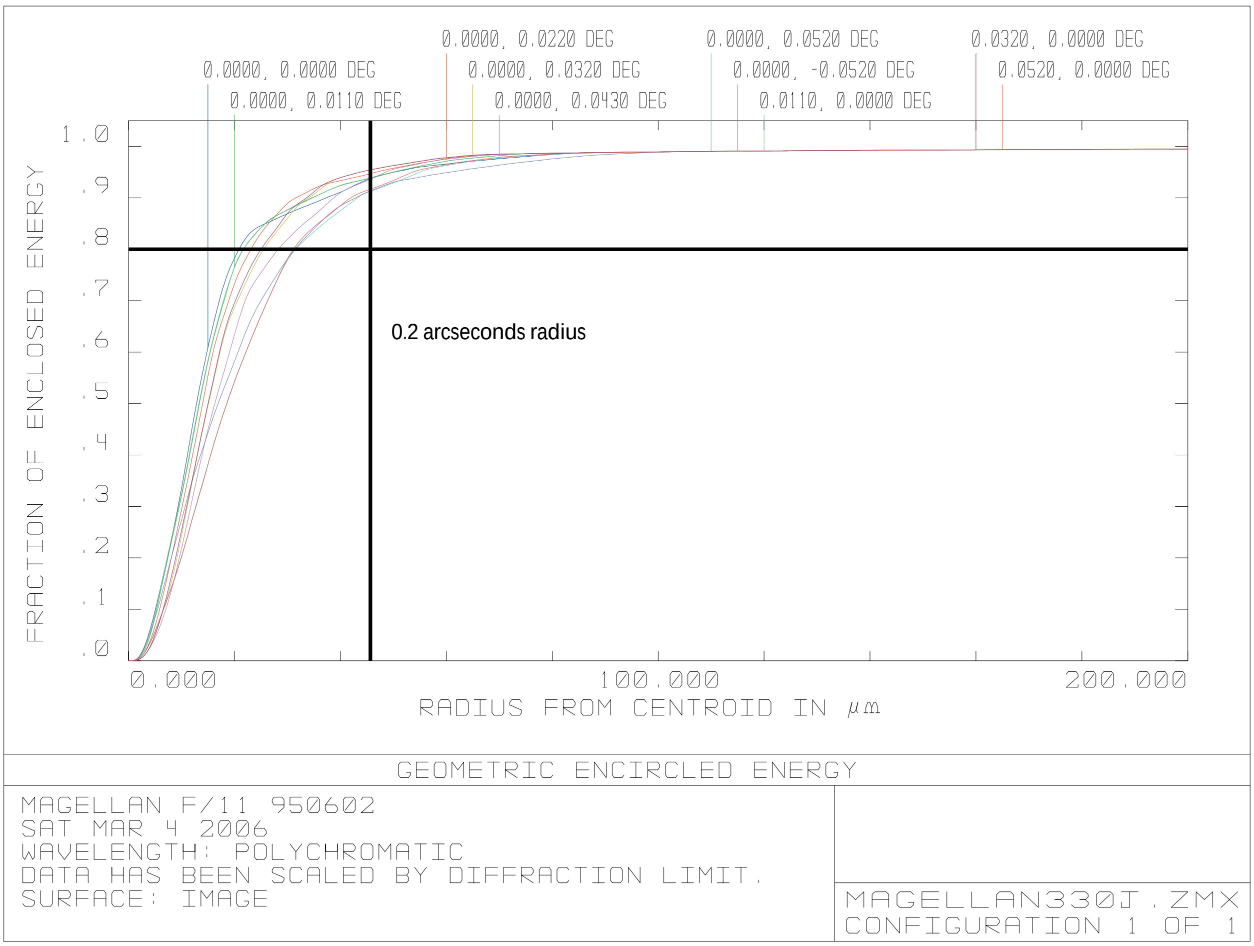

Fig. 4.— Encircled energy plot of the `magellan330.zmx` design.

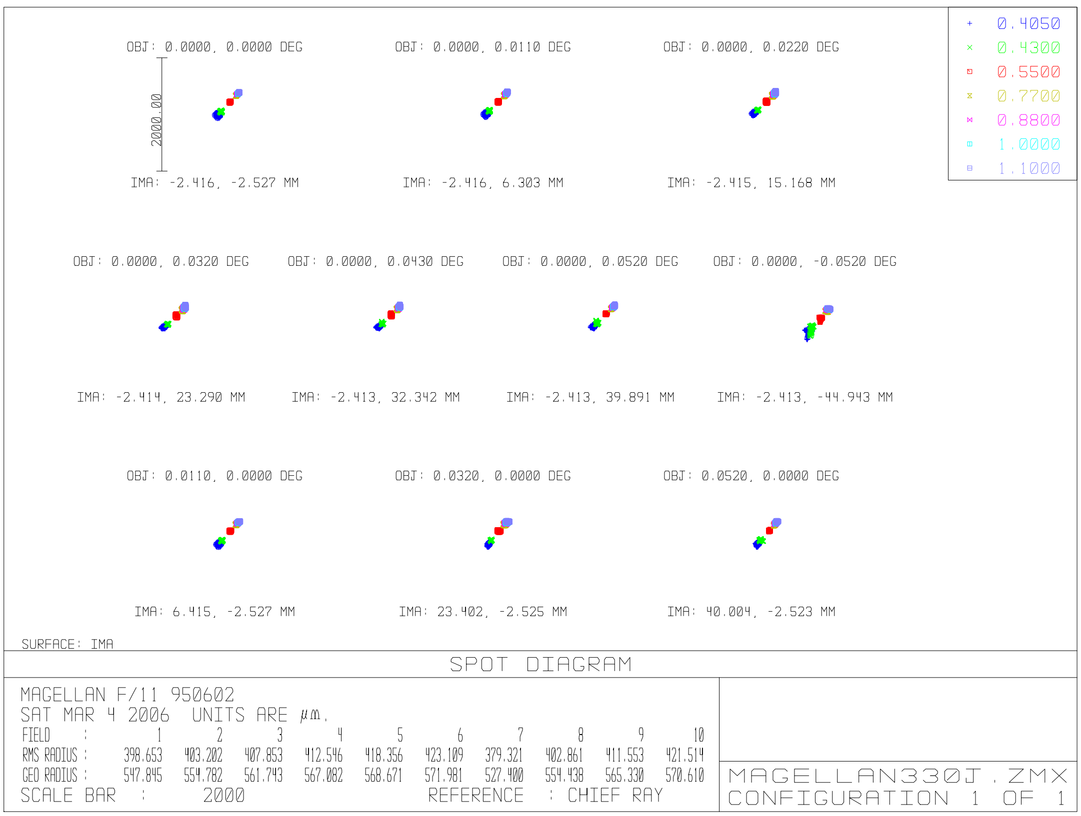

Fig. 5.— Spot diagram of the `magellan330.zmx` design, with the ADC set to half its maximum dispersion.

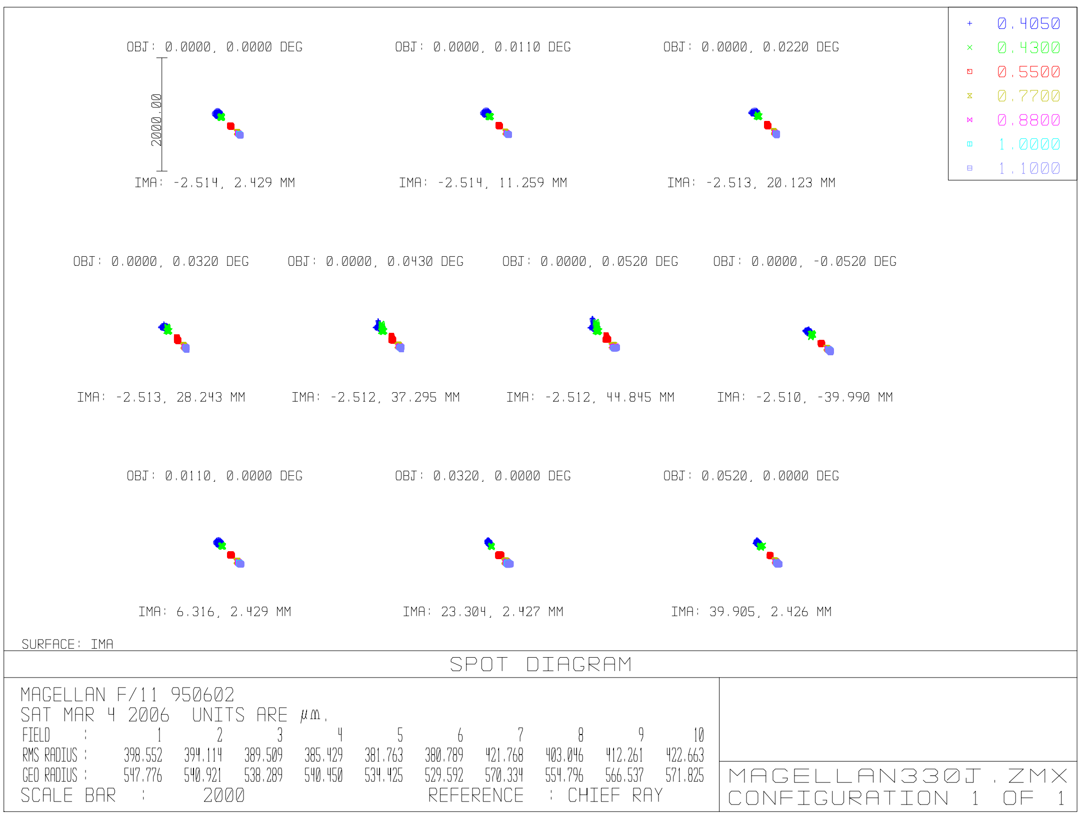

Fig. 6.— Similar to figure 5, a spot diagram of the `magellan330.zmx` design, with the ADC set to half its maximum dispersion, and the ADC rotated.