REQUIRMENTS FOR PYRAMID MIRROR

Spartan IR Camera for the SOAR Telescope

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8 February 2002	Addition of lyot stop and sky position information

This document lists the requirements for a pyramidal mirror in the camera. This mirror will break up the field of view of the camera into quadrants. Like all camera elements, it will operate in vacuum at liquid nitrogen temperatures.

1 Design Considerations

The following sections describe the considerations that limit the dimensions and placement of the pyramid mirror. The discussion assumes a field-flattening lens 7.8 mm thick and 65 mm in diameter and a detector with a 57 mm square housing. The quadrants are numbered by position in the beam travelling from the camera mirror to its focus. Upper left quadrant is 1, upper right is 2, lower left is 3, and lower right is 4.

1.1 Tilted pyramid or tilted detector?

The focal planes of the f/12 and f/21 beams are tilted 9° with respect to each other. To accommodate this tilt, one can either tilt the pyramid mirror or tilt the detectors.

While simple to implement, tilting the pyramid mirror will not reduce overall dead space. If the pyramid is tilted 9° between configurations, the beam will move 18 degrees in space. Given an 80 mm distance from the apex of the mirror to the detector, the beam will move 10 mm on the detector surface. This distance effectively adds 13 mm of dead space to our design, so tilting the pyramid will not work.

Tilting the detectors is more difficult to implement but optically yields the correct solution. A stationary pyramid mirror will only add 3 mm of dead space due to the expansion of the f/12 beam. Therefore, this design assumes a stationary pyramid mirror and detectors that tilt between focal ratios.

1.2 Beam-Lens interference

Interference between the incoming beam and the field-flattening lens drives the allowed distance between the pyramid mirror and the lens. If the lens is too close to the pyramid mirror, the beam coming from the camera mirror will hit the lens before reaching the pyramid mirror. The closest approach between the incoming beam and the lens occurs in quadrant 1 of the f/21 channel (see Figure 1). If the center of the lens is 33 mm from the center of the pyramid mirror, the incoming beam misses the lens by 1.5 mm. The incoming beam misses the lens by 6 mm in quadrant 1 of the f/12 channel. The separations for quadrant 2 are 4 and 8 mm for the f/21 and f/12 channels, respectively. Both quadrants 3 and 4 have separations of 8 mm for the f/21 channel and 4 mm for the f/12 channel (see Figure 2).

1.3 Mirror-Lens interference

Interference between the field-flattening lens and the pyramid mirror is not a problem. There must be a 33 mm space between the center of the lens and the center of the pyramid mirror to prevent beam-lens interference. This distance means the bottom corner of the lens will be 3 mm from the pyramid mirror for quadrants 1 and 2 (see Figure 1). The bottom corner of quadrants 3 and 4 will be 4 mm from the pyramid mirror (see Figure 2). These separations are larger than the smallest beam-lens separation, so the distance from the lens to the pyramid mirror is not a problem.

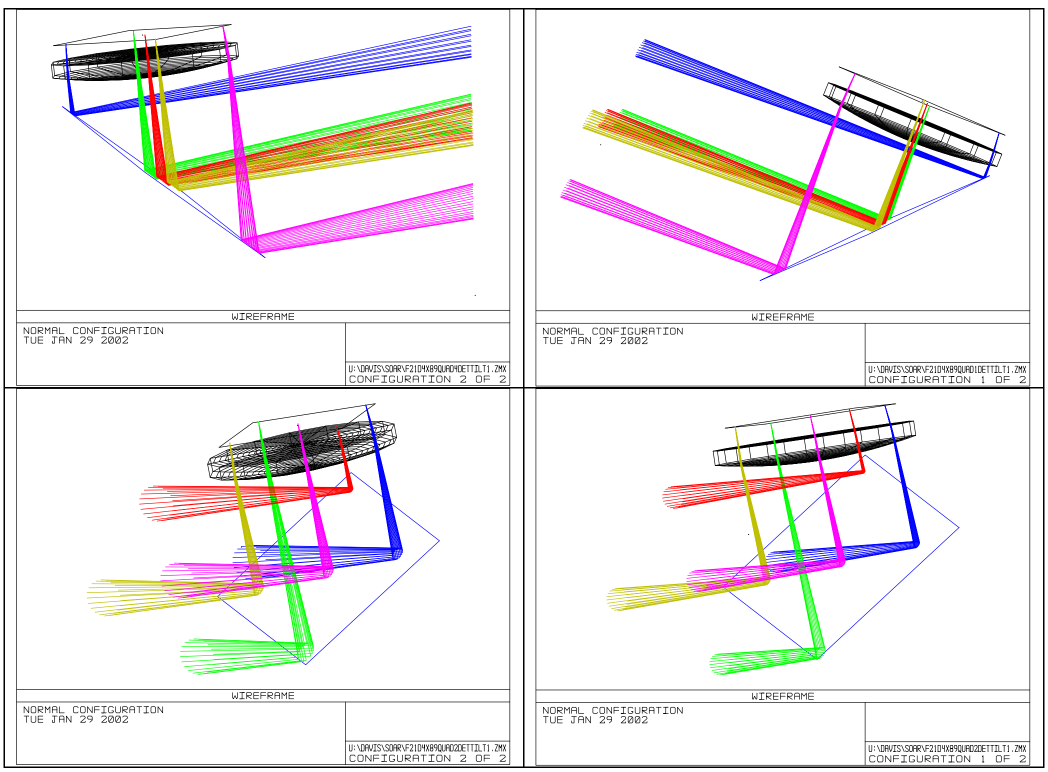

Figure 1 Interference between incoming beam and field flattening lens for (top left) f/12 channel quadrant 1, (top right) f/21 channel quadrant 1, (bottom left) f/12 channel quadrant 2, and (bottom right) f/21 channel quadrant 2.

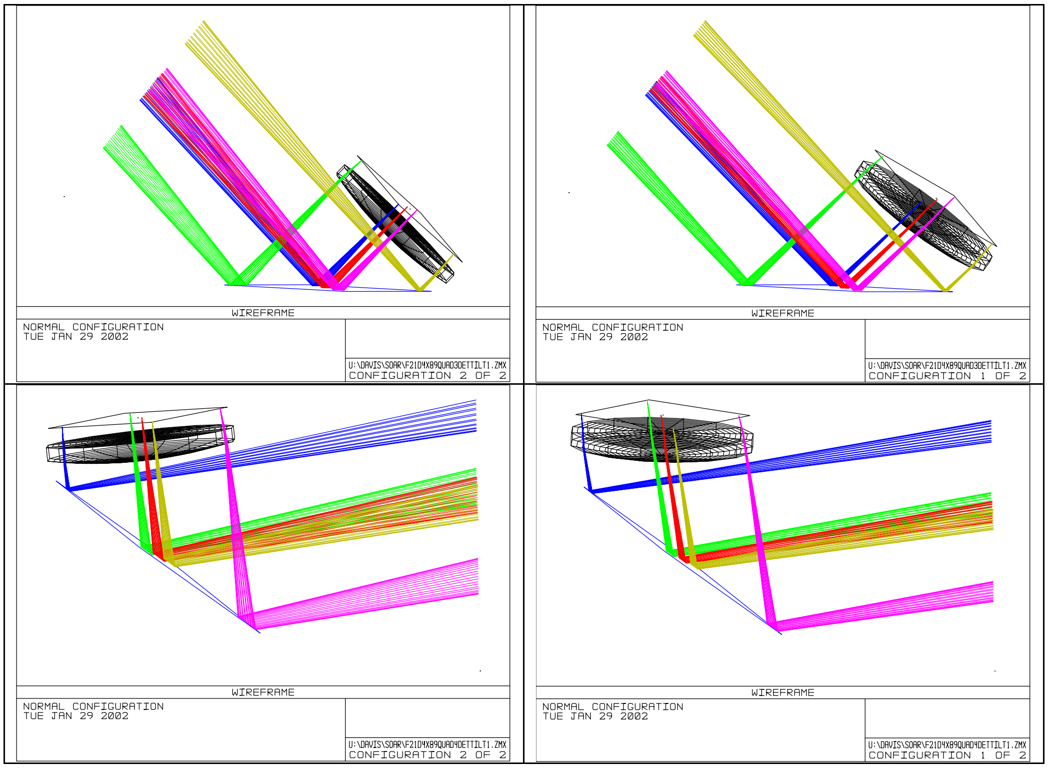

Figure 2 Interference between incoming beam and field flattening lens for (top left) f/12 channel quadrant 3, (top right) f/21 channel quadrant 3, (bottom left) f/12 channel quadrant 4, and (bottom right) f/21 channel quadrant 4.

1.4 Detector corner separation

The pyramid mirror will use a significant amount of the 4 mm dead space allotted to each detector. The pyramid mirror will separate the field of view into four quadrants. This separation means that light in the absolute center of the field of view will not focus on just one detector. A beam that focuses on one detector must be reflected off the pyramid mirror. The apex of the pyramid mirror is 80 mm from the detector. Therefore, a beam that comes to a focus from the apex is roughly 3 mm in radius at the apex in the f/12 channel. The corner of the detector must be offset by 3 mm from the apex.

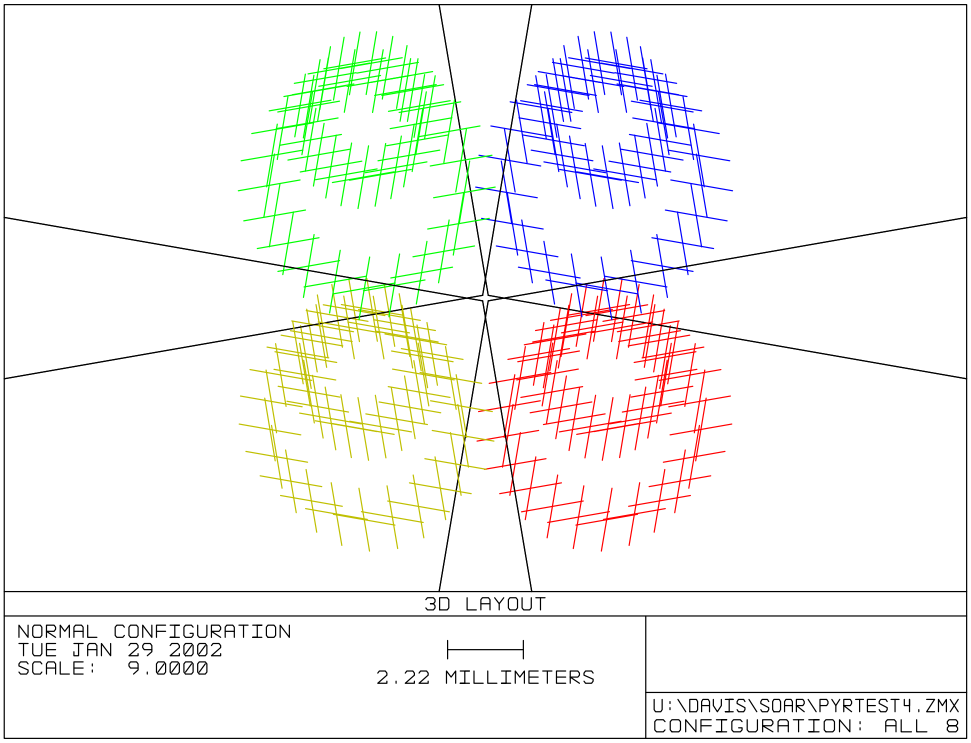

Figure 3 – Apex of pyramid mirror with 3.5 mm dead space surrounding each detector. The pyramid is simulated by four square mirrors tilted 45° with respect to the apex and rotated 90° with respect to each other. Because the mirrors are square instead of diamond shaped, the edges do not appear correct in this figure. The rings represent beams that focus at the corner of each detector. The large rings represent the f/12 channel, while the small rings represent the f/21 channel.

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Furthermore, there is a slight offset between the f/12 and f/21 channels at the pyramid mirror. This offset is caused by the differing incoming tilt between the two beams. The center of field for each channel will be separated by roughly 1.5 mm at the pyramid mirror. Fortunately, the f/12 beam is 2.6 mm wider than the f/21 beam at the pyramid apex. Therefore, most of the offset between channels will be covered by the wider f/12 beam.

A more careful analysis using ZEMAX reveals that if the detectors are offset by 3.5 mm, there is 1.6 mm separating the beams at the apex (see Figure 3). The f/21 beams will come within 0.5 mm of the edge of the pyramid face. This offset would leave 0.5 mm of dead space for other uses.

1.5 Thermal contraction

There will be some thermal contraction as the pyramid shrinks from room temperature to 77 K. The coefficients of expansion for aluminum and fused silica are $2.4 * 10^{-5}$ and $5.5 * 10^{-7}$ per degree, respectively. The contraction of the fused silica may be ignored. The aluminum will shrink by 0.5

% from room temperature to 77K. Given a corner-to-corner distance of 88 mm, the mirror will shrink 0.4 mm over this temperature change. Therefore, there should be 0.2 mm of space at the edge of each mirror to allow for thermal contraction.

1.6 Lyot stop

The center of the lyot stop is in the same position for both channels.

1.7 Sky position

The sky position is virtually unchanged between channels. There is a shift of 0.18 arcseconds between channels.

2 Dimensions

2.1 Pyramid Dimensions

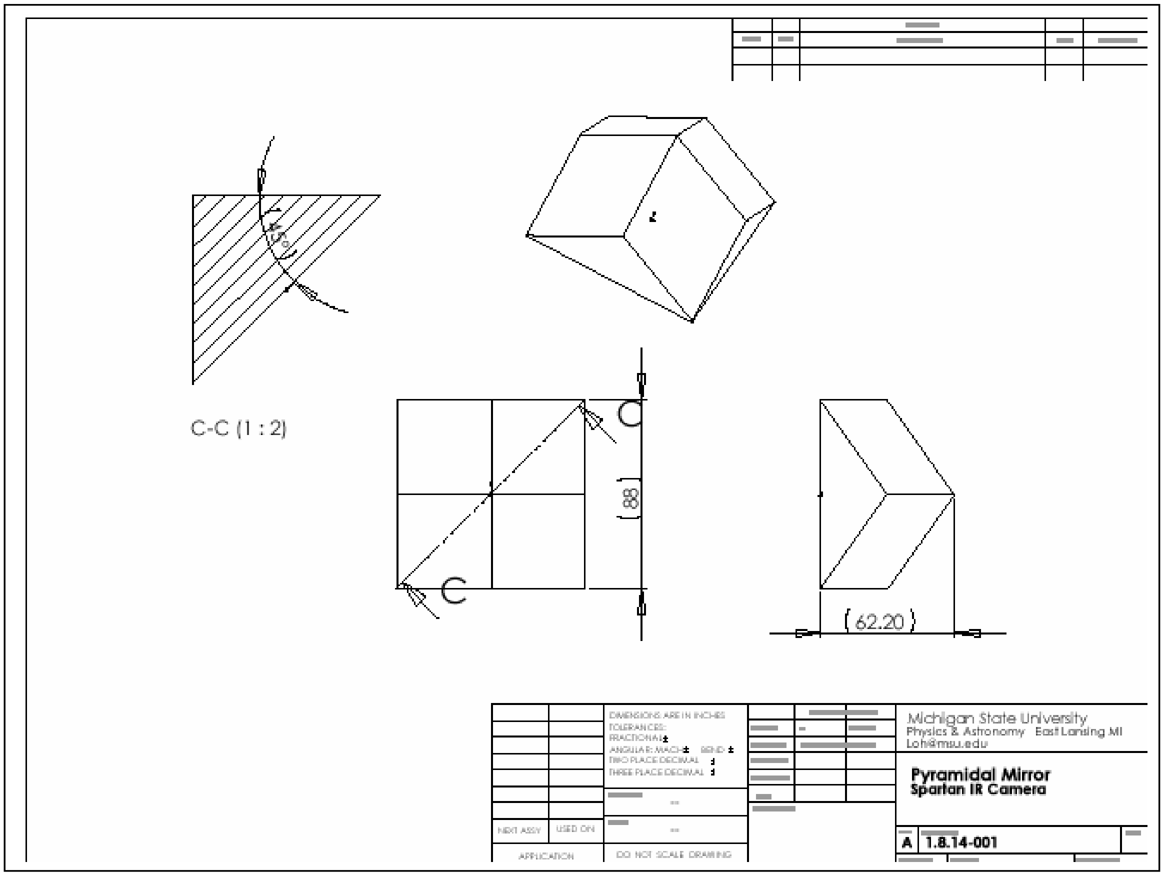
The faces of the pyramid mirror will be diamond shaped due to the angle of incidence. The long axis is 85 mm long, while the short axis is 60 mm long.

2.2 Angle

The sides of the pyramid should be tilted at a 45-degree angle. The angle should be within $\pm$5 arcminutes and measured within $\pm$1 arcminute to satisfy the tilt tolerance ($\pm$2 arcminutes) of the detector plane. This tilt tolerance comes from the 30 μm focus tolerance of the detector.

2.3 Surface Flatness

The surface flatness should contribute no more than 0.0067 degradation to the Strehl ratio. Using Marechal's formula, this degradation relates to surface error (SE) as $(1-0.0067) = \exp[-(2\pi * SE/\lambda)^2]$ at $\lambda = 1.65\ \mu$m. The result is a surface error of 86 nm, or $\lambda/8$ at 633 nm.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ANGULAR: MACH ± BEND ±
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THREE PLACE DECIMAL ±
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APPLICATION
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