Solar-C Prime Focus Field Stop

A progress report for the ATST design group

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Background

The SOLARC off-axis coronagraph is being developed at the Haleakala facilities of the Institute for Astronomy. Jeff Kuhn is the project scientist and Roy Coulter the project engineer. This report describes some interim work to minimize the non-specular scattered light from the primefocus optics assembly. Our experience with the SOLARC Mark I light dump stimulated this effort to modify the original design so that non-focal plane light is dumped to the surrounding telescope dome enclosure. As we show here the modification significantly improves the scattered light performance.

Solar-C is a 0.45 m diameter, f/3.8 off-axis Gregorian system with some similarity to the baseline ATST optical design. The prime focus plate scale is 120 arc-sec/mm. The system is diffraction-limited over an 18 arc-minute field at 1 micron. The final focal ratio is f/18 and the plate scale at Gregorian focus is 40 arc-sec/mm. In practice a 5 arc-minute field stop is used at prime focus to limit down-stream heat loading and better match our current detectors at the Gregorian focus. Figure 1 - 3 detail the optical configuration for SOLARC and the prime focus region.

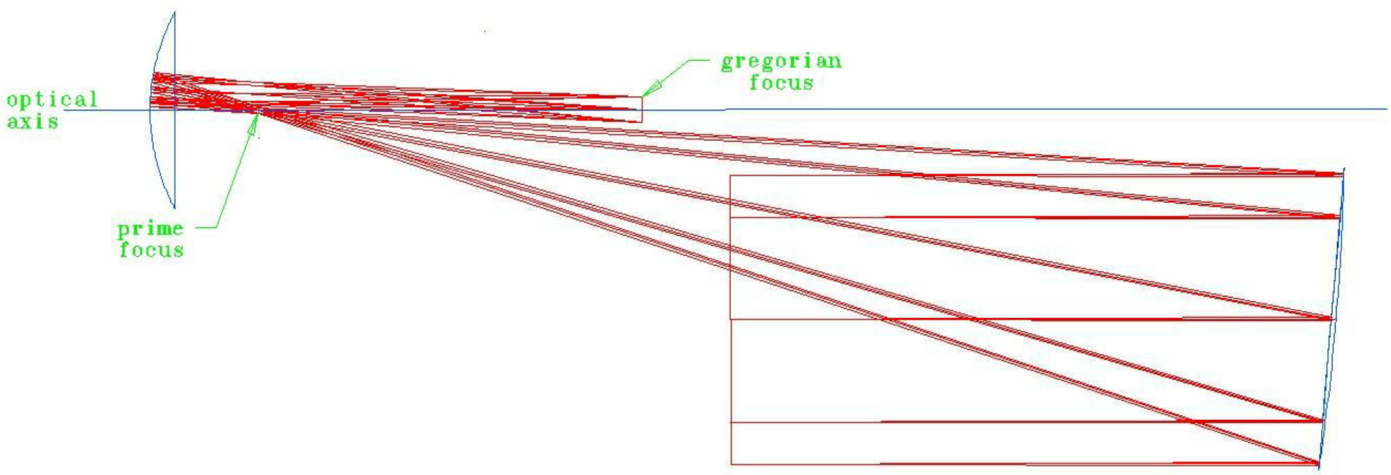

Fig.1 -- A ray trace of the Solar-C off-axis coronagraph.

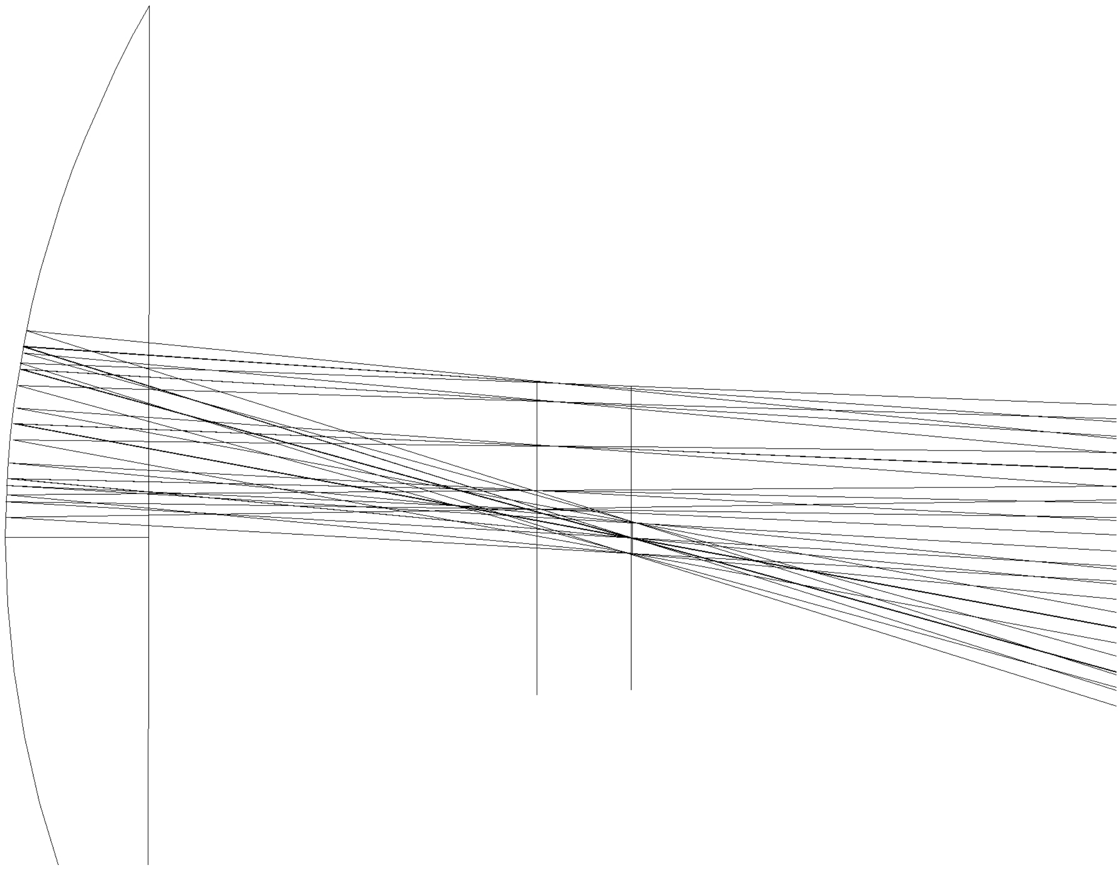

Fig. 2 -- A ray tracing of the prime focus region for the full 18' field.

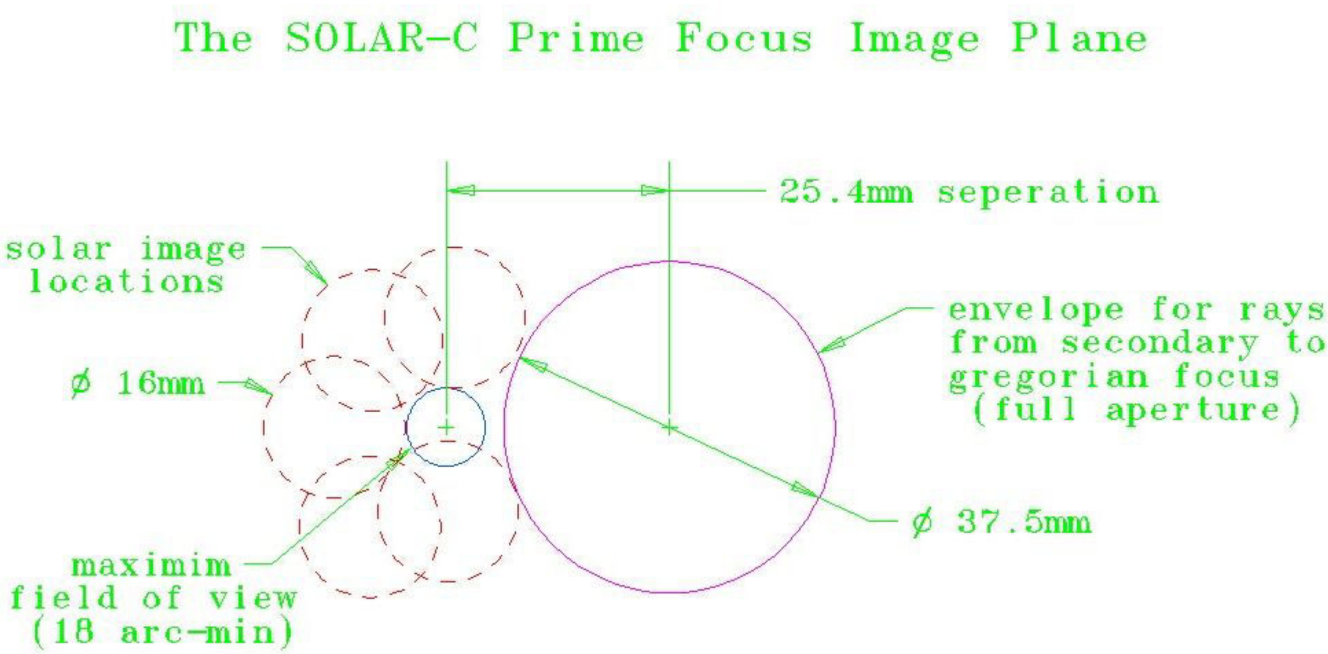

Fig. 3 -- A plan view of the prime focal plane.

The Heat Stop

Our initial efforts produced a heat stop system designed to absorb all the 'waste' solar radiation using a simple, black-anodized aluminum plate as a heat trap near the prime focus. The plate has ¼ in. ID copper tubing embedded in the back surface and the heat is carried away via chilled fluid from a re-circulating chiller. This system performed reasonably well at absorbing the waste radiation except for some heating of the un-cooled base plate due to the small amount of radiation that reflected from the black plate. This problem could have been overcome using a slightly more complex cooling scheme. However, non-specular reflection from the polished aluminum surface that feeds the heat trap proved impossible to baffle. This problem results from a combination of the limited space available and the fact that the rejected light path crosses through the optical axes feeding to and from the secondary mirror. Figures 4 and 5 show the mechanical layout of this system. The cooling system is based on a Neslab re-circulating chiller, model M-33 with a 1.3 gal/min pump. It is easily capable of absorbing the ~200 watts at Solar-C prime focus.

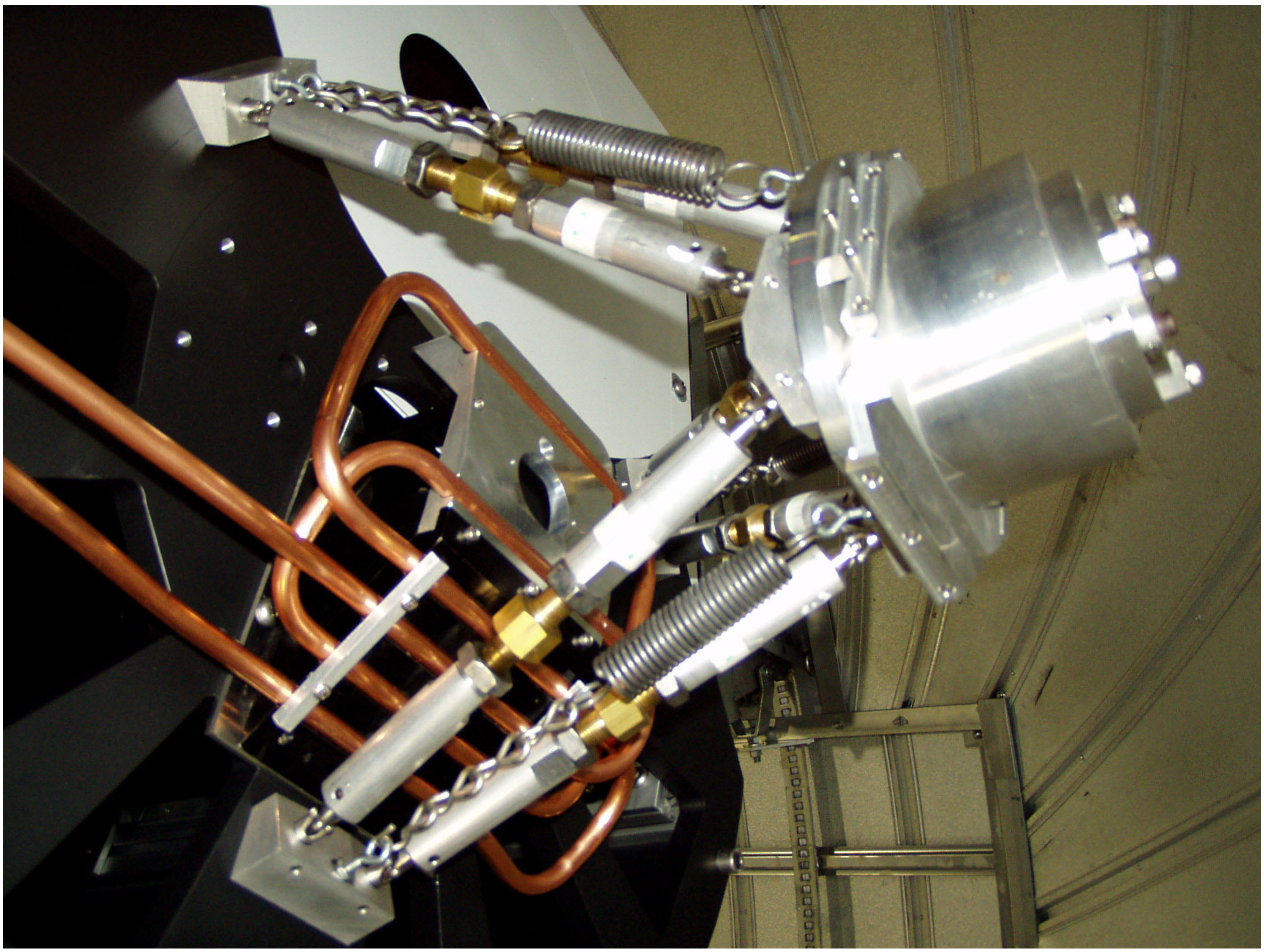

Fig. 4 -- The heat stop in place below the secondary support hexapod. Normally the volume around the secondary is encased in a shroud which was removed for this photograph.

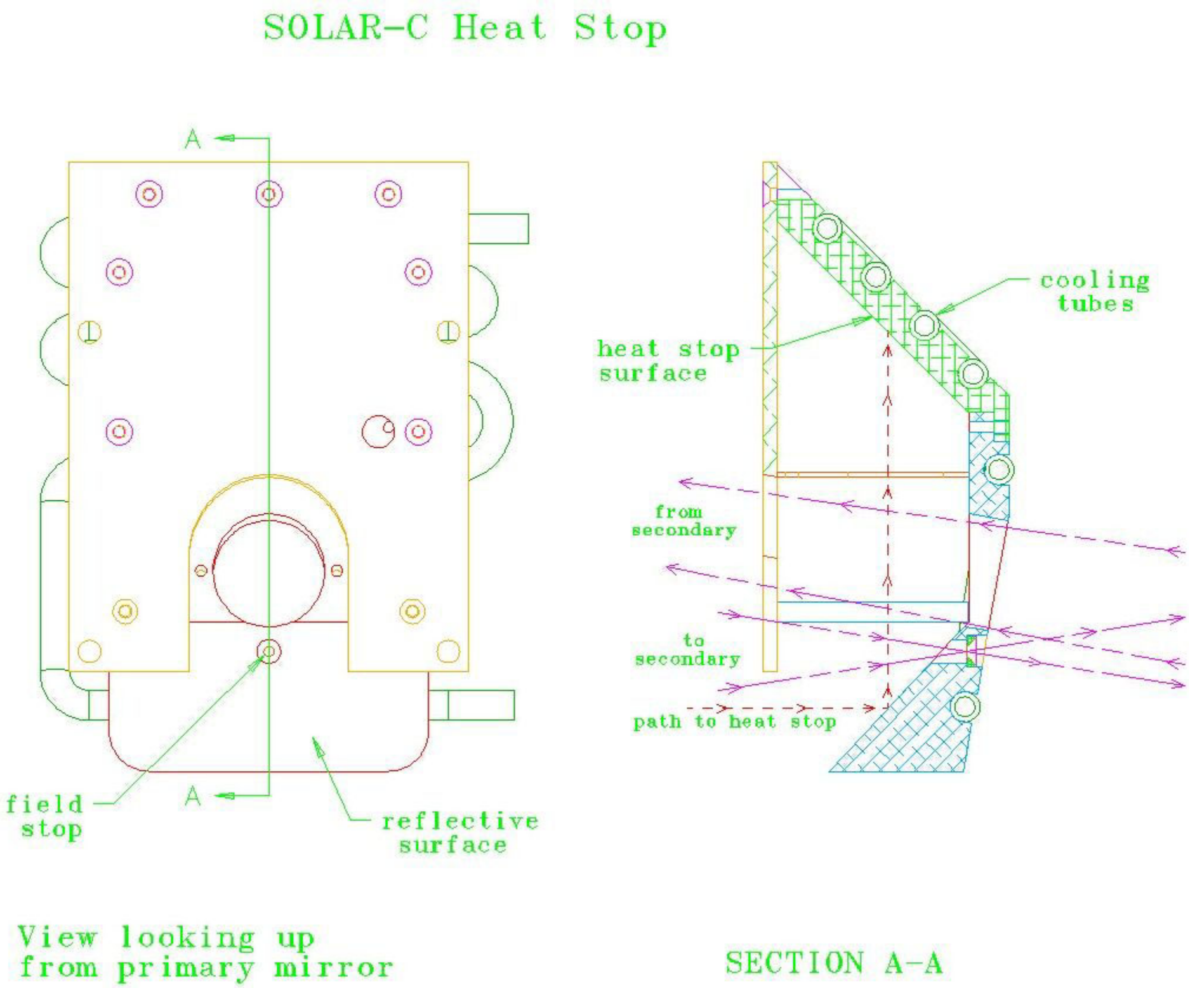

Fig. 5 – A schematic of the heat stop system.

The Heat Reflector

The unacceptable contamination of the Gregorian focal plane by scattered light from the previous heat stop system led us to a new design that completely separates the prime and Gregorian focal spaces except for the path through the field stop. In this case we are no longer able to absorb all the radiation but reflect the 'waste' light into the surrounding dome structure. While this was not considered desirable initially, it is obvious that the rejected image is only a small percentage of the total sunlight passing through the dome slit and onto the internal dome structures. It is, therefore, not a significant addition to the scattered light and dome heating issues that we are already coping with by enclosing the instrument and forcing air flow through the slit and out through the access door at the side of the dome. The heat reflector system is detailed in Figures 6 and 7.
This assembly again uses a tilted aluminum plate with embedded cooling tubes, but here the plate is a polished, reflective surface. A removable field stop isolates the unwanted portion of the solar image allowing a small field (nominal stop is 5 minutes) to pass through to the secondary. A baffle tube blocks any scatter from the reflecting surface and a lateral baffle isolates the continuing path to Gregorian focus and prevents sunlight from passing up through the baffle tube. The baffle tube provides a convenient support for the Lyot stop. Both the field stop and Lyot stop are removeable, so various stop sizes can be utilized.

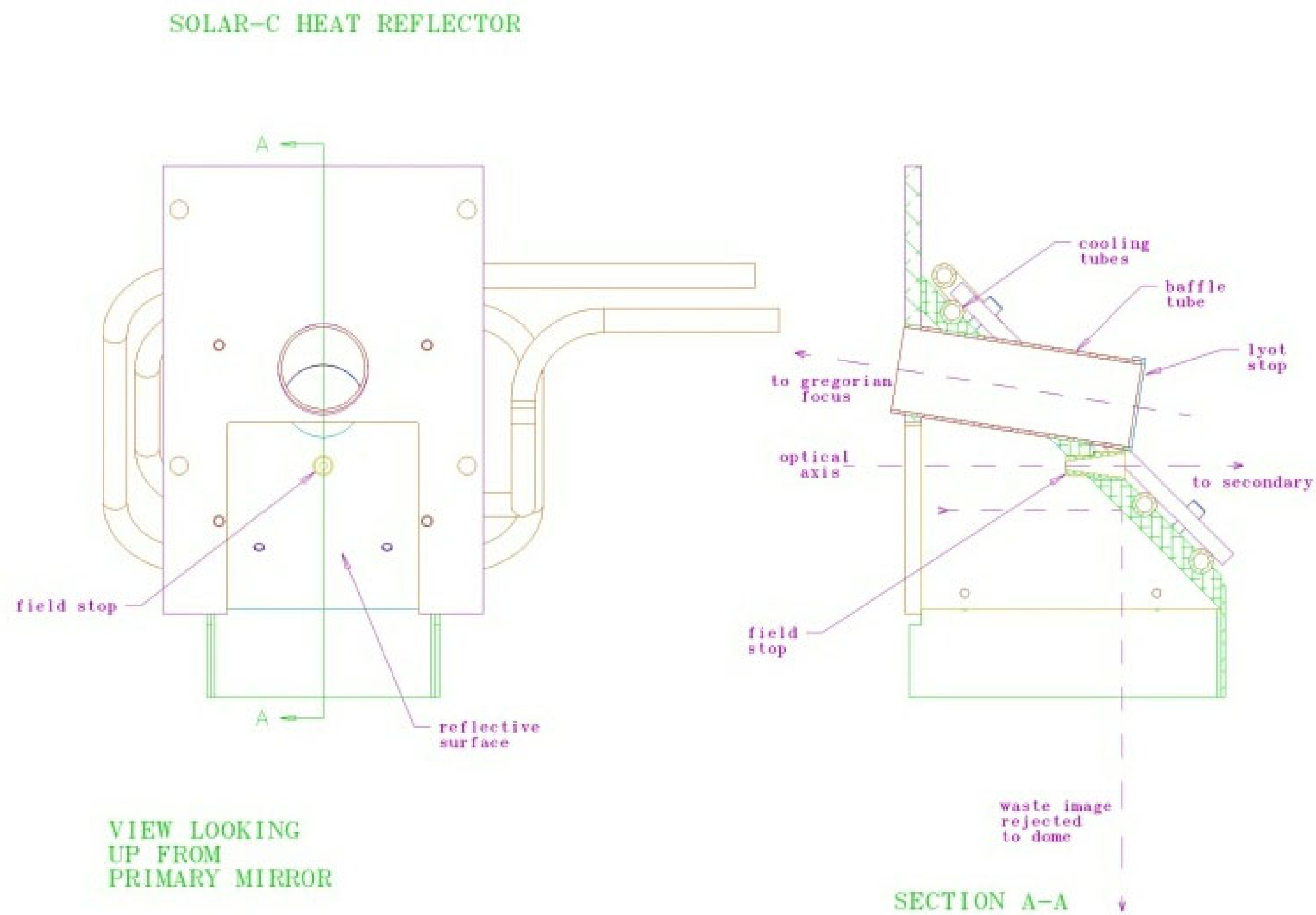

Fig. 6 – Schematic of Heat Reflector. This system, combined with a lateral baffle, isolates the Gregorian focus from the scattered light generated by the reflective plate.

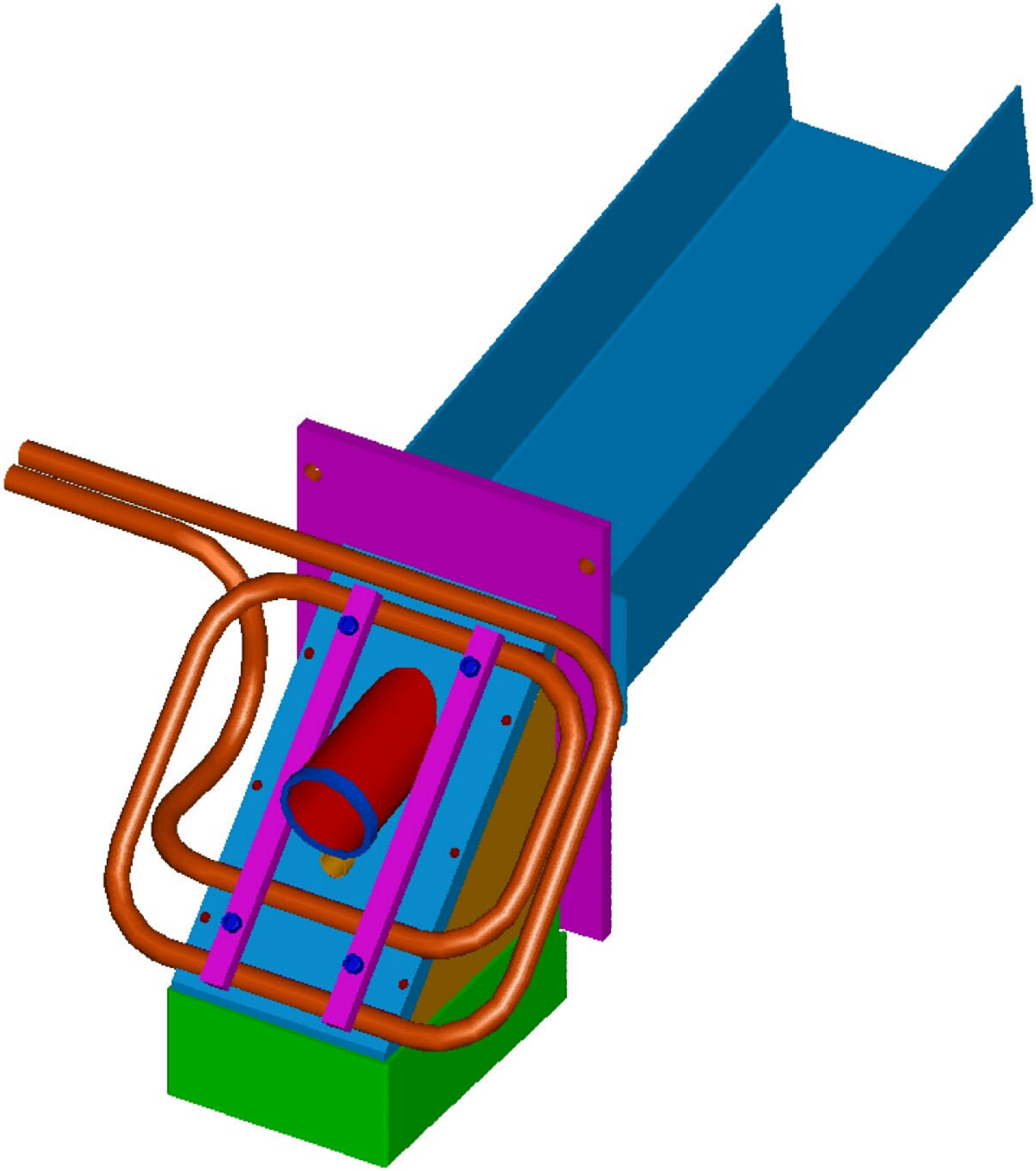

Fig. 7 –Rendered drawing of the heat reflector showing the lateral baffle that protects the Gregorian focus.

Results

Initial results with the heat reflector are quite promising. The chiller easily maintains the assembly within 1 degree of the fluid temperature. An upgrade to a temperature servo that holds the assembly at ambient temperature by means of a flow metering bypass valve should be possible.

We've measured scattered light with a lockin amplifier and optical chopper placed directly between the detector at gregorian focus and the last mounting plate at the top end of the telescope. The detector is a thermoelectrically cooled PbSe single channel photovoltaic detector (EOS Inc. model PBSE 050-TE2-H). It typically operates at a temperature of –50C. We are using a filter mounted on the detector assembly (Spectrogon model BP-3900-200-D) with a center wavelength of 3.9 microns and FWHM of 200nm. The normalized scattered light is measured at a chopping frequency of 100Hz. The telescope aperture is replaced with a 1.2cm diameter hole to observe the disk center. Typical detector voltages are 100mV. The full telescope aperture yields signal levels of about 1mV during coronal observing, with a noise level of about 0.1mV. Observations reported here were obtained from Haleakala on 9/18/02 and 1/30/03. The largest improvements occur for small observing angles from the solar limb.