Infrared Artifact

Characterization: The most puzzling and aggravating artifact of the MOBY 350-700 nm system is a slightly curved line crossing the image plane at about three-fourths height in the spectral dimension (short to long wavelengths). The strength of the artifact is measured to be about 1.5% of signal.   An image of this artifact is provided in Figure 1.

Figure 1. The infrared artifact as it appears under 900-1100 nm light. . Look carefully for a slightly curved vertically oriented line three-fourths of the way across the detector (from left to right).

Careful characterization of the artifact (thanks to Casey Smith) revealed two key features of the artifact, as follows:

1. It is caused (predominantly) by radiation in excess of 900 nm. This can be inferred because: (a) the artifact is not observed when an Edmund Optics 730 nm low pass filter is placed in front of the halogen light source, and (b) the filter blocks almost all light in the 700-900 nm wavelength range.
2. The artifact has a “handedness” to it. When a single fiber is illuminated, the artifact appears one side of that fiber and it appears one the same side of each fiber across the detector array.

The second item was particularly puzzling. Since it is an asymmetry in a symmetric system, it implies that there is a tilt in the system. We measured the tilt of every lens in the system, however, and no material tilt was identified. Since I couldn’t even think of where to look for a tilt, I ignored this matter and sought to find some reflection or combination of reflections that could cause the phenomenon.

Cause: The artifact appears to be caused by a double bounce ghost reflection. The first "bounce" is a reflection off the filter coating on the front face of the prism; the second "bounce" is a reflection off of the front surface of the doublet lens immediately before this prism. Figure 2 illustrates the phenomenon and Figure 3 shows how it appears in a FRED model of the image plane.

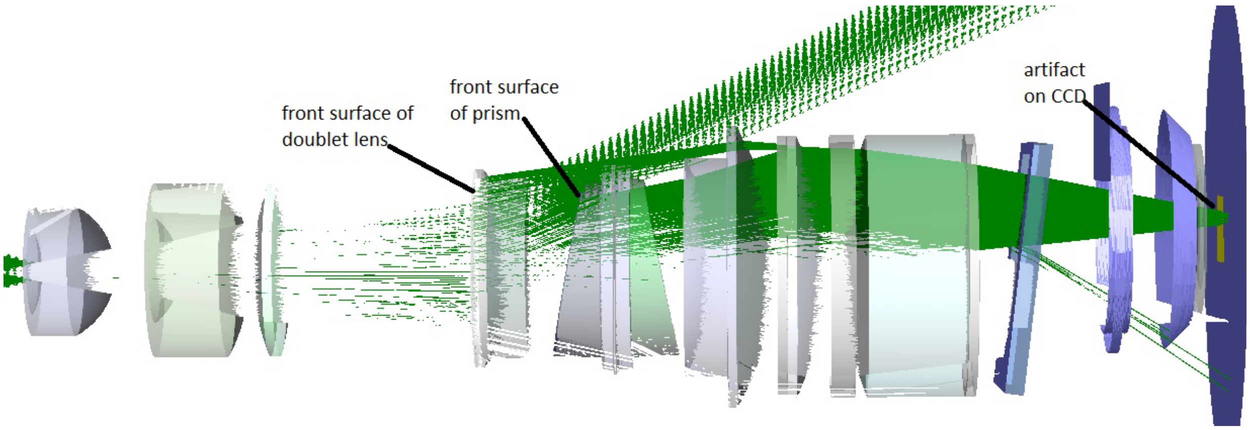

Figure 2. Illustration of the infrared artifact in FRED. Incoming light from slit is colored white. Light reflecting off of the front surface of doublet lens is colored green.

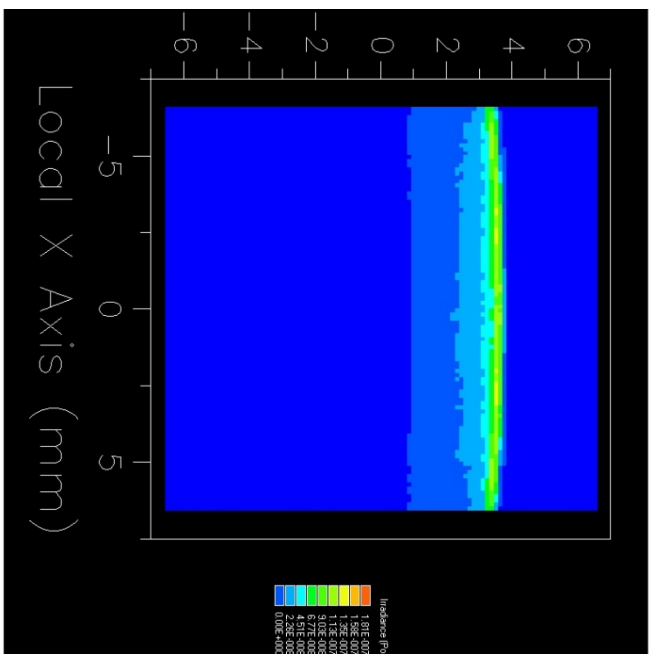

Figure 3. FRED model of infrared artifact on the CCD.

Discussion: Two questions arise here. First, why is this particular double bounce ghost reflection so strong? Second, why does it have the "handedness" noted above? These questions will be addressed in turn.

Most double bounce ghost reflections result a weak signal on the detector and can reasonably be ignored. This infrared artifact is usually strong for several reasons. First, the low pass filter on the front face of the prism reflects a lot of infrared light. Figure 4 shows the amount of reflection off of this filter as a function of wavelength. Note that if the amount of reflection is either 0% or 100% then no signal from the optical pathway described above will appear on the detector. This follows because light that reflects from the prism filter can only reach the image plane is it later passes through this same filter. On the other hand, if the level of reflection is near 50%, then quite a bit of light can make its way through the filter as a result of a double bounce ghost reflection. This 50% level of reflection occurs multiple times in the 900-1100 nm wavelength range.

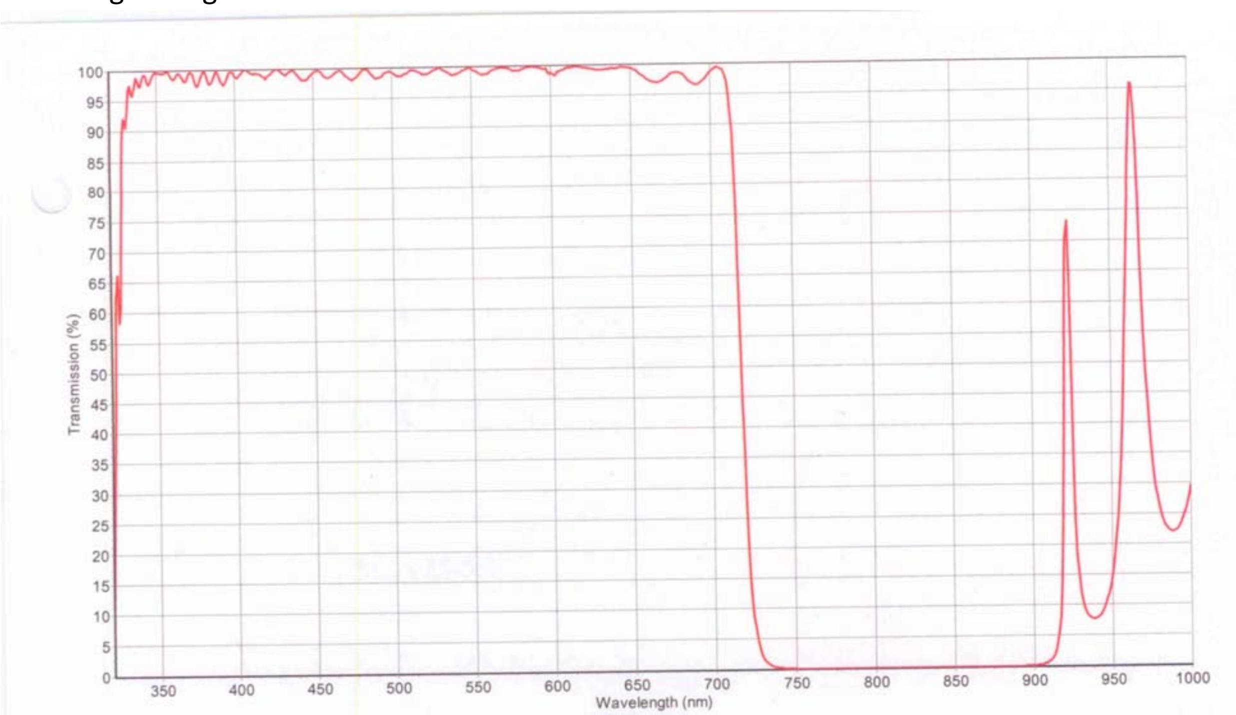

Figure 4. Reflectance of the prism low pass filter as a function of wavelength.

Light reflecting off of the filter then reflects off of the front surface of the doublet lens. This surface has an AR coating with low reflectance in the 350-700 nm waveband, but it has much higher reflectance in the 900-1100 nm range. The coating curve for this surface is shown in Figure 5.

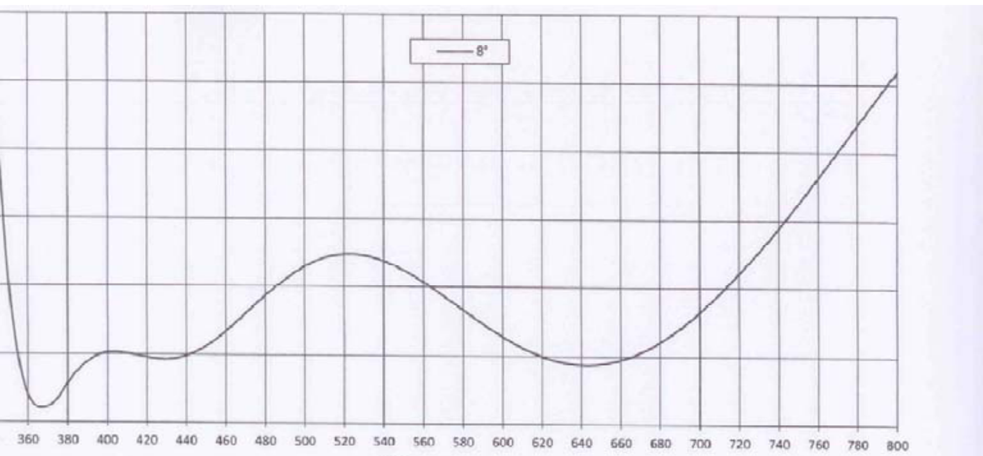

Figure 5. AR coating curve for the surface causing the second “bounce” of the infrared artifact.

After the second “bounce”, radiation causing the infrared artifact passes through the system and onto the CCD. The signal remains strong because the path through the system follows the zero order and hence does not disperse the light spectrally. Zero order diffraction efficiency tends to be pretty low in the 350-700 nm range, since the grating is specified to have high first order diffraction in this range. But in the 900-1100 nm range, much and perhaps most of the radiation takes the zero order path. The net effect of all of this is that the path described above has a pretty strong signal on the detector in the 900-1100 nm wavelength range.

As to the “handedness” effect, this stems from imperfect orientation of the front face of the prism. This prism is attached to the grating, which in turn is mounted in a rotating “clock” mount to facilitate alignment with the slit and CCD. A small tilt in this face is normally compensated for by an offsetting small rotation of the slit. But the effect of the tilt is doubled upon reflection from the prism surface and doubled again by the reflection from the front surface of the doublet lens. The net effect is on the CCD is therefore a noticeable shift in position.

Addressing the problem. Going forward, the simplest way to minimize this problem is to specifying the low pass filter on the prism to block all radiation out to 1100 nm. We will plan on doing so going forward. For the current system, a filter coating that blocks 900-1100 nm radiation can be placed on the filter substrate at the rear of the system. A low pass filter on the light source might be practical as well.