MOBY Blue 397 nm Artifact

As we all know, there is an artifact in the MOBY blue system at about the 397 nm wavelength row. This artifact is readily observed by shining broadband light in the 500-700 nm range into one fiber. This light should and does appear as a spectrally dispersed band of radiation in the appropriate fiber channel. At the same time, however, an artifact or ghost image appears at around the 397 nm row of the diametrically opposite fiber channel. In contrast to the broadly dispersed nature of the radiation in the correct fiber channel, the radiation appearing in the ghost image is spectrally integrated.

Apparently what we are observing is a ghost image of the fiber input that is generated when zero order or undiffracted radiation passes through the diffraction grating. This phenomena is always present in a diffraction grating, although the magnitude of it varies significantly with wavelength. The strength of zero order radiation in the Blue system as a function of wavelength is shown in the attachment, "Blue grating 0th order transmission.jpg." It is evident that zero order radiation becomes strong above 500 nm.

Normally, zero order radiation is not a problem because it hits the image plane well below the CCD. This is evident in Figure 1, where the place where the main 0th order beam hits the image plane is labeled. This beam hits the shutter, where most of it is absorbed. Some radiation from this beam glances off, then reflects off of other elements within the spectrometer and eventually finds its way to the CCD. This radiation is unfocused, however, and does not present a material problem.

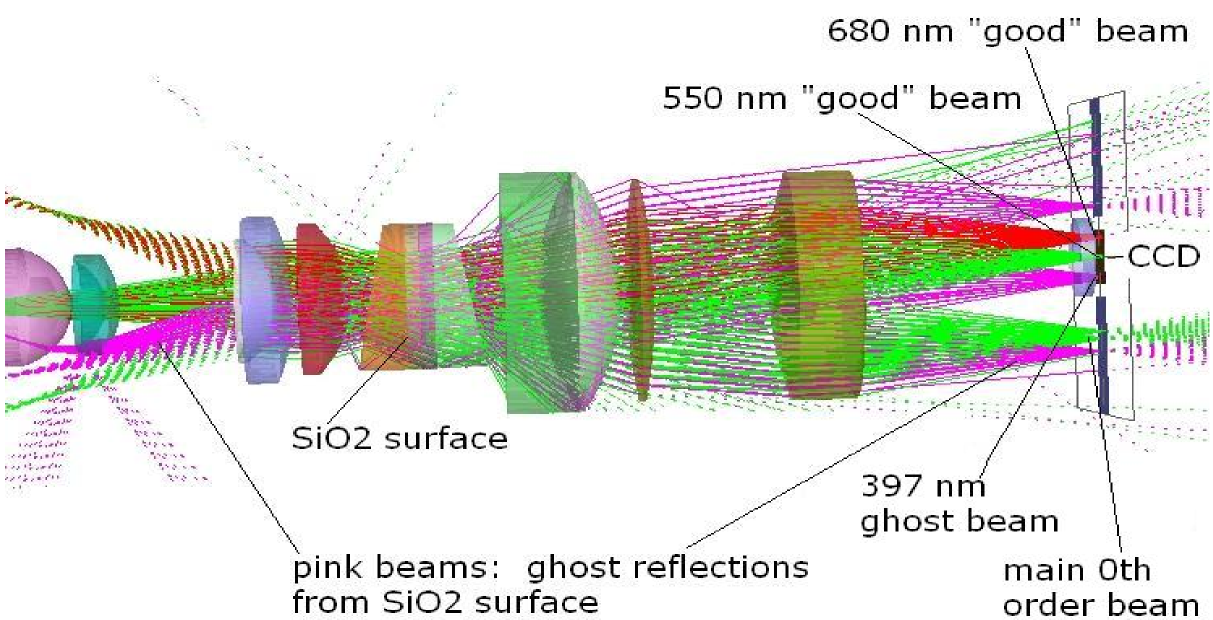

Figure 1: Ghost images from SiO2 surface.

Zero order radiation that reaches the detector in focused form takes a different pathway. The latter pathway originates at the CCD at the pixels at which the "good" radiation is focused. According to source data, the Pixus camera with a broadband coating reflects about 20% of incident radiation at 550 nm and somewhat more at longer wavelengths. This radiation retraces the forward path in reverse, passing through the grating and becoming spectrally reintegrated in the process. It then hits a planar SiO2 surface immediately before the grating. The problem of concern occurs at this point.

During the manufacturing process, I had an SiO2 protective coating placed on the flat face of the prisms that comprise the PGP in the Blue system. This was done because the material is very acid sensitive (other materials used in the system are worse) and I knew the prisms needed to be sent to one manufacturer for the filter coating and another to bond the prisms to the grating. With all this handling, a protective coating seemed prudent. Unfortunately, this coating created a larger index of refraction differential that would otherwise occur. The index of refraction of the SiO2 coating is about 1.46, while the index of refraction of the prism on one side of it is 1.55 and the index of the optical cement on the other side is 1.56. These index differentials cause a reflection of about .1% per interface, which normally would not be significant. But in this case the reflection is significant for two reasons: 1) the surface is planar and the light is collimated, so the reflected radiation hits the image plane in almost perfect focus, and 2) the beam that actually hits the CCD after a bounce off this surface is the zero order beam, which is spectrally integrated and hence two orders of magnitude more intense than is its spectrally dispersed counterpart.

After reflecting off of the SiO2 surface, radiation in the ghost pathway under analysis passes through the grating as 0th order radiation and passes through the optics to the CCD. It hits the CCD at just about the 397 nm wavelength row. It hits the CCD in the fiber channel that is diametrically opposite to the channel corresponding to the illuminated fiber. This is illustrated in Figure 2.

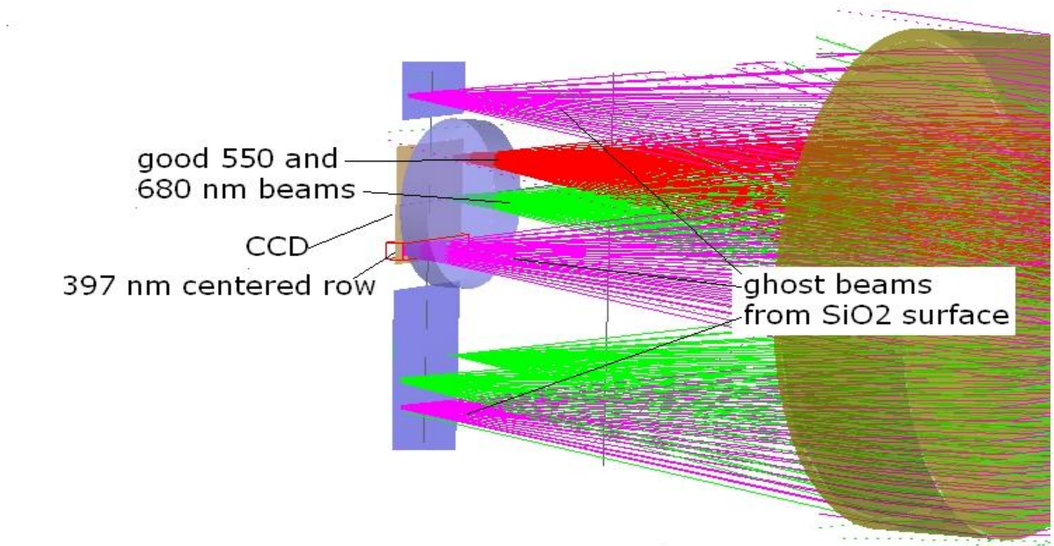

Figure 2: Positions of the "good" beams and the ghost beam on the CCD.

The intensity of this ghost pathway is computed in Table 1. Only the major sources of transmission loss are included, as other transmission losses are not material to the outcome. As Table 1 shows, the total power of the ghost beam on the detector is a factor of .00002 time the incident beam power when calculations are made at 550 nm and .00006 times the incident beam power of the calculations are made at 650 nm. The power of the specular or "good" beams at these wavelengths are .58 and .50, respectively. In order to get the relative intensity of the two beams, we must take account of the fact that the ghost beam is spectrally integrated. Somewhat arbitrarily, I multiplied the intensity of each ghost beam by a factor of 100 to account for this fact. With this adjustment, the relative intensity of the ghost beam to that of the spectrally dispersed beam seems to be between 0.5% and 1.0%. This conclusion seems to be consistent with Stephanie's data.

Table 1: Computation of Relative Intensity of Ghost Beam

Power of ghost beam		
surface/event	550 nm	650 nm
transmission of 1st order radiation through grating	0.7200	0.6500
reflection off of CCD	0.2000	0.2300
transmission of 1st order radiation through grating	0.7200	0.6500
reflection off of SiO2 surface on prism face	0.0020	0.0020
transmission of 0th order radiation through CCD	0.1400	0.3800
efficiency of CCD	0.8000	0.7700
total power	0.00002	0.00006
Power of specular beam		
transmission of 1st order radiation through grating	0.7200	0.6500
efficiency of CCD	0.8	0.77
total power	0.58	0.5
Spectral integration factor	100	100
Relative intensity	0.0041	0.0116

In order to mitigate this ghost image, the Blue PGP must be remade without the SiO2 protective coating. This would reduce the intensity of the ghost image by an order of magnitude. Further reductions could be realized by index matching the grating substrate (currently BK7, index = 1.52) with the optical cement (index = 1.56).