Progress in Implementation of the Portable Remote Imaging Spectrometer (PRISM) Coastal Ocean Sensor.

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Abstract: **PRISM is a pushbroom imaging spectrometer currently in its second year of development at the Jet Propulsion Laboratory, intended to address the needs of airborne coastal ocean science research. We give an overview of the instrument functionality and then describe progress in component and subsystem fabrication. In the second year, all critical components have been received and most have been integrated into their respective subsystems. The design of the vacuum enclosure has also been completed. We present results from the telescope and spectrometer subassemblies, the focal plane electronics, and the overall system assembly implementation.**

I. INTRODUCTION

PRISM fills a need in coastal ocean science for high spatial and temporal resolution spectral measurements to complement the capabilities of Earth-orbiting satellites. It was conceived in response to a proposal call from NASA's Ocean Biology and Biogeochemistry Program. Development was initiated in September 2009 and delivery is scheduled for 2012, at which time PRISM is expected to become available for use by NASA investigators. The rationale guiding PRISM design has been described in [1].

PRISM integrates two independent instruments in one package: an imaging spectrometer covering the visible and near-infrared (VNIR) range, and a short-wave infrared (SWIR) spot radiometer. The basic specifications are given in Tables 1 and 2.

TABLE 1
SPECTROMETER SPECIFICATIONS

Spectral	Range	350-1050 nm
	Sampling	3.1 nm
Spatial	Field of view	33.1 deg
	Instantaneous FOV	0.95 mrad
	Spatial swath	610 pixels
	Spatial resolution	0.3-20 m
Radiometric	Range	0 – 75% R
	SNR	2000 @ 450 nm *
	Polarization variation	< 2%
Uniformity	Spectral cross-track	>95% **
	Spectral IFOV mixing	< 5% ***

*: at an equivalent 10 nm sampling and 12 fps, reference radiance R = 0.05, 45° zenith angle
**: straightness of monochromatic slit image (pixel fraction)
***: registration of spectrum to array row (pixel fraction)

TABLE 2
SWIR SPECIFICATIONS

Spatial	FOF/IFOV	1.9x1.9 +/-0.1 mrad
Spectral	Channel 1 center	1240 nm
	Ch. 1 bandwidth	20 nm
	Channel 2 cener	1610 nm
	Ch. 2 bandwidth	60 nm
Radiometric	SNR	>350
	Ch. 1 ref. radiance	0.054 $\mu W/cm^2$ sr nm
	Ch. 2 ref. radiance	0.017 $\mu W/cm^2$ sr nm

II. SPECTROMETER OPTICAL SYSTEM

The complete spectrometer unit comprises the telescope and spectrometer subassemblies. The design has been given in some detail in references [1.2]. At present, the telescope and spectrometer optomechanical subassemblies have been completed. The telescope was tested interferometrically and found to exhibit a wavefront error similar to the design, indicating that alignment tolerances have been met. The telescope performance through field is shown in Fig. 1. Although the telescope is designed as an axisymmetric system, small deviations from that condition can actually improve performance. Integration of telescope and spectrometer is scheduled for summer 2011.

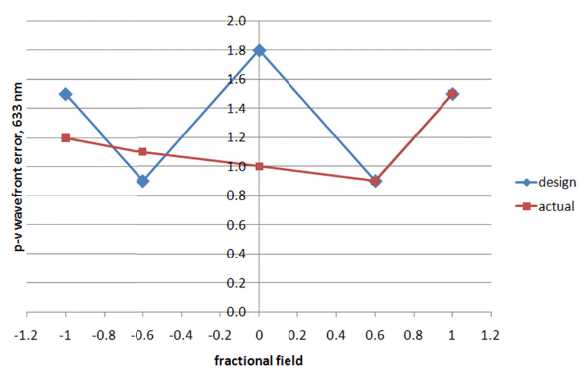

Fig. 1. Measured wavefront error of assembled telescope for five field positions.

The spectrometer subassembly is shown in Fig. 2 during the alignment stage. Its most critical component is the diffraction grating. The grating has been fabricated by JPL's Microdevices Laboratory through electron-beam lithography techniques. Fig. 3 shows a photograph and Fig. 4 the groove profile taken with an atomic force microscope.

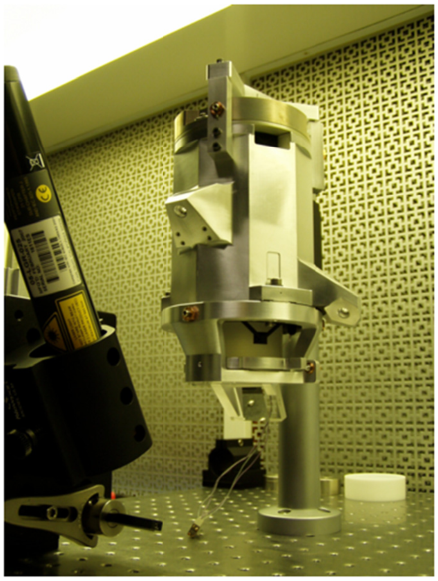

Fig. 2. Spectrometer subassembly and alignment laser.

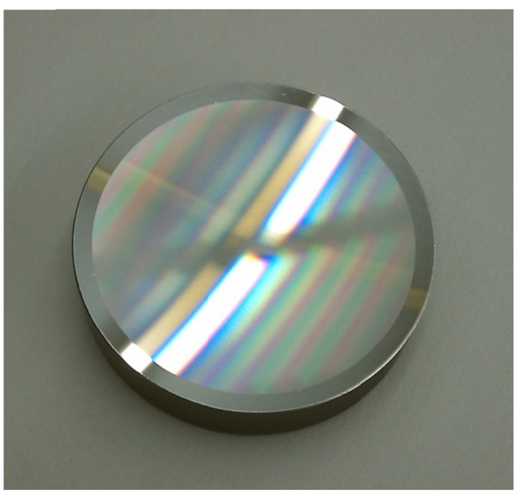

Fig. 3. Photograph of shaped-groove concave diffraction grating.

The expected efficiency and polarization sensitivity can be predicted from the measured groove profile with high accuracy by modeling the groove profile in PCGrate software. The prediction is shown in Fig. 5. Close agreement between such predictions and measured efficiency has been found in all cases. The measurements indicate that the grating passes its requirement of <1% polarization sensitivity. The groove shape also achieves the required broadband response that balances the signal to noise ratio through the wavelength band 350-1050 nm.

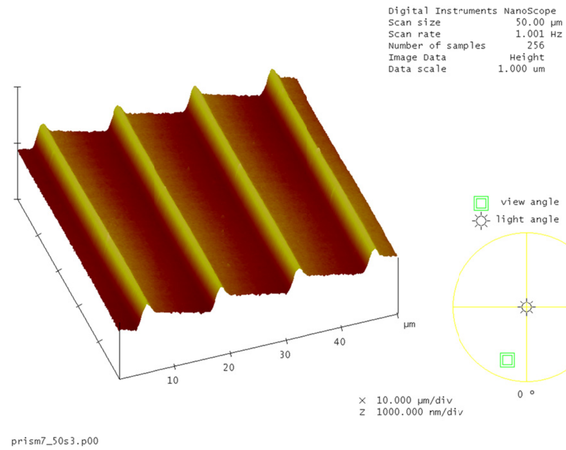

Fig. 4. Atomic force microscope scan of grating grooves.

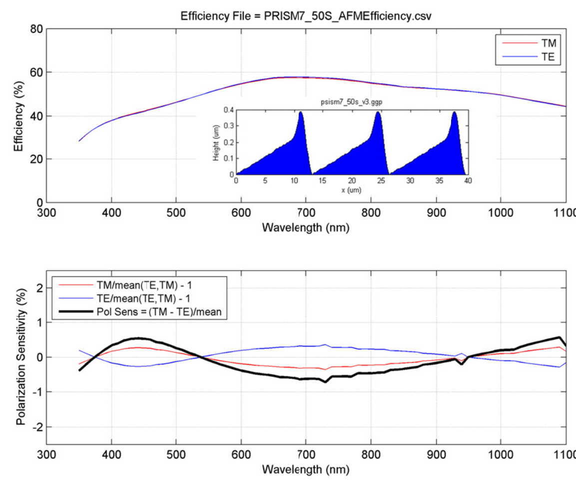

Fig. 5. Predicted efficiency (top) and polarization sensitivity (bottom) for the groove profile of Fig. 4.

III. SLIT ASSEMBLY AND STRAY LIGHT CONTROL

Several precautions have been implemented to mitigate stray light concerns in PRISM. The spectrometer slit has been displaced off-axis so that reflected light from the detector does not find a direct path back through a different grating order. The main optical element has been sized so as to avoid reflections from the ground cylindrical surface. Two baffles are used inside the spectrometer. The detector area has been isolated from the slit and telescope through black-painted surfaces. High-quality broadband anti-reflection coatings have been applied on the order-sorting filter front surface and the refractive element surfaces. Finally, a novel slit assembly has also been implemented that utilizes an absorbing Si surface and practically eliminates back-reflection from the slit. This is achieved by etching a subwavelength structure on the surface of the wafer. The slit itself is formed microlithographically on a thin silicon nitride membrane. The slit is then bonded on the input prism face with a suitable spacer. The assembly is shown in Fig. 6.

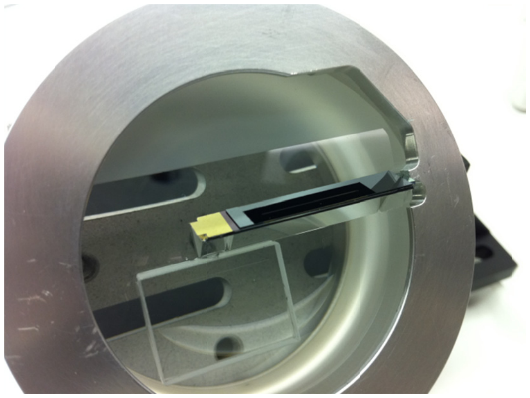

Fig. 6. Slit assembly bonded to the input prism face, as seen from the telescope side.

A high quality antireflection coating has been applied to the spectrometer refractive parts and the absence of a strong reflection is discernible in Fig. 6. The coating reflectivity was measured by the manufacturer on a witness sample and is shown in Fig. 7.

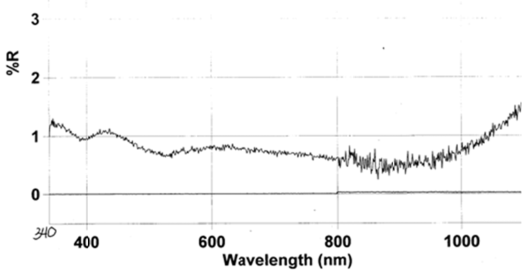

Fig. 7. Reflectivity of spectrometer refractive surfaces through wavelength.

Finally, we show in Fig. 8 the measured scatter background between grating orders. It can be seen that this background remains well below 1E-3 which is the overall system requirement for a bright spectral line.

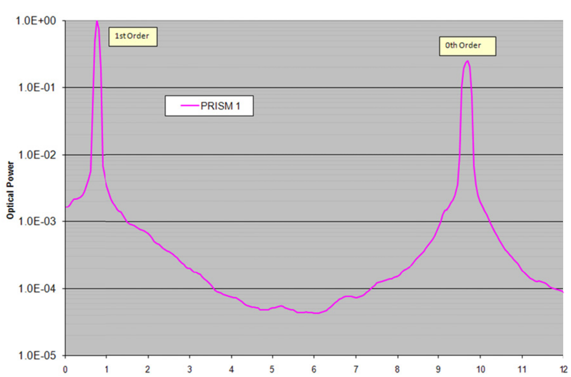

Fig. 8. Scatter background from grating between diffracted orders.

IV. PHOTODETECTOR AND ELECTRONICS

PRISM utilizes the Teledyne HyVISI 640x480 area array with snapshot readout. The detector has been delivered and tested. It was found that the edge pixels (a band of about 25 pixels all around the array perimeter) exhibit unacceptably high dark current at room temperature. The effect however diminishes rapidly with decreasing temperature. This issue is expected to force operation at a lower temperature than originally envisioned, by perhaps 10-15°C. Fortunately our thermal system design is capable of delivering this performance. The exact temperature of operation will be decided at system integration, when it will be possible to balance this dark current effect against temperature stability at various operating temperatures.

The detector readout electronics and cabling have also been completed and noise and linearity tests performed. Fig. 9 shows the result of the linearity test. A small correction will be required to bring the response into the specified 99% linear range.

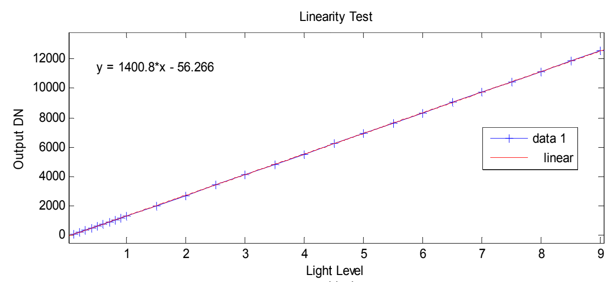

Fig. 9. Detector linearity test result.

V. SWIR AND SYSTEM ASSEMBLY

PRISM is comprised of two instruments, a VNIR imaging spectrometer and a SWIR spot radiometer. The SWIR radiometer design is detailed in reference [1]. It is composed of a telescope, and relay with beam splitter / filters for the 1240/1610 nm channels. Fig. 10 shows the assembled SWIR radiometer optical sub assembly.

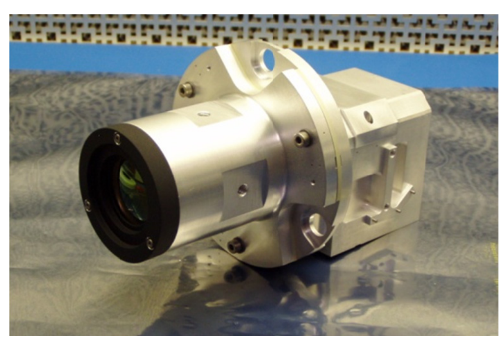

Fig. 10. SWIR opto-mechanical assembly

In order to maintain stability in varying thermal environments during operation, both instruments are thermally isolated in a vacuum enclosure. Temperature stability is maintained using thermoelectric coolers. Fig. 11

shows a cross section of the optical head assembly with outer thermal enclosure, imaging spectrometer (left) and SWIR radiometer (right).

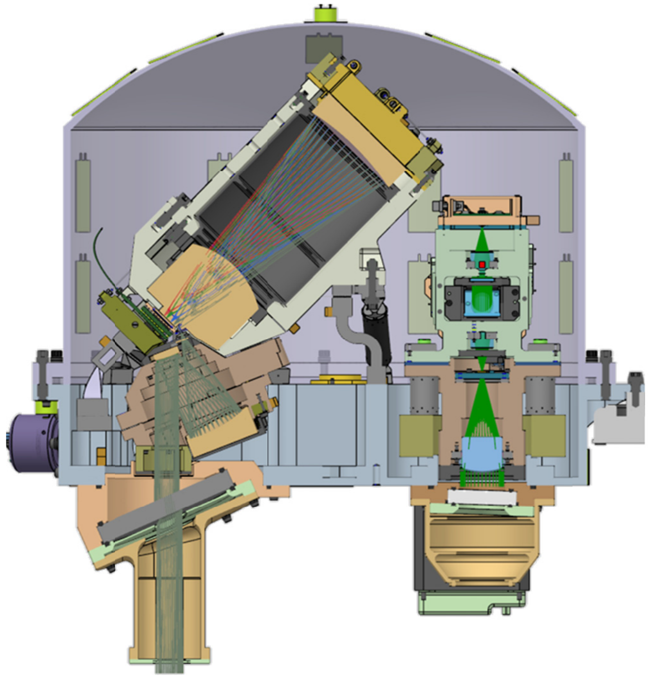

Fig. 11. Mechanical design of complete system.

The optical head is mounted to the aircraft interface using passive vibration isolators center about its center of gravity. Fig. 12 shows the optical head assembly with INS/GPS, vacuum transducer, feedthroughs, vacuum valve, and a notional aircraft interface with the focal plane electronics box. The instrument with aircraft interface fits in a 0.5x0.5x0.5m volume.

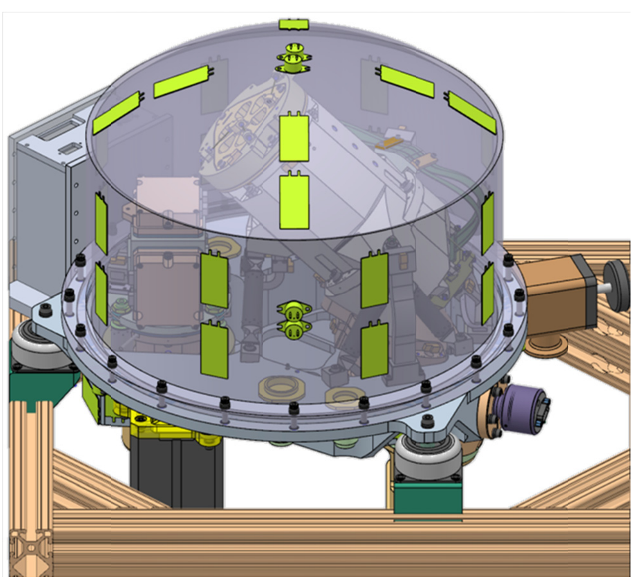

Fig. 12. Optical Head System Layout.

VI. CONCLUSIONS

PRISM implementation is progressing as planned. Important subsystems have been assembled and the performance of components is within tolerance. Complete system integration is scheduled for the fall of 2011, followed by system characterization and calibration.

ACKNOWLEDGMENTS

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