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RSS Acceptance Tests and Pre-deployment Characterization

Summary

The RSS was originally developed at ASRC. Several versions of RSS prototypes (including UV-RSS) were deployed at SGP and NSA ARM sites between 1997-2003 At least 12 papers were published with research based on data from these deployments (see tables in Appendix I and publication list in Appendix II).

The RSS technology with a new opto-mechanical design was transferred to YES, Inc. The first unit ever built by YES, Inc. was purchased by ARM in 2001. The unit arrived to ASRC in September 2001 for acceptance testing and characterization. Hereafter this instrument is referred to as RSS105 (see Appendix III).

The tests at ASRC discovered several problems that required investigation and subsequent return (on two occasions) to YES, Inc. for modifications. The modifications included: (1) pre-amp retuning to reduce the pulse undershoot, (2) adding aperture and painting black parts of the foreoptics to eliminate ghosts and reduce stray light, (3) redoing the casting impregnation and eliminating grease coupling in CCD-TEC interface to eliminate outgassing, (4) replacing CCD after discovering thermoluminescence effect that most likely resulted from previous contamination, (5) moving the dynamic range suppressing color glass filters from the before-the-slit location to the before-the-lens location to improve radiometric stability (see Appendix IV).

Additionally a frame was designed and built at ASRC to mount the RSS105 on the pad SGP. The frame permits to change RSS position from vertical to horizontal for calibration with the Licor calibrator which currently is the only NIST traceable radiometric field calibrator.

To process RSS raw output into irradiances responsivity, wavelength-to-pixel registration, cosine response and linearity had to be measured. To provide scientists ability to model RSS irradiance resolution, slit function (including stray light) and noise had to be characterized. The characterization was performed at ASRC in April and May 2003 (see Appendix V).

The results of characterization showed that resolution and the spectral range are within the specs. Stray light is similar to that in RSS prototypes. The readout noise is better than in RSS102 prototype by factor of 2. As expected, the dominant noise component behaves like Poisson noise. Linearity does not require correction. Cosine response is typical for this type of diffuser.

RSS105 was deployed on May 10, 2003 to participate in the Aerosol IOP. SGP staff was trained to calibrate with Licor, Portable Calibrator and Oriel spectral lamp calibrator.

Appendix I: Comparison of RSS103 and RSS102 prototypes with RSS105

Table 1. Field Experience

	RSS103	RSS102	RSS105
Successful Deployments	SGP 08/97-08/98 NSA 02/99-08/99 SGP 09/01-06/02	SGP 07/99-08/01	SGP 05/03-??/??
Instrument's major shortcomings	Wavelength stability in NIR due to poor temperature control and air pressure changes Temperature control during hot Summer days	Temperature control during hot Summer days	TBD
Failure mode	Enclosure TE cooler Communication between RSS micro and CCD micro boards	CCD array CCD control board	TBD
Number of papers published that used RSS data	12^*	1	0

^*) See the Appendix II

Table 2. Irradiance Spectrum

	RSS103	RSS102	RSS105
Useful pixels	450 out of 512	990 out of 1024	990 out of 1024
Spectral Range	360-1050nm	360-1050nm	360-1050nm
Resolution fwhm	0.97nm at 360nm 3.65nm at 550nm 15.90nm at 950nm	0.27nm at 360nm 0.83nm at 550nm 3.13nm at 950nm	0.26nm at 360nm 0.83nm at 550nm 3.13nm at 950nm
Out of band rejection	<10-5	<10-5	<10-5
Slit function	Symmetric truncated Gaussian	Symmetric truncated Gaussian	Asymmetric, undershoot on rhs of downward slope

Table 3. General Design

	RSS103	RSS102	RSS105
Mechanical design	ASRC: aluminum box and foreptics	ASRC: aluminum box and foreptics	YES/ASRC: aluminum casting and stainless steel foreoptics
Optical design	ASRC: fused silica, two 60° prisms, plncvx lenses, f1=100mm f2=150mm AR coatings and black paint on prism bases	ASRC: fused silica, two 60° prisms, plncvx lenses, f1=200mm f2=200mm No coatings	ASRC: fused silica, two 60° prisms, plncvx lenses, f1=200mm f2=200mm No coatings
Foreoptics	Spectralon diffuser, 100micr slit	Spectralon diffuser, 20micr slit	Spectralon diffuser, 20micr slit
Filters*	none	Dynamic range compressing: BG24-airgap-UG3 before the slit	Dynamic range compressing: BG24-epoxied-UG3 before first lens
Shutter	Uniblitz : exposure defined by shutter, 5 clicks per shadowband cylce	Uniblitz : electronic exposure, 2 clicks per shadowband cylce	Uniblitz : electronic exposure, 2 clicks per shadowband cylce
Temperature control And parameters	Bang-bang analog TE Enclosure Cooler Enclosure 18°C Optics 25*C Foreoptics 29*C	Digital PID's A/C Enclosure Cooler Enclosure 16°C Optics 25*C Foreoptics 29*C Slit/Filters 35° C	Analog PID's No Cooler Enclosure N/A Optics 49*C Casting 45 Foreoptics 45*C
Air purge pressure control**	Close loop filtered air purge pressure=ambient+Δ	External dry air purge pressure control valve	Dry air filled sealed optics and foreoptics external dry air purge
Shadowband attachment and control	From MFRSR RSS micro board ASRC firmware	From MFRSR RSS micro board ASRC firmware	From MFRSR RSS micro board section of combo board ASRC firmware
Data output	19200 bauds serial port from RSS micro board to external computer	19200 bauds serial port from RSS micro board to external computer	19200 bauds serial port from RSS micro board section of combo board to "linux box"
Frame	ASRC: A-frame	ASRC: A-frame	ASRC: Box frame

			with calibrator shelf
Calibration position	Vertical and horizontal	Vertical and horizontal	Vertical and horizontal

*) In RSS105 filters without a spacer originally were mounted before the slit. At ASRC the filters were removed and replaced with 1” epoxied filters mounted before the first lens where a better temperature control was expected.

**) Originally RSS105 came from YES, Inc. filled with dry nitrogen. To finish modifications at ASRC prior to RSS105 deployment in time we were unable to refill the casting with nitrogen and we ended up filling it with dry air.

Table 4. Detector Array

	RSS103	RSS102	RSS105
Detector array	Hamamatsu: 512 NMOS	EEV: 1024 CCD open electrode	EEV: 1024 CCD open electrode
Detector cooling	None 24°C	ASRC: 2 TECs, +7°C, Wavelength Electronics PID	YES: 1 TEC –3°C YES control PID
Detector array control	Hamamatsu control board ASRC16 bit A/D board	ASRC control and 16 bit A/D board Digital emulation of dual slope integrator	YES control and 16 bit A/D board with analog dual slope integrator
Signal linearity	No correction necessary	Necessary 5% correction	Excellent
Readout noise 1 sigma***	±3.5cts	±5.0cts	±2.3cts
Pulse response	Symmetric truncated Gaussian	Symmetric truncated Gaussian	Asymmetric, undershoot on rhs of downward slope

***) This is a single readout noise per pixel in counts. Counts range from 0 to 65535. RSS103 has low readout noise but it operates on significantly higher flux levels than RSS102 and RSS105.

Appendix II: Publications with RSS data in refereed journals

Harrison, L. , P.Kiedron, J.Berndt and J. Schlemmer, The Solar Spectrum 360 to 1050 nm from Rotating Shadowband Spectroradiometer (RSS) Measurements at the Southern Great Plains Site, Journal of Geophysical Research (2003)

Kiedron, P.; Berndt, J.; Michalsky, J.; Harrison, L., Column water vapor from diffuse irradiance, Geophys. Res. Lett. Vol. 30, No. 11, 1565, (2003)

Kiedron, P., J. Michalsky, B. Schmid, D. Slater, J. Berndt, L. Harrison, P. Racette, E. Westwater and Y. Han, A Robust Retrieval of Water Vapor Column in Dry Arctic Conditions Using the Rotating Shadowband Spectroradiometer, , J. Geophys. Res. 106, 24,007-24,016, 2001.

Michalsky, J.J., Q. Min, P.W. Kiedron, D.W. Slater, and J.C. Barnard, A Differential Technique to Retrieve Column Water Vapor Using Sun Radiometry, Journal of Geophysical Research, 106, D15, 17,433-17,442. 2001.

Min, Qilong and Lee C. Harrison, and Eugene E. Clothiaux Joint statistics of photon pathlength and cloud optical depth: Case studies, Journal of Geophysical Research, 106, 7375-7386, 2001.

Schmid, B., J. Michalsky, D. Slater, J.C. Barnard, R.N. Halthore, J. Liljegren, B. Holben, T. Eck, J. Livingston, P. Russell, T. Ingold, and I. Slutsker, Comparison of columnar water vapor from solar transmittance methods, Applied Optics, 40, 1886-1896, 2001

Mlaver , E.J., S.A. Clough, Brown, P.D., L. Harrison, J. Michalsky, P. Kiedron, and T.R. Shippert,Comparison of Spectral Direct and Diffuse Solar Irradiance Measurements and Calculations for Cloud-Free Conditions, Geophys. Res. Lett., 27, 2653-2656, 2000

Harrison , L., M. Beauharnois, J. Berndt, P. Kiedron, J. Michalsky, and Q. Min, The rotating shadowband spectroradiometer (RSS) at SGP, Geophys. Res. Lett., 26, 1,715-1,718, 1999.

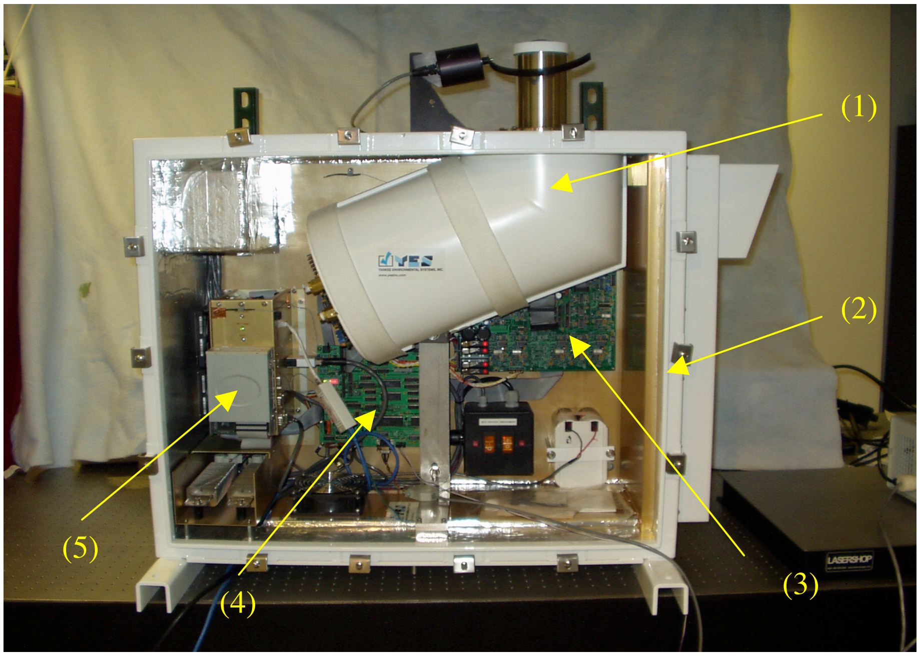
Kiedron , P.W., J.J. Michalsky, J.L. Berndt, and L.C. Harrison, Comparison of spectralirradiance standards used to calibrate shortwave radiometers and spectroradiometers, Appl. Optics, 38, 2,432-2,439, 1999.

Michalsky, J., M. Beauharnois, J. Berndt, L. Harrison, P. Kiedron and Q. Min, O2-O2 absorption band identification based on optical depth spectra of the visible and near-infrared, Geophys. Res. Lett. 26, 1581-1584, 1999

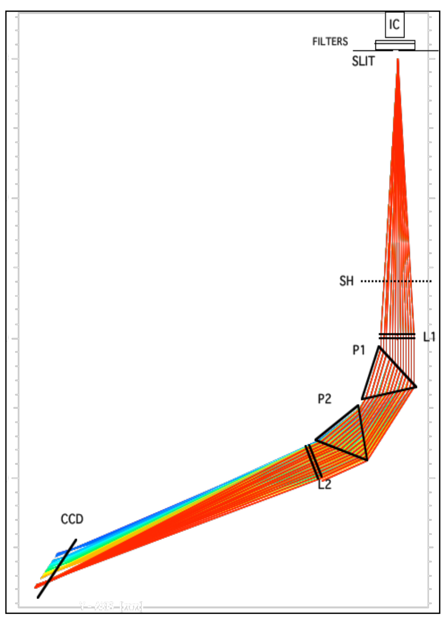
Min, Q.-L. and L. Harrison, Joint statistics of photon pathlength and cloud optical depth, Geophys. Res. Lett. 26, 1425-1428, 1999

Schmid, B., J. Michalsky, R. Halthore, M. Beauharnois, L. Harrison, J. Livingston, P. Russell, B. Holben, T. Eck, and A. Smirnov, "Comparison of Aerosol Optical Depth from Four Solar Radiometers during the Fall 1997 ARM Intensive Observation Period," Geophys. Res. Lett. 26: 2725-2728, 1999.

Appendix III: YES Inc. RSS and optical layout



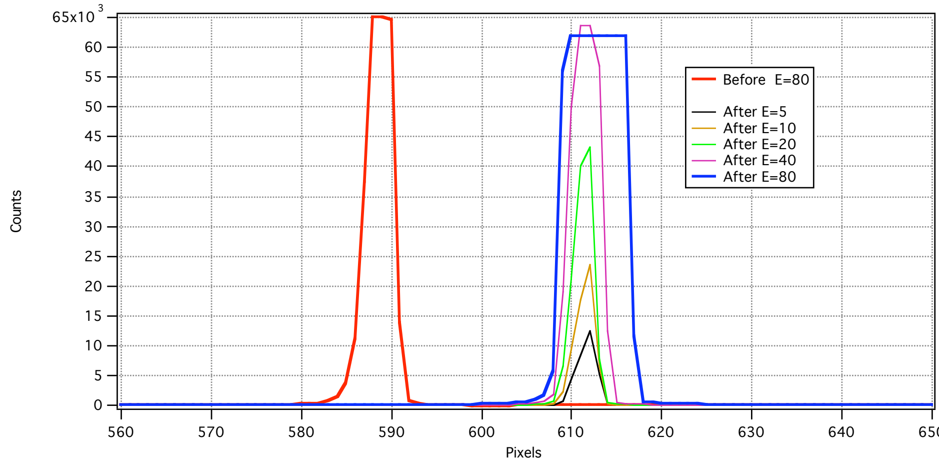
RSS: (1) insulated casting, (2) enclosure, (3) PID's board, (4) combo board with serial port, (5) linux box

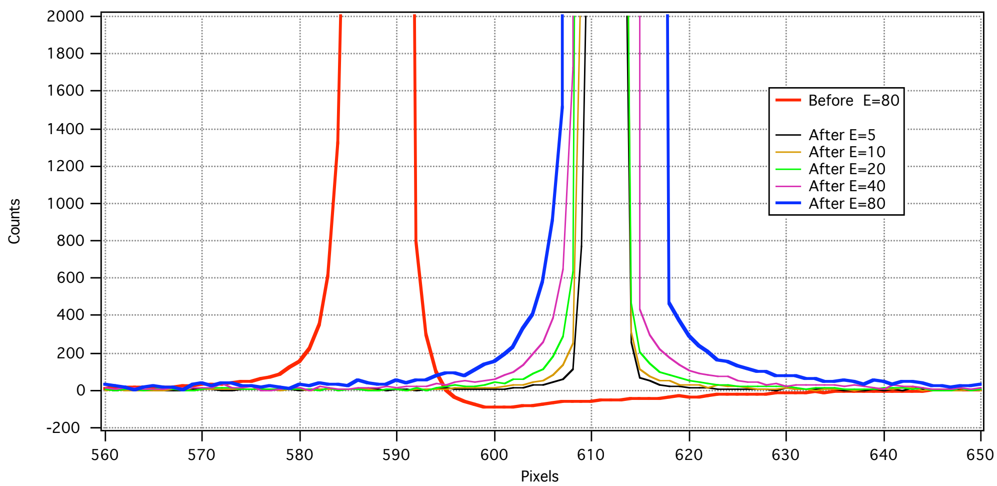


Optical Layout of RSS: (1) integrating cavity, (2) filters in RSS102, (3) slit , (4) shutter, (5) filters in RSS105, (6) lens-prism-prism-lens, (7) CCD

Appendix IV: Acceptance testing and modifications

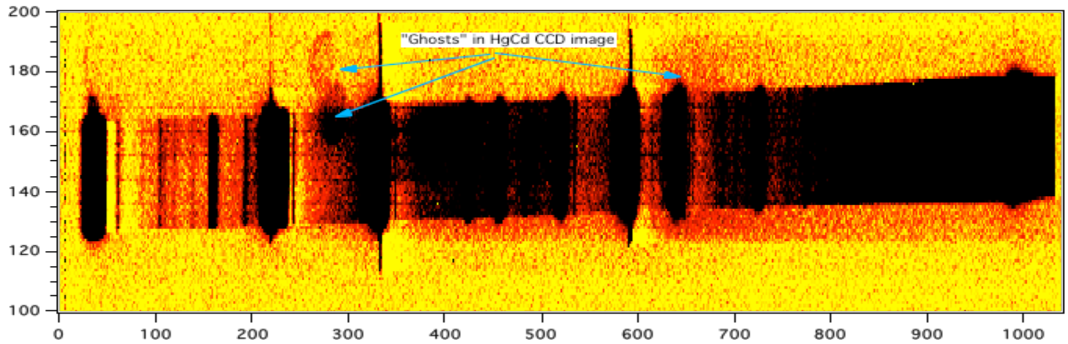
Preamp Overshoot (November 2001)



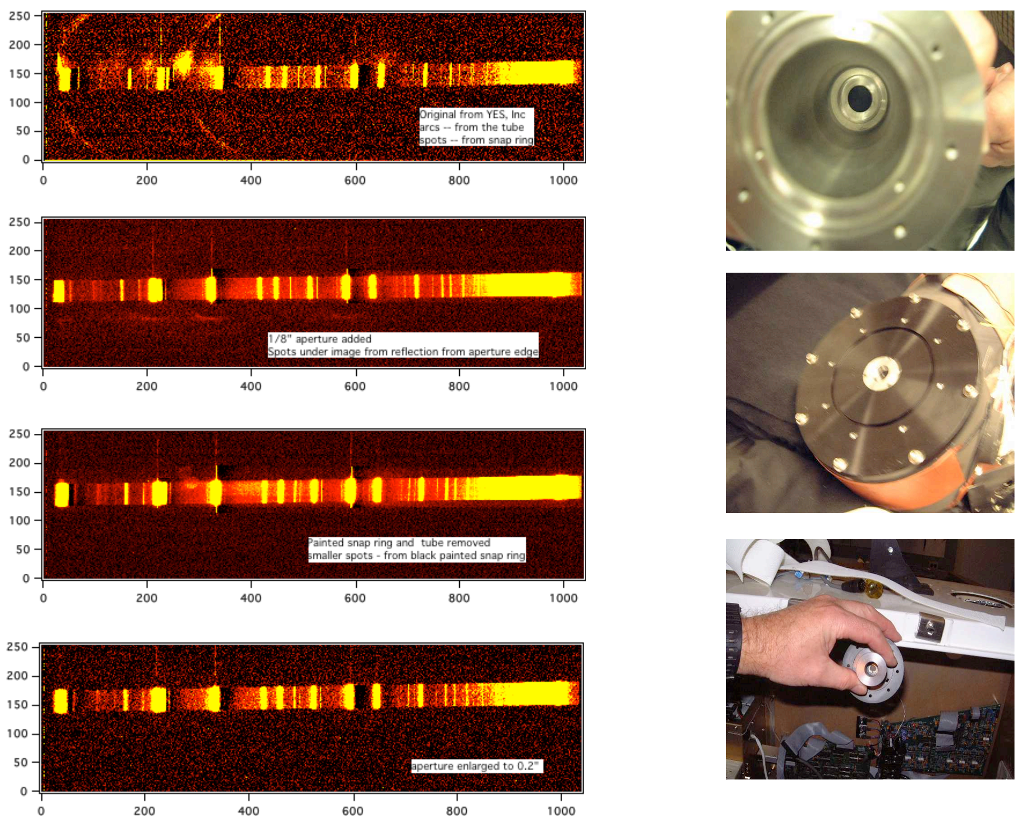


Laser line at different exposures before and after preamp modification.

Tracking ghosts and scattered light (November-December 2001)

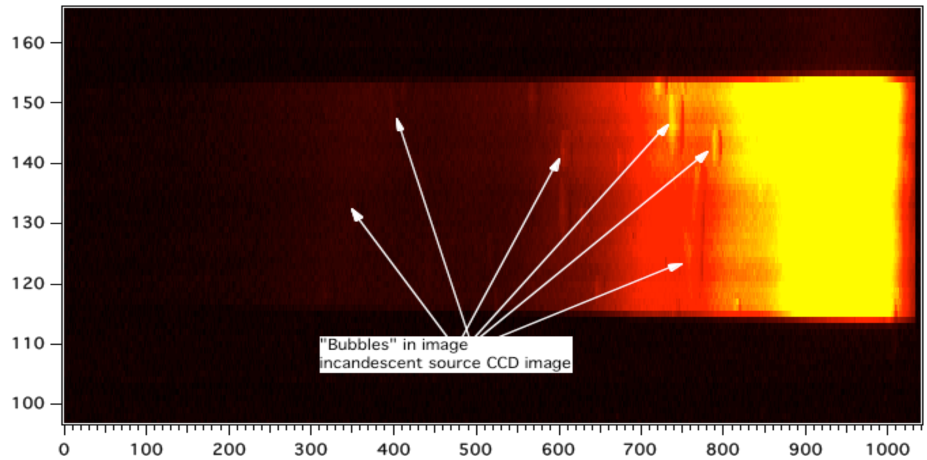


Ghost in image on CCD when RSS exposed to Hg-Cd spectral lamp.

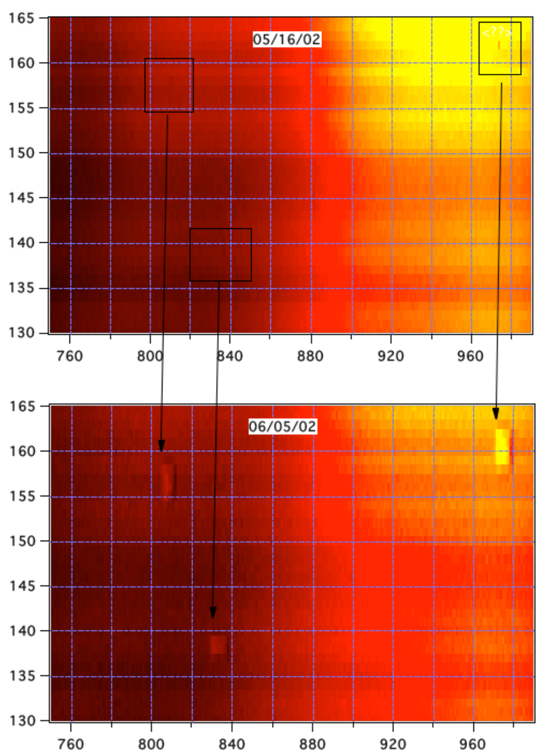


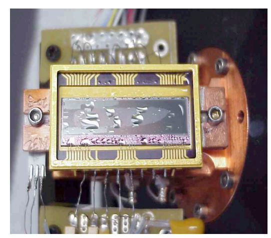
Identification of ghost sources and their elimination

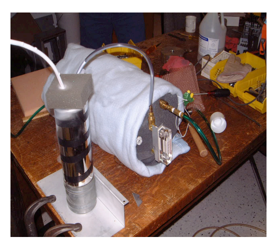
Oil Condensation on cooled CCD (January-September 2002)



Apparent "bubbles" in image of incandescent source on CCD



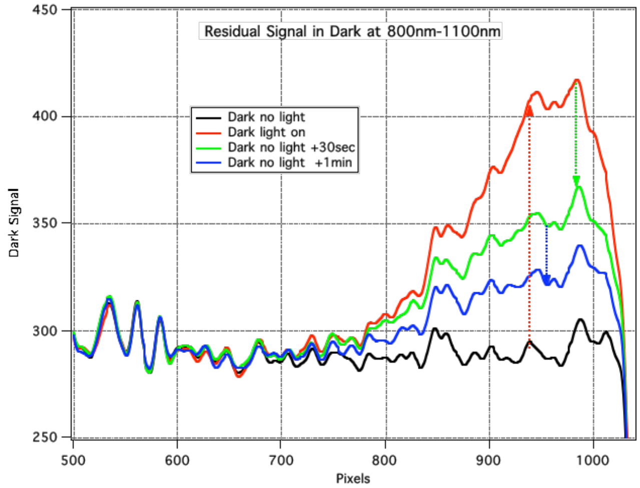


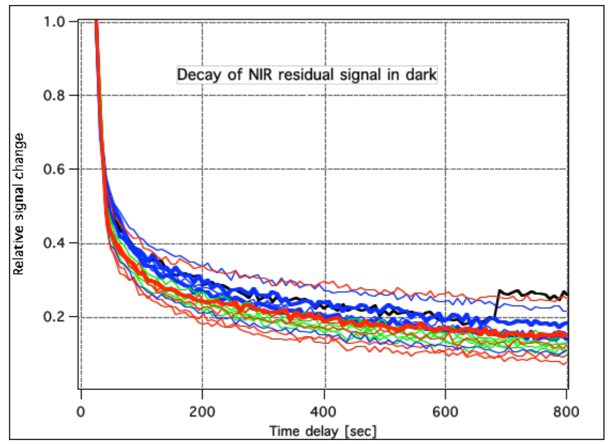


(1) Growth of "bubbles" on CCD after failed repair at YES, inc. (2) CCD with oil drops after being removed from RSS. (3) Purging RSS casting with dry nitrogen through "cold trap" to collect sample of outgassed substance

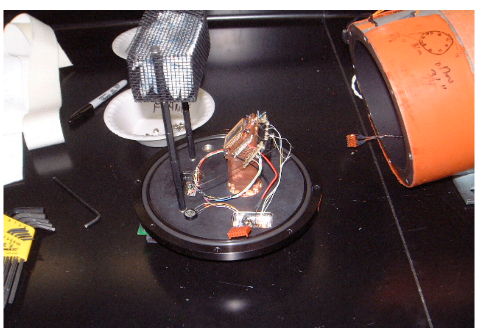
<u>Note:</u> prior to deployment image of incandescent source showed small artifacts on CCD. In field measurements must be performed whether the condensation of oil on CCD continues.

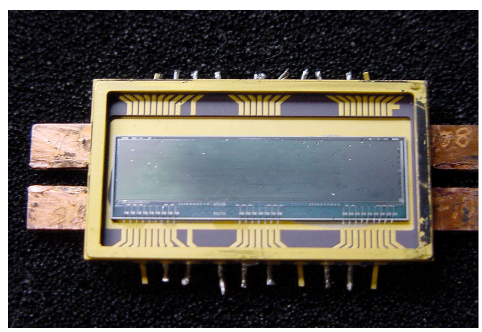
CCD Thermoluminescence (December 2002 - February 2003)





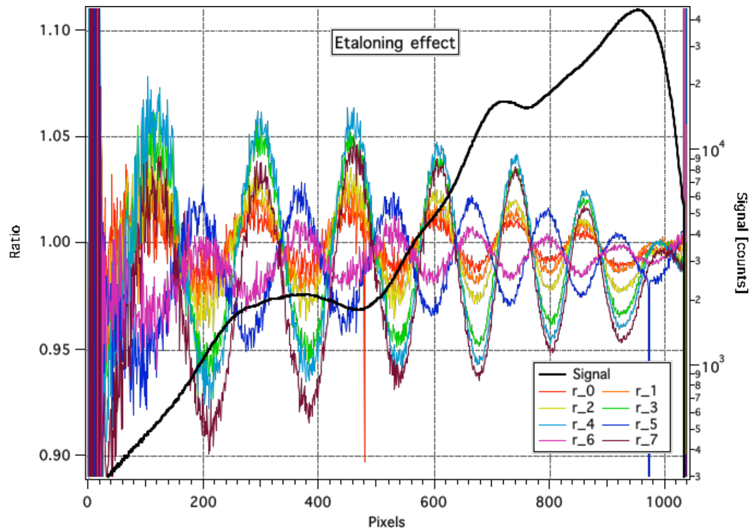
In NIR (pixels 800-1024) residual signal existed after exposure with a very long decay time.



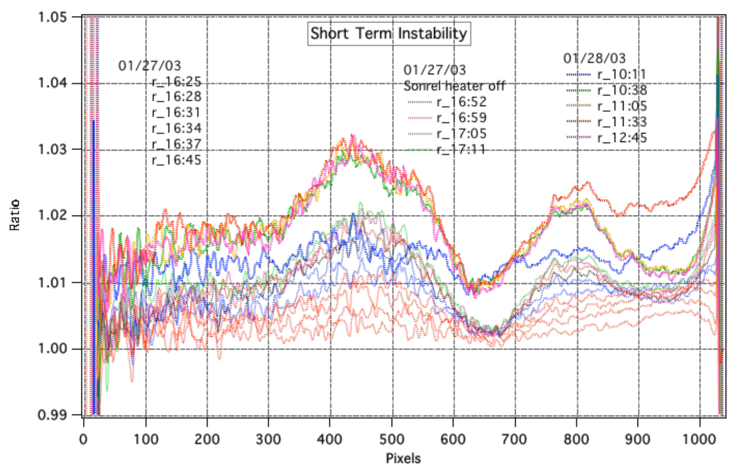


CCD was replaced at ASRC. New contamination (micro oil drops) on CCD surface was discovered.

Radiometric instability (January-April 2003)



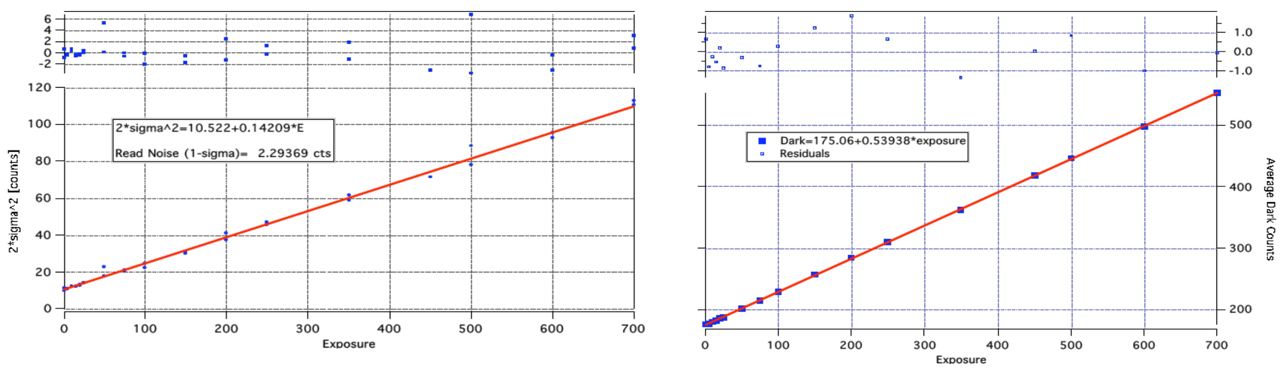
Etaloning effect between color glass filters



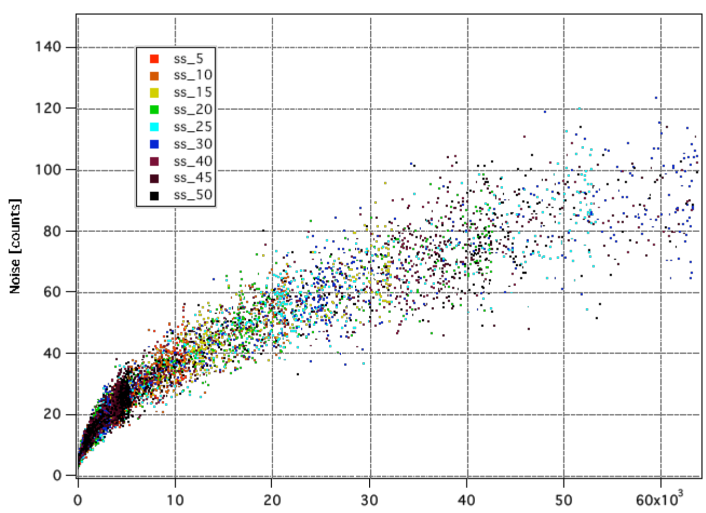
Radiometric stability tests: filters were epoxied and relocated between lens and shutter where a better thermal stability is expected.

Resolution and stray light in the RSS is comparable to that of earlier ASRC-built prototypes. The readout noise is better by factor of 2. This is because YES, Inc. implemented an analog dual-slope integrator prior to A/D conversion.

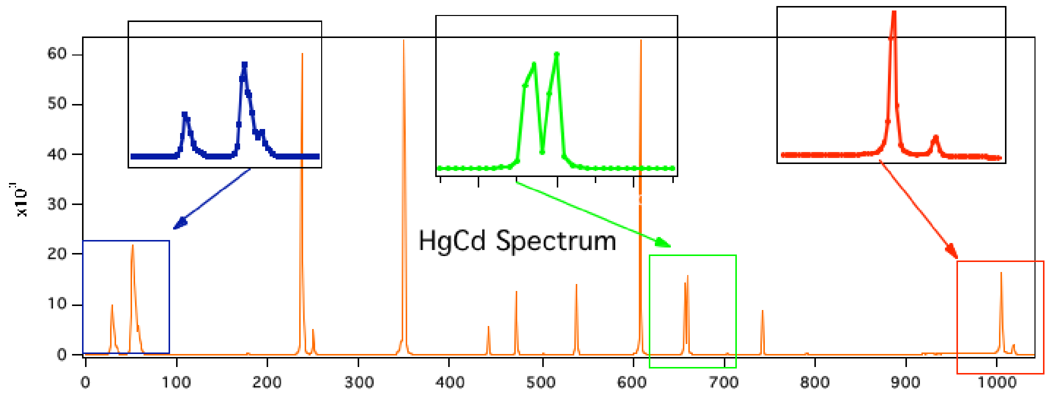
After the RSS was modified and rebuilt at ASRC a complete characterization was performed in April and May 2003. The following parameters and functions were measured: (1) noise, (2) linearity, (3) wavelength-to-pixel assignment, (4) resolution, (5) responsivity, (6) two dimensional cosine response.



Determination of readout noise by extrapolating exposure to 0 and dark counts dependence on exposure



Noise as function of counts: square root dependence as in Poisson noise



Hg-Cd spectrum

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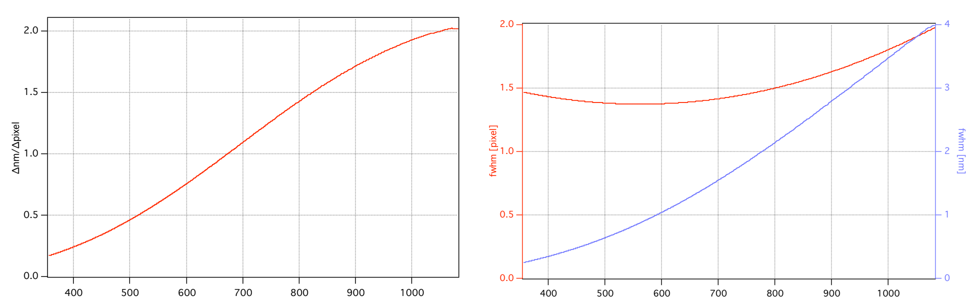
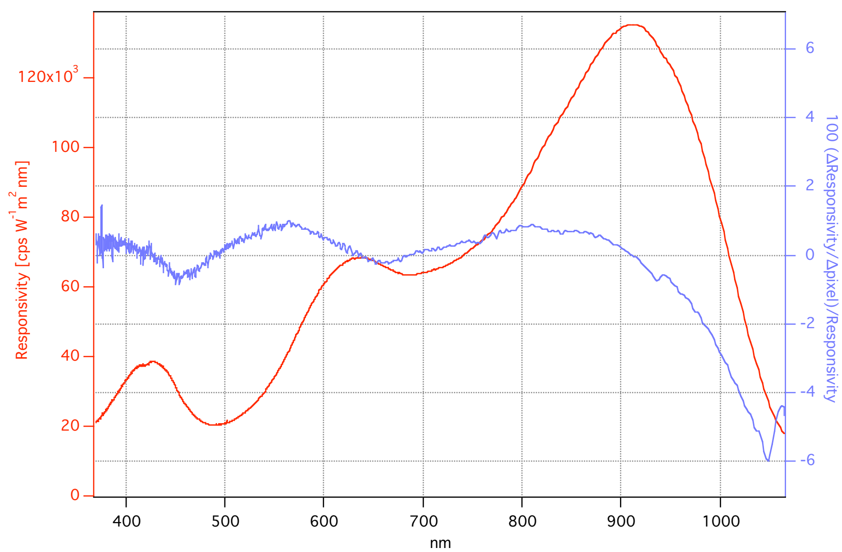
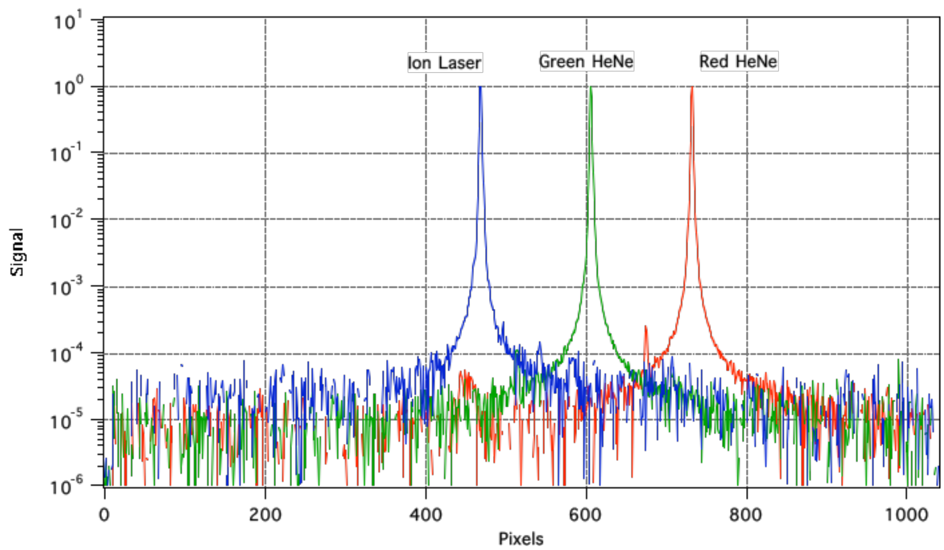


Δnm/Δpixel and fwhm as functions of wavelength (the dependence was derived from Hg, Cd, Ar, Ne, Xe and Kr lines)



Responsivity as function of wavelength

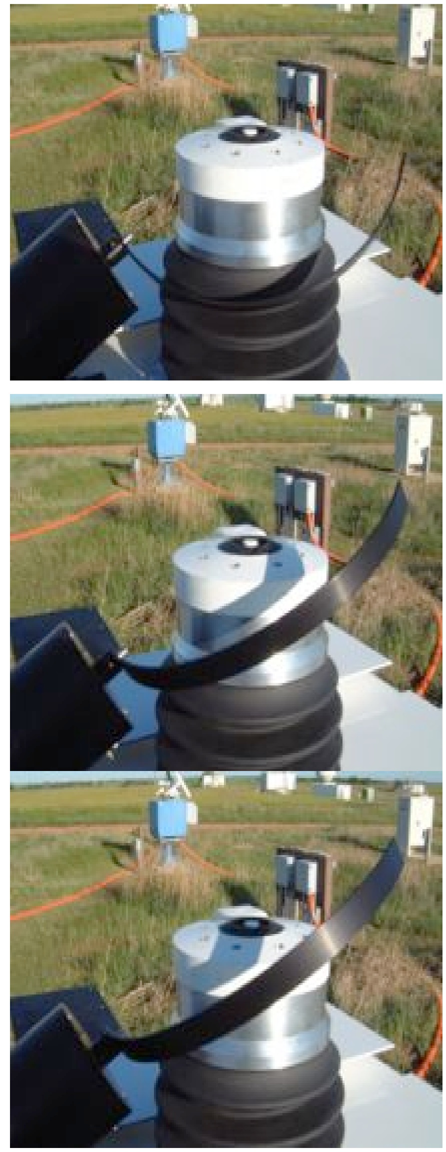


Laser lines used to determine stray light level and to derive the slit functions model

Appendix VI: Deployment at SGP (May 2003)

RSS103, UV-RSS104 and RSS105 at Aerosol IOP in May 2003

Erik Yager of ASRC demonstrates Portable Calibrator



Shadowband check