MOBY NET Stability System

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UNIVERSITY OF MIAMI

Moss Landing Marine Laboratories

NASA

Concept

A stable source and radiometer, transported with the MOBY-NET optical system to verify system performance pre/post deployment at the remote site.

Objective

We wish to quantify changes to the MOBY-NET radiance and irradiance system level radiometric responsivities during all phases of the operation (in situ deployments excepted) with an uncertainty goal of 1% (standard uncertainty).

Method

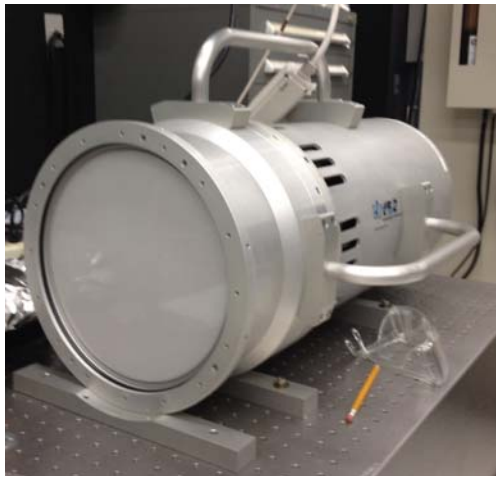
We will employ a source (SQM) specifically designed to assess stability – it is not for absolute radiometric calibration – with heavy redundancy in the form of internal monitor detectors, an external stability system radiometer (CAS), as well as good kinematic design, thorough characterization, standard protocols, and automated data processing.

Commercial Instruments

Spectroradiometer: CAS140CT-156 UV-VIS-NIR spectrograph, Instrument Systems, Inc., Konica Minolta (IS/KM)

Initial TRL = 5

Source: Satellite Quality Monitor (SQM), Yankee Environmental Systems, Inc. (YES)



Initial TRL = 4.5

Role in MOBY NET

Instrument Operation Cycle

MOBY NET Swap cruise, instrument taken to shore facility

On Shore: 1) assembled MOBY NET measures stability system
2) MOBY NET radiometer removed from buoy
3) MOBY NET radiometer measures stability system

MOBY NET radiometer and stability system sent to central calibration facility (CCF)

At CCF: 4) MOBY NET radiometer measures stability system
5) MOBY NET radiometer post deployment calibration – SI traceable
6) MOBY NET radiometer refurbished & characterized as necessary
7) Option: CAS measure MOBY reference standards; MOBY (if available) measure SQM
8) MOBY NET radiometer pre deployment calibration – SI traceable
9) MOBY NET radiometer measures stability system

MOBY NET radiometer and stability system sent back to measurement site

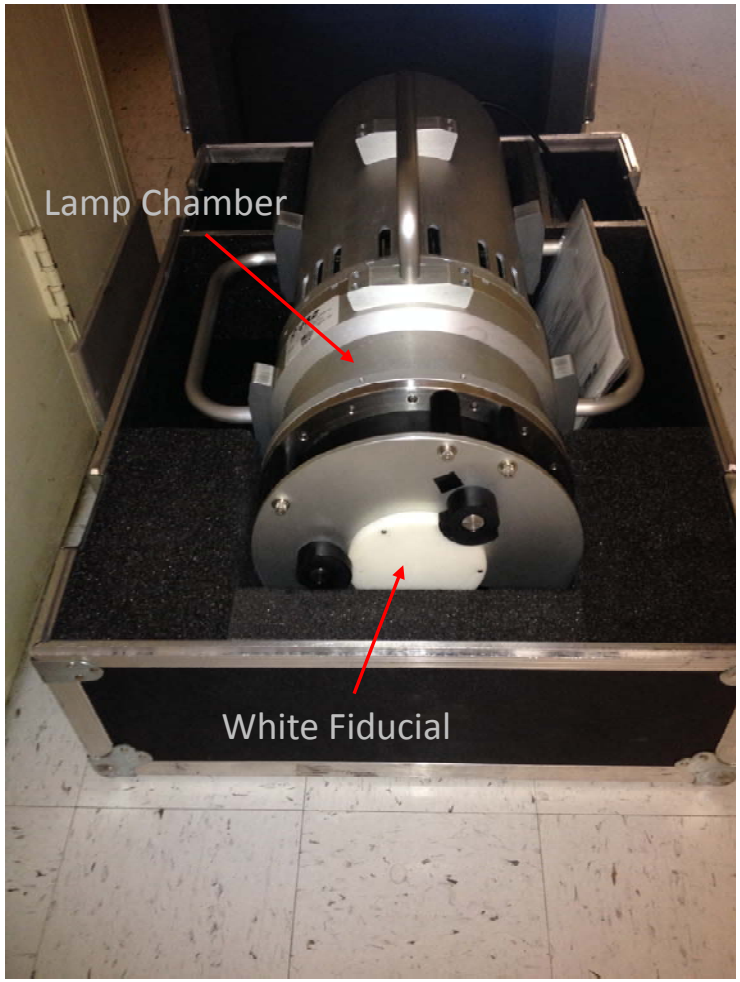
On Shore: 10) MOBY NET radiometer measures stability system
11) MOBY NET radiometer installed on buoy
12) assembled MOBY NET measures stability system

Newly calibrated MOBY NET is swapped with MOBY NET in the field, and the cycle continues

SQM TRL 4.5 to 6

Date	Issue / Event	Solution
May 2015	**Arrived at NIST**	
Jul 2015 Feb 2016 Oct 2016 Jul 2015	• Software inoperable • YES software inadequate • Analysis of results • YES manual obsolete • Document runs	• Implemented YES version logging software in LV2013 (LV2017) • Finalized LV2015 DAQ (V2.0) that captures the SQM buffer, saves data, captures manual operations, records metadata • Finalized SQM processing software in Mldbase • Manual a living document incorporated into LV DAQ program • Developed system for capturing and archiving conditions
Dec 2016 Oct 2017	• Adaptor plate • Saturates with white fiducial	• Made a CAS Lu foreoptic kinematic with existing plate • Made a black fiducial kinematic with existing plate for the MED and HI levels
Aug 2015 Oct 2015	• No spare lamps • Outer shell binds	• Ordered replacement lamps, manufactured mounting fixtures • Machined inner diameter to make circular
Aug 2015	• No UV	• Replaced acrylic diffuser with quartz diffuser
Jul 2015 Dec 2016 Dec 2017 Aug 2018	• Tests began • Reproducibility • Stability w shipment • Reproducibility	• Match output data to hardware; software development, etc. • Began time series with CAS, VXR, SEI 4500 • Deployed to Univ of Miami • Terminated time series, which included other sources

SQM Arrival



- Two lamp sets (8 lamps each) for three different levels
- Three internal monitor detectors (blue, red, broadband)
- Transmitting diffuser
- Lamp chamber nearly identical to SeaWiFS Quality Monitor, but the SQM-5002 has all the electronics packaged in the device
- Internal detectors are temperature stabilized
- Automatic control of lamp power, cooling fan, and pre-heater
- Monitoring software
- Manual control of SQM status (“off”, “standby”, “LO”, “MED”, “HI”)
- 46 kg (100 lbs) w/o shipping container, 41 cm diam w/ handles, 76 cm length
- RS 232 interface
- Operates for environments -30°C to +34°C
- 115/230 VAC, 50/60 Hz
- Mounting brackets mate to ¼ -20 thread on 1” bolt pattern

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Software and Analysis

```
%\Begin_Header:
%\Filename: [SQM_20180802_001]
%\---------- Set Up Info ----------
%\DAQ_Program_Name: [2] {SQM Monitor_2.1.vi}
%\DAQ_Program_Version: [19]
%\File Format Version: [2] %Ver 2 NIST DAQ designed by Tom Larason
%\Cruise_Name: [1] {NIST} %MOBYNET Cruise ID
%\Cruise_Number: [2018-001] %MOBYNET Cruise Number
%\Investigator: [1] {Carol Johnson}
%\Location_of_Measurement: [2] {NIST B019_221}
%\Latitude: [39.133935] %Degrees (+/- 90, N+ and S-) [DD.dddddd]
%\Longitude: [-77.217356] %Degrees (+/- 180, E+ and W-) [DDD.dddddd]
%\Purpose: [1] {Stability Measurement}
%\Deployment: [999] {unknown} %MOBYNET Deployment
%\MOBY_NET_Sequence_Position: [1] {Calibration Facility}
%\Ambient_Air_Temp: [22.9] %deg C
%\Relative_Humidity: [53.9] %percent
%\---------- Comments Info ----------
%\---------- Device Under Test (DUT) Info ----------
%\DUT_White_Fiducial: [1]
%\DUT_Black_Fiducial: [2]
%\DUT_Net_CAS_Lu: [5]
%\DUT_VXR: [401]
%\DUT_SEI: [402]
%\---------- SQM Info ----------
%\Source_ID: [350] {SQM} %Satellite Quality Monitor (SQM-5002)
%\SQM_Instrument_CFG_File: [1001] {SQM1001.txt} %Current hardware attributes
%\Time_of_Last_Servicing: [20151218.000000] %Date format GMT YYYYMMDD.HHMMSS
%\#_of_Levels: [3] %Approx # of lamp levels in data file: off, low, medium, high
%\Initial_Lamp_State: [0] {All Off}
%\Time_Step: [10] %sec
%\DAQ_Computer: [15] {EOS EQUIP 13}
%\SQM_120VAC_On: [20180802.124500] %Date format GMT YYYYMMDD.HHMMSS
%\SQM_Off_to_Standby: [20180802.125132] %Date format GMT YYYYMMDD.HHMMSS
%\SQM_Standby_to_Off: [20180802.200531] %Date format GMT YYYYMMDD.HHMMSS
%\SQM_120VAC_Off: [20180802.200700] %Date format GMT YYYYMMDD.HHMMSS
%\---------- Misc Info ----------
%\Time_adjustment_to_GMT: [00.00.00] {Adjust file times to GMT (HH.MM.SS)} %Manual edit of SQM_yyyymmdd_xxx.txt file during processing.
%\VR_Number: [15] %number of data columns
%\Column_Headers: %Date.Time [ymd.hms], Low Beam Set Pt [A], Low Beam [A], Low Beam Code, High Beam Set Pt [A], High Beam [A], High Beam Code, Red [V], White [V], Blue [V], Shunt
%\End_Header@
20180802.125058 0.000000    0.005992    10.000000   0.000000    0.004393    10.000000   0.002661    0.003453    0.048702    23.217102   22.798217   22.781798   22.796111   0
20180802.125109 0.000000    0.005985    10.000000   0.000000    0.004381    10.000000   0.002667    0.003448    0.048599    23.235962   22.801024   22.783202   22.800353   0
20180802.125119 0.000000    0.005991    10.000000   0.000000    0.004441    10.000000   0.002627    0.003477    0.049007    23.255035   22.804015   22.784545   22.804778   2
20180802.125130 0.000000    0.005987    10.000000   0.000000    0.004438    10.000000   0.002707    0.003445    0.048730    23.273834   22.806487   22.786101   22.808837   2
20180802.125140 0.000000    0.005975    10.000000   0.000000    0.004470    10.000000   0.002574    0.003427    0.047804    23.293457   22.809539   22.823150   22.831542   2
```

Software and Analysis

Home

The purpose of this web page is to look at the SQM data that are matched with the CAS start and stop times in the Excel file supplied by Carol. The Excel file contains rows of CAS file information. Each two rows makes a pair. I have added a Pair Number column to make it clear which pairs go together. For each Pair I find the SQM file (a data rows) that were collected betweem the "Start Time" of the first CAS file in the pair and the "End Time" in the second CAS file in the pair. The first 7 graphs show the SQM data means and standard deviations (std) for each CAS pair. The CAS pair number is the x-axis for these data sets.

XLSfile: CAS XLS Matchup file

CAS Data Type meanings in the table below
10 = means this was a transition, e.g. the SQM current was changing between levels while the CAS was taking data
15 = means the SQM was at full current but perhaps had not stabilized fully, and the CAS was taking data
20 = means I thought the SQM was fully stabilized and expect these CAS data, and the SQM photodiode data, to be repeatable.
Data Type 10 is not plotted in the group plots.

CAS Positions meanings in the table below
There are other parameters we could denote. An interesting one is if the CAS was in the SQM or on the table.
"on the table" = 20 for distance of about 20cm and "mounted in the CAS" = 0 (zero). In the plots the "on the table" are diamonds and the "mounted in the CAS" data are circles.

Top of table

Pair#	SQMfile	CAS Start-End	CAS Total Minutes	CAS Strt -> SQM standby Minutes	CAS Strt -> Lamp On Minutes	CAS Data Type	CAS Position	Lamp Level	Red PD Mean	Red PD %std	White PD Mean	White PD %std	Blue PD Mean	Blue PD %std
1	SQM_20161208_001	08-Dec-2016 19:00:46 -> 20:31:38	90.9	8.6	7.0	15	on the table	4.0	1.557	0.125	1.690	0.191	1.598	0.167
2	SQM_20161208_001	08-Dec-2016 20:35:46 -> 20:46:38	10.9	103.6	102.1	20	on the table	4.0	1.557	0.083	1.691	0.087	1.598	0.128
3	SQM_20161208_001	08-Dec-2016 20:55:46 -> 21:36:38	40.9	123.6	2.8	15	on the table	2.0	1.352	0.089	1.490	0.112	1.443	0.124
4	SQM_20161208_001	08-Dec-2016 21:40:46 -> 21:51:39	10.9	168.6	47.8	20	on the table	2.0	1.351	0.105	1.491	0.126	1.442	0.147
5	SQM_20161213_001	13-Dec-2016 14:41:47 -> 15:52:39	70.9	14.3	13.0	15	on the table	1.0	0.208	0.257	0.202	0.284	0.188	0.814
6	SQM_20161213_001	13-Dec-2016 15:52:46 -> 15:55:38	2.9	85.3	83.9	20	on the table	1.0	0.208	0.146	0.202	0.037	0.190	0.316
7	SQM_20161213_001	13-Dec-2016 16:08:46 -> 18:55:38	166.9	101.3	12.3	15	on the table	2.0	1.352	0.093	1.491	0.171	1.444	0.125
8	SQM_20161213_001	13-Dec-2016 18:55:46 -> 18:58:38	2.9	268.3	179.2	20	on the table	2.0	1.352	0.101	1.491	0.100	1.444	0.126
9	SQM_20161213_001	13-Dec-2016 19:10:46 -> 20:01:38	50.9	283.3	10.0	15	on the table	4.0	1.558	0.089	1.691	0.117	1.600	0.127
10	SQM_20161213_001	13-Dec-2016 20:01:46 -> 20:04:38	2.9	334.3	61.0	20	on the table	4.0	1.558	0.093	1.690	0.107	1.600	0.132
11	SQM_20161214_001	14-Dec-2016 20:27:22 -> 20:38:25	11.0	399.7	26.6	15	on the table	1.0	0.208	0.262	0.202	0.068	0.188	0.899
12	SQM_20161214_001	14-Dec-2016 20:38:52 -> 20:42:01	3.2	411.2	38.0	20	on the table	1.0	0.207	0.246	0.202	0.074	0.186	0.583
13	SQM_20161214_001	14-Dec-2016 20:42:23 -> 20:45:32	3.1	414.7	NaN	10	on the table	2.7	0.118	173.83	0.116	181.377	0.117	136.470
14	SQM_20161214_001	14-Dec-2016 20:47:22 -> 21:13:25	26.1	419.7	4.0	15	on the table	2.0	1.351	0.119	1.483	0.354	1.442	0.177
15	SQM_20161214_001	14-Dec-2016 21:18:40 -> 21:21:48	3.1	451.0	35.4	20	on the table	2.0	1.351	0.038	1.490	0.032	1.442	0.076
16	SQM_20161214_001	14-Dec-2016 21:27:22 -> 21:38:24	11.0	459.7	5.4	15	on the table	4.0	1.556	0.041	1.692	0.042	1.598	0.069
17	SQM_20161214_001	14-Dec-2016 21:43:48 -> 21:46:57	3.2	476.2	21.9	20	on the table	4.0	1.556	0.044	1.692	0.044	1.598	0.063
18	SQM_20161215_001	15-Dec-2016 19:51:13 -> 20:24:05	32.9	291.1	1.8	15	on the table	1.0	0.208	0.292	0.202	0.221	0.188	0.830
19	SQM_20161215_001	15-Dec-2016 20:25:36 -> 20:28:13	2.6	325.5	36.1	20	on the table	1.0	0.208	0.072	0.202	0.059	0.189	0.375
20	SQM_20161215_001	15-Dec-2016 20:32:13 -> 20:41:05	8.9	332.1	2.8	15	on the table	2.0	1.348	0.634	1.473	0.725	1.436	0.874
21	SQM_20161215_001	15-Dec-2016 20:42:39 -> 20:45:17	2.6	342.6	13.2	20	on the table	2.0	1.352	0.046	1.482	0.067	1.443	0.053
22	SQM_20161215_001	15-Dec-2016 20:47:13 -> 20:55:05	7.9	347.1	1.2	15	on the table	4.0	1.554	0.447	1.684	0.528	1.596	0.510
23	SQM_20161215_001	15-Dec-2016 20:56:35 -> 20:59:12	2.6	356.5	10.7	20	on the table	4.0	1.557	0.063	1.688	0.060	1.598	0.102
24	SQM_20161216_001	16-Dec-2016 13:44:50 -> 14:11:42	26.9	6.3	4.2	15	on the table	1.0	0.207	0.255	0.203	0.569	0.188	0.771
25	SQM_20161216_001	16-Dec-2016 14:13:15 -> 14:15:53	2.6	34.7	32.6	20	on the table	1.0	0.208	0.095	0.202	0.045	0.188	0.572
26	SQM_20161216_001	16-Dec-2016 14:28:50 -> 14:46:42	17.9	50.3	3.2	15	on the table	2.0	1.351	0.246	1.477	0.462	1.441	0.373
27	SQM_20161216_001	16-Dec-2016 14:48:50 -> 14:53:42	4.9	70.3	23.1	20	on the table	2.0	1.351	0.040	1.486	0.060	1.443	0.096
28	SQM_20161216_001	16-Dec-2016 15:07:58 -> 15:10:36	2.6	89.4	12.3	20	on the table	4.0	1.556	0.037	1.691	0.041	1.599	0.050
29	SQM_20161216_001	16-Dec-2016 15:27:39 -> 15:30:17	2.6	109.1	13.8	20	on the table	1.0	0.208	0.178	0.202	0.033	0.190	0.273
30	SQM_20161223_001	23-Dec-2016 17:35:17 -> 18:03:24	28.1	10.8	2.8	15	on the table	1.0	0.207	0.278	0.203	0.437	0.188	0.836
31	SQM_20161223_001	23-Dec-2016 18:07:29 -> 18:10:09	2.7	43.0	34.9	20	on the table	1.0	0.208	0.156	0.201	0.061	0.188	0.954

Date/Time

SQM TRL 4.5 to 6

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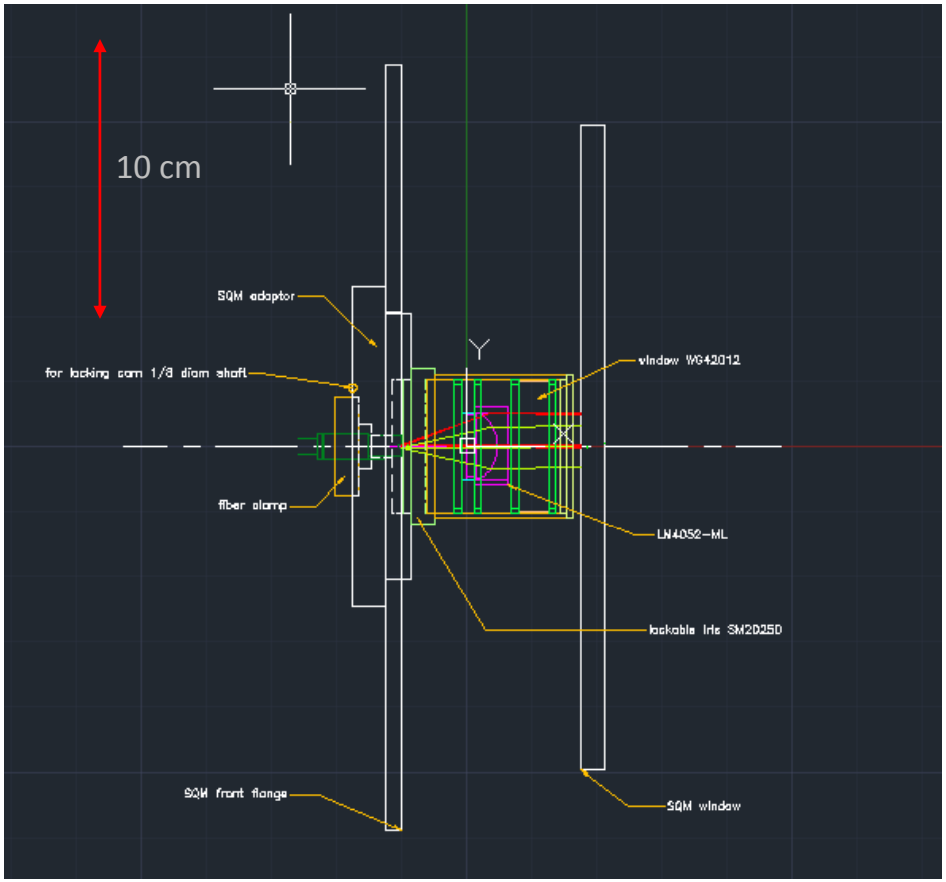
Mating the Device Under Test to the SQM

SQM adaptor plate is made for 4” OD cylindrical sensors, with the azimuthal position fixed by two pins.



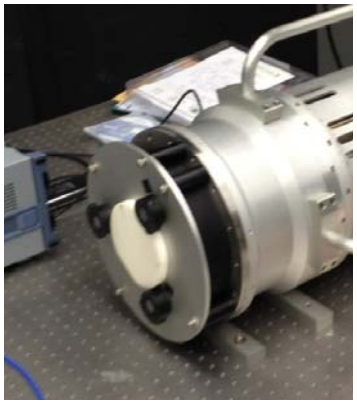
Output side of fiber bundle goes here – PLG port

Lu fiber bundle, input side (10 mm diam)

Mating the Device Under Test to the SQM

YES white plastic fiducial

Fiducials are faux radiometers, presenting a stable reflectance “target” for the internal monitor photodiodes. They are kept clean and protected during deployments. Different reflective surfaces (black, white, colored, diffuse, specular, etc.) can be used.



- Track stability of SQM via the internal monitor photodiodes;
- Provide a “dark” measurement for the internal monitor photodiodes when the lamps are off;
- Protect the SQM foreoptics during shipping or storage.

The SQM monitor photodiode signals saturated with the white fiducial on the MED and HI levels, so we manufactured a black fiducial out of black Delrin with the same dimensions as the YES white fiducial.

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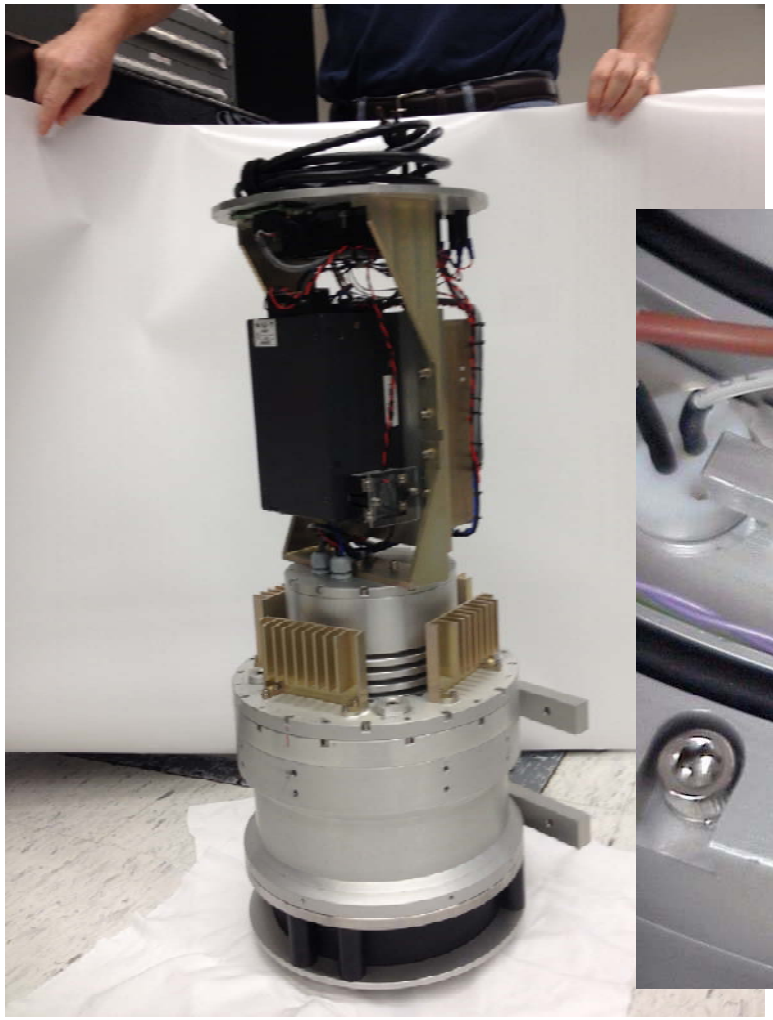
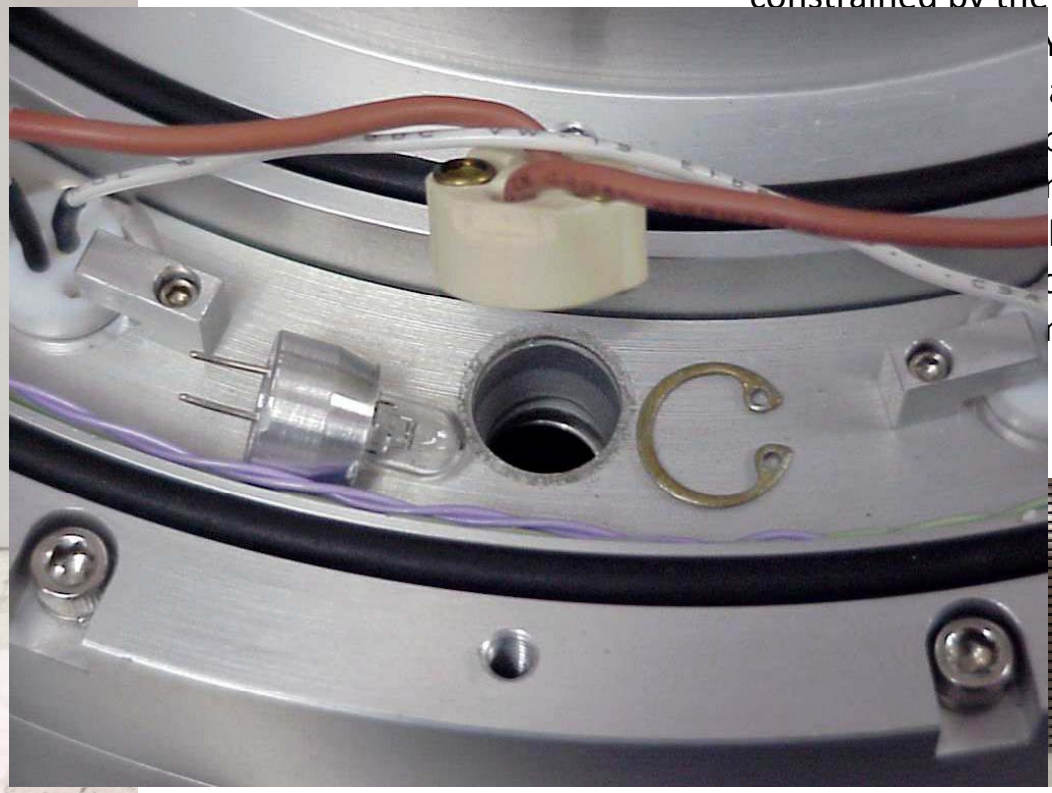
Making of spare lamp sets





We had to identify the lamp model numbers and find replacements. For the 3A lamp set, that lamp had been discontinued and we had to find a substitute. We were constrained by the fixed lamp
YES control
ad no lamp
lenty of spare
nd 3A sets. The
lamps is
d, and we
nall parts such as
and made a

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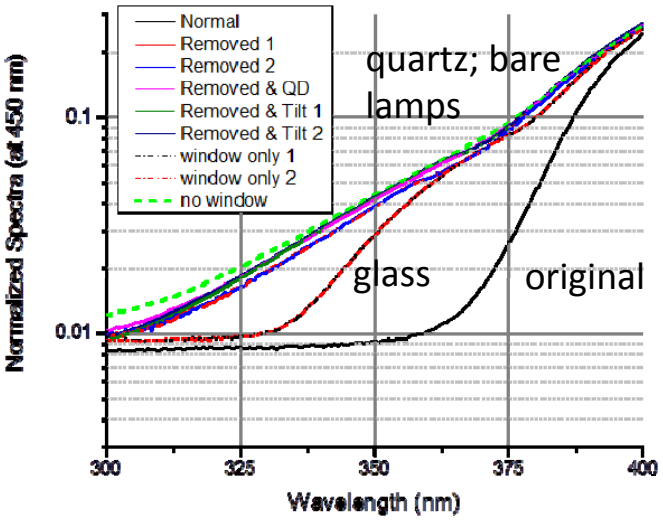
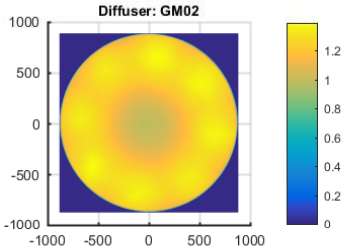
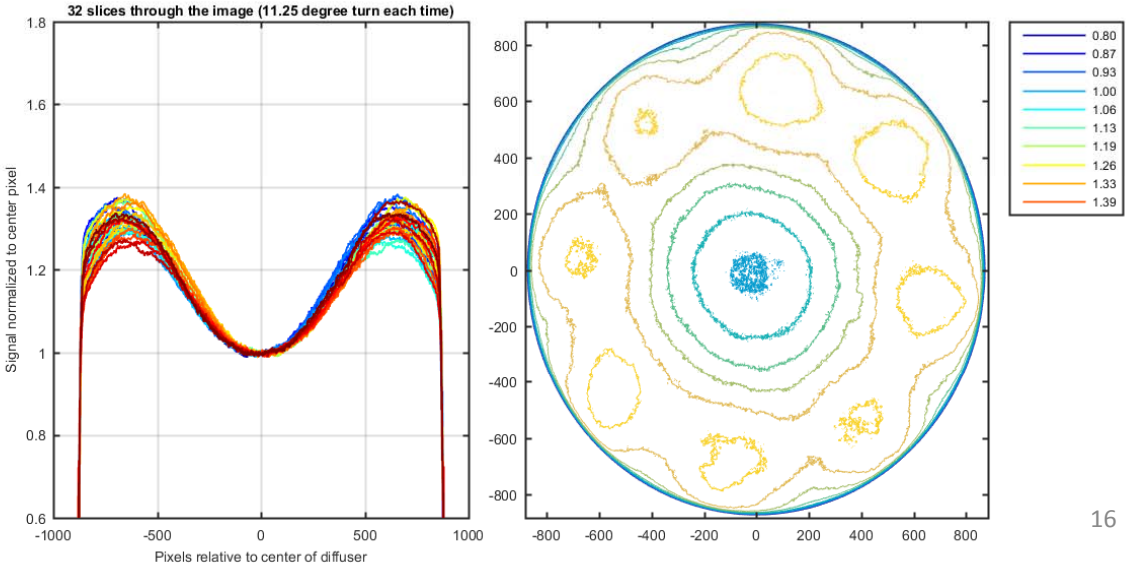
No Ultraviolet



The new quartz diffuser is two-sided bead blasted quartz. It is not as uniform as the original acrylic diffuser, but the Lu head of the DUTs will only see the central region, and the attachment is kinematic.





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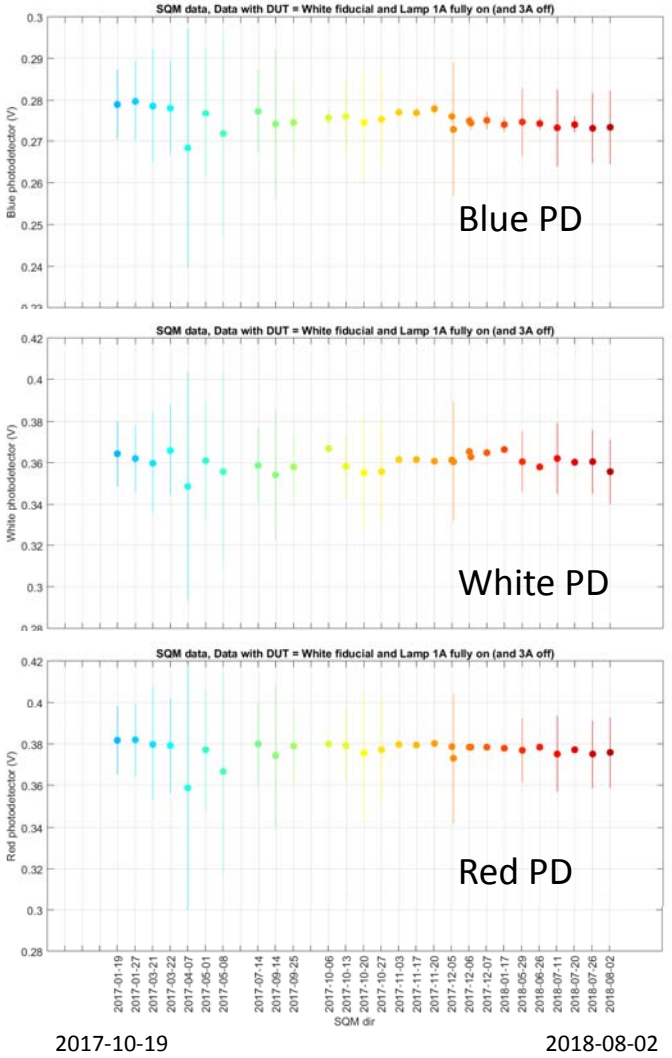
Dec 2016 Oct 2017	• Adaptor plate • Saturates with white fiducial	• Made a CAS Lu foreoptic kinematic with existing plate • Made a black fiducial kinematic with existing plate for the MED and HI levels
Aug 2015 Oct 2015	• No spare lamps • Outer shell binds	• Ordered replacement lamps, manufactured mounting fixtures • Machined inner diameter to make circular
Aug 2015	• No UV	• Replaced acrylic diffuser with quartz diffuser
Jul 2015 **Dec 2016** **Dec 2017** **Aug 2018**	• **Tests began** • **Reproducibility** • **Stability w shipment** • **Reproducibility**	• **Match output data to hardware; software development, etc.** • **Began time series with CAS, VXR, SEI 4500** • **Deployed to Univ of Miami** • **Terminated time series, which included other sources**

Time Series of SQM photodiodes with fiducials

White Fiducial, 1A Lamp Set



7.7%

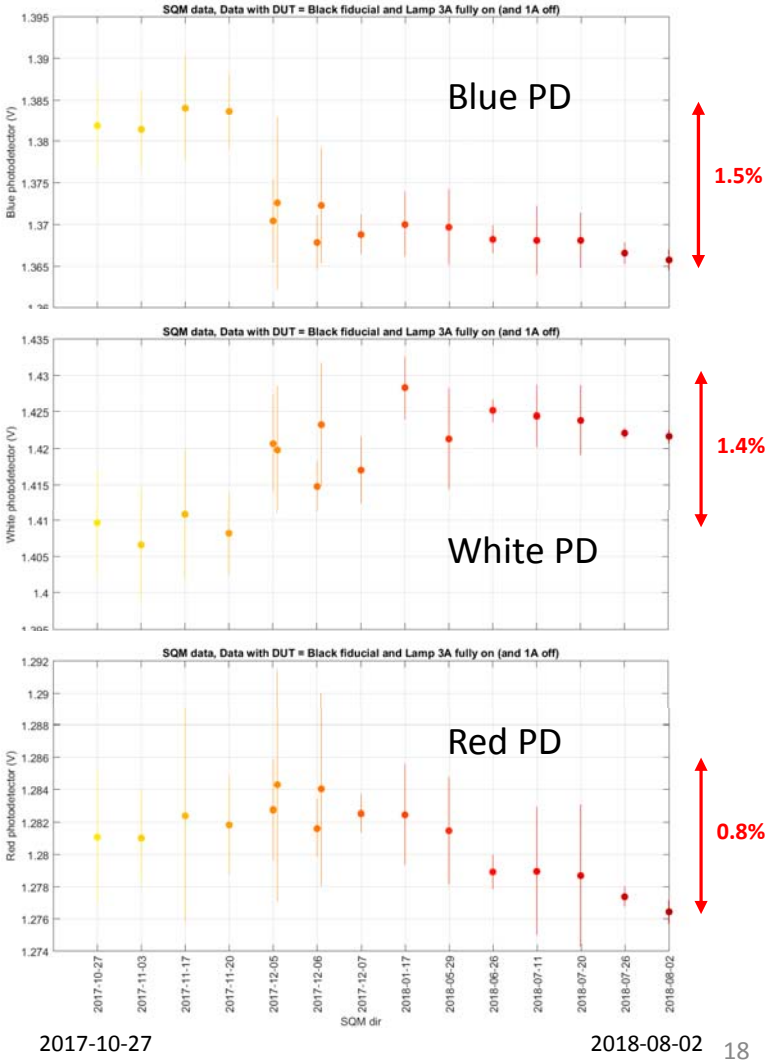
12%

11%

←LO

MED→

Black Fiducial, 3A Lamp Set



1.5%

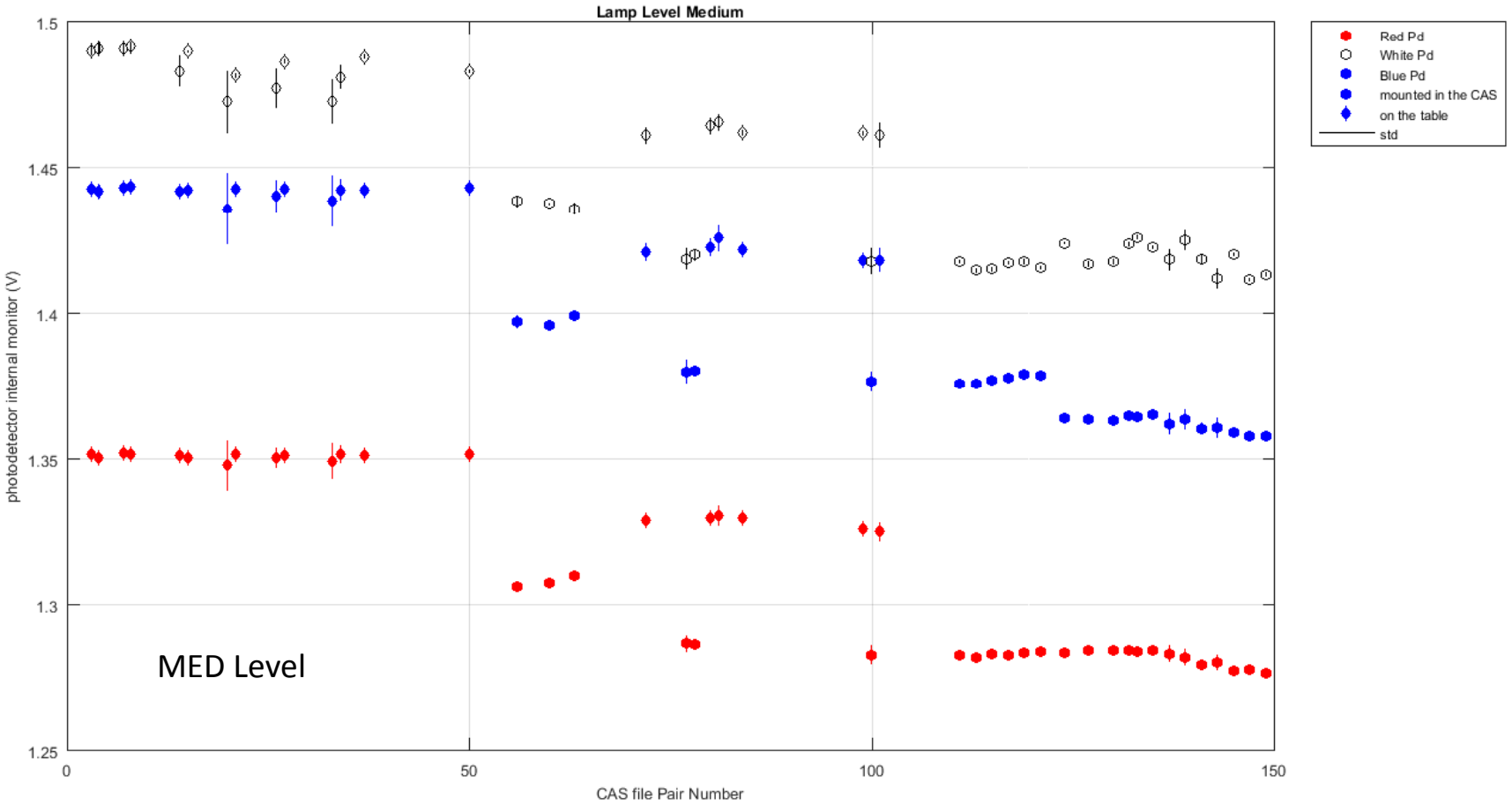
1.4%

0.8%

2017-10-19 2018-08-02

2017-10-27 2018-08-02

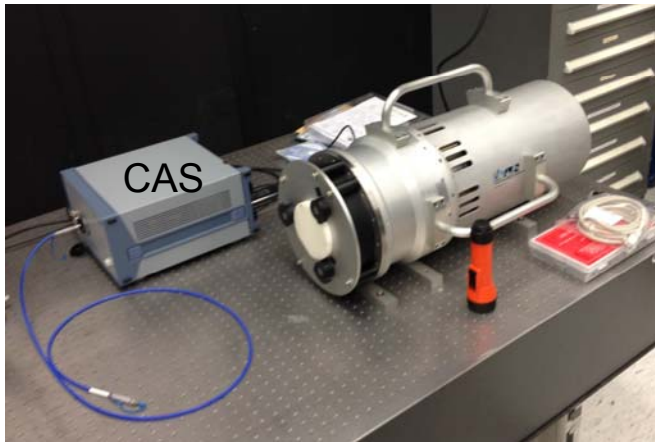
Time Series of SQM photodiodes during CAS measurements (mounted to SQM and on the moving table)



CAS TRL 5 to 6

Date	Issue / Event	Solution
May 2015	**Arrived at NIST**	
Jul 2015 Mar 2016	• Software • Documentation • Analysis of results	• Implemented NIST heritage version of CAS DAQ in LabView • Record filename, date, & other key parameters in bound notebook • Processing programs written in Matlab
Apr 2015 Apr 2016	• No foreoptics	• Bare fiber bundle and Es fiber bundle purchased • Lu head designed; kinematic; couples to SQM
May 2017	• No shipping container	• Custom shipping container, fiber optics remains attached
Feb 2016 Mar 2016 Jul 2016 Mar 2018 Aug 2016 Dec 2016 Varies	• Testing began • Es stability • Es calibration • Es calibration • Stability w shipment • Lu stability & calibration • Characterization	• Es foreoptic • Time series w S195, S194 in Bldg 220 (multiple times) • Measured four FEL lamps in FASCAL II • Measured HTBB in FASCAL II • Used as Es validation xfer radiometer at MOBY facility • Time series with SQM, NPR, NPR-Jr, OL455-12 sources • Linearity, Wavelength, 1/r2 on Es, sensitivity to alignment, darks

Arrived at NIST



- Heritage
  - numerous CAS' were in the SSD (from 2004)
- Specifications
  - 300 nm to 1100 nm
  - 3.7 nm spectral resolution (100 um slits)
  - 0.8 nm/pixel data point interval
  - built in shutter and order sorting filter
  - 15 bit A/D converter
  - 1024x128 back-illuminated CCD detector
  - LabVIEW driver software
  - bare fiber input, optimized for UV
  - irradiance collector input, optimized for UV

CAS TRL 5 to 6

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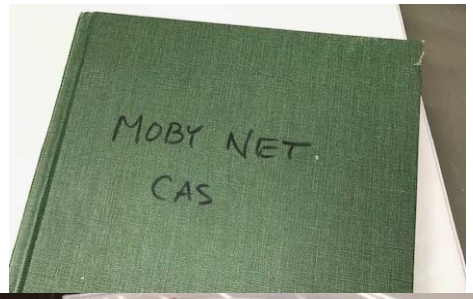
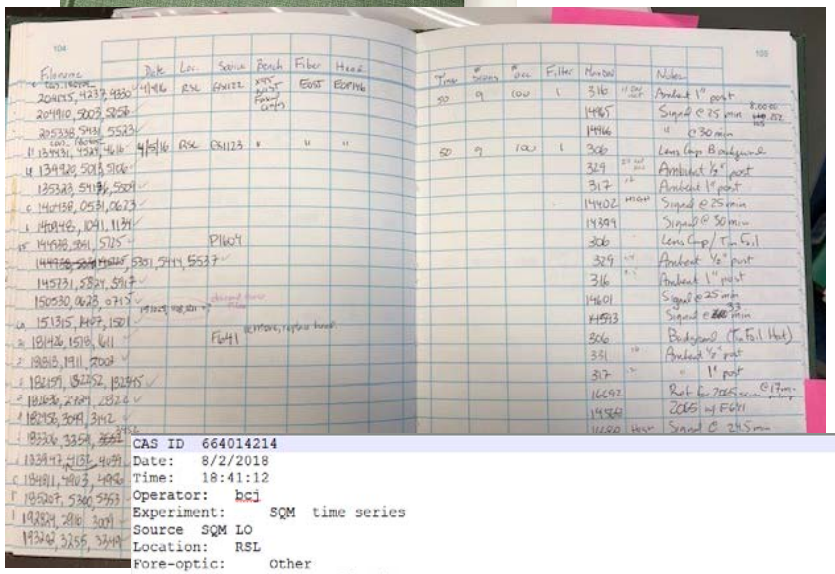
Software and Analysis





CAS ID 664014214
Date: 8/2/2018
Time: 18:41:12
Operator: bcj
Experiment: SQM time series
Source SQM LO
Location: RSL
Fore-optic: Other
Stray light correction Identity
Comment

Filter: 0
Integration time: 50
Accumulation: 100

WL	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Mean	% STD	Corrected Spectrum
2.974940E+2	-4.097819E-10	3.852667E-3	-1.013860E-3	1.419403E-3	-8.110885E-4	-4.097819E-10	-1.622177E-3	-1.013860E-3	3.0			
2.983183E+2	3.041579E-3	2.838808E-3	3.649896E-3	3.244352E-3	-8.110883E-4	5.069300E-3	2.433264E-3	-1.013860E-3	6.285932E-3	2.74868		

- Filenames, Date, Location, Source, Fiber, Bench, Integration time, # of scans, # accumulations, CAS filter, Datatype, and Notes are recorded manually in the CAS logbook
- DAQ program is heritage from NIST, records some metadata, but not all available CAS housekeeping data
- MatLab codes:
  - Combine multiple files of the same datatype, save as a mat file;
  - Manual input to the CAS Event Log Excel spreadsheet to identify “dark” and “light” filenames
  - Set flag in Excel spreadsheet for files to process to net
  - Final code for responsivity determinations

CAS TRL 5 to 6

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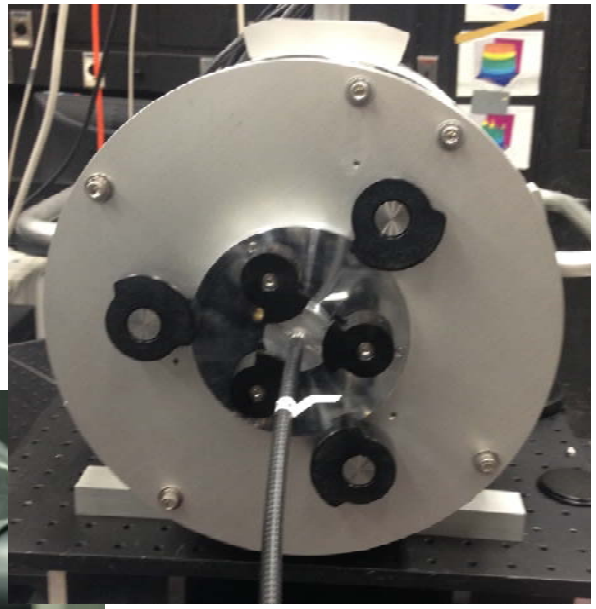
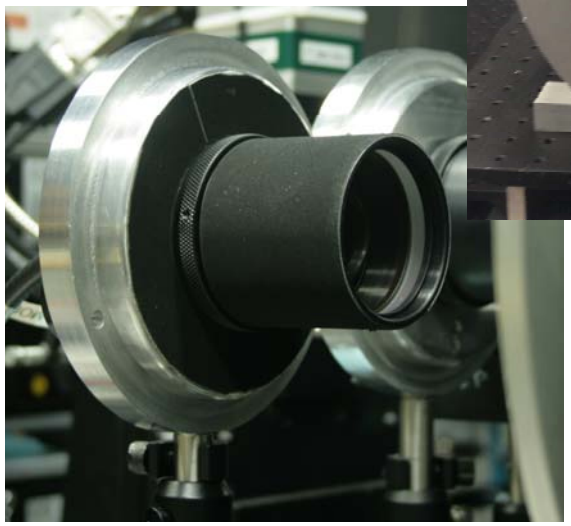
Foreoptics

MOBY NET Es irradiance head & fiber bundle from Instrument Systems





MOBY NET Lu fiber bundle from Instrument Systems, lens foreoptic NIST custom

CAS TRL 5 to 6

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Shipping Container

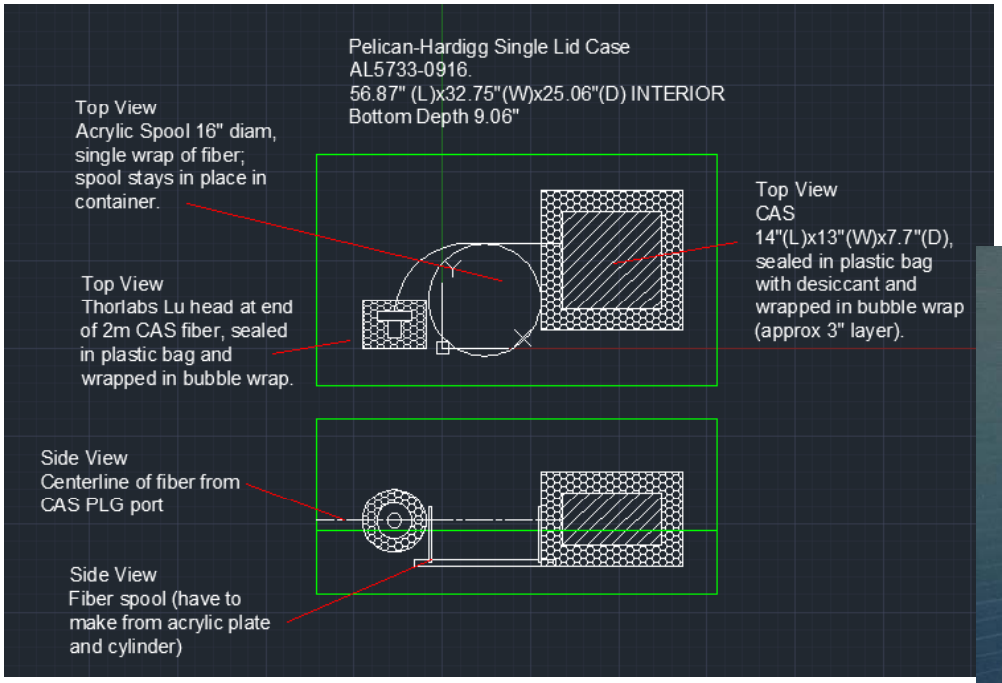

Photo of container not available, but we did use it! Here outside Voss' lab at Univ Miami

Shipping container is large – 57"x33"x25" in order to not bend fiber tighter than specified radius and to keep Lu head attached to spectrometer at PLG

CAS TRL 5 to 6

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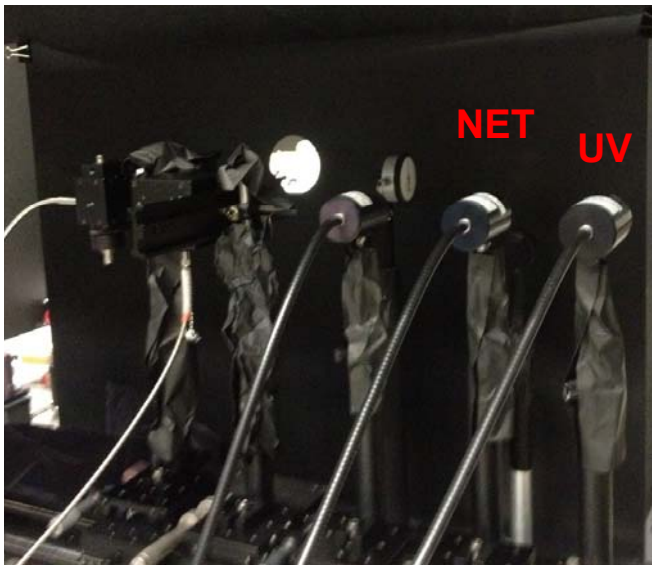
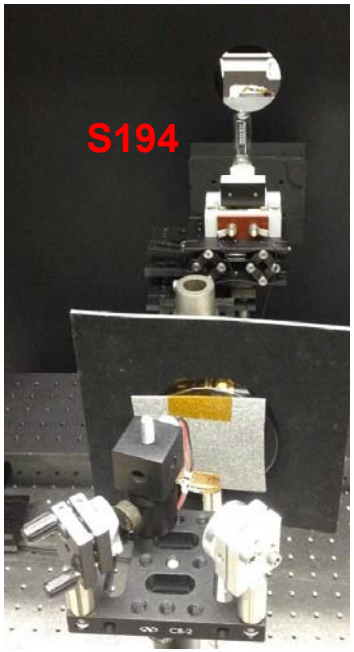
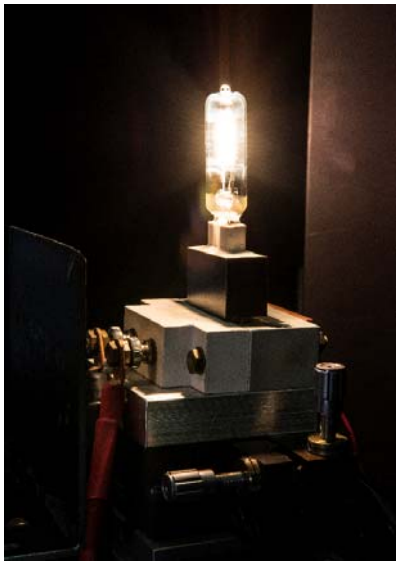
Time Series – Es Irradiance



Four CAS' and one SEI on an x,z translation stage



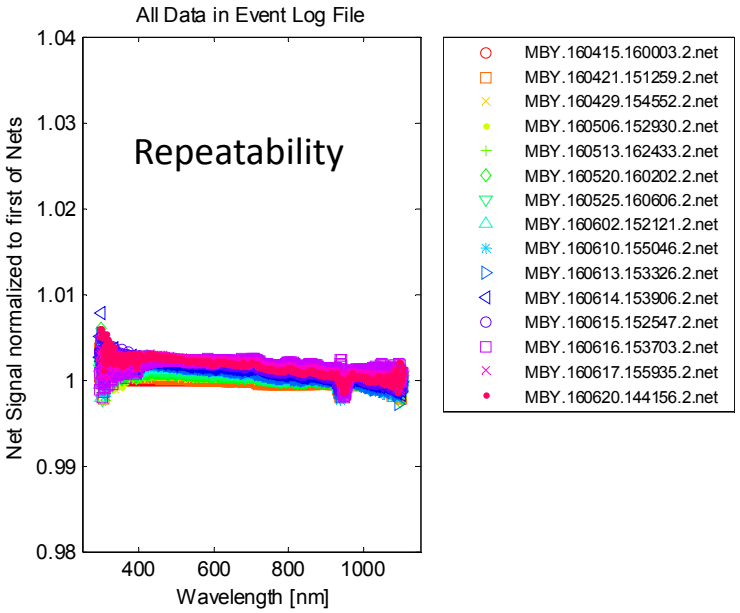


An 1000 W FEL spectral irradiance standard lamp is 50 cm away

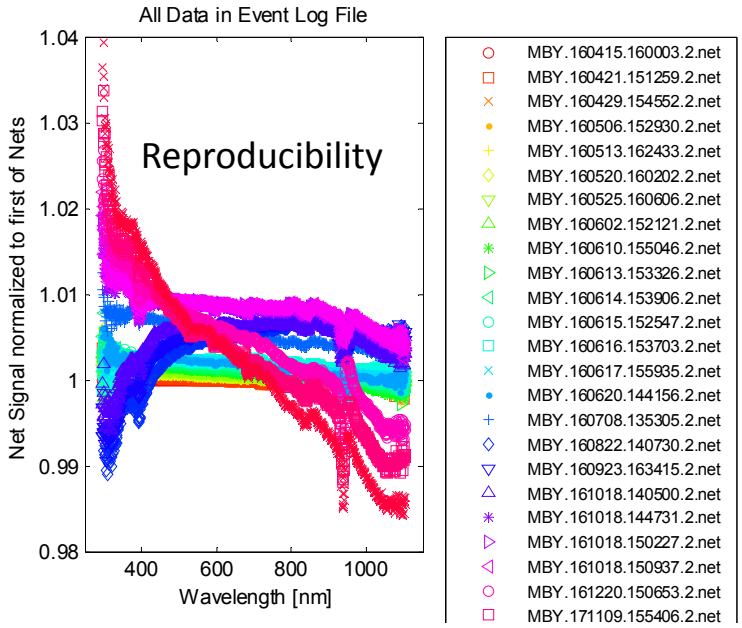
Initial goals: daily for 1 week; weekly for 3 months; monthly for 1 year

Repeatability & Reproducibility with Es Head

S194 4/15/16 to 6/20/16

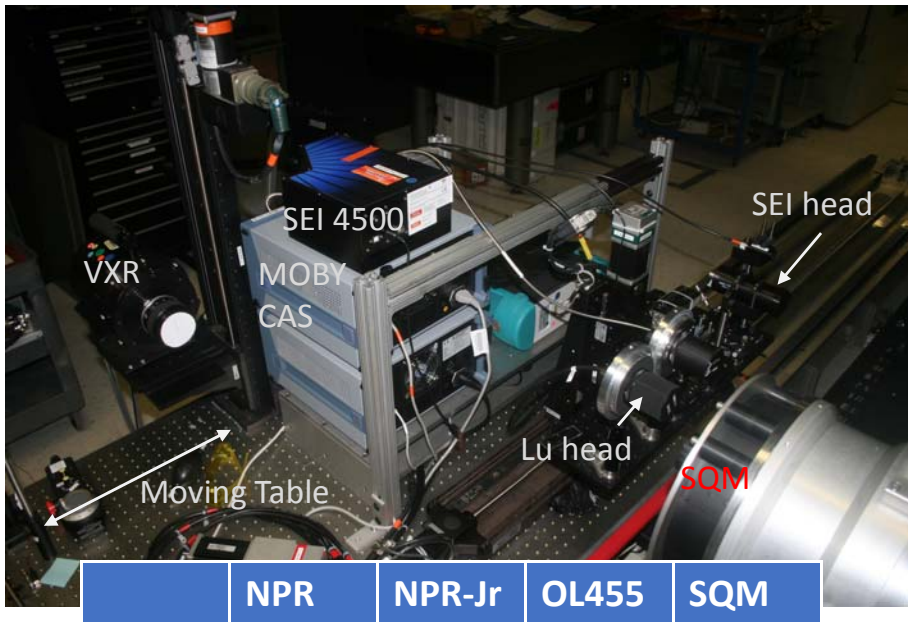


S194 4/15/16 to 1/17/18



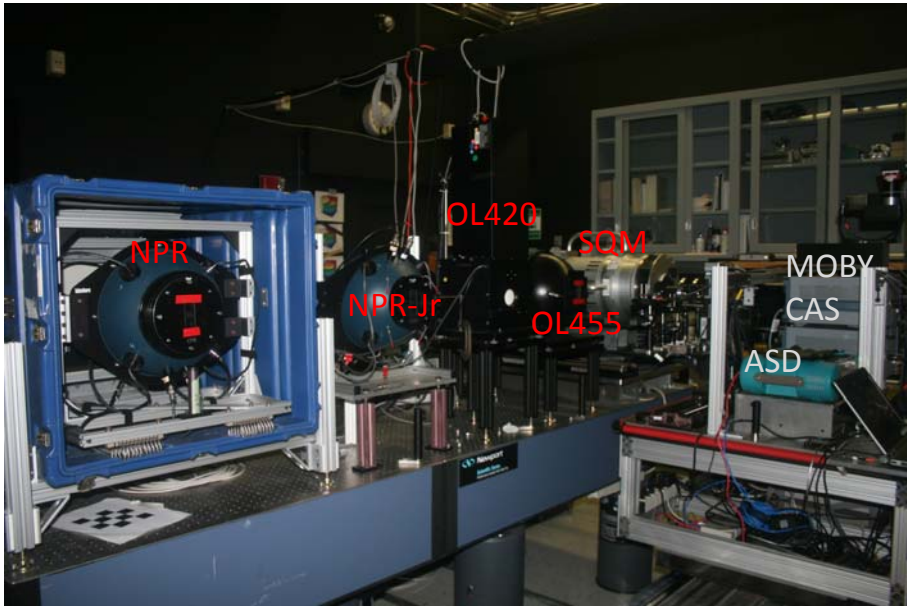
Data normalized to the first run. Groupings are generally associated with some type of perturbation – moving the CAS or switching the foreoptic.

Time Series – Lu Radiance



	NPR	NPR-Jr	OL455	SQM
CAS	Y	Y	Y	Y
VXR	Y	Y	Y	Y
SEI	Y	Y	Y	Y
ASD1	Y	Y	Y	N
ASD2	Y	Y	Y	N

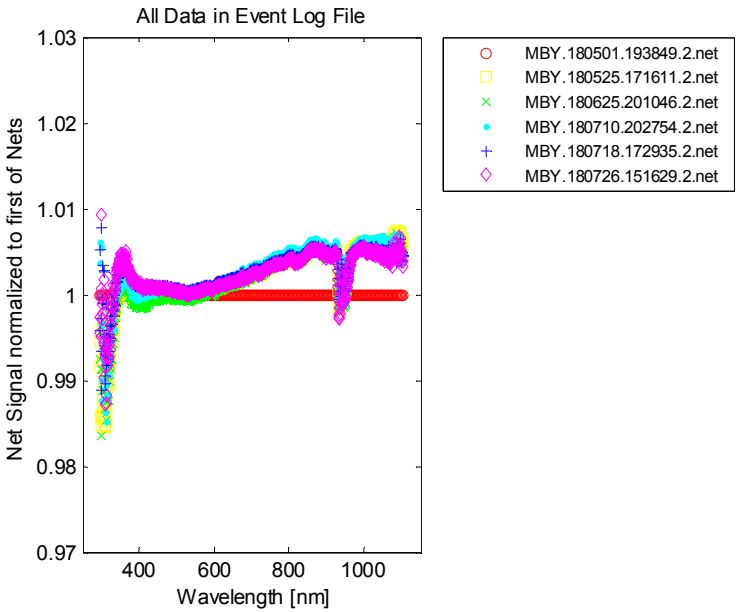
The SQM sits on the fixed source table. The radiometers sit on the moving table. Two co-aligned lasers and the moving table encoder are used to align everything. A LabVIEW program selects the correct location. The Lu head must be realigned about the vertical axis after being mated to the SQM.



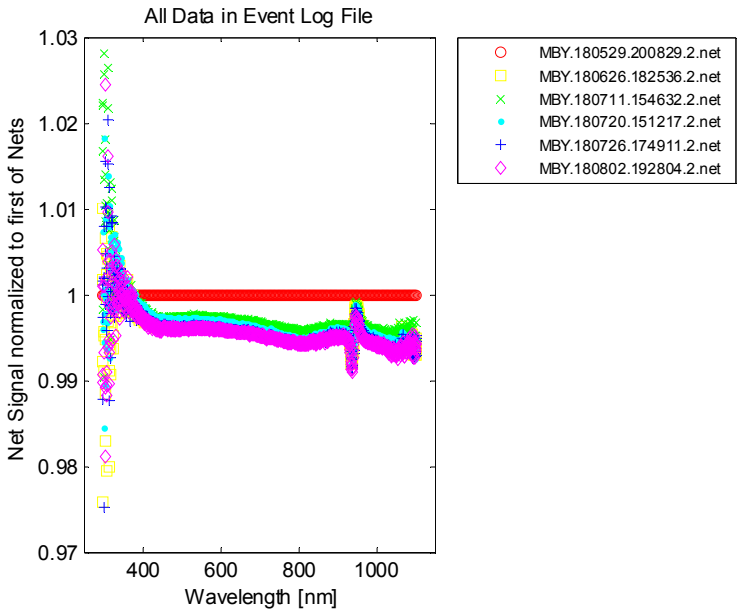
Time Series – Lu Radiance

Repeatability w CAS Lu Head

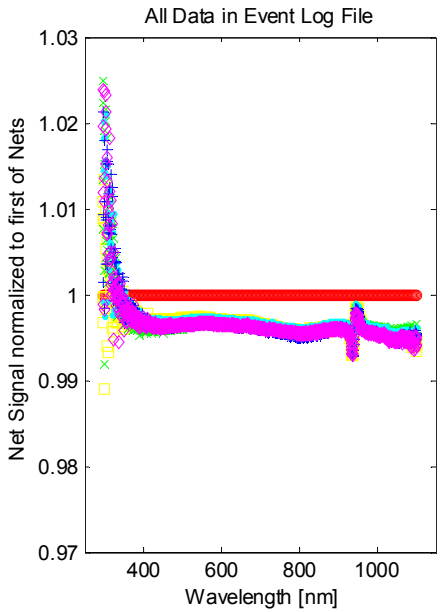
NPR 5/1/18 to 7/26/18



SQM MED 5/29/18 to 8/2/18



SQM LO 5/29/18 to 8/2/18

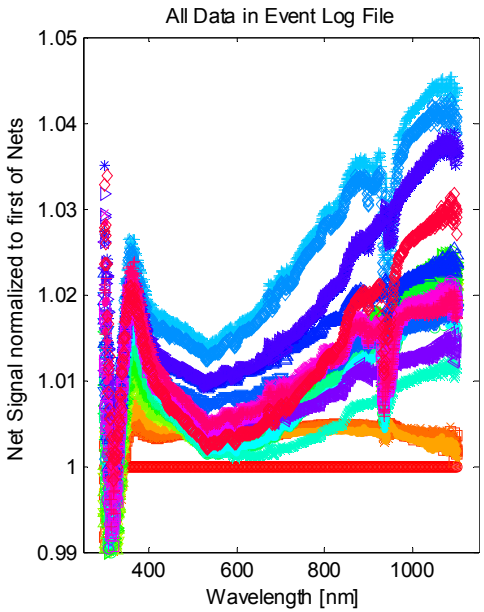


Data normalized to the first run. The changes in the NIR for May 2018 are not understood.

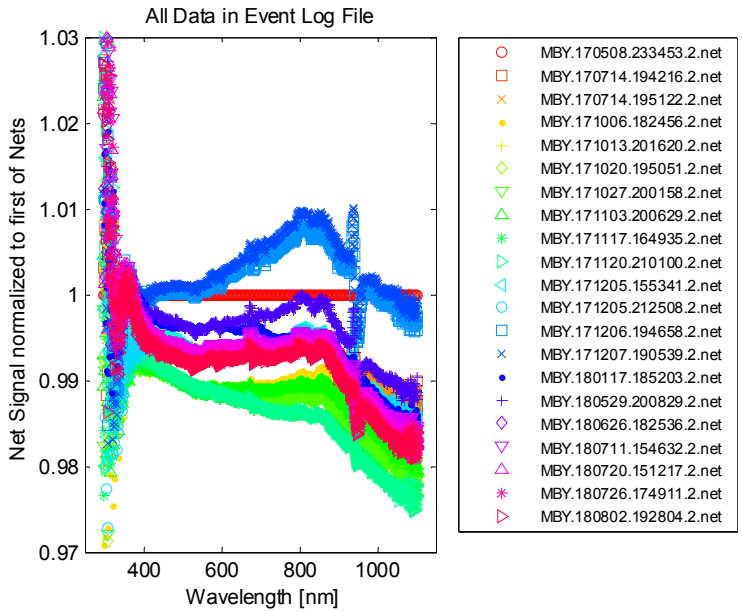
Time Series – Lu Radiance

Reproducibility w CAS Lu Head

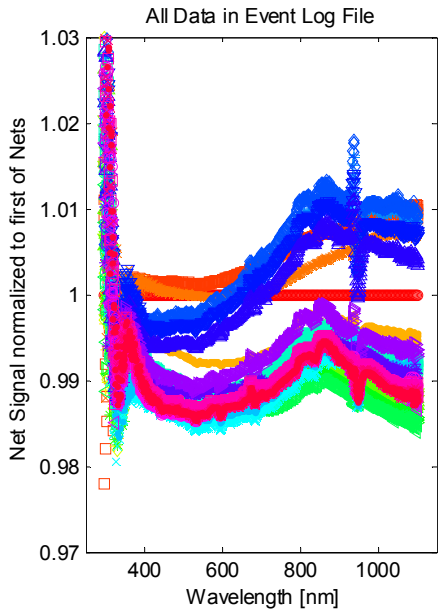
NPR 12/8/16 to 7/26/18



SQM MED 5/8/17 to 8/2/18

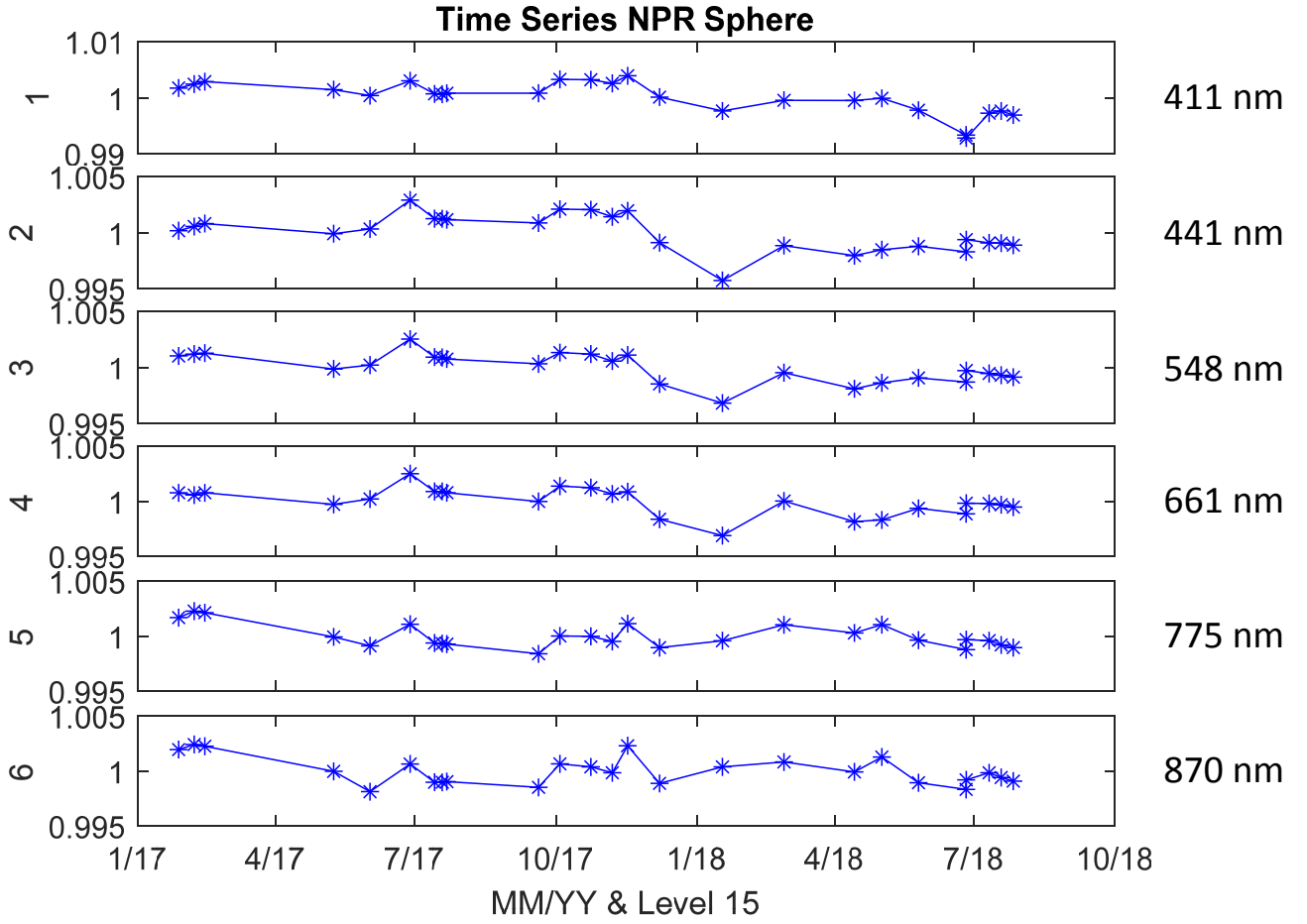


SQM LO 4/7/17 to 8/2/18



Data normalized to the first run. Groupings are generally associated with some type of perturbation – moving the CAS, switching the foreoptic, or operating in different laboratories. Note the spectral differences between the two sources.

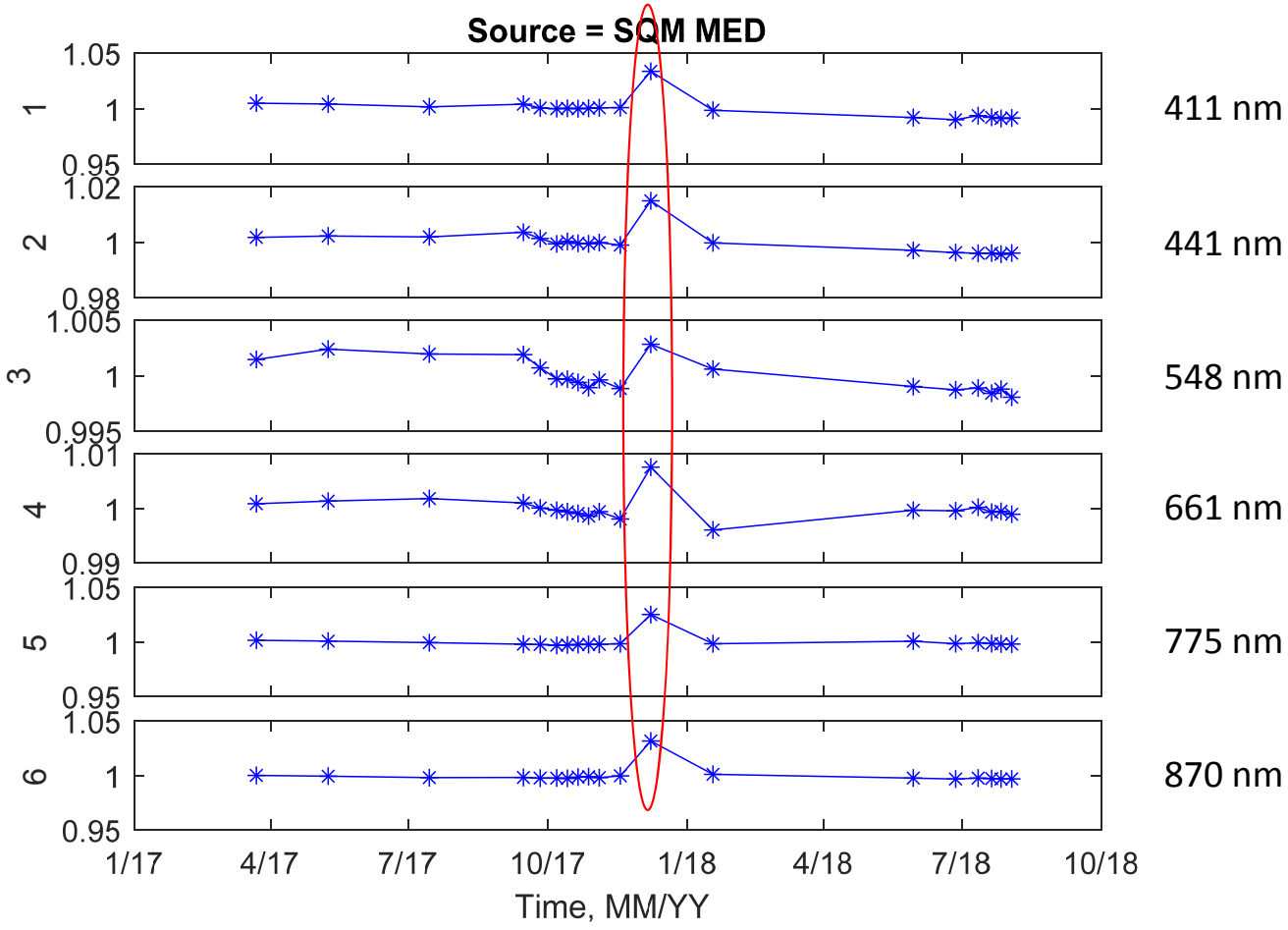
NPR with VXR illustrates stability



Similar results with NPR-Jr

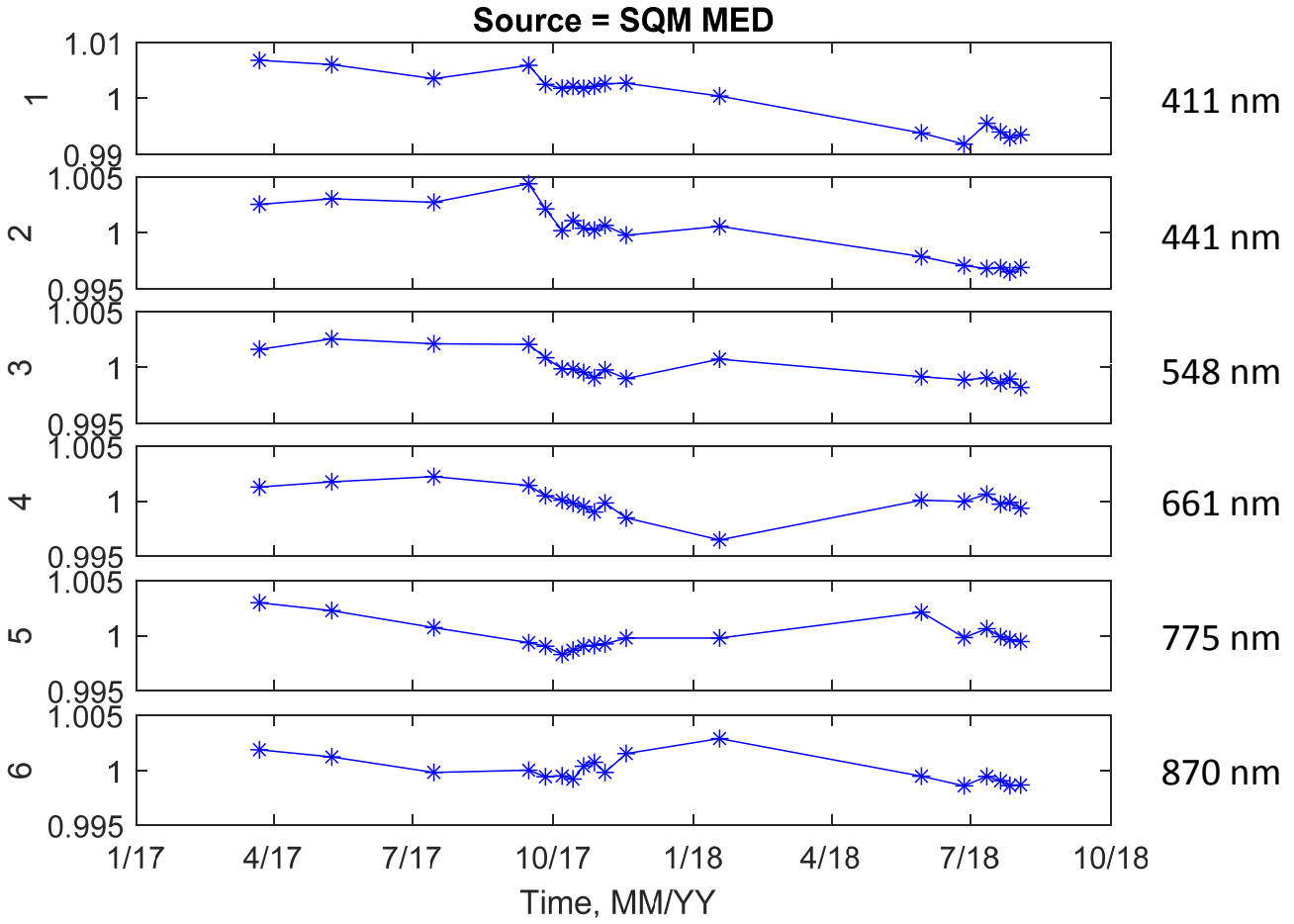
Compare these results to "Reproducibility with CAS Lu head"

SQM MED and VXR



The outlier is at UM where the VXR was on a tripod and aligned to the SQM through the VXR eyepiece. As the SQM is not uniform we believe the difference is from alignment sensitivity

Remove UM result



Now the results are very comparable with VXR – NPR, indicating the SQM is stable.

The spectral changes observed with the Lu CAS are not observed here.

We conclude the reproducibility of the CAS is driving the uncertainty budget

Stability System Preliminary Uncertainties*

Component	Evaluation is COV = std/mean in %	400	550	600	700
CAS COV, Lu head, 36 scans	NPR SQM MED SQM LO	0.060 0.099 0.097	0.020 0.046 0.042	0.018 0.044 0.036	0.016 0.039 0.031
CAS Lu Repeatability, same setup	NPR SQM MED SQM LO	0.098 0.105 0.138	0.097 0.123 0.135	0.098 0.131 0.135	0.104 0.142 0.140
CAS Es Repeatability, same setup	S194	0.080	0.080	0.078	0.078
CAS Lu Reproducibility, all data w/ final Lu head	NPR SQM MED SQM LO	0.420 0.260 0.389	0.389 0.325 0.453	0.389 0.361 0.485	0.418 0.403 0.518
CAS Es Reproducibility, all data	S194	0.461	0.386	0.350	0.337

Component	Evaluation is COV = std/mean in %	Blue	Red	White
SQM Reproducibility	White Fiducial, LO Black Fiducial, MED	0.87 1.53	1.22 1.58	1.14 1.37

*CAS distributions are not normal, so standard deviation not proper approach. It is also improper to include multiples for similar conditions in unequal numbers. Anticipate these values are underestimated.

Discussion – Repeatability & Reproducibility

- Independent of Lu or Es foreoptic – COV's about the same
- Short term repeatability (over ≈2 min) is comparable to the long term repeatability, as long as the only thing you do is turn the CAS off and on, flex the fiber bundle, and, in the case of Lu, realign the optic about the vertical axis
- The NPR is a bright and stable source, and we get comparable values for repeatability of SQM – says SQM is stable and CAS has adequate SNR
- Reproducibility ("changed conditions of measurement") is about 4x the repeatability using this COV method (probably an underestimate)
- The reproducibility changes are spectral
- The SQM internal monitor photodiodes are not as repeatable as the CAS Lu