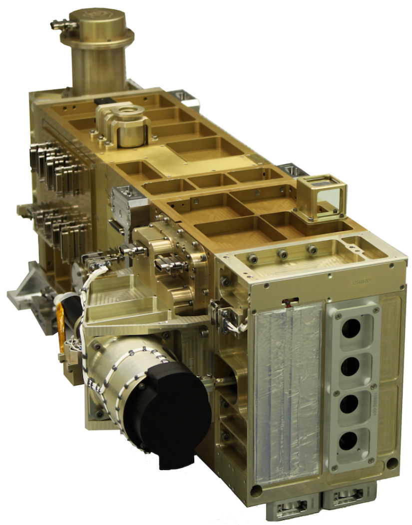
Calibration of the Spectral Irradiance Monitor in the LASP Spectral Radiometry Facility



David Harber, Erik Richard, Joel Rutkowski,
Kasandra O'Malia, Matt Triplett, Peter Pilewskie

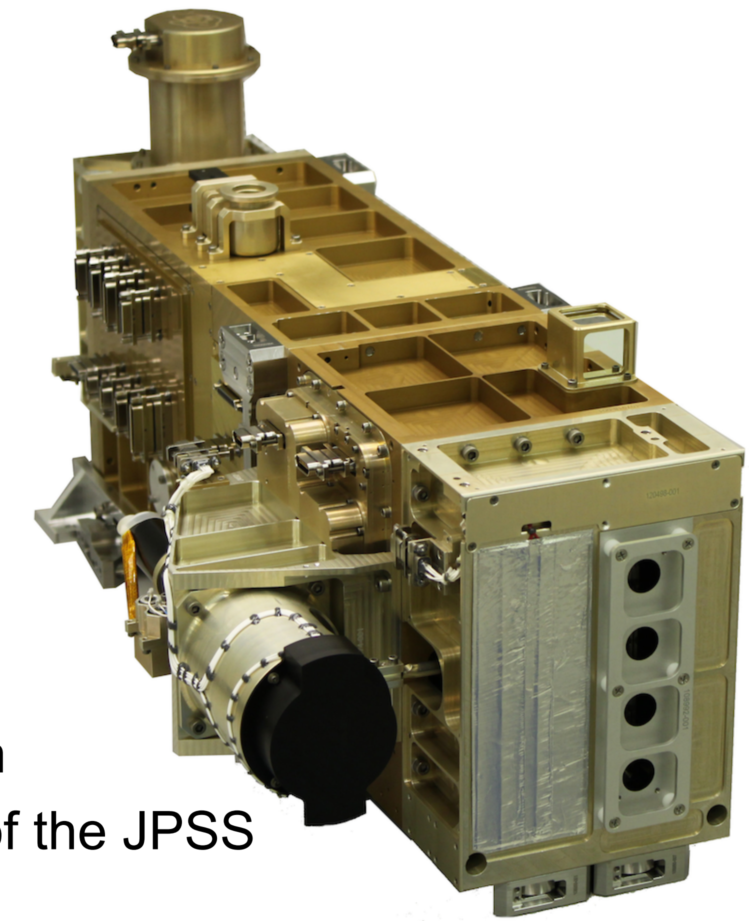
LASP, University of Colorado

Thanks to: Steven Brown, Keith Lykke, Allan Smith at NIST

The Solar Spectral Irradiance Monitor (SIM)

The TSIS SIM Instrument:

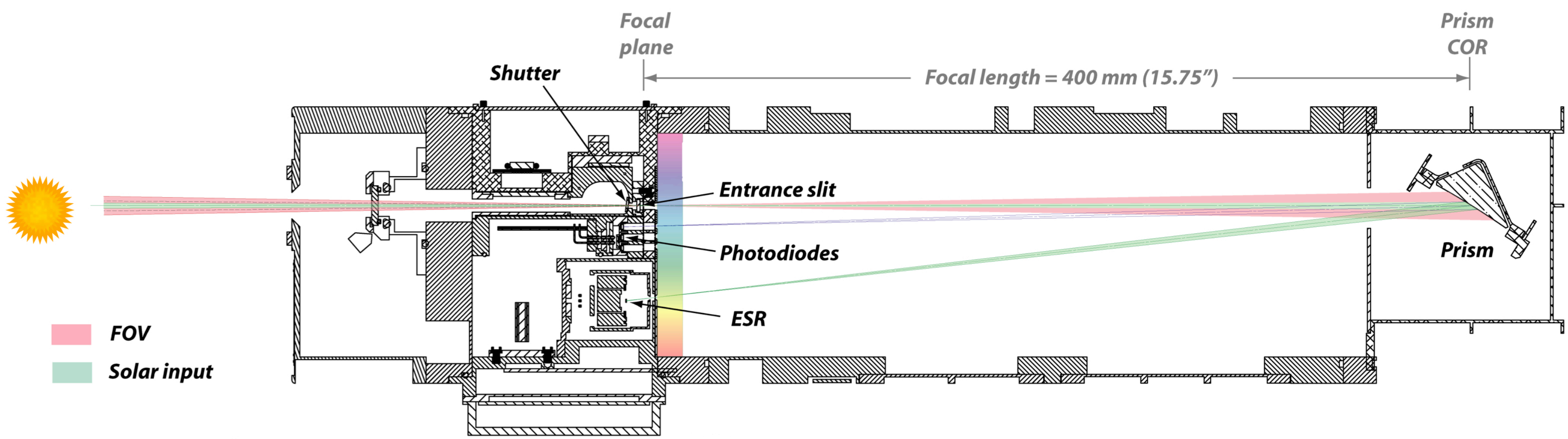
- Measures the solar spectrum from 200-2400 nm with an accuracy of 0.25%
- Has a long-term stability of 0.01%/year to allow tracking of solar variability
  - This is accomplished by using three redundant channels to track solar degradation
- Uses a single fused silica prism to focus and disperse the spectrum
- Planned launch mid-2017 as part of the JPSS



More detail in Erik Richard's talk on Wednesday at 4:30, "The Next Generation Solar Spectral Irradiance Monitor for the JPSS-TSIS Mission: Instrument Overview and Radiometric Performance"

The Solar Spectral Irradiance Monitor (SIM)

- Simple light path: entrance slit-prism-exit slit-detector
- Wavelength is scanned by rotating the prism
- Two types of detectors
  - Silicon and InGaAs photodiodes
    - High S/N and fast
    - Used to take two solar spectra per day
  - Miniature electrical substitution radiometer (ESR)
    - Carries the absolute calibration
    - Provides long-term stability



LASP Spectral Radiometry Facility: Motivation

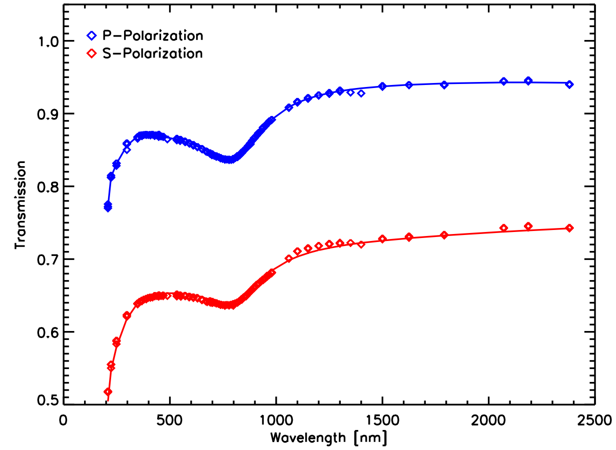
In order to achieve 0.25% accuracy:

- Calibrate each of the key SIM components
- Use these component-level calibrations to build a radiometric model of the instrument

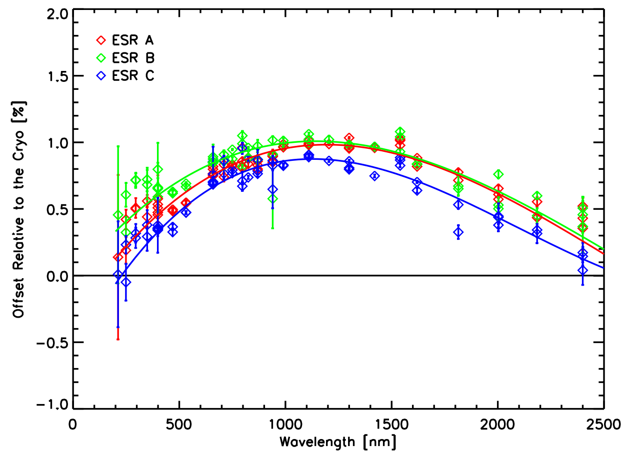
To verify that this model is accurate to 0.25% we need to perform an end-to-end validation

- For this we have built a facility that allows us to illuminate both SIM and a cryogenic radiometer with monochromatic laser light
- Can check the measurement of SIM directly against a standard detector
- Similar to the TSI Radiometer Facility

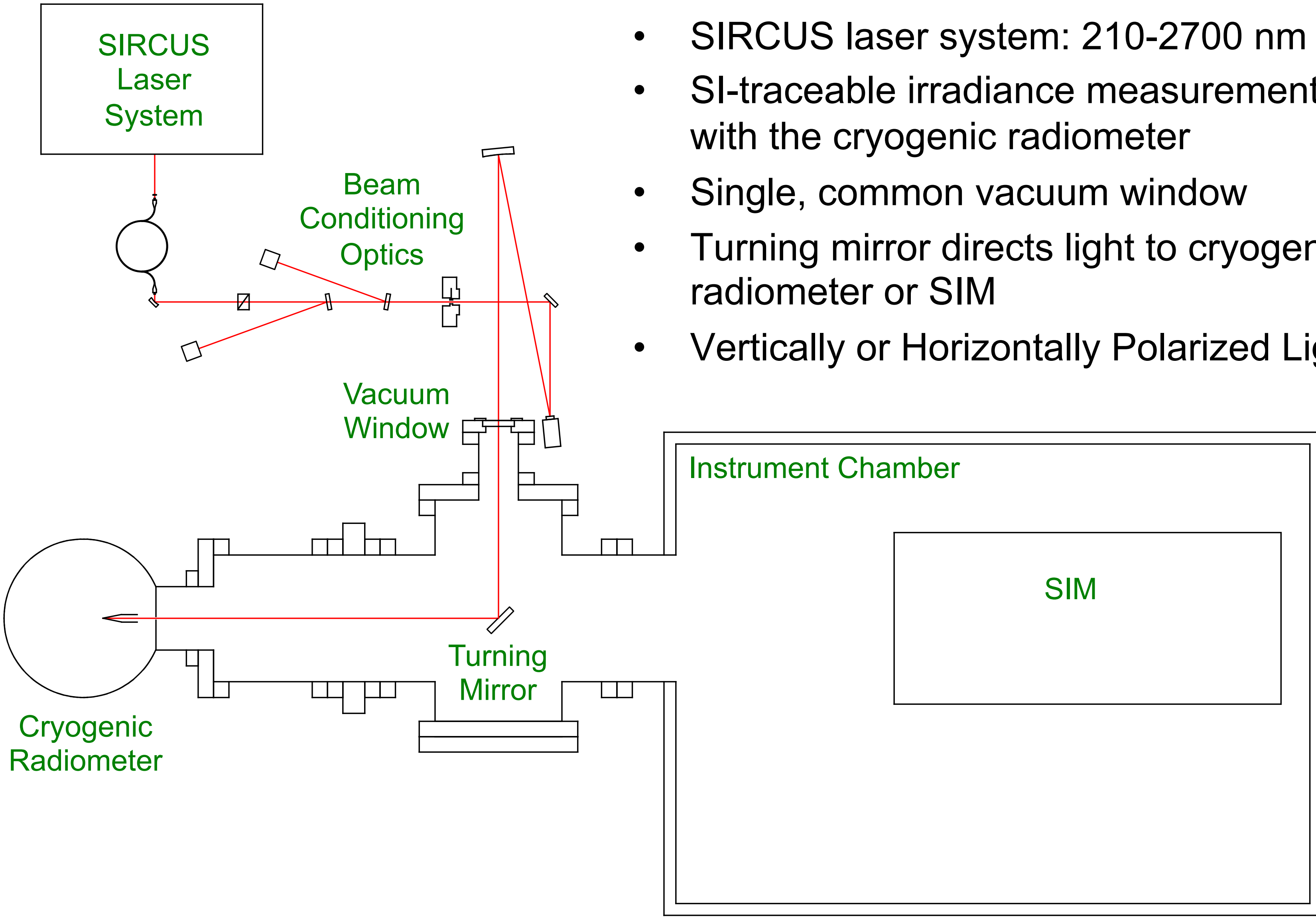
Transmission of the Dispersing Prism



Calibration of the ESR Detectors



LASP Spectral Radiometry Facility: Overview



- SIRCUS laser system: 210-2700 nm
- SI-traceable irradiance measurement with the cryogenic radiometer
- Single, common vacuum window
- Turning mirror directs light to cryogenic radiometer or SIM
- Vertically or Horizontally Polarized Light

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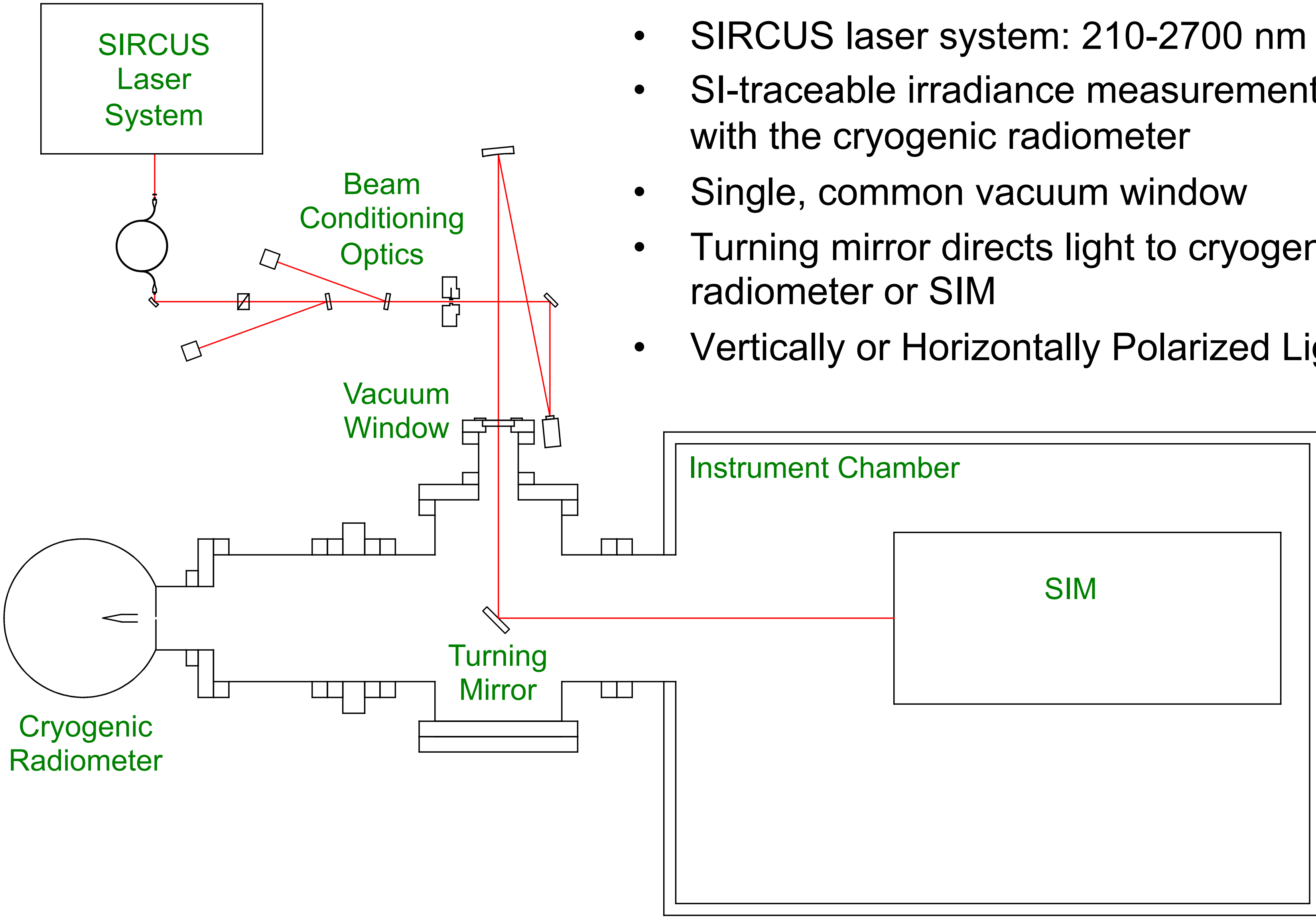

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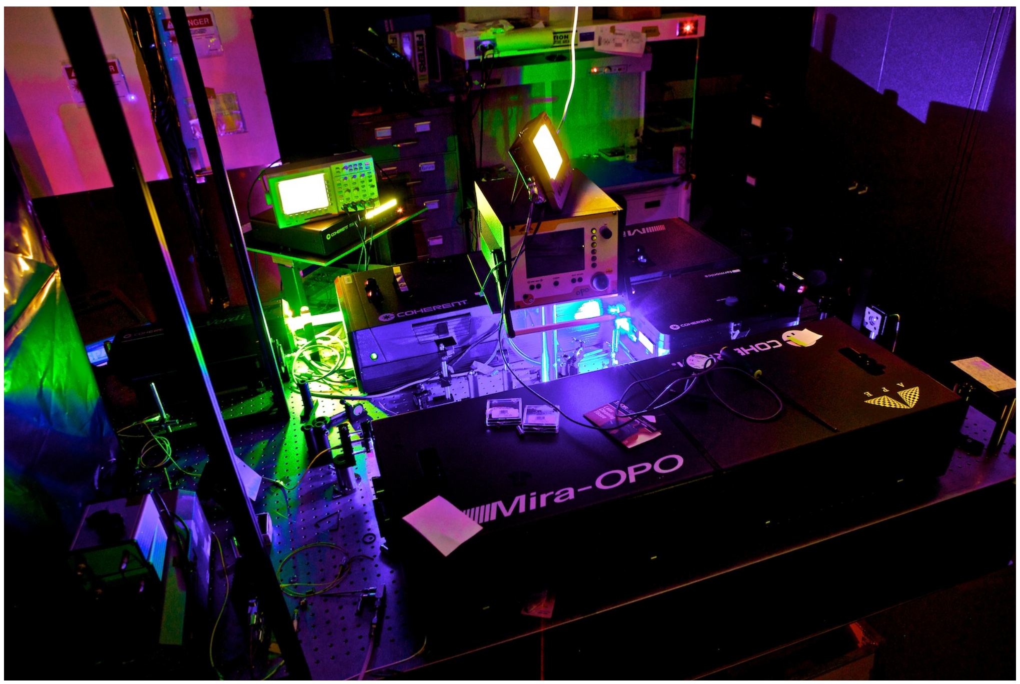
NIST Traveling SIRCUS Laser System

We are using a NIST traveling SIRCUS to generate stable, narrow monochromatic light from 210 to 2700 nm

18W CW 532nm DPSS Laser → Mode-Locked Ti:Sapph 700-1000 nm

Mode-Locked Ti:Sapph 700-1000 nm →

- Quadrupler 210-230 nm →
- Tripler 236-327 nm →
- Doubler 355-490 nm →
- Doubled OPO Signal 505-700 nm →
- OPO Signal 1050-1600 nm →
- OPO Idler 1750-3300 nm →



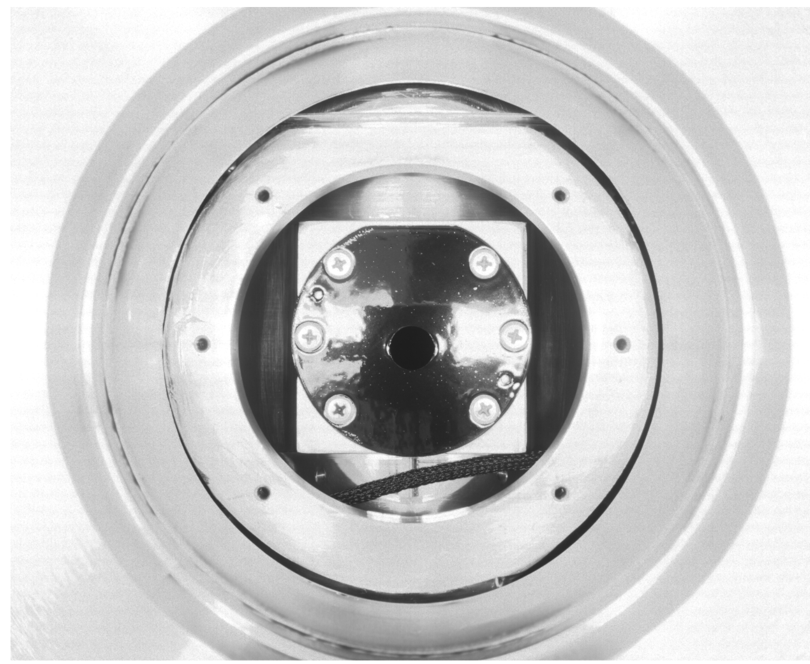
Cryogenic Radiometer

SI-traceable irradiance measurements are performed with a cryogenic radiometer

To measure irradiance we use a SIM entrance slit (6.5x0.3mm) as the limiting aperture

- The area of this slit was measured at the NIST aperture area measurement facility
- Cooled to LN2 temperature to reduce thermal background
- This reduces the aperture area by 0.655%
  - This was measured by Precision Measurements and Instruments Corporation

View of the cryogenic radiometer showing the LHe baffle without the limiting aperture



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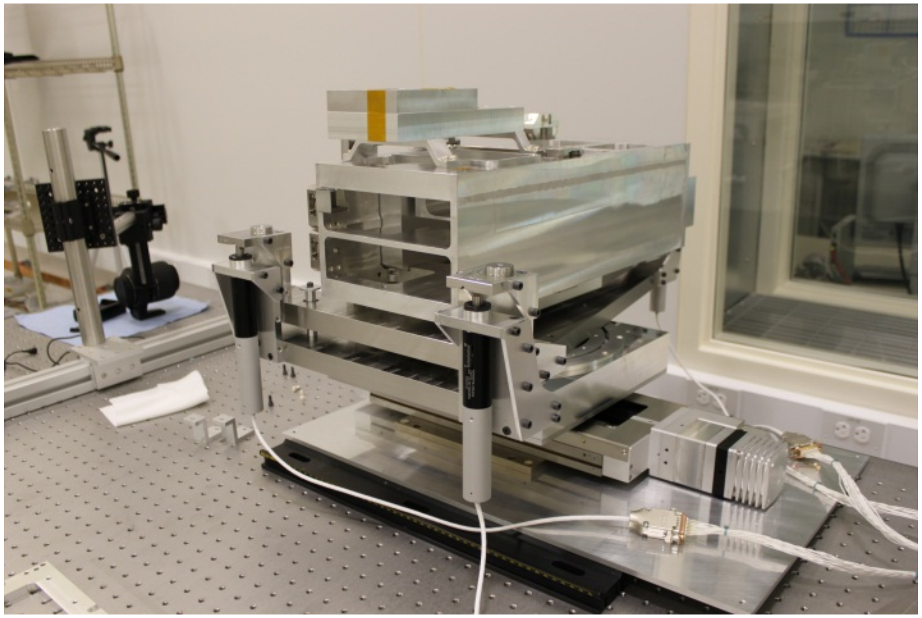
Instrument Chamber

The SIM instrument is mounted in the test chamber on a 5-axis manipulator

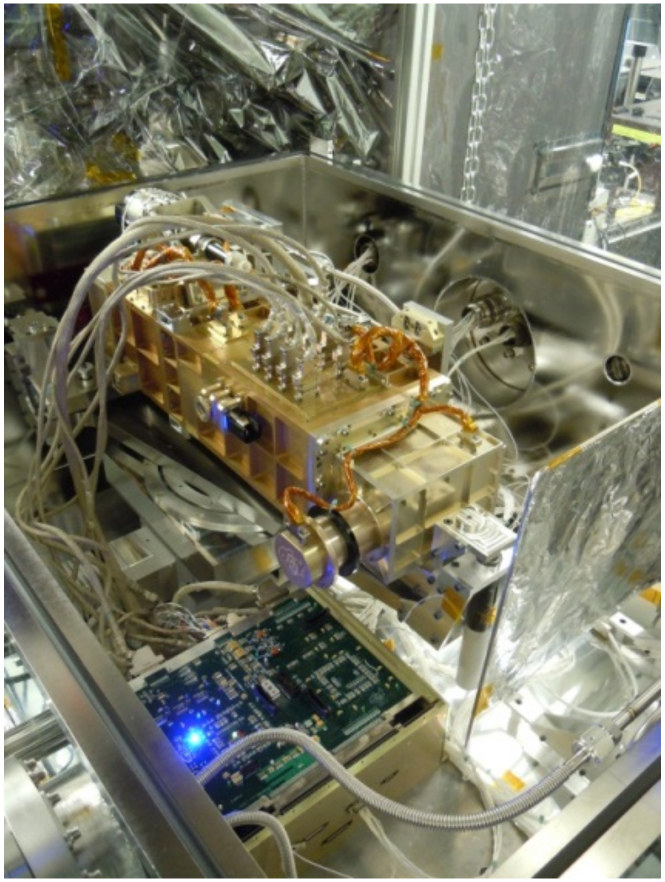
We need the manipulator to:

- Align SIM to the cryogenic radiometer
- Translate between the three SIM channels
- Test off-axis performance

SIM mass model on the 5-axis manipulator



SIM in the chamber

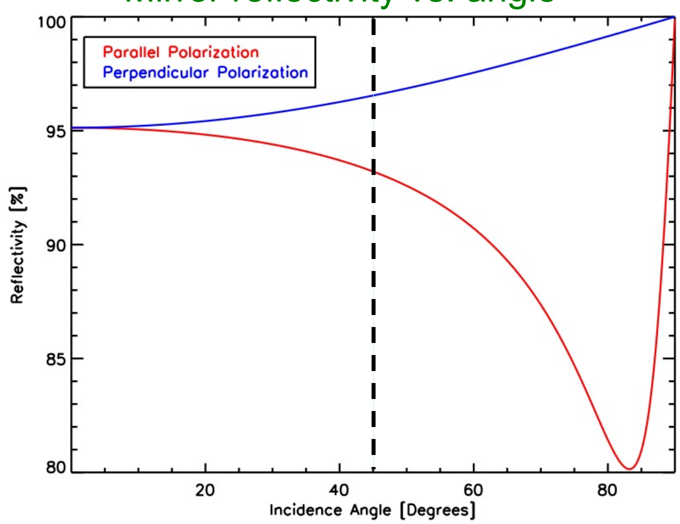


Turning Mirror

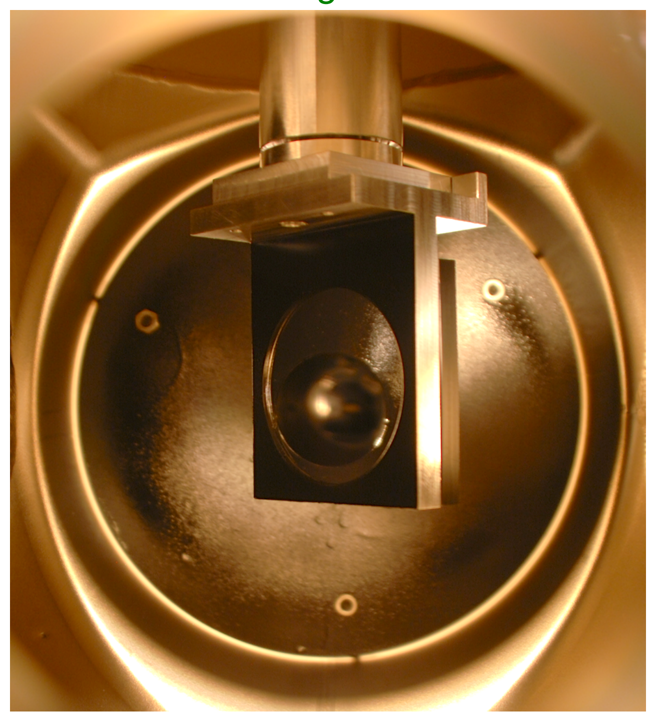
2” diameter mirror coated with UV enhanced aluminum

- Must accurately rotate to +/- 45.00°
  - Reflectivity vs. angle sensitivity ~0.15% per degree
  - Stage accuracy is 0.023°
  - *Cryo-SIM power difference uncertainty from the mirror ~50 ppm*
- Front surface of the mirror is coincident with axis of rotation to <50 μm
  - Ensures mirror translation <100 μm

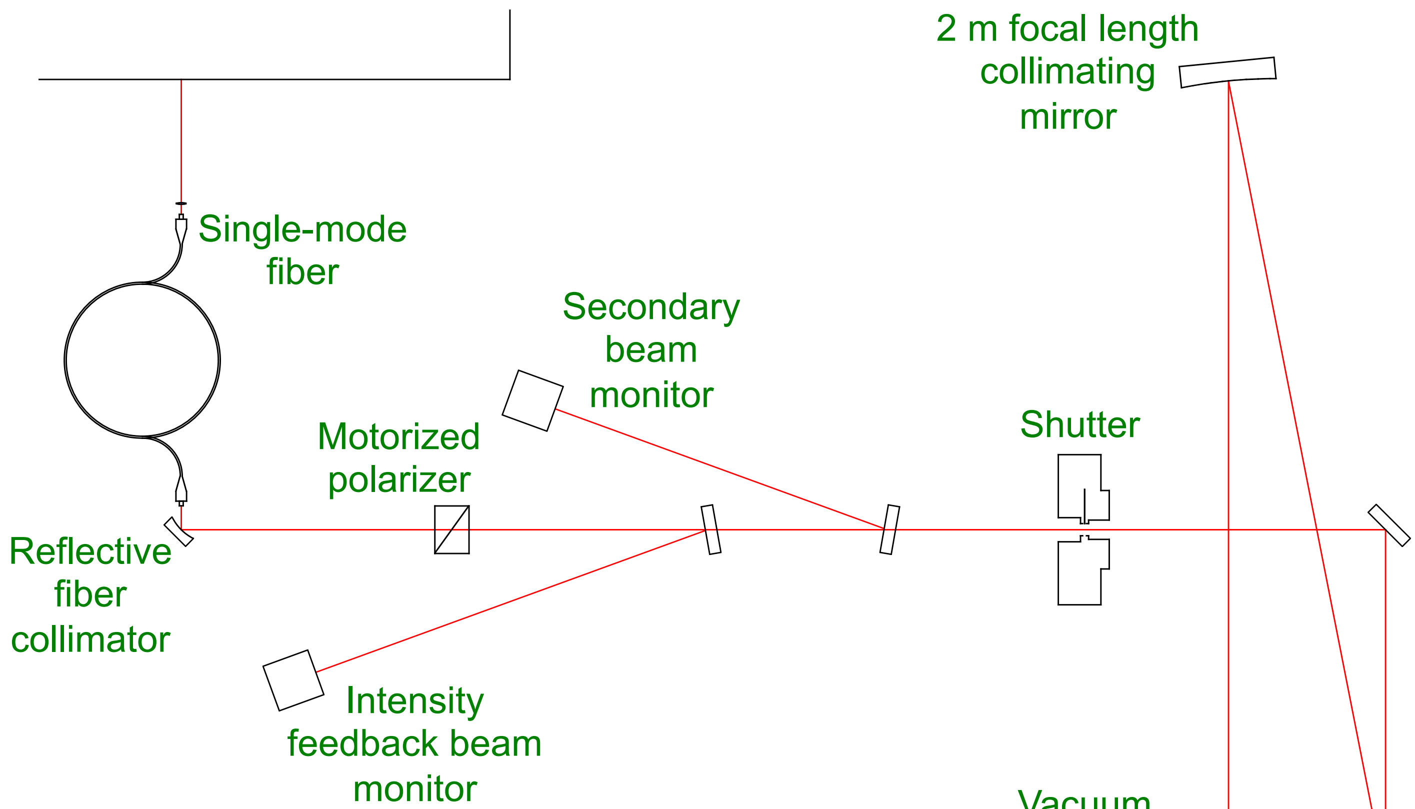
Mirror reflectivity vs. angle



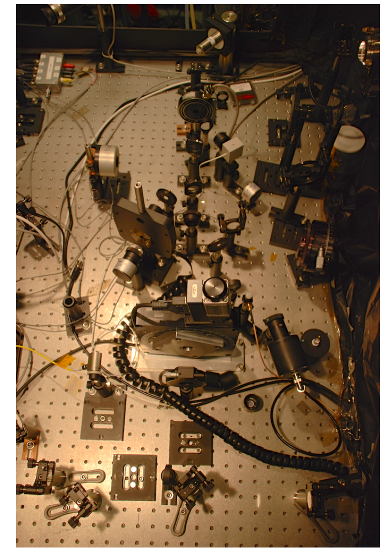
Turning mirror

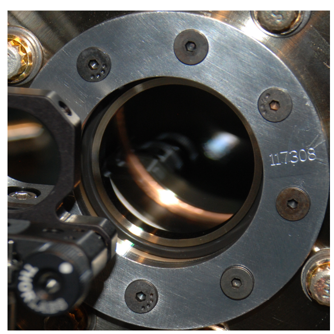


Optical Layout



Actual optical layout

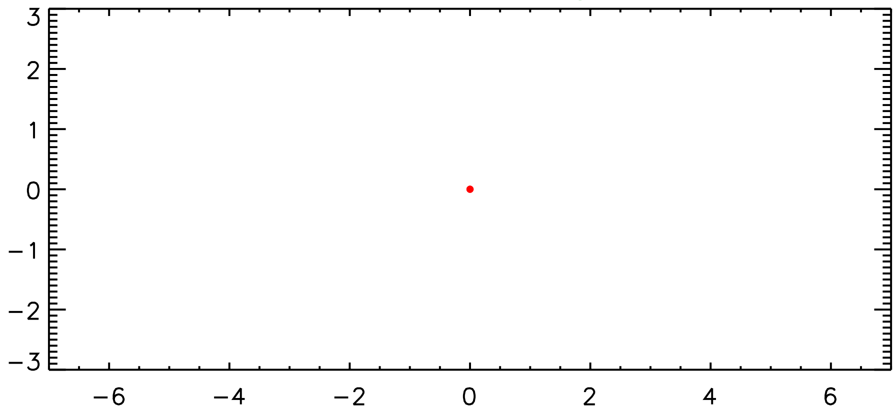




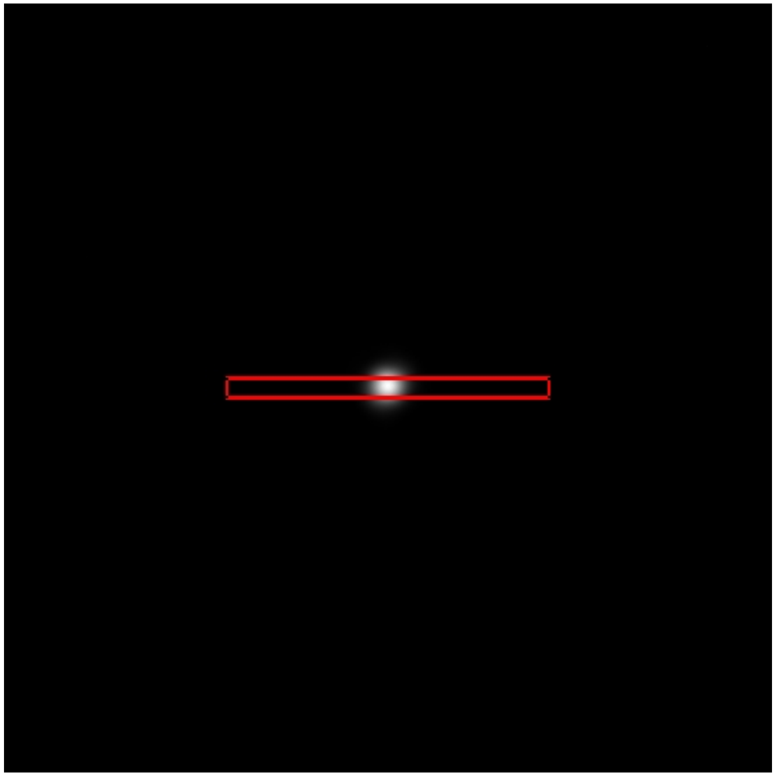
Fast Steering Mirror

To generate a uniform irradiance over the entrance slit we scan the fast steering mirror in a rectangular pattern

FSM control signal



CCD image of the beam



Slit dimensions indicated in red

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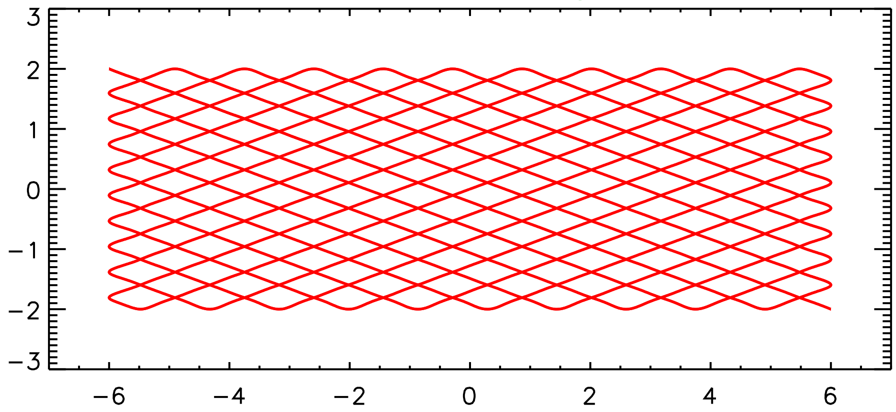

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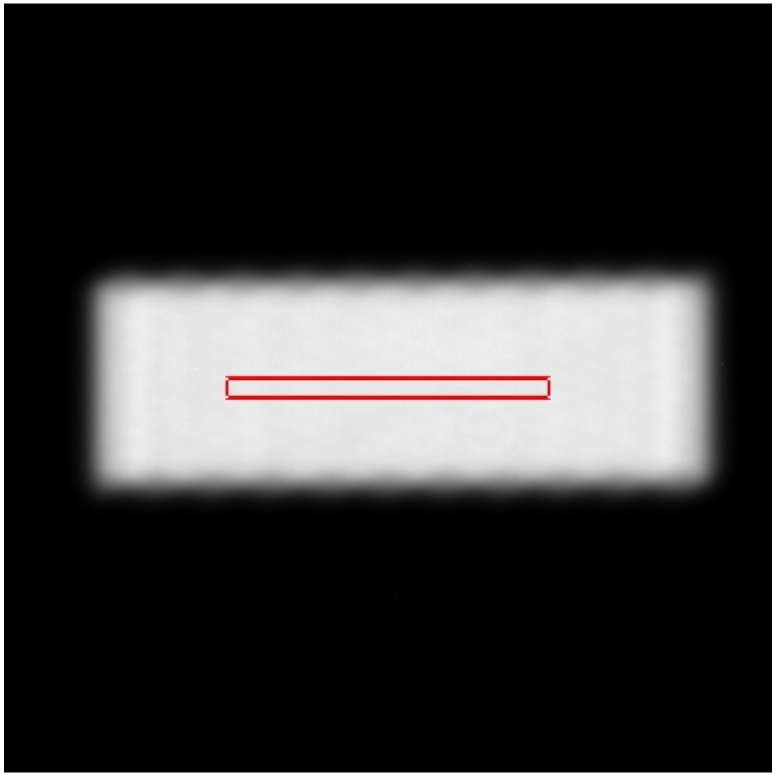


Slit dimensions indicated in red

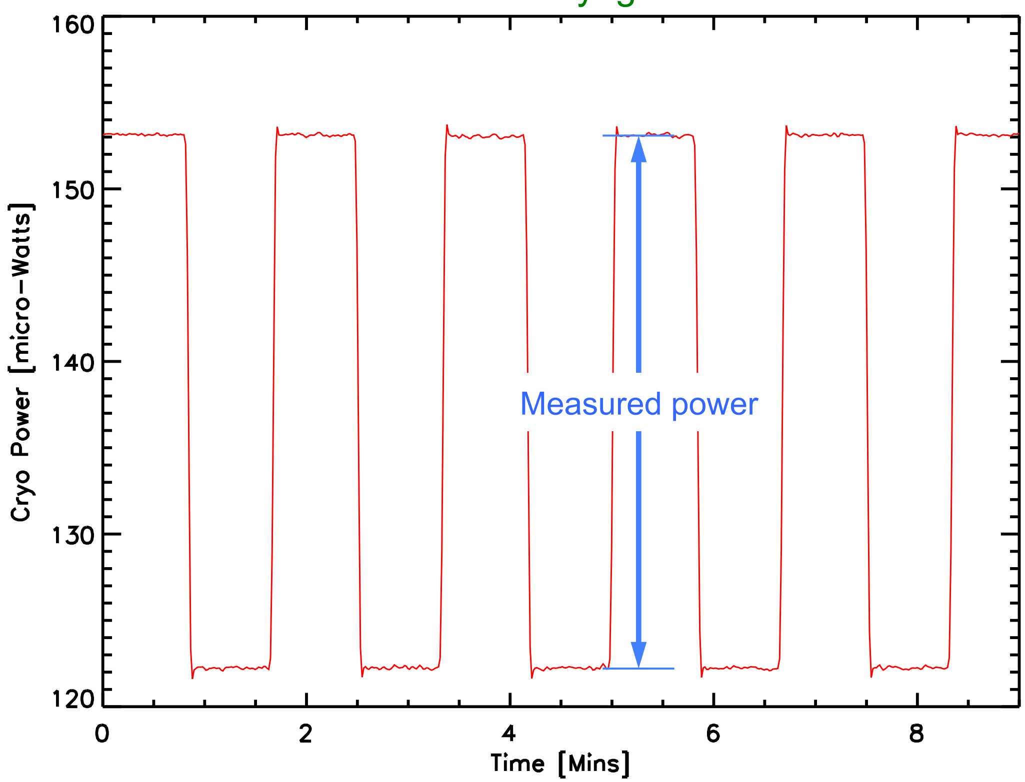
How we make a measurement?

1. Setup and align the optics for a particular wavelength
2. Center the beam on the cryogenic radiometer
   - Using the fast steering mirror
3. Center SIM on the beam
   - Using the 5-axis manipulator
4. Turn on the fast steering mirror scan pattern
5. Measure the power with the cryogenic radiometer
   - Then convert the measured power to irradiance
6. Take a spectrum with SIM
   - Then integrate the measured spectrum to get the SIM irradiance

Cryogenic Radiometer Measurement

- The laser beam is chopped with a 100 second period
- Measured power is the difference between shutter open & closed

Raw data from the cryogenic radiometer



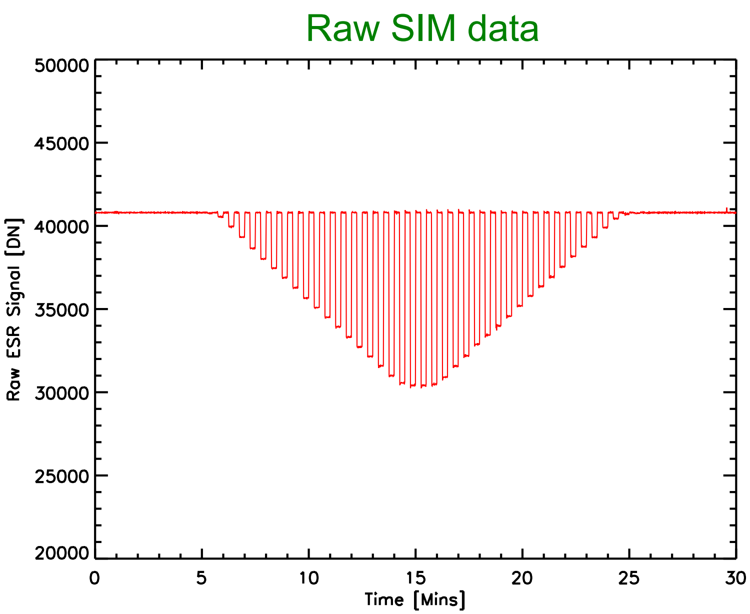
Measured power = 30.88 μW

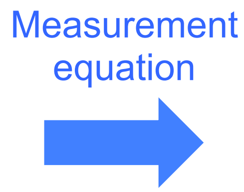
Divide by slit area and apply diffraction and cavity reflectance corrections:

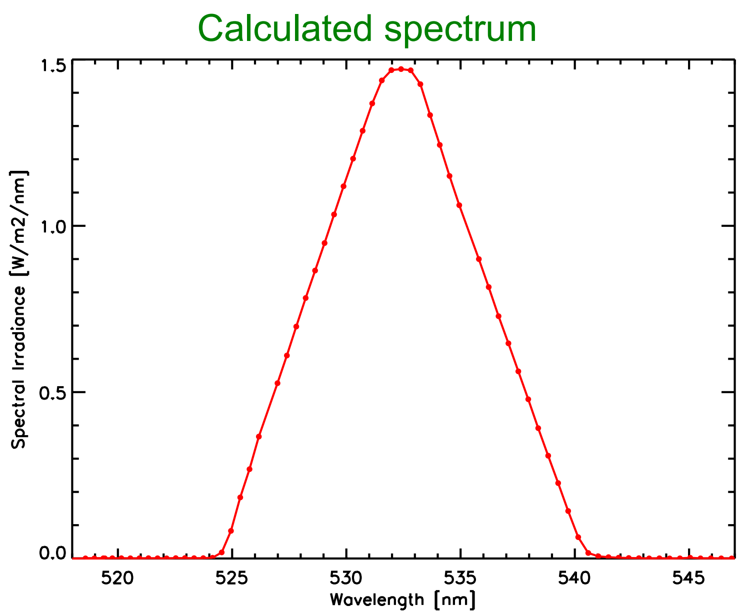
Measured irradiance= 15.96 W/m^2

SIM Measurement

- Take a spectrum around the laser wavelength with SIM
- The SIM ESR is similar in operation to the cryogenic radiometer so for each point in the spectrum SIM opens and closes its shutter



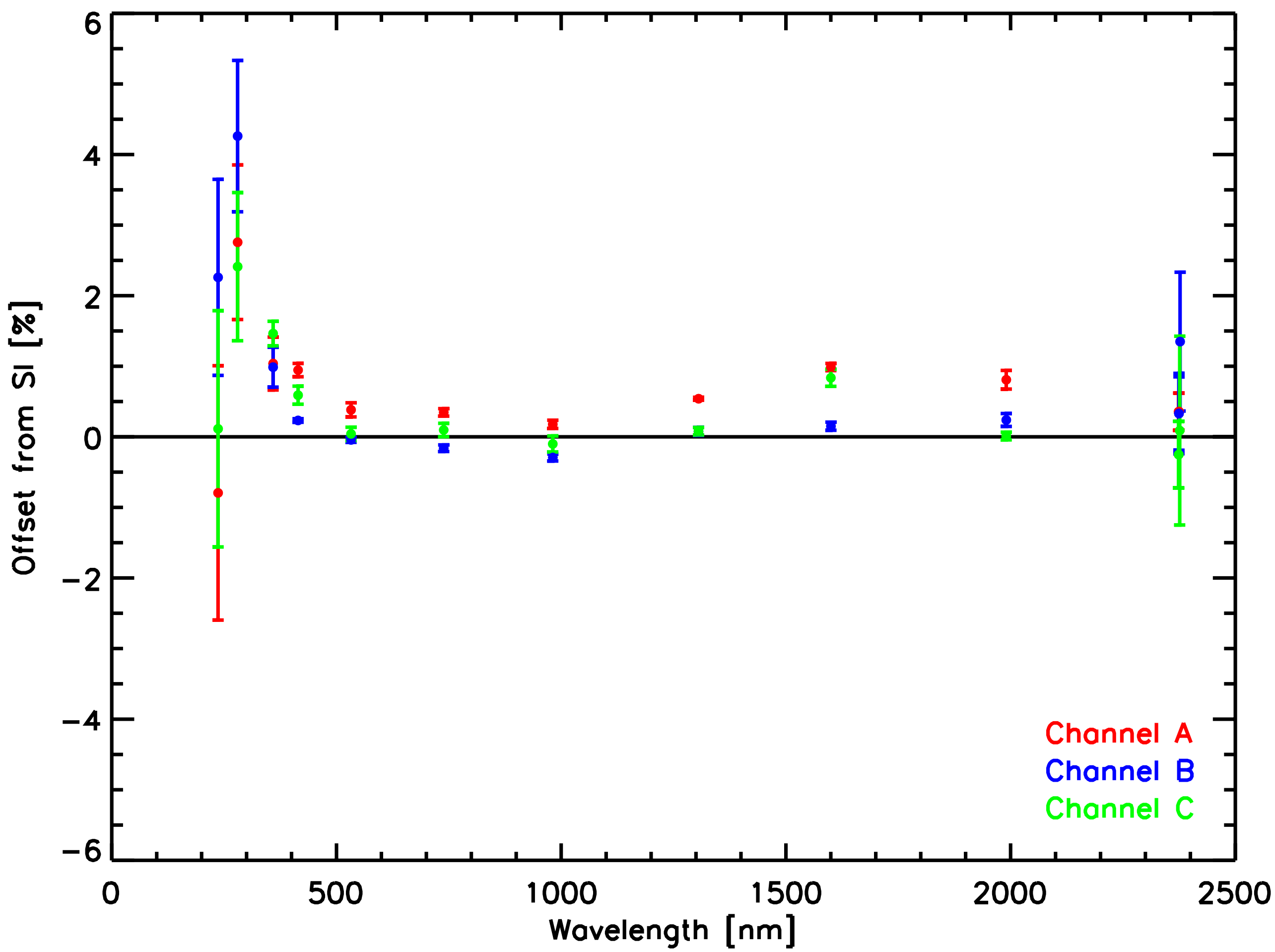




This spectrum is then numerically integrated to get the irradiance

Preliminary Results

- Compare the irradiance from the cryogenic radiometer and SIM
- Repeat for all three channels, both polarizations and multiple wavelengths



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