Solar Irradiance Monitor (SIM) instrument calibration techniques on the TSIS missions

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I. Introduction

The Spectral Irradiance Monitor (SIM) measures solar spectral irradiance (SSI) and is part of the Total and Spectral Solar Irradiance Sensor (TSIS) mission and its successor mission, TSIS-2. To achieve the high degree of accuracy required for the SSI dataset produced by SIM to meet its science requirements, LASP has developed a high-fidelity instrument model and utilized its Spectral Radiometry Facility (SRF) to calibrate SIM. The SRF at LASP is used to perform absolute calibrations of the instrument using both tunable laser sources and a NIST-traceable detector called SNACR (SRF Not A Cryogenic Radiometer). Upgrades and improvements to SRF have been made since TSIS-1 was calibrated in the SRF, most notably the addition of SNACR. However, the concept and method of calibration is very similar between TSIS-1 and TSIS-2 SIM.

In preparation for its upcoming launch, the TSIS-2 SIM instrument has undergone a calibration campaign where measurements of a common laser source were performed by both the SIM instrument and SNACR over a wide swath of wavelengths inside of a vacuum environment with temperatures that simulate those that will be encountered by the instrument during on-orbit operation. These measurements provide a way to both refine the existing SIM instrument model and derive absolute uncertainty values across the instrument's wavelength measurement range. In this poster, we review LASP's SRF facility, the aforementioned TSIS-2 SIM calibration campaign, and the techniques used to analyze the calibration data collected.

II. Methods and Results

SIM is a spectrometer using a single optical element, a Féry prism, to measure solar spectral irradiance from 200nm – 2400nm. The instrument contains three redundant channels which are operated at different rates to correct for degradation on the prism. Additionally, there is a CCD channel which contains a mirror attached to the shared prism yoke which allows for controlling the angle of the prisms, correlating to the measured wavelength. Each channel contains 3 diode detectors used between 200nm and 1620nm and an Electro Substitution Radiometer (ESR). The diodes have a fast response time and are used to do daily measurements of the solar spectra as they can measure 200nm – 1600nm in two orbits. The ESR detectors are slower but more stable over time and are used to correct trending in the diodes as well as measure the daily spectra past 1600nm where the response of the diodes drops off.

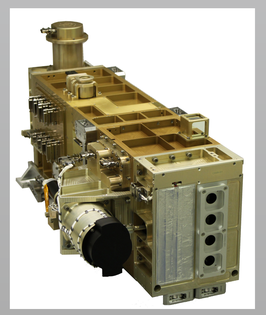


Figure 1: The TSIS-1 SIM instrument, which is nearly identical to its TSIS-2 counterpart

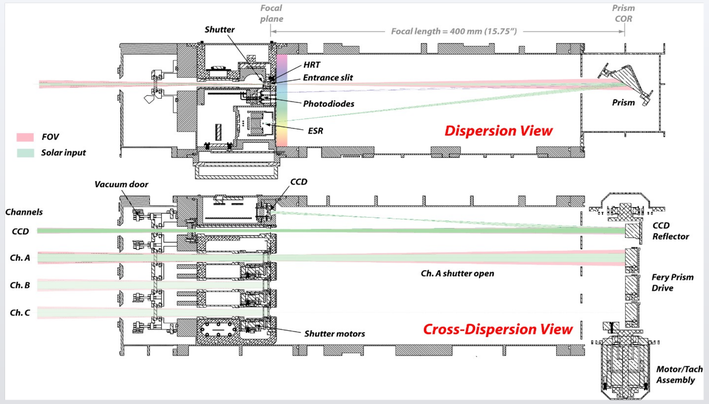


Figure 2: Overview diagram showing the dispersion and cross-dispersion views of the SIM instrument. The CCD channel uses reflected light and a CCD to control the rotation angle of the Fery Prism Drive (FPD) and thus the wavelength measured by the main channels.

SIM Scans

During a scan on the SIM instrument the FPD drive is rotated causing the dispersed laser to scan across one of the detectors. Below is the resulting signal measured by the VIS diode for a typical scan with a laser at 532nm. The key values derived from each scan are the CCD centroid position and the irradiance of the scan derived from the integral of the signal.

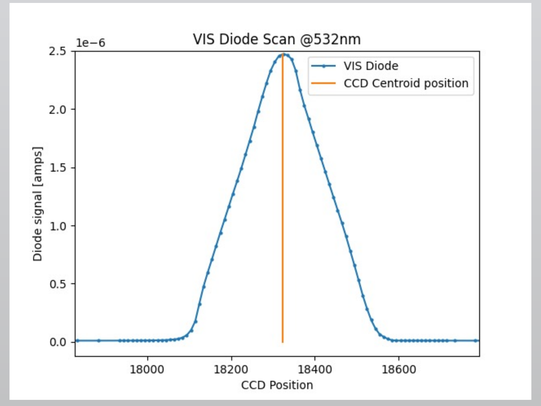


Figure 4: Typical SRF scan on SIM as a 532nm laser is moved across the entrance slit of the diode.

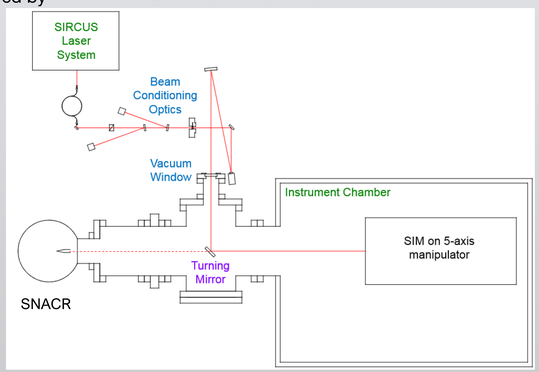
SIM Irradiance Calibration

For each SIM scan we can calculate an initial irradiance value by converting the measured signal to power via the detector response function and applying the aperture area. However, this leaves out several key corrections such as dispersion and prism transmission. Using our instrument model, we can derive values for these corrections to get an accurate irradiance value to compare with the measured irradiance on SNACR. Using these comparisons, we iteratively optimize the physical parameters of our SIM instrument model in order to get our calculated irradiance values to match SNACR as closely as possible. Any remaining difference can be corrected via a calibration function.

Calibration in SRF

The TSIS-2 calibration campaign spanned multiple months and hundreds of calibration scans in total covering a wide array of different wavelengths. The SRF facility at LASP contains a Spectral Irradiance and Radiance Responsivity Calibrations with Uniform Sources (SIRCUS) Laser system that allows the calibration team to generate stable laser sources of various wavelengths and polarizations. At the end of the system is mirror which can point the beam at either SNACR or SIM. Additionally, a fast-steering mirror paints a rectangular pattern on the aperture slits of the detectors multiple times per second to mimic a diffuse source like the Sun instead of the point like laser source.

Figure 3 (below): Diagram of SRF



SNACR Scans

Each calibration scan involves two scans on SNACR bracketing a scan of the same source on SIM. The detector is made of black carbon nanotubes which absorb nearly 100% of incoming radiation. The detector is held at a steady temperature and the power required to hold it at that temperature is measured. When exposed to a light source the power required to maintain the same temperature is reduced and the difference in power is the measured power of the light source.

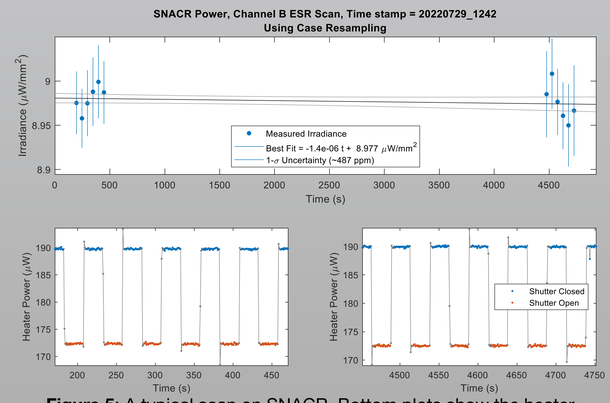


Figure 5: A typical scan on SNACR. Bottom plots show the heater power with the shutter cycling and the laser pointed at SNACR. The top plot shows the calculated irradiance values and uncertainty.

SIM Wavelength Calibration

Analysis of each SIM scan in the SRF allows for the determination of the central CCD position for the scan. The wavelength of the laser used for each scan is well known and thus a relationship between CCD position and wavelength can be determined. By iteratively comparing these results with the predicted wavelengths from the instrument model the physical parameters of the model can be refined.

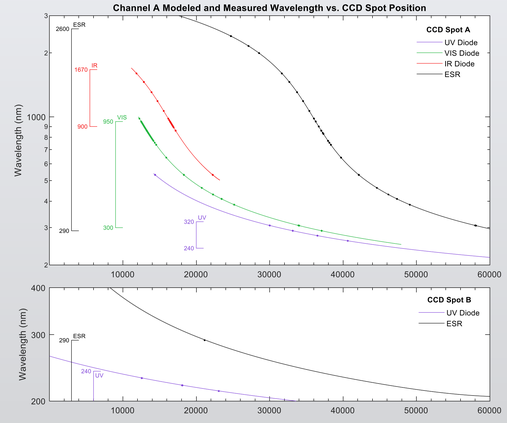


Figure 6: SRF Laser wavelength vs SIM CCD Position plots which show the wavelength range covered by each detector.

III. Conclusions

We have presented here, first, an overview of the TSIS-2 SIM instrument's mechanical and optical operation. Additionally, we have described the key points of the TSIS-2 SIM instrument's calibration campaign at LASP's Spectral Radiometry Facility (SRF). Furthermore, the essential elements of both the irradiance and wavelength calibration of the TSIS-2 SIM instrument were described, including how an iterative process is employed to refine our model of the instrument.

Calibration in the SRF facility led to excellent results on the TSIS-1 mission, with the TSIS-1 SIM instrument meeting or exceeding all accuracy and precision requirements. The TSIS-2 SIM calibration campaign has been a success so far and we expect to achieve similar on-orbit accuracy and precision as TSIS-1 SIM.

IV. Future Work

- Continued analysis of the SRF scan data
- Refinement of the instrument model physical constants by iteratively comparing the model results and the SRF results and optimizing parameters
- Incorporate changes into production data processing pipeline prior to launch
- Comparison studies of TSIS-1 SIM and TSIS-2 SIM on-orbit (an undetermined amount of temporal overlap of the two missions is anticipated)