SI-traceable absolute radiometry for measuring top-of-atmosphere radiation balance: New detectors, measurements, and opportunities

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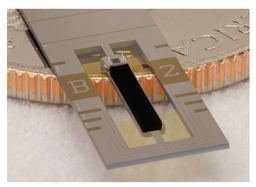
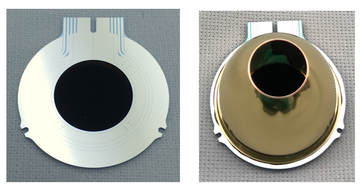
Bolometers are the only viable detector for measuring the extremely-broadband wavelength range of the incoming and outgoing elements of the Earth Radiation Budget. NIST-LASP collaborations have led to a family-tree of electrical substitution radiometer (ESR) detector technology developments that have fueled advances in the accuracy and SI-traceability of current and future solar irradiance and earth outgoing radiance observations.

CSIM ESR Detector



Richard *et al.* Proc. SPIE 11131 (2019), 1113105; doi: 10.1117/12.2531268

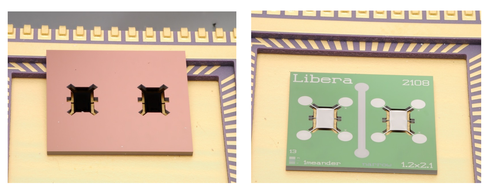
CTIM Silicon Detector & Integrated ESR Detector



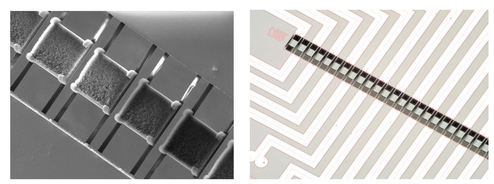
Harber *et al.* Proc. SPIE 11131 (2019), 111310D; doi: 10.1117/12.2531308

From Solar Irradiance To Outgoing Earth Radiation

Libera ESR Detector front (left) and back (right) sides



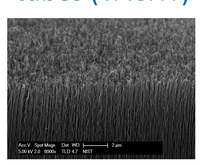
BABAR-ERI ESR (at each pixel) Detector Array front (left) and back (right) sides

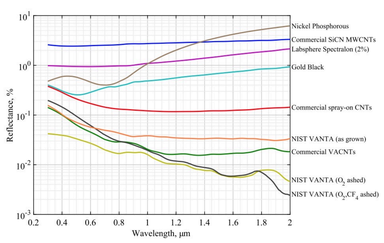


From Single Pixels to Linear Arrays (Adds Spatial Resolution)

These detectors have many pluses. They are "Blacker than Black", Micromachine Fabricated with Planar Geometry, Low Noise and Fast, Ambient Temperature, and more.

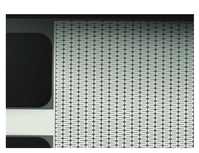
Vertically Aligned Carbon Nano-tubes (VACNT)



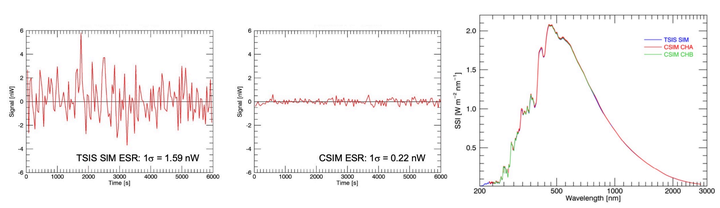


Lehman *et al.* Appl. Phys. Rev. 5, 011103 (2018)

Metal traces on SiN Membrane

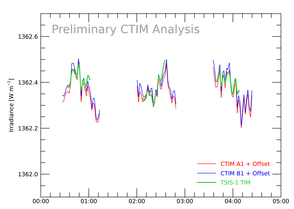


TSIS SIM vs CSIM ESR Noise & Accuracy Performance



Richard *et al.* Proc. SPIE 11131 (2019), 1113105; doi: 10.1117/12.2531268

TSIS TIM vs CTIM Performance



Intercomparison & Calibration Facilities

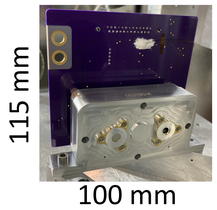
NIST-LASP collaborations have led to dedicated facilities at LASP where SI-traceable reference standards are intercompared using stabilized lasers with instruments under vacuum and under flight-like power levels.

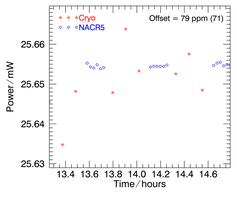
TSI Radiometer Facility (TRF)
SSI Radiometer Facility (SRF)
Earth Radiance Radiometer Facility (ERRF)
(under development)

The TRF was built to resolve systematic offsets between different TSI instruments. A cryogenic radiometer reference detector, traceable to NIST POWR, was used.

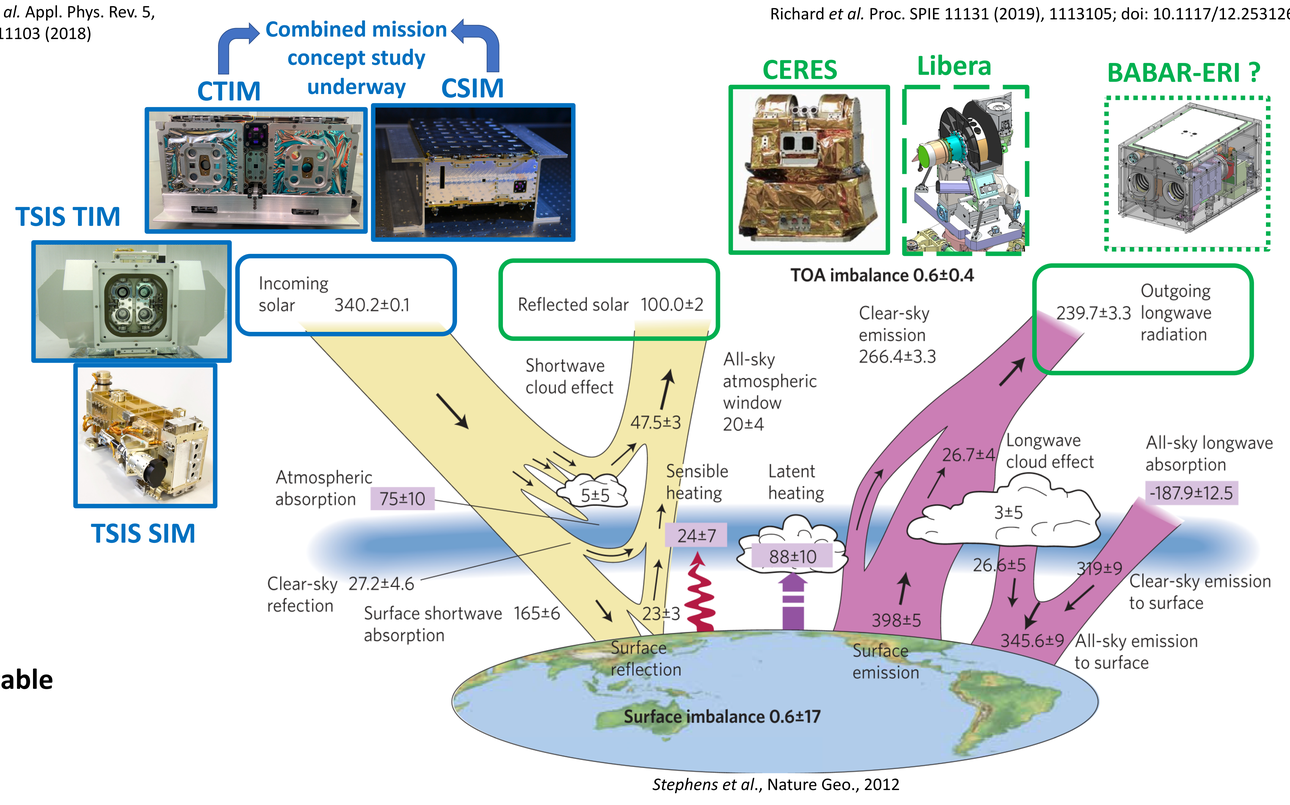
NACR: A Small, Lower Noise, & Transportable Reference Standard.

(Based on CTIM design)





White et al. Metrologia (2022), in press.



Stephens et al., Nature Geo., 2012

Validating the Traceability of the Solar Irradiance and Earth Radiation Budget Data

Power comparisons with photodiode trap detectors at 532 nm link NACR, TRF cryo, LASP1, NIST TT4 to NIST POWR

TRF Cryo Relative to NIST POWR: +213 (285) ppm
NACR relative to POWR: +133 (247) ppm

White et al. Metrologia (2022), in press.

Current Missions / Tech Demonstrations

Future Missions

Instrument Development

Future Work

A leading challenge with ambient temperature detectors is the inequivalence between optical and electrical heating that needs to be modeled or measured for any given detector.

- Validation through intercomparisons in important

New Opportunities

There is a need for national metrology labs to develop in-vacuum irradiance and radiance standards, in order to validate more key observational records.

This will require commitment in order to maintain, and continue developing, these standards and intercomparison techniques.

- Planned international periodic intercomparison cycles would be necessary.

LASP intercomparison facilities could be used for future in-vacuum intercomparisons, similar to what has been done for a number of TSI instruments in the TRF facility.