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Advances in the SI-traceability of ground-based solar irradiance measurements

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A new Cryogenic Solar Absolute Radiometer (CSAR) has been built by PMOD/WRC, NPL and METAS. We will present the component-level characterization and end-to-end calibration of the CSAR against the World Radiometric Reference (WRR). Metrology institutes use cryogenic radiometers to define the SI radiant power scale and key comparisons between the national institutes guarantee the stability of this scale. By adapting the advantages of cryogenic radiometry for solar radiation measurements and eventually replacing the WRR by CSAR, we make the important step from a conventional standard to a directly SI traceable solar radiation reference scale.

Whilst all terrestrial Total Solar Irradiance (TSI) measurements are traceable to the WRR, some space TSI experiments are rather characterised than calibrated against a reference scale. This resulted in unexplained offsets between different instruments. The ground calibrations and on orbit measurements of our most recent space experiment – PREMOS on the the French PICARD satellite – show a difference of 0.34 % between the WRR and a laboratory SI irradiance scale. Thus offering an explanation for the observed offsets in space. A main source for the difference is stray light which has been underestimated in the characterisation of most absolute solar radiometers. The preliminary CSAR measurements are 0.3 % lower than the WRR – confirming the PREMOS results. Thus a CSAR based reference scale would also represent the newly found absolute TSI value.

Compared to existing cryogenic radiometers the major challenges of the CSAR instrument are the determination of the transmittance of the entrance window, and the optical effects of the illuminated aperture.
The integral transmittance of the CSAR entrance window will vary due to the changing solar spectrum on the Earth's surface. We have characterised the spectral transmittance of our windows and generated synthetic MODTRAN spectra. Our calculations show that the atmosphere induced changes of the transmittance are larger than the intended uncertainty of the CSAR. Thus we developed the Monitor to Measure the Integral Transmittance (MITRA) of windows.
The aperture area has been measured by NPL and the diffraction correction was calculated with state-of-the-art code. By placing the smallest aperture at the entrance of the CSAR we avoid internal stray light. The volcano-like shape of the aperture eliminates stray light due to inter-reflections between the aperture and the entrance window.
The advantages from which we profit with the cryogenic radiometer are the large cavities with a very high absorptivity, the nearly perfect equivalence between optical and electrical heating, and the use of superconducting wires which eliminate the need for a lead-heating correction.

In our work we will show: 1) The CSAR prototype together with the MITRA instrument 2) The component-level characterisations and calibrations of the instruments. 3) The end-to-end comparison to the WRR. 4) A concept of future operation of the CSAR alongside the WRR.