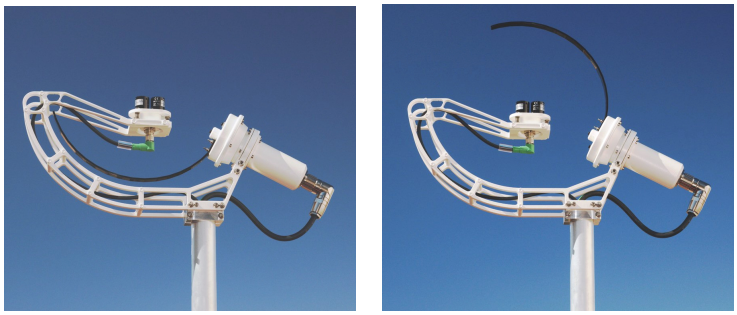
Sunshape measurements with Rotating Shadowband Irradiometers (RSI)

Upgrade of RSI-equipped automatic weather stations with additional parameter

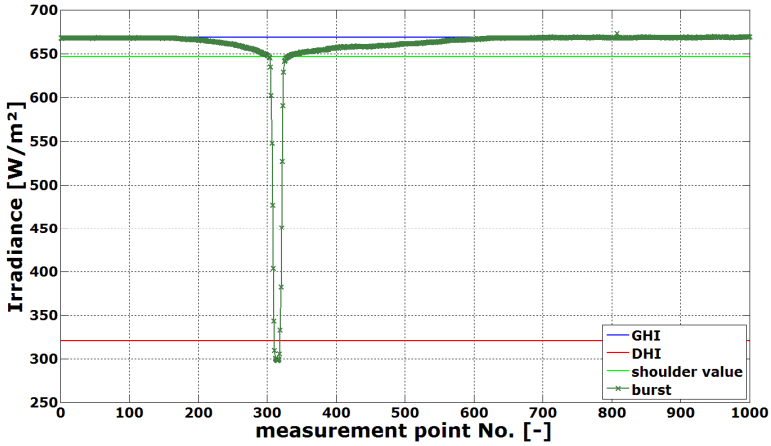
Due to forward-scattering of direct sunlight in the atmosphere, the circumsolar region closely surrounding the solar disk looks very bright. The radiation coming from this region, the circumsolar radiation, is in large part included in common direct normal irradiance (DNI) measurements, but only partially intercepted by the receivers of focusing collectors. This effect has to be considered in the performance analysis of concentrating collectors in order to avoid overestimation of the intercepted irradiance.

Circumsolar radiation can be characterized using the angular distribution of the radiance around the center of the sun – the so-called sunshape. The amount of circumsolar radiation varies strongly with time, location, and sky conditions. Therefore, sunshape measurements are recommended to be included in solar resource assessment.



CSP Services' Twin-Sensor Rotating Shadowband Irradiometer (RSI) in rest position (left) and during the rotation (right)

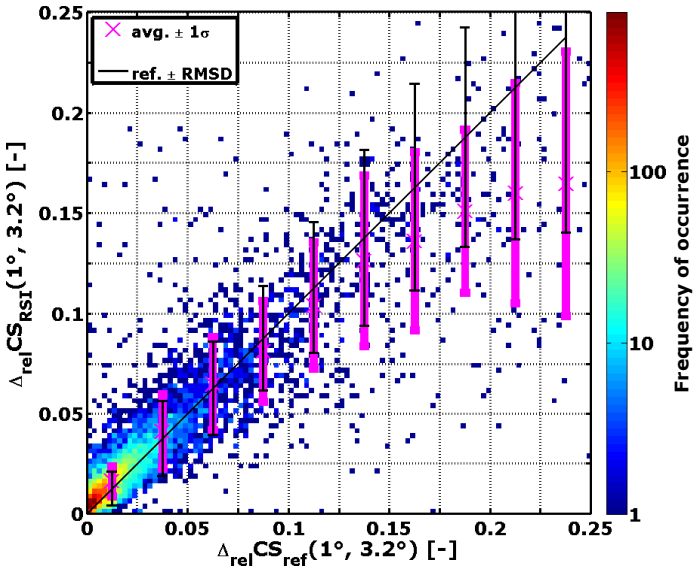
Sunshape measurement methods have been developed and validated by scientists in the DLR Institute of Solar Research. One of these methods successfully uses the Rotating Shadowband Irradiometer (RSI). During the rotation of the shadowband, the irradiance signal of the pyranometer is logged with high frequency. In common RSIs this signal is analyzed in order to obtain the diffuse irradiance. DLR enhanced the analysis algorithm such that the circumsolar irradiance is measured with the same hardware equipment. The RSI used for solar resource assessment can be calibrated for sunshape measurements in addition to DNI and GHI.



Irradiance signal logged during the rotation of the shadowband ("burst"), and derived irradiance

The sunshape algorithm for the RSI has been developed and validated with three years of sunshape data obtained with the SFERA sunshape measurement system at Plataforma Solar de Almería with financial support of the European Union. The SFERA sunshape measurement system consists of Visidyne's Sun and Aureole Measurement instrument, an AERONET sun photometer, and dedicated software developed by DLR. While half of the available dataset was used for the development and the calibration of the new algorithm, the other half was used for its validation. The algorithm allows the calculation of the circumsolar normal irradiance coming from different angular intervals around the sun, e.g. 1° to 3.2° from the sun's center.

The result of the validation is shown below with the circumsolar contribution $\Delta_{rel}CS(1°, 3.2°)$: It is the ratio of the circumsolar normal irradiance, calculated from radiation coming from angles between 1° and 3.2° away from the center of the sun, and the irradiance received from the total innermost 3.2° around the sun's center. On the y axis the results from the RSI are shown, on the x axis the results from the reference system. The average of the RSI-derived circumsolar contributions for bins of the reference values, including the standard deviation and the root mean square deviation (RMSD), are shown. The result indicates good agreement of the measurements with an underestimation of the RSI values only at very high and less frequent circumsolar irradiance ratios that occur only for low DNI values.



Comparison of the circumsolar contributions derived from the RSI and the SFERA reference instrument

The RSI based method has significantly lower maintenance effort, less data gaps and lower instrument cost compared to other sunshape measurement systems with cameras or various pyrheliometers with different acceptance angles. It delivers the required data for advanced raytracing analyses of concentrating collectors.

References:

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Patent ES 2423359 B2: Procedimiento para la Determinación de la Intensidad de la Radiación Circunsolar

S. Wilbert: Determination of Circumsolar Radiation and its Effect on Concentrating Solar Power, PhD thesis, RWTH Aachen, DLR, 2014, http://darwin.bth.rwth-aachen.de/opus3/volltexte/2014/5171

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