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SFERA - Verification Test SunCatch II **2010**
(SFERA-VTS)

By

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Background

Since the beginning of operation of solar concentrating facilities around the world, many working groups focused their efforts in the field of concentrated solar irradiance measurements.

All experiments such as material research, solar chemistry and space components test need exact flux measurements. Therefore the European laboratory alliance SolLab with its manifold fields of activities is working on outstanding measurement equipments and processes. This alliance has been initiated in 2004 by the Laboratoire Procédés, Matériaux et Energie Solaire (PROMES-CNRS), the Solar Research Division of DLR’s Institute of Technical Thermodynamics (DLR), the Plataforma Solar de Almeria (PSA-CIEMAT) and the Renewable Energy Carriers Laboratory of the ETHZ (REC-ETHZ). In 2004 the consortium declared the calorimeter “SunCatch I” as standard device for all other calorimetric devices used for solar flux measurements because of its high accuracy and repeatability. SunCatch I has been developed by DLR. Nowadays it is used by the SolLab members as reference for the calibration of measurement instruments for flux density.

Preparation

At the last conferences the consortium expressed its interest in a further development of the master device SunCatch I and supported the design of an upgraded system, implemented by DLR.

By now an enhanced calorimeter SunCatch II is realized (see Fig. 1). It is based on the calorimetric principle (see Fig. 2).

SunCatch II is based on the normal calorimetric formula of heat flow

$$Q = c_p \cdot \dot{m} \cdot \Delta T$$

Noticeable improvements have been made particularly referring the measurement time and the use of industrial standard software like Lab View (see Fig. 3) and standard data acquisition system (see Fig. 4). Also standard water connectors are used.

Fig. 1 Cavity of the new SunCatch II

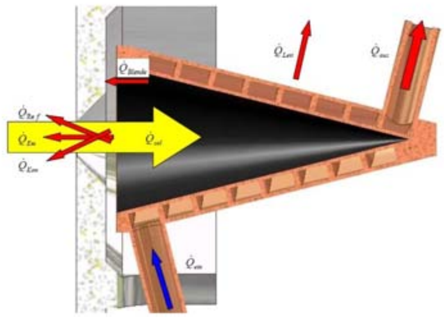

Fig.2 Calorimetric principle

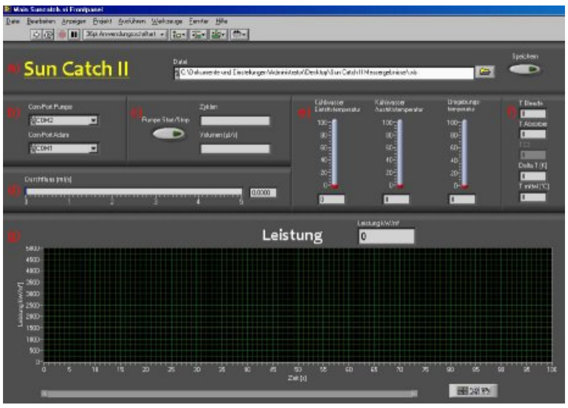

Fig. 3. Screenshot of the operator interface

Fig. 4. Data acquisition system

Improvements with respect to the accuracy are expected and have to be verified. Within the project SFERA-VTS a new generation of the calorimetric standard device

SunCatch can be provided. SunCatch II has a simple design and can easily be reproduced by its user (see Fig. 7).

The diaphragm (see Fig.7a) is constructed to support different opening angles for all kind of concentrated sun or artificial light applications.

The Project within SFERA (SFERA-VTS)

Successful measurements in SFERA-VTS and implementation of the updated and improved calorimetric device SunCatch II offer new perspectives for the measurement quality in solar furnaces. Because of its high demand as standard device on accuracy and repeatability, SunCatch II has to be tested systematically and precisely. We therefore apply for active participation in the SFERA project task12 work package 2.

The approach is to compare SunCatch II with the actual master device SunCatch I, to check its calibration and to compare the two devices at different flux levels. The new SunCatch II has a power Range up to 40kW. The power range of the DLR Solar furnace is 22kW. To go up to higher flux ranges the MWSF of Odeillo (see Fig. 5 and 6) is needed. Further the comparison with another calorimeter as for example the calorimeter of CNRS would be preferable. This device was successfully used as additional reference during the comparison campaign in Cologne, 2006.

After a successful implementation elaborated comparison campaigns with further devices can follow.

Fig. 5. Heliostat and concentrator of the CNRS MWSF

Fig. 6. Working platform and concentration area of the CNRS MWSF

Time Schedule

Table 1: Time schedule of SFERA VTS

Date (Calendar)	Task	Person
6.-08. Oct. 2010	SunCatch II and instrument carrier preparation	Ch. Willsch, DLR
9.-10. Oct. 2010	Travelling to Odeillo	Ch. Willsch, DLR
11.-12. Oct. 2010	Mounting SunCatch II in the MWSF	N. Boullet, CNRS Ch. Willsch, DLR
12. Oct.-14.Oct. 2010	Mounting second Measurement device	N. Boullet, CNRS Ch. Willsch, DLR
15-21.Oct. 2010	Testing	Ch. Willsch, DLR G Dibowski, DLR E. Guillot, CNRS N. Boullet, CNRS J.-L. Sans, CNRS
22. Oct. 2010	Dismounting SunCatch II Travel back	Ch. Willsch, DLR N. Boullet, CNRS Jan L. J.-L. Sans, CNRS
20.-23. Nov. 2010	Final data evaluation, report	Ch. Willsch, DLR

Testing

The testing was started in low flux ranges with heliostats 44, 45, 46 (see Fig. 7) This picture shows the geometry of the heliostat field and it opening angels.

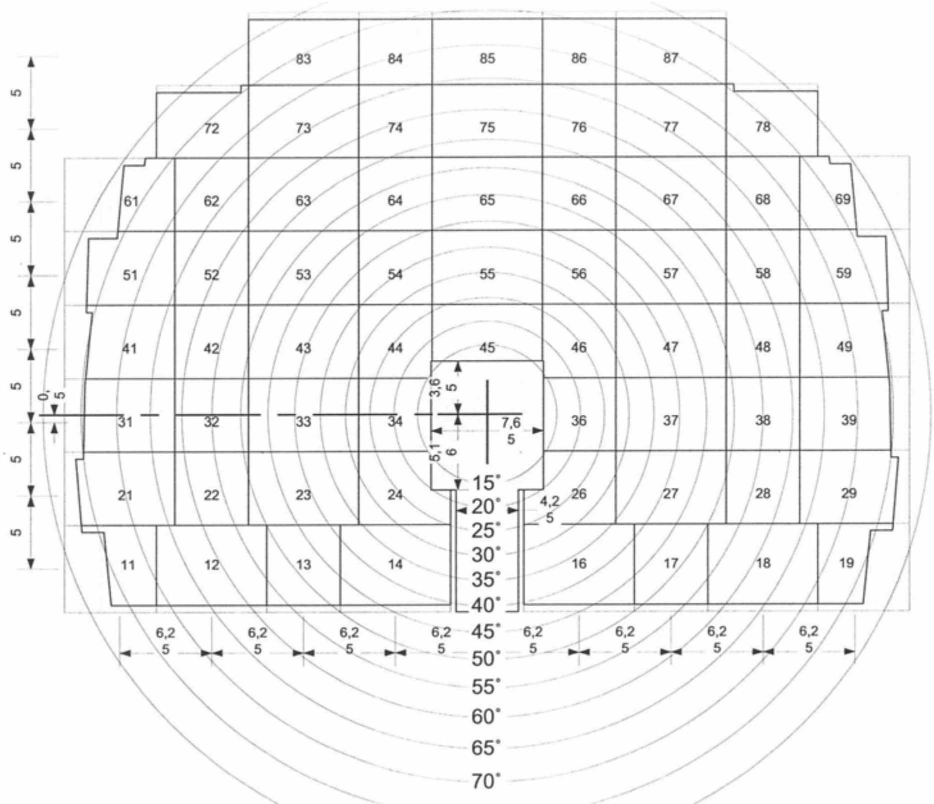

Fig. 7. Heliostat field of the CNRS MWSF

The first goal was to check the behaviour of SunCatch II under low radiation, referring i.e. the flow meter, pump, temperature, heat shield, data acquisition. Everything worked properly.

After these first checks in lower levels, test on higher flux levels were performed.

In sum three different flux levels were tested. The first flux level at 1000 kW/m² (see Fig. 10) was followed by 2000kW/m² (see Fig. 11) and ended at a flux level of 2.5 MW/m² (see Fig. 12).

All measurement devices were irradiated in the focal plane of the MWSF.

Figure 8 and 9 show the measurement device assembling.

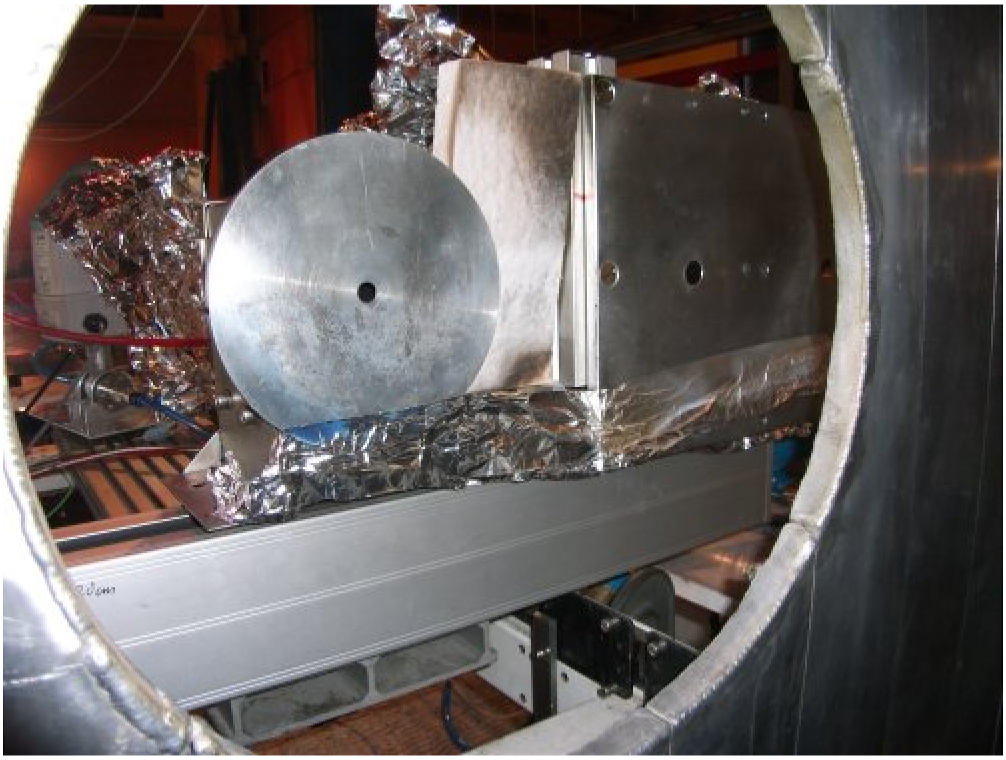

Fig. 8 Front view of assembling, SunCatch II (left), Gardon in cooling plate (right)

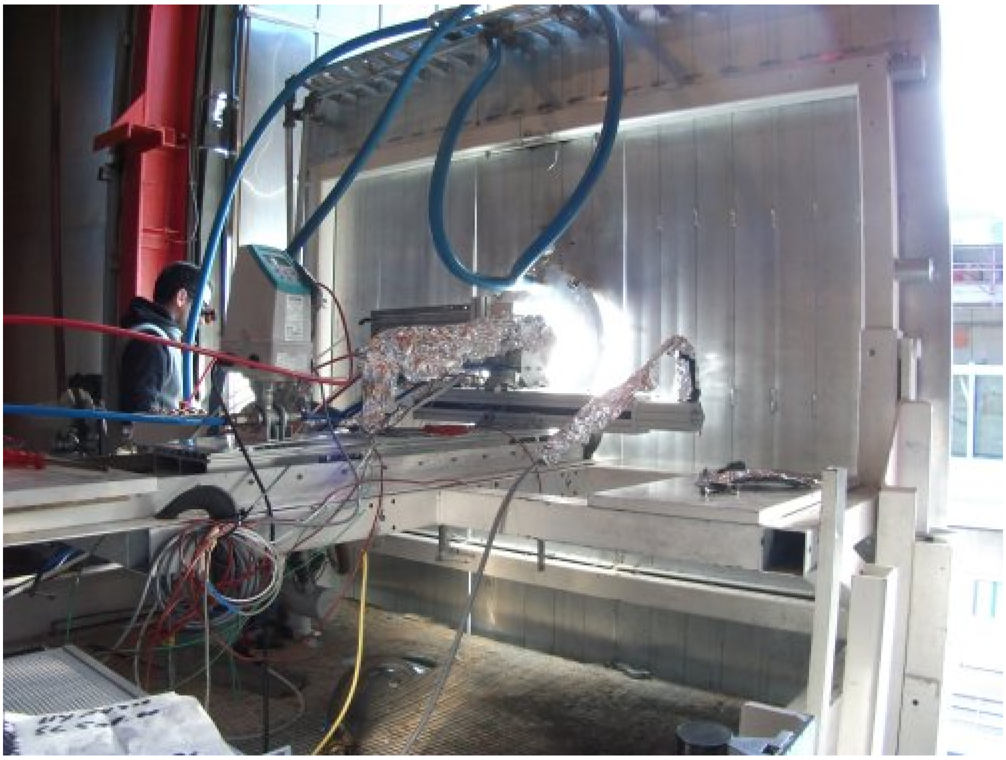

Fig. 9. Back view during exposure. Flow meter, cooling devices and sliding bar are visible

To compare two devices consecutively as quick as possible, the whole assembly was mounted on a sliding bar to exchange the devices within three seconds during exposure.

To alternate quickly is important for a precise measurement and comparison under the same spherical conditions.

SunCatch II was compared to a well known radiometer based on the Gardon [1] principle. The DLR Gardon Radiometer was calibrated in a former InterComparison Campaign 2006 in Cologne [7]. It was a trusted source to compare with SunCatch II.

Table 2: Instruments used in the MWSF Odeillo

Name*	Institution	Manufacturer	Serial No.	Rim Angle	Active Area	Flux Range kW/m²	Comments
DLR Gardon Ser. 503	DLR	HyCal	503	90		11000	Recalibrated by DLR: 2006
SunCatch II	DLR	DLR	SCII	52	10 mm diam.	6000	

Comment on Data Presentation

The graph in the following data analysis sheets shows on the Y axis the concentration factor as the main parameter. The solar concentration is calculated as measured flux density normalized to 1000 W/m² direct normal irradiance. In order to have an easy interpretation of the measurement results all data are plotted against the concentration of the reference instrument DLR Gardon Ser. 503.

To process the results one simple definition is used for representing the error:

$$APD = \frac{1}{n}\sum_{1}^{n}\frac{C_{instrument} - C_{reference}}{C_{reference}} \cdot 100$$

APD Average deviation in %

n being the number of data points

$C_{instrument}$ Measured value SunCatch II

$C_{reference}$ Measured value DLR Gardon Ser. 503

Concentration:

$$Concentration = \frac{Flux}{DNI} = \frac{W/m^2}{W/m^2}$$

$Flux$ Irradiation divided by square meter

DNI Direct Normal Irradiation

Results

Results of flux densities at 1MW/m²

Figure 10 displays the measurements recorded at the flux level of 1000kW/m², DLR Gardon Ser. 503 used as reference.
Used heliostat numbers: 44, 45, 46 (see Fig. 7)

SunCatch II, at flux level 1000 kW/m²:

APD with DLR Gardon Ser. 503 as reference: APD= -4%

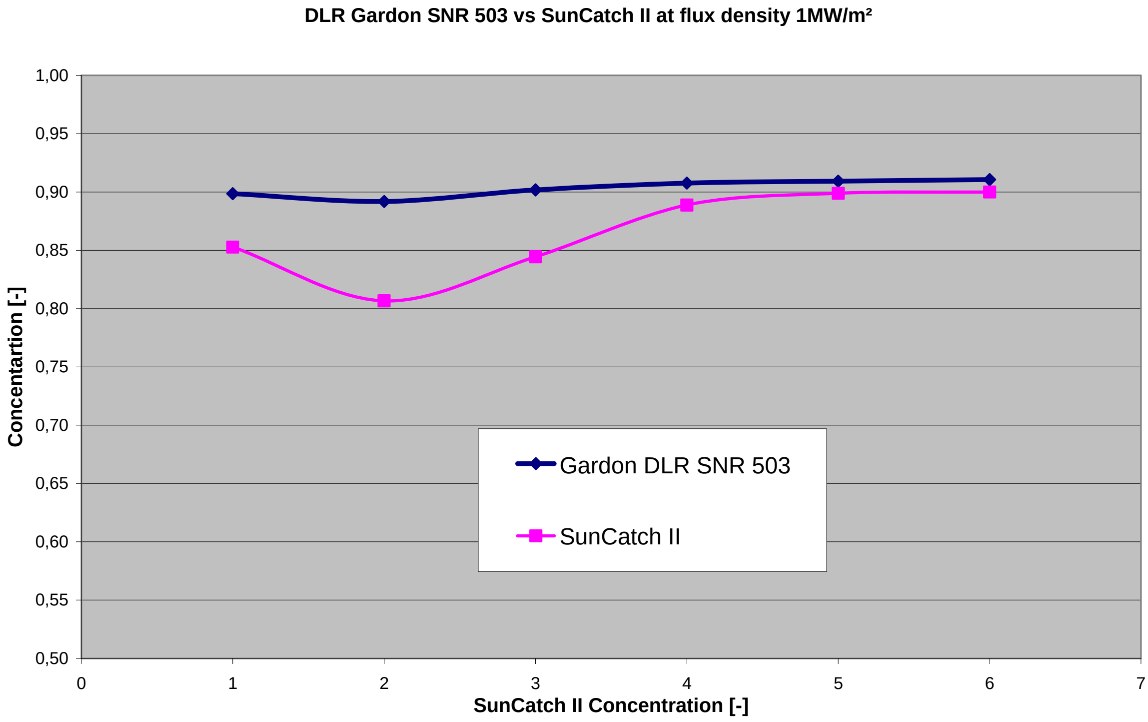

Fig. 10 DLR Gardon Ser. 503 vs SunCatch II at flux density 1 MW/m²

Results of flux densities at 2 MW/m²

Figure 11 displays the measurements recorded at the flux level of 2000kW/m², DLR Gardon Ser. 503 used as reference.
Used heliostat numbers: 45, 45, 46, 65, 66, 64, 54, 56, 36, 34 (see Fig. 7)

SunCatch II, at flux level 2000 kW/m²:

APD with DLR Gardon Ser. 503 as reference: APD= -4%

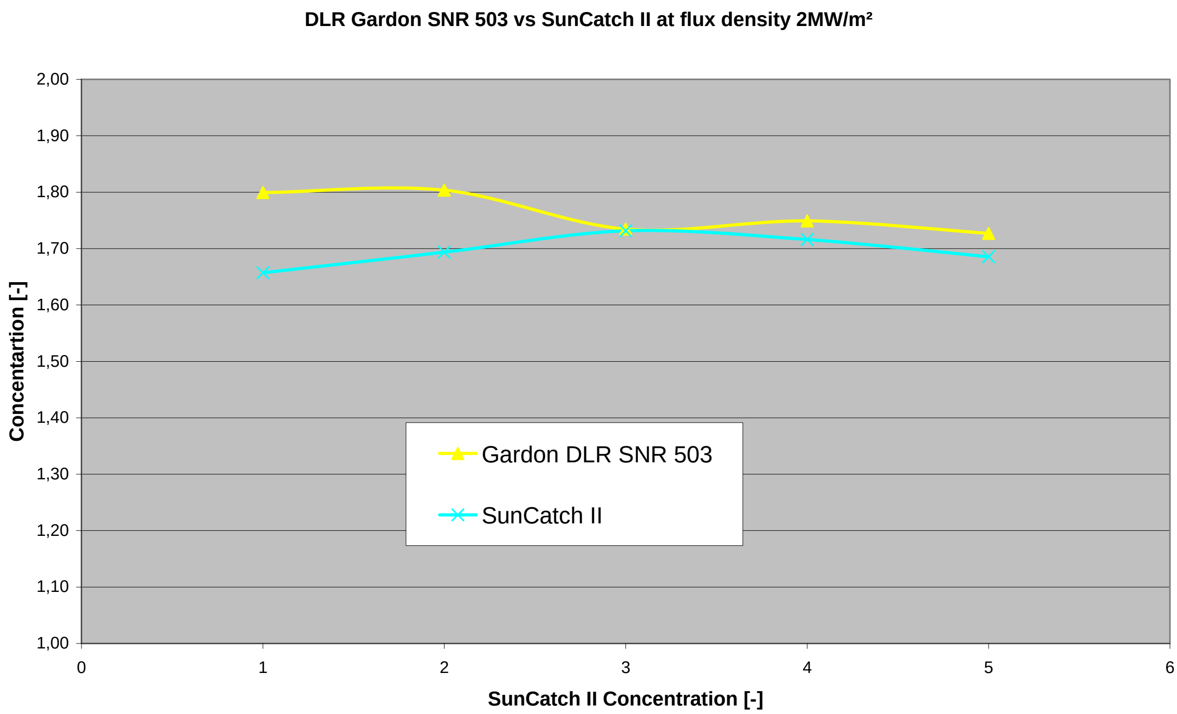

Fig. 11 DLR Gardon Ser. 503 vs SunCatch II at Flux density 2 MW/m²

Results flux densities at 2,5 MW/m²

Figure.12 displays the measurements recorded at the flux level of 2500kW/m², DLR Gardon Ser. 503 used as reference.
Used heliostat numbers: 45, 45, 46, 65, 66, 64, 54, 56, 36, 34 24, 26, 14, 16 (see Fig. 7)

SunCatch II, at Flux level 2500 kW/m²:

APD with DLR Gardon Ser. 503 as reference: APD= -5%

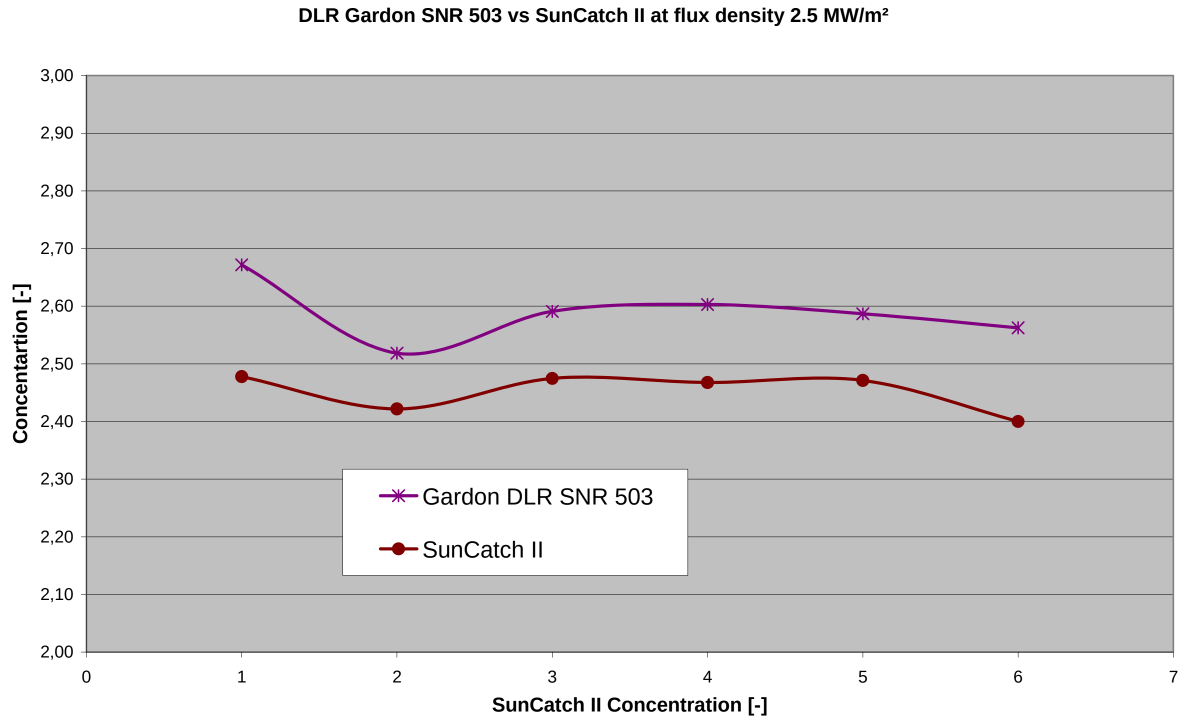

Fig. 12 DLR Gardon Ser. 503 vs SunCatch II at flux density 2.5 MW/m²

Summary and Outlook

The first phase of testing SunCatch II at the MWSF of Odeillo looks very promising. All parts of SunCatch II worked properly, starting from the cavity ending at the industrial standard used software Lab View. No damages occurred during exposure of SunCatch II. Because of the little time more tests on SunCatch II have to be carried out.
The error referring the incident angle has to be checked by varying this angle. This is one of the most interesting aspects for of all members of SFERA not only with the device SunCatch II.
A further interesting goal is to analyse the influence and error of varying the water flow through the cavity during stable flux conditions. To learn more about the behaviour of SunCatch II in higher flux levels, tests up to 6 MW/m² have to be carried out.

To perform flux measurement tests especially for comparing flux measurement devices, the MWSF of CNRS is an appropriate facility. To use this solar furnace for future measurements, a concept for the creation of a standard uniform flux profile for all kinds of flux measurement devices must be developed. The fact that every flux measurement device has it own special opening angle must be considered. The opening angles are one of the biggest error sources for the comparison of flux measurement devices.

Thanks to all the staff people at the MWSF of Odeillo for their great support.

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