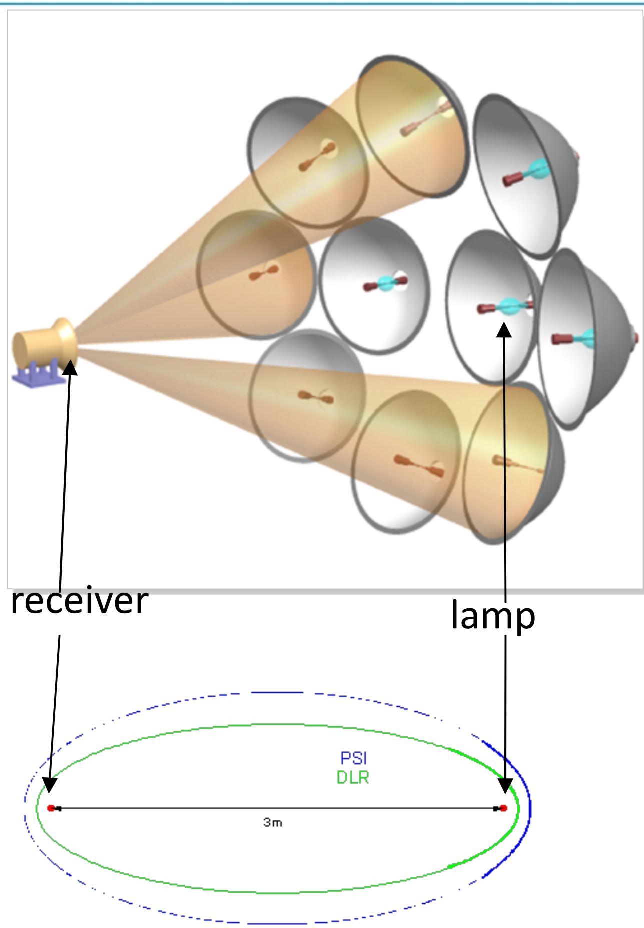
SFERA - Solar Facilities for the European Research Area

Joint Research Activities

Coordinator: Robert Pitz-Paal, DLR

Objectives of Joint Research Activities

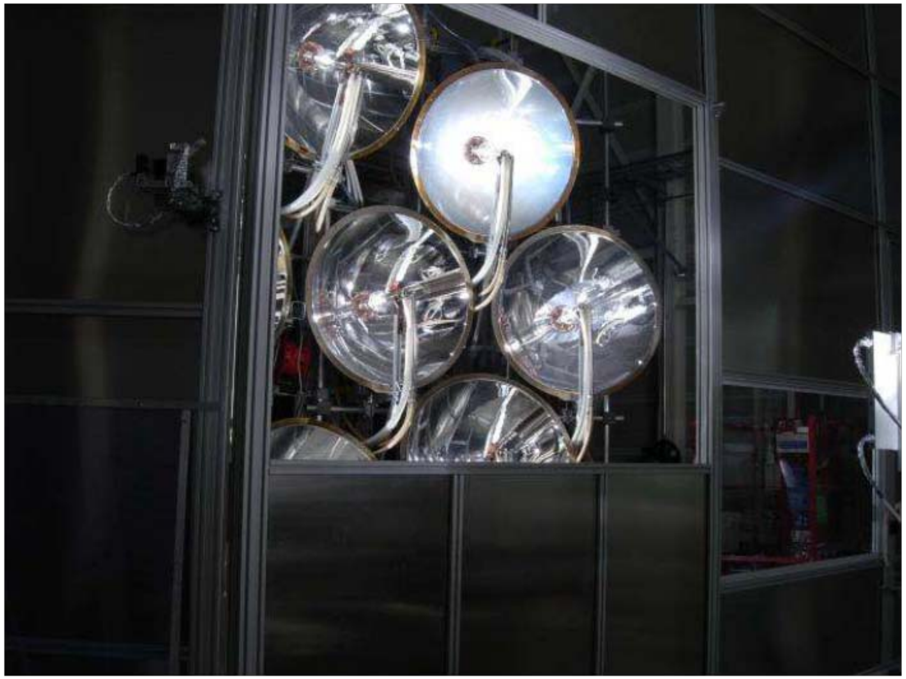
- Improve Quality of Testing Services at R&D Infrastructures for CSP
- Improving Capabilities to Achieve Ultra-High Concentration
- Infrastructure improvements to perform durability predictions of CPS components accelerated aging
- Methodology for Testing, Assessment and Characterisation of Storage Technologies and Materials



At PSI: 10 water-cooled Xe arc lamps (15 kW_e)

At DLR: 10 air-cooled Xe arc lamps (6 kW_e)

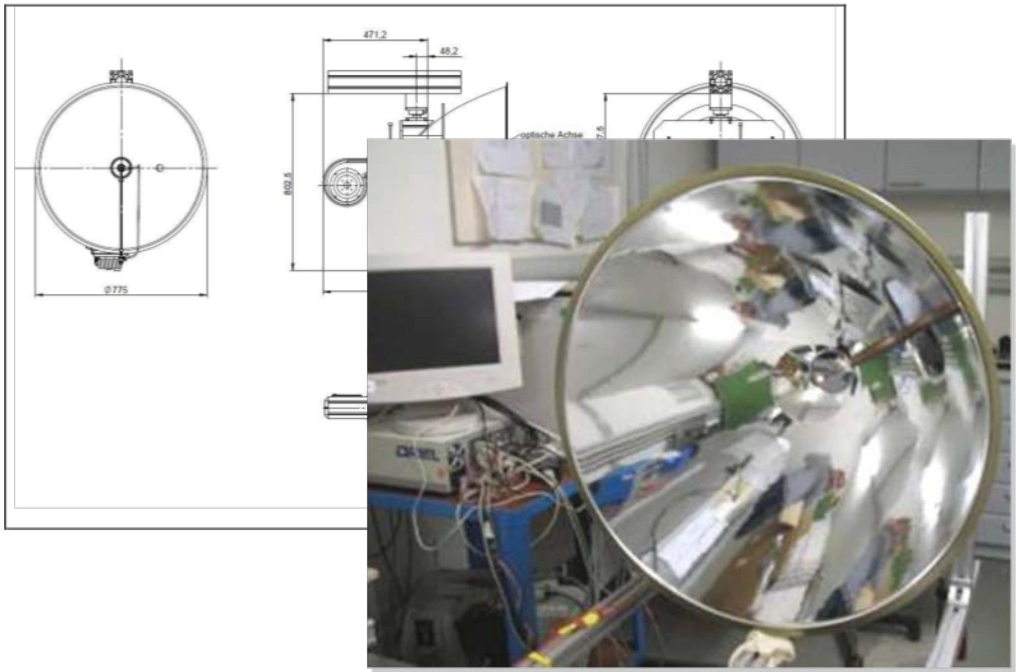
***Example 1: High Flux Solar Simulators:** for controlled testing*



PSI: lamp/reflector array with one lamp in operation

PSI: The protective window and the shutter closed

High Flux Solar Simulators: *for controlled testing*

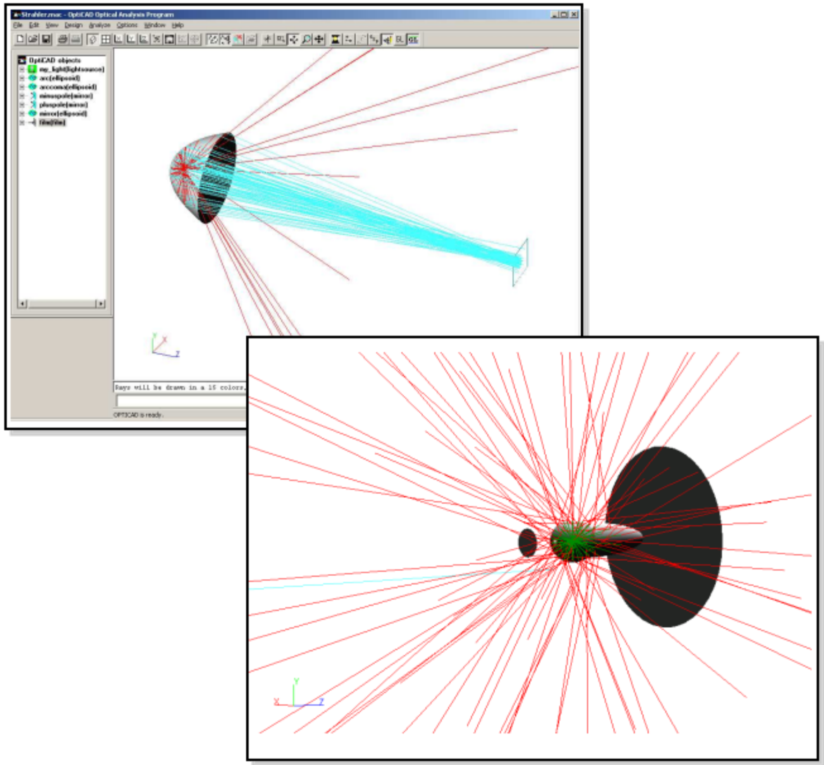


Evaluation of one reflector at DLR.

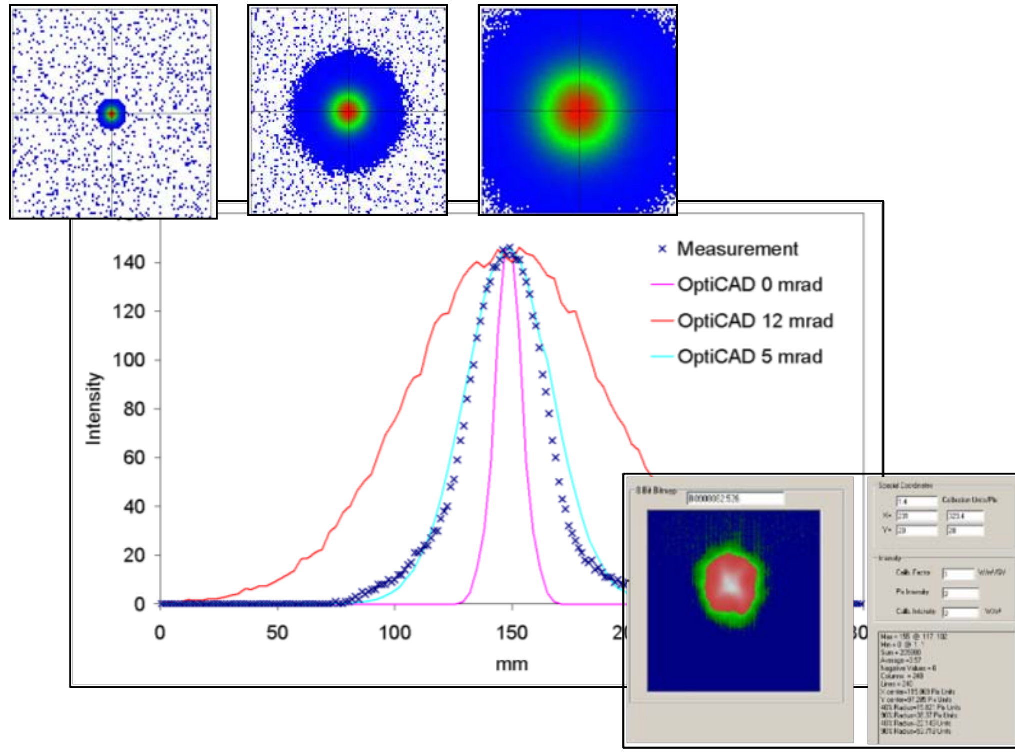
*Reflection on a **plasma coated $Al_2 0_3$** target at DLR.*

***Characterization** of the lamps with their reflector:*

- *Assess the **flux distribution***
- *Assess the **spectrum**, if possible spatially*
- *Assess the **UV contributions** for safety consideration*



Optical modelisation with OptiCad® DLR.



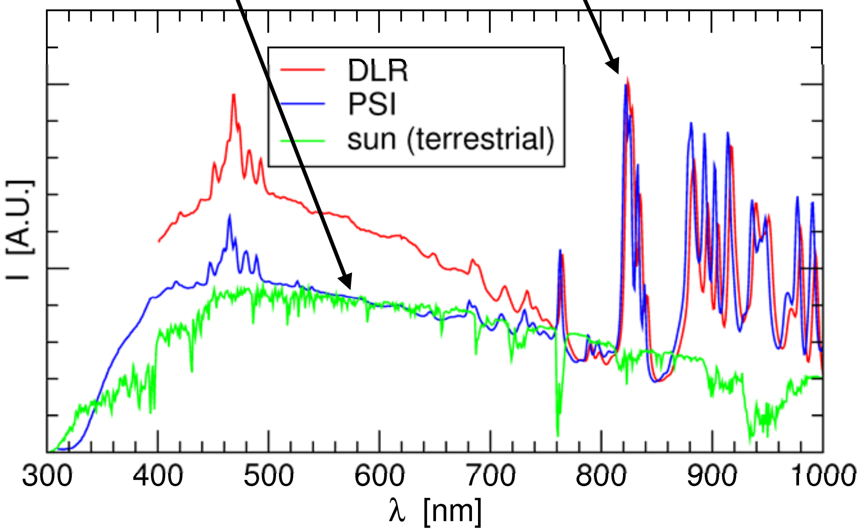
Top: calculated flux map with varying optical errors.
Bottom: actual measurements.

The Xe lamp (with electrodes and plasma core) and its reflector have been modeled.
*Several **ray-tracing flux maps** have been compared to the **measures**:*
a reflection error in the model **σ = 5 mrad** *accurately describes the measured data.*

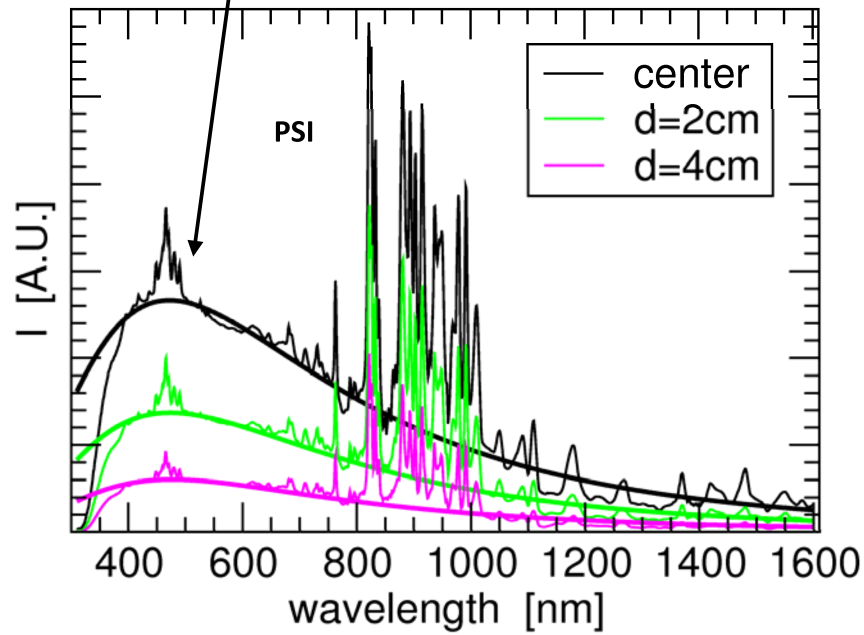
normalization / scaling

maximum overlap PSI / sun

normalized (PSI, DLR)



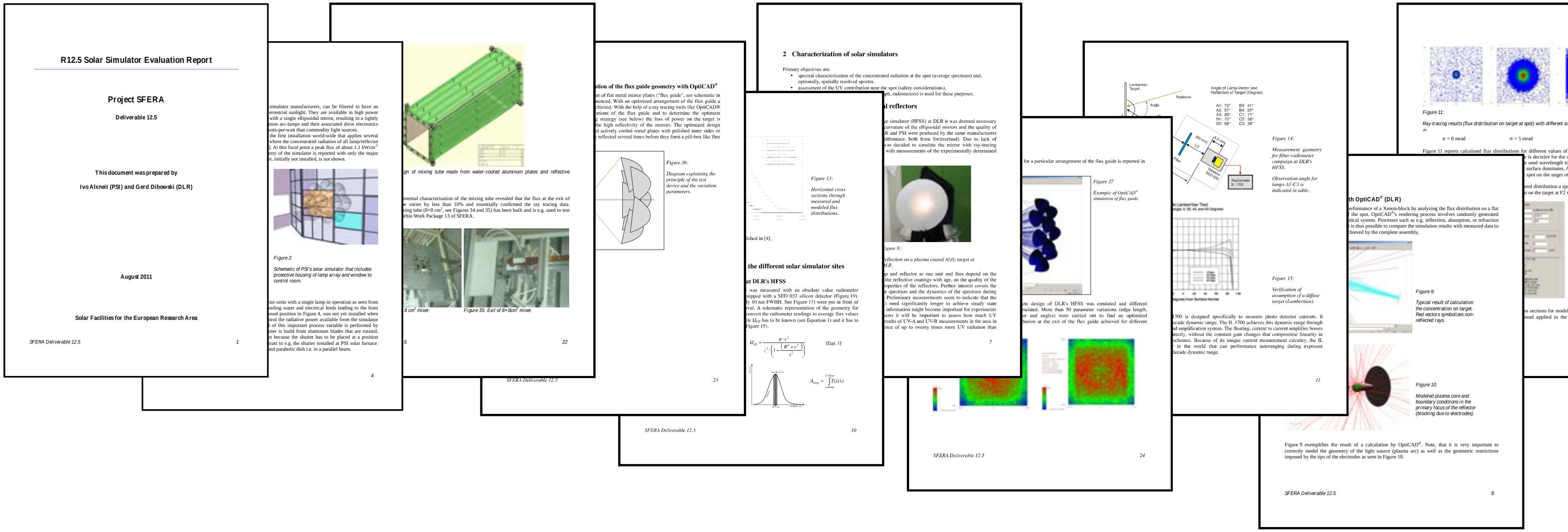
absorption of window / bulb



Differences assumed due to
- different electrode gap (DLR: 7mm, PSI: 9mm)
- different numerical eccentricity (DLR:0.94, PSI: 0.89)

Spectrums recorded at distance of spot center
- all spectra decomposed into black body (T=6000±200K)
- larger (relative) UV contribution at center
- smaller (relative) contribution of lines

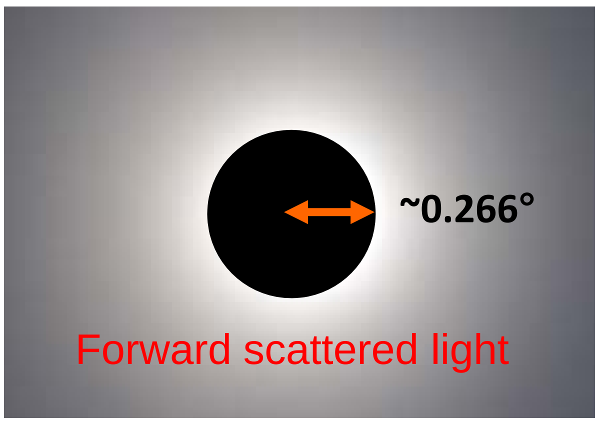
*The **spectral differences** from simulators to **solar spectrum** are only **relevant for processes relying on individual photons***

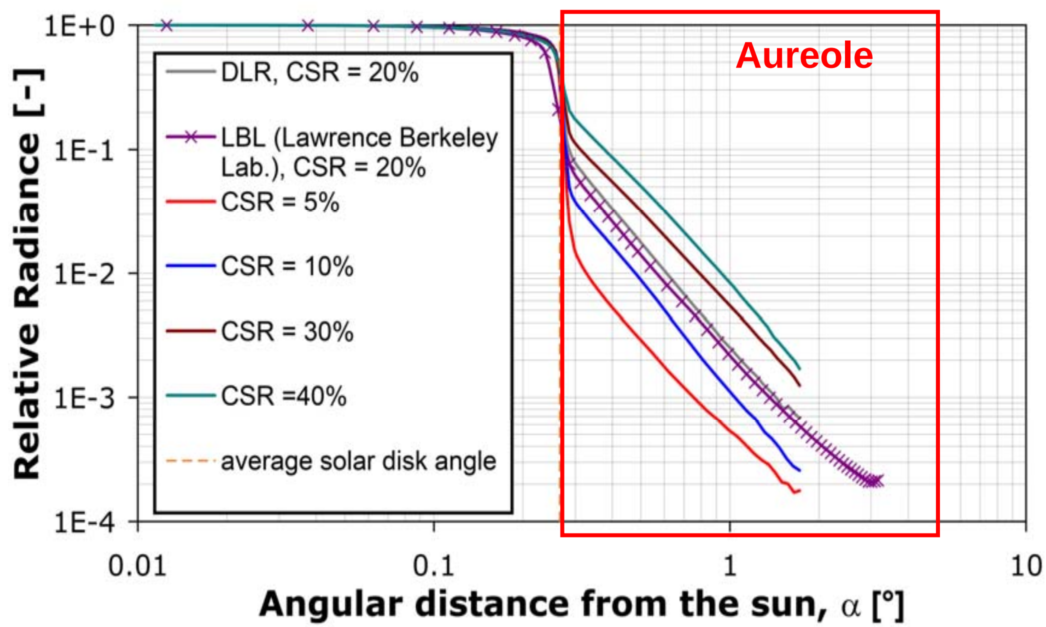


*For the **detailed information** and more (flux homogenization, radiometric measurements with filters…): the **deliverable 12.5** will be shortly available on the **SFERA website***

*http://sfera.sollab.eu/ Joint **R**esearch **A**ctivities WP 12*

Example 2: Development of **standardized tools** to measure and evaluate the **impact of the sunshape**:





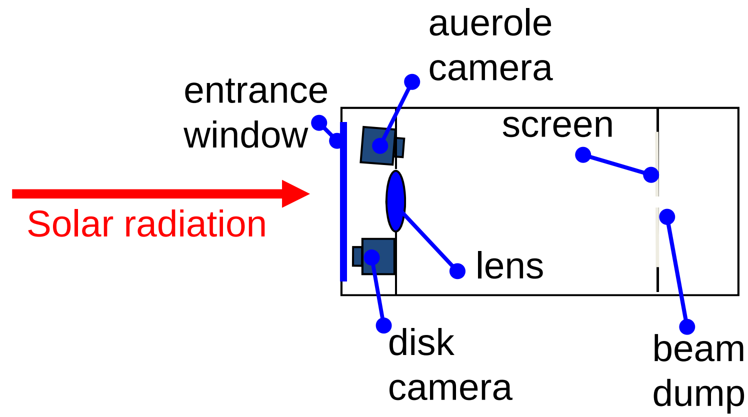
CSR = **C**ircum**S**olar-**R**atio

= normal irradiance from **aureole** / normal irradiance from **disk** & **aureole**

- System based on **sun photometer**, **SAM** (Sun & Aureole Measurement) & **software**
  - **autonomous** measurements
  - Determination of **broad band** & ***spectral*** **sunshape** and Circumsolar Ratio (CSR)
  - additional measurement of **aerosol & cloud properties**
    - allows physical interpretation and modelling of sunshape
  - Instruments are part of **Aeronet** and **SAMnet,** data available on the internet
  - Better accuracy than previous sunshape measurement systems (LBL, DLR)
- **Master-system** running at PSA
  - CNRS currently orders **replica**, Masdar Institute **replica** is already running

SAM

- Designed for measurement of cloud properties
- Measurement @ 670nm allows physical interpretation
- Data gap between information from two cameras (0.266°-0.475°)



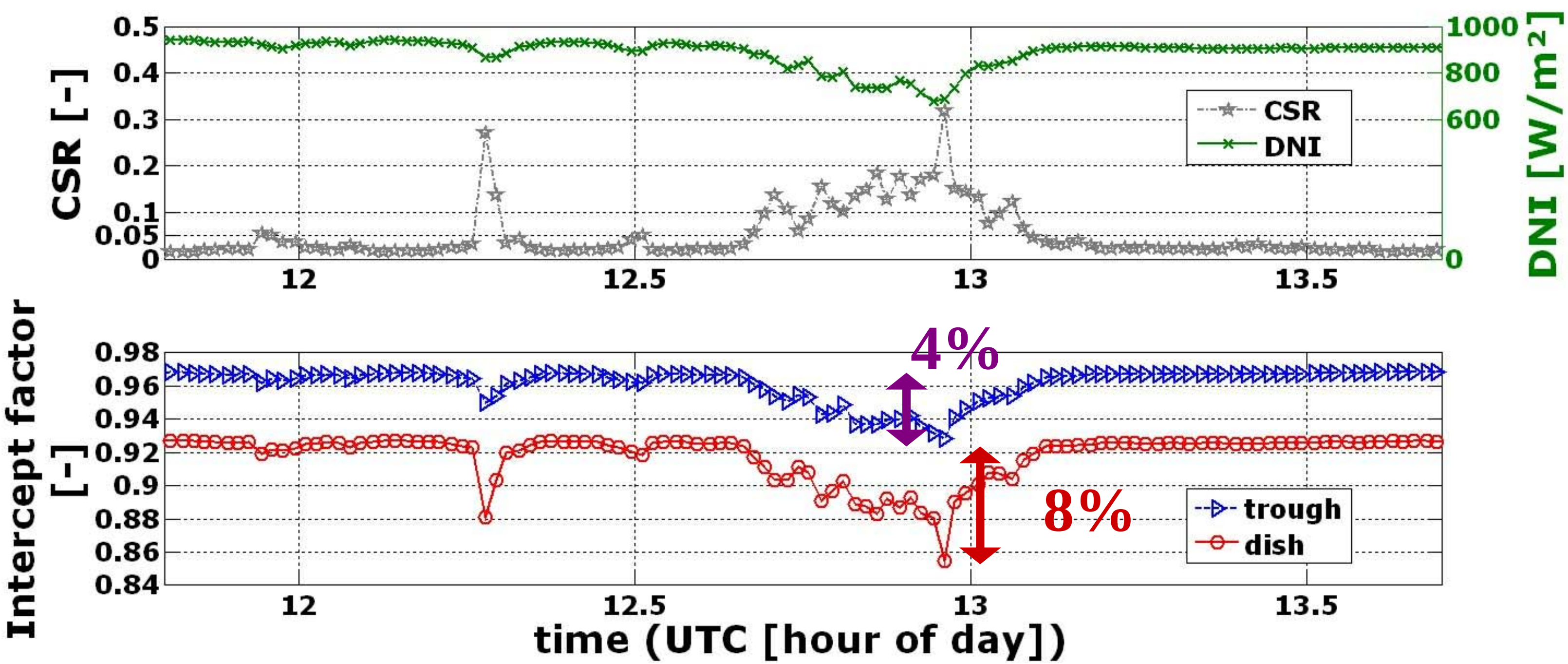
Sun photometer

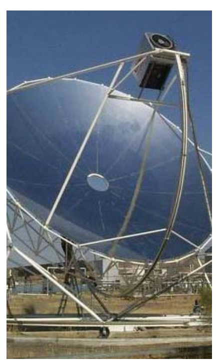
- Measurement of spectral DNI
- Measurement of spectral sky radiance (2°-180°)
  - 9 different wavelengths
- Measurement of how light is scattered and absorbed

  → Information on aerosols

Post processing software

- Spectral dependence of sunshape
  - radiative transfer model: SMARTS with input from sun photometer
  - Effect of clouds described by Fraunhofer theory
- Gap fitting





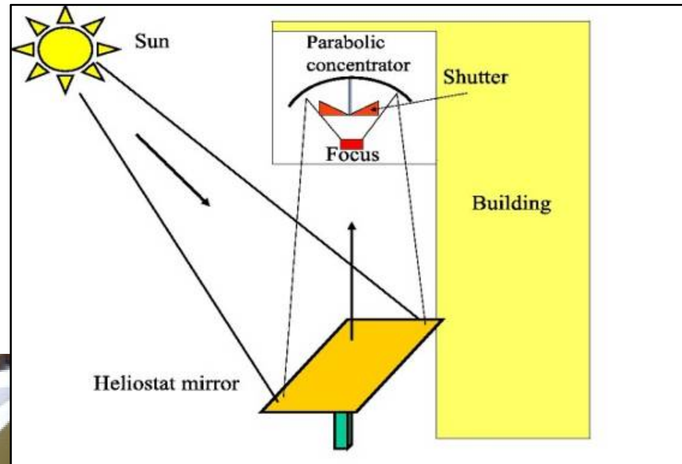
Raytracing tools for calculation of intercept factors (based on sunshape timeseries)

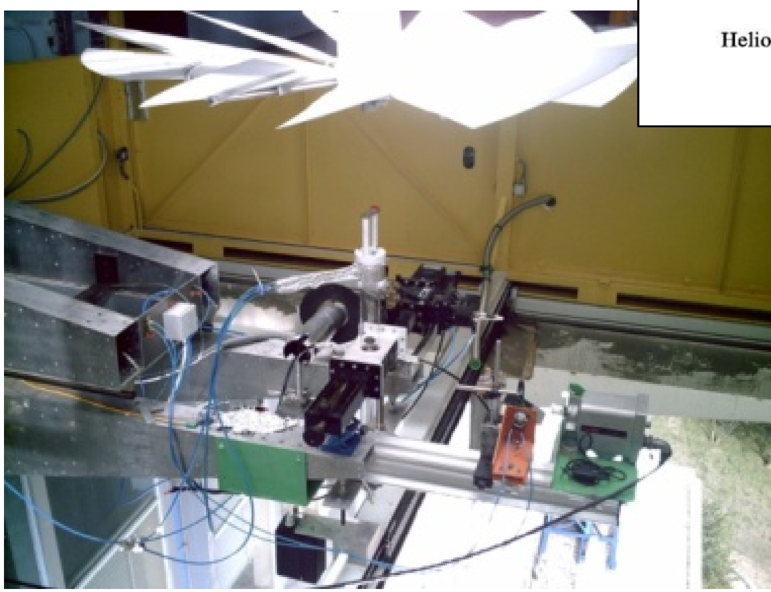
-**Rabl/Bendt** model

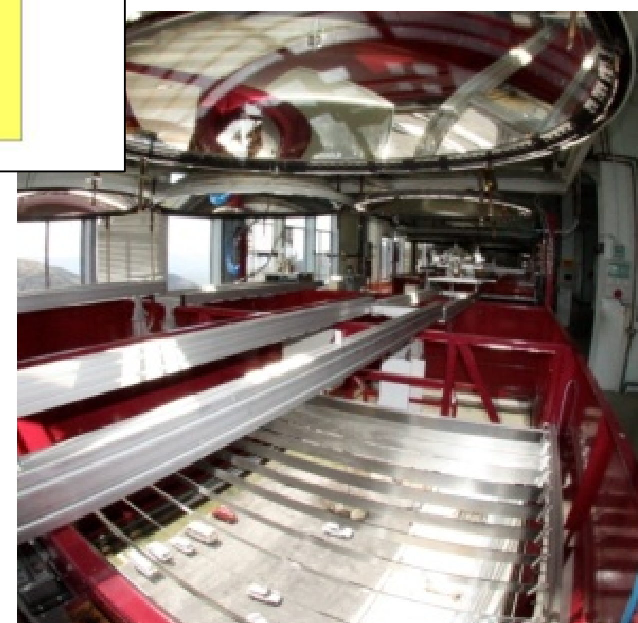
-**SPRAY** (all CSP options)

- **Example 3 Adapt Shutter control of Solar furnace to allow accelerated ageing test**

CNRS + INESC: Two solar furnaces with different shutters





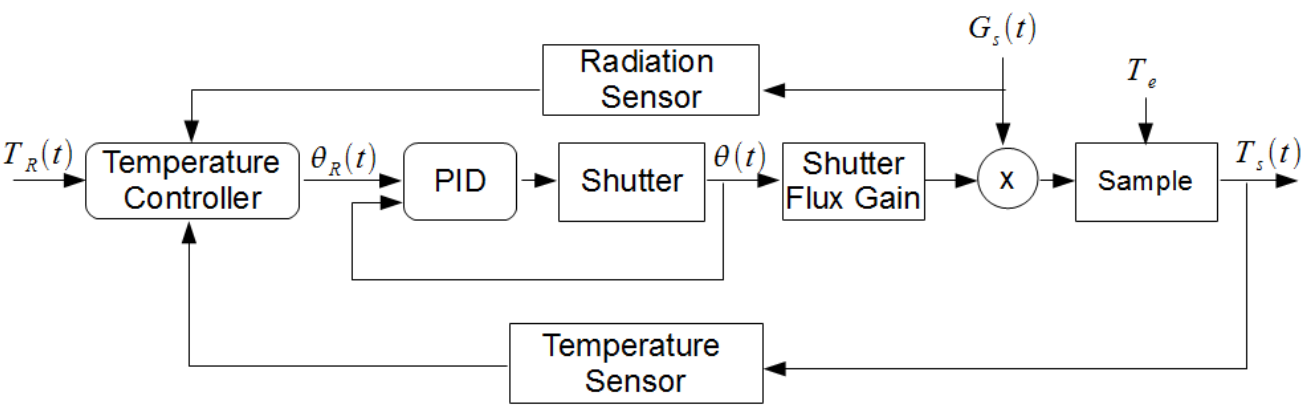


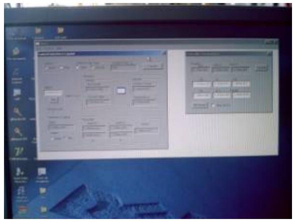
•*Shutters with different dynamics but with similar nonlinear static functions.*

- **Exampe 3 Adapt Shutter control of Solar furnace to allow accelerated ageing tests**
  -

CNRS + INESC: Two solar furnaces with different shutters

Control system architecture

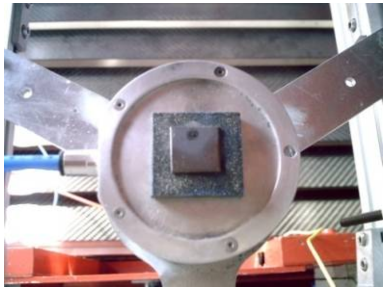




•Dynamics much faster than the temperature dynamics.

•Process dynamics also depend on the material sample.

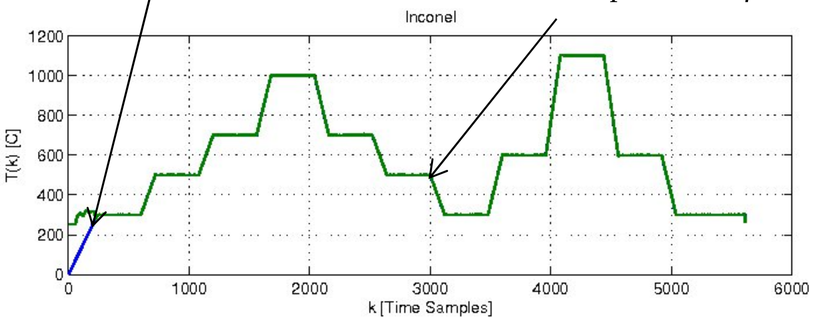
Experimental Results: Inconel

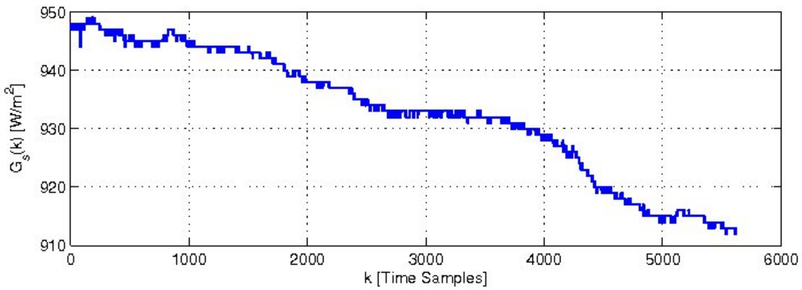


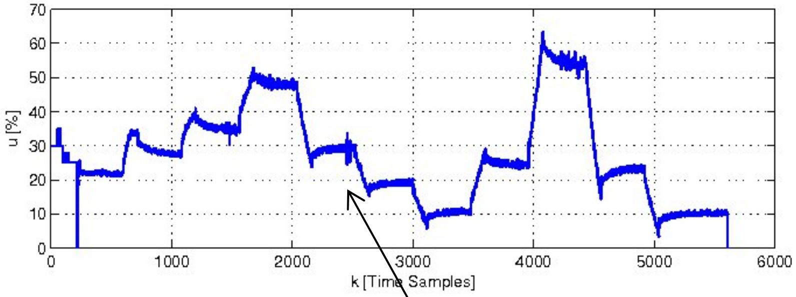
Ts = 0.5s

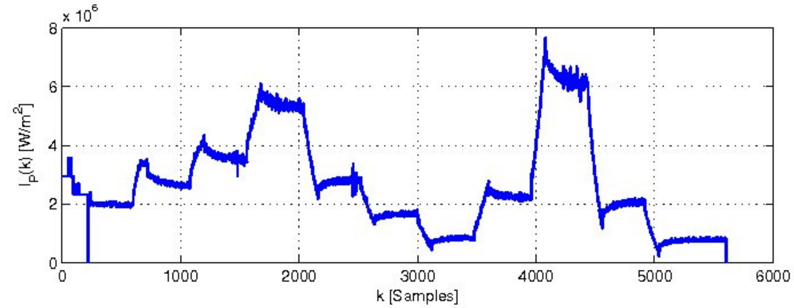
Temperature Reference

Temperature of the sample





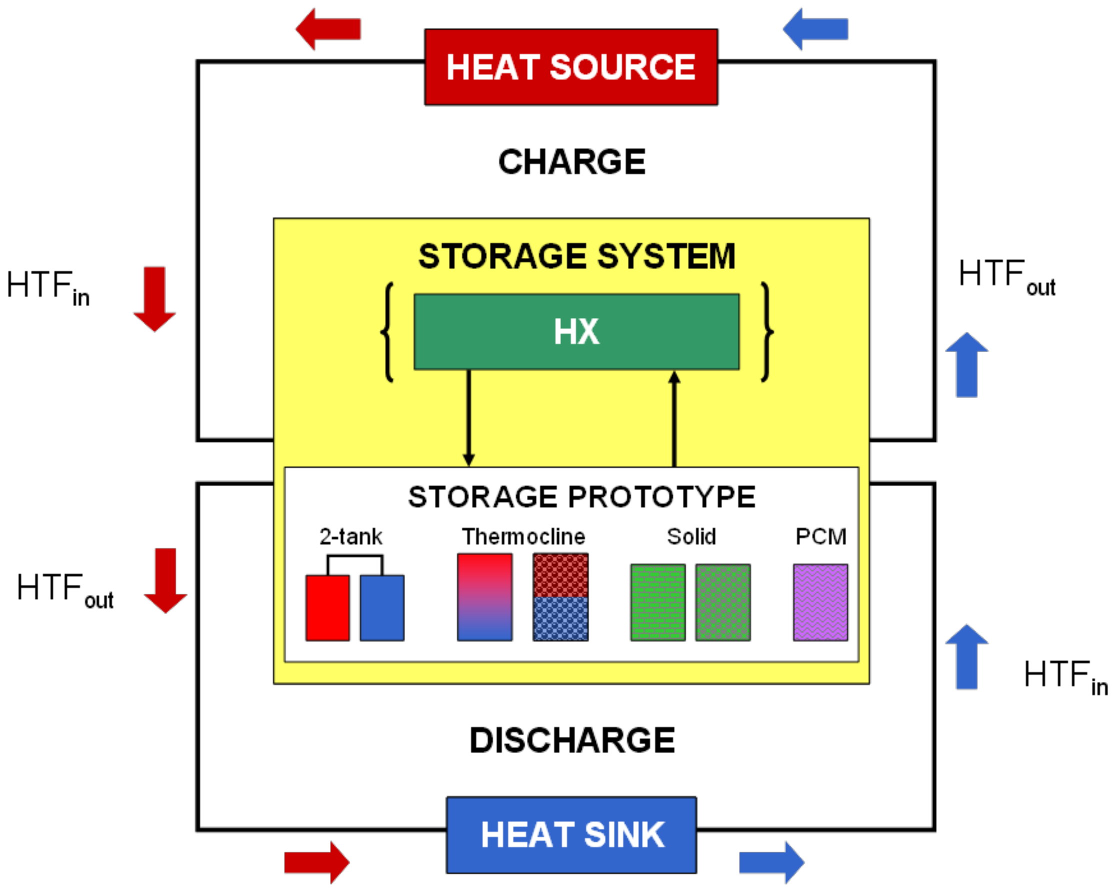




Control Signal

Example 4: Scheme of a test facility for TES prototypes

- **Heat source:**
  - Electric heater
  - Gas heater
  - CSP facility
- **Heat sink:**
  - Air cooler
  - Water cooler
- **Storage system:**
  - TES prototype
  - HX (sometimes)



General Concepts

- Nominal conditions:
  - HTF working conditions defined in TES design:
  - $\dot{m}, T_{HTF,in}, T_{HTF,out}, p_{HTF,in}, p_{HTF,out}$
- Charge process and charging time
  - Energy is transferred to TES system
  - (Characteristic) Nominal charging time
- Discharge process and discharging time
  - Energy is transferred from TES system
  - (Characteristic) Nominal discharging time

Characterisitc parameters

- Charging / discharging power
- HTF power in charge / discharge
  - Sensible heat transferred
  - Latent heat transferred
  - Electric source in charge
- Stored/delivered energy power
- Thermal capacity or storage capacity
- Mean thermal energy
- Thermal efficiency at time t

Still under discussion…

- Evaluation of thermal losses
  - For calculating prototype's power
- Long term performance
  - Some kinds of storages degrade with time (thermocline)
- How temperatures inside the prototype can be measured
  - Both distribution and evolution of temperature inside a prototype depend on the type of storage, TES configuration, kind of heat and media involved

Summary

- Joint approaches to harmonize test and evaluation in large scale infrastructure at CNRS, DLR, PSA, PSI and WIS
- Extension of capabilities beyond performance testing under solar condition to create test facilities for accelerated aging
- Concept on how to test and evaluate protototype storage systems

Target: High competence and excellent service for Industry and Research to accelerate technology innovation speed