New online flux density and temperature measuring systems for Monitoring and optimized operation of external Tube receivers

“TubeMon”

Name of the person presenting

Organisation

Address / contact

Overview

WP1: Flux density & absorptivity measurement

WP2: Emissivity and temperature measurements

WP3: Demonstration at commercial plant

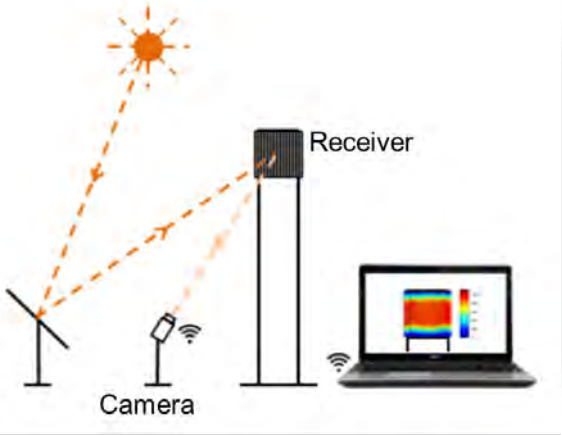
WP4: Heliostat Field Control using GPU

Flux density & absorptivity measurement

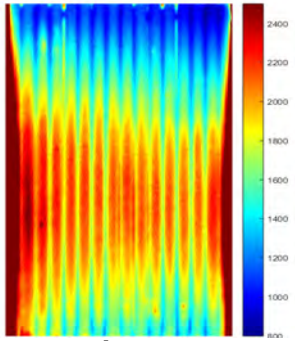
DLR, Germany

Principle of measurement

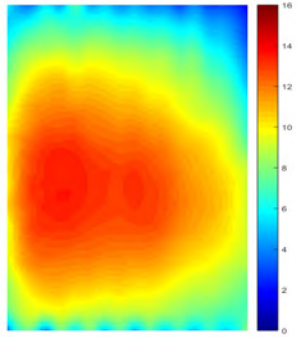
Reflection off the Absorber



Raw image



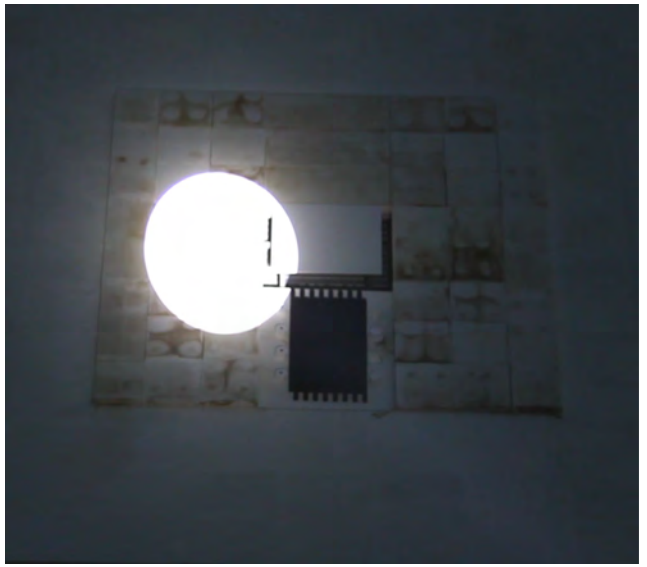
Raw image, rectified, false colors

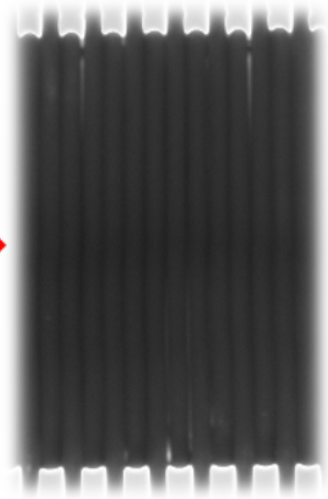


Corrected with scan method, interpolated

Scan method

Determination of the Reflection Properties



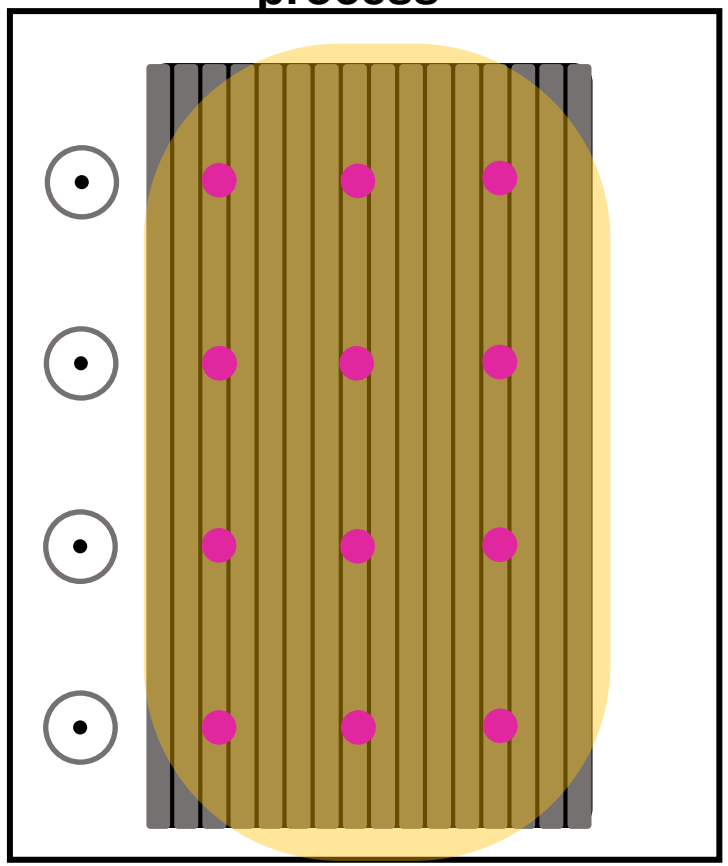


- Meander-shaped path of the light spot
- Simultaneous high-frequency series image recording
- Determination of maximum image
  ⇨ virtual image of a homogenously illuminated receiver

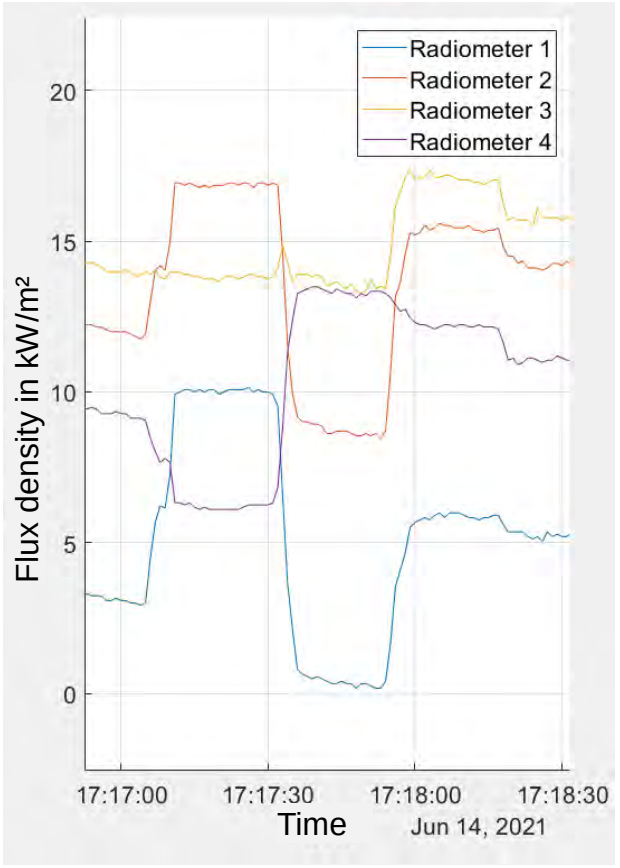
Flux density & absorptivity measurement

Radiometer method

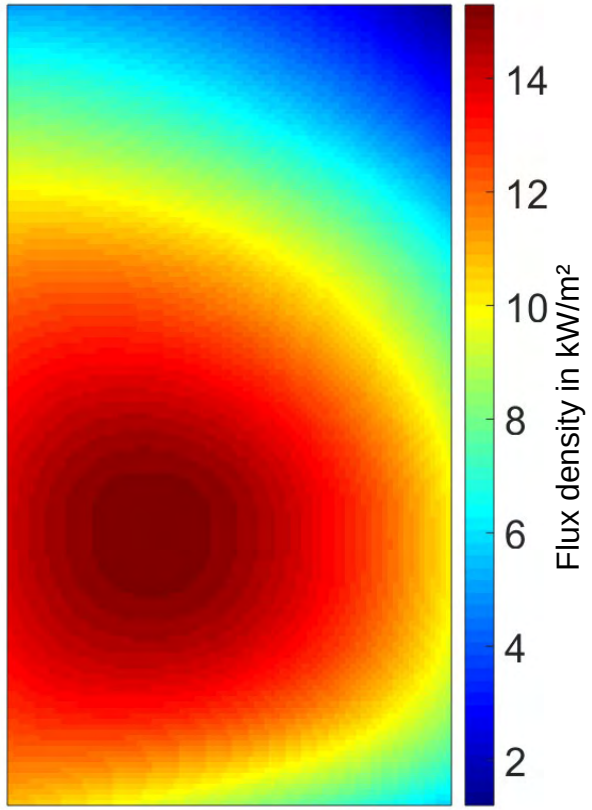
process



data of radiometers



result

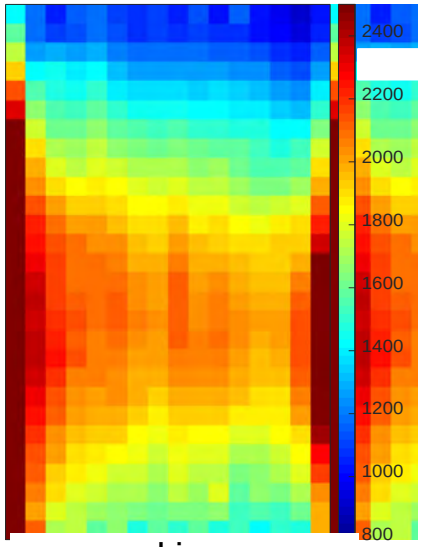


Flux density & absorptivity measurement

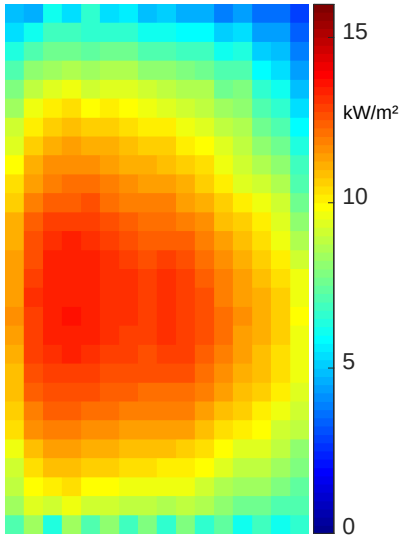
Flux maps determined by reflection off the receiver

Tests on the experimental tube receiver

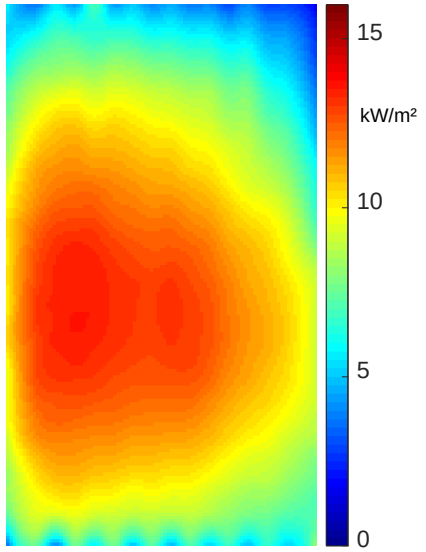
qualitatively similar images



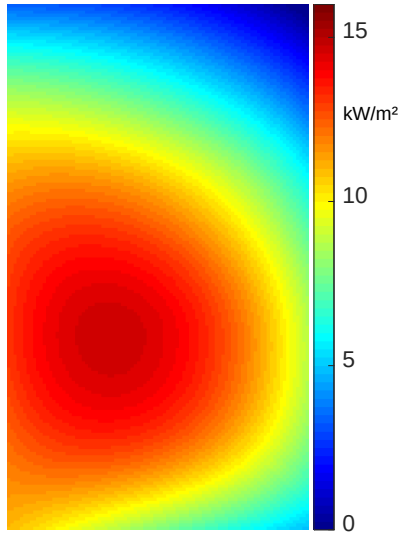
averaged image,
segment by segment



corrected image



Corrected and
interpolated image



Result with **radiometer method**

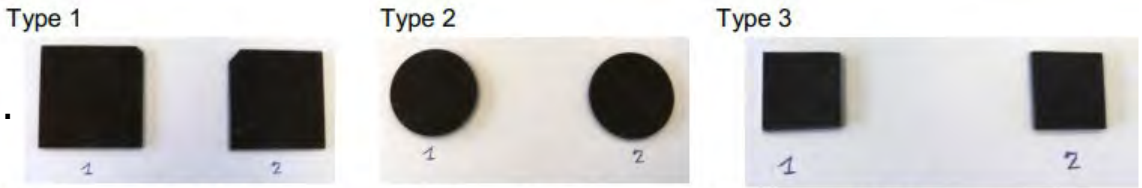
Emissivity and temperature measurements

DLR, Spain

develop a non-contact field measurement technique for the local determination of emissivity and temperature distributions on a tower receiver.

1. Adaptation to Brightsource coating
2. Set-up of the measurement system Hardware Setup
3. Programming of the software and preliminary tests

1.



2.

Figure 12: Test sequence for calibration and pre-tests

NUC (Non-Uniformity Correction)
- HDRi (High Dynamic Range Image)
- Intensity-based image registration (ratio)
- Radiometric calibration
- Model-based atmospheric correction
- Temperature - Emissivity Separation

3.

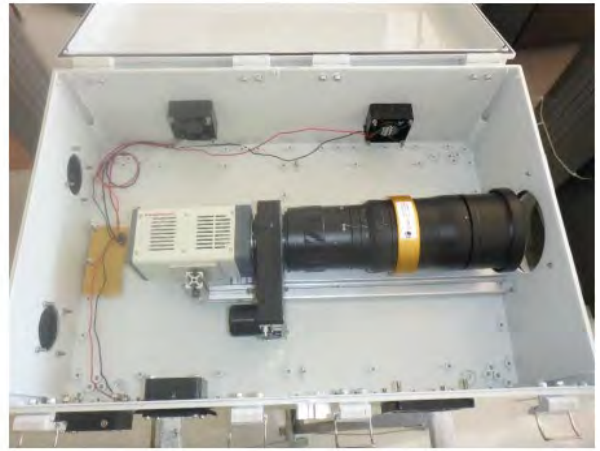


Figure 11: Structure of the infrared camera system in the protective housing

- e-SWIR camera module (Hamamatsu, C16090-03)
- Control software (Hamamatsu, HC Image DIA)
- motorised filter wheel (LUDL 96A351, 6 filter positions)
- Controller (LUDL, MAC6000) for controlling the filter wheel
- Narrowband filters (supplier: Spectrogon)
- Infrared teleoptics (OPTEC, OB-SWIR 300)

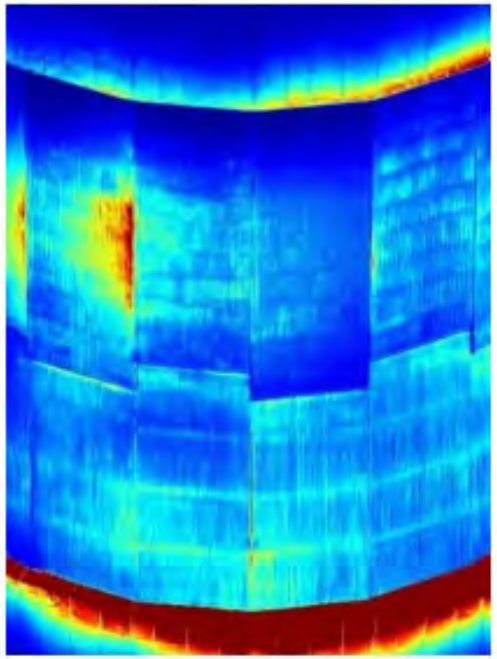
Patent Application Number /License:212069DE Rü/STM/ol
Vorrichtung und Verfahren zur Ermittlung einer Temperatur und eines spektralen Emissionsgrads einer mit Solarstrahlung bestrahlten Fläche
Simon Caron (DLR)

Demonstration at commercial plant

DLR, Germany; CSPS, Spain

(a) T
cam
tube

(a)



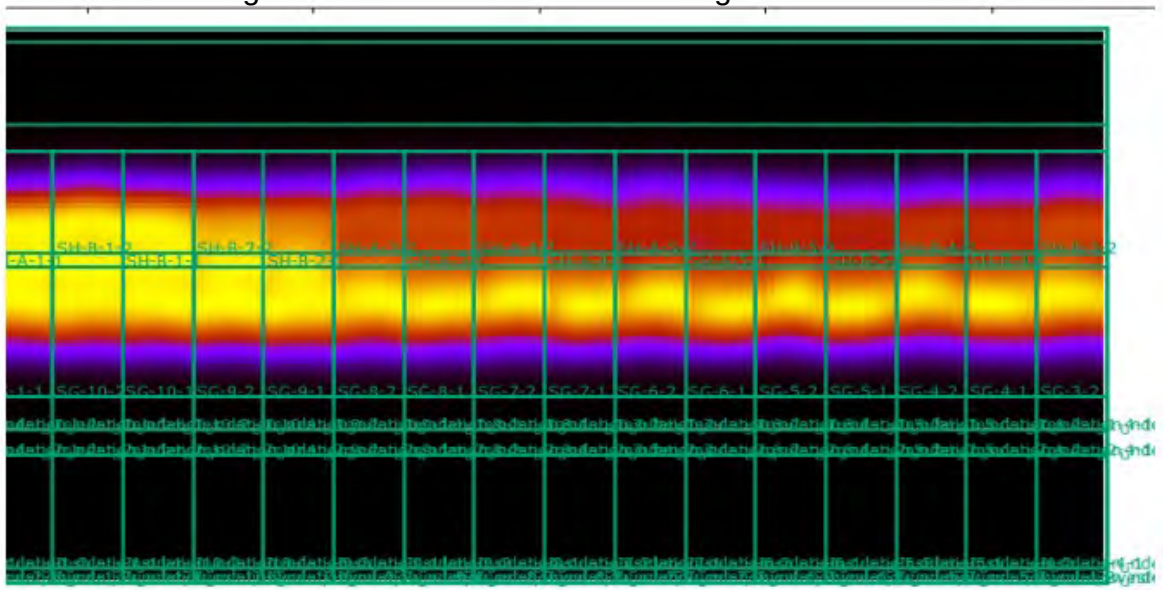
(b)

Figure 1: (a)scan result (maximum image) of the tube receiver, (b) false color image of the irradiated tube receiver

Heliostat Field Control using GPU

Brighsource Energy, Israel

Image of the unwinded receiver during irradiation



The Y axis of the grid represents the height axis, and the X axis represents the peripheral dimension on the receiver, where x=0 is the north

The objective of this task was to develop **GPU-tailored software** and to integrate it into the heliostat field control system. Using GPUs in the **aiming control procedure** has the potential to significantly shorten its running time which is especially precious during cloudy or transient situations.

- using GPU for calculation of projection on the flux map
- each thread deals with a small number of pixels
- several thread configurations have been tested to achieve the best result

Threads per block	Avg Runtime, 100X180 [msec]	Gpu time [msec]	Avg runtime 1000X1800 [msec]	Gpu time [msec]
64	3.113	299.345	8.553	5.654,09
256	3.070	340.961	8.564	5.618,82
512	3.331	428.812	9.379	6.381
1024	3.310	433.553	10.073	7.055,77

optimal runtime using **256 threads** per block – for **high flux map resolution** (1800X1000) and 64 threads per block for the normal resolution

Results

- A camera based system was developed to **measure the flux density** on tube receivers
- A camera based **emissivity and temperature measurement system** was developed
- A **Heliostatfield optimisation** was developed by means of a GPU based simulation tool
- A **measurement campaign** was performed at the MEGALIM Solar Tower Plant

- Delays in another project forced us to build and set up a test receiver on own expenses.
- Due to the Covid-pandemia several constraints and delays were experinced
  - Emissivity and temperature measurement system could not be sent to Israel due to long lead time
- A request for a cost-neutral extension of the project was unfortunately not answered