Experimental Demonstration of a Two-color Shortwave Infrared Thermometer for the Opto-thermal Characterization of Receivers and Hot Surfaces

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Motivation:

- The **absorber temperature** of CSP tower systems needs to be **monitored** constantly **to avoid overheating**.
- The temperature monitoring system of such absorbers is commonly based on longwave infrared (LWIR) thermography.
- **Coatings** on the absorbers of state-of-the-art CSP tower systems **degrade** over time, affecting their optical properties.
- If a **LWIR camera system** is set up with incorrect values for the absorber's emittance, an **incorrect temperature** reading will be measured (see Fig. 2).

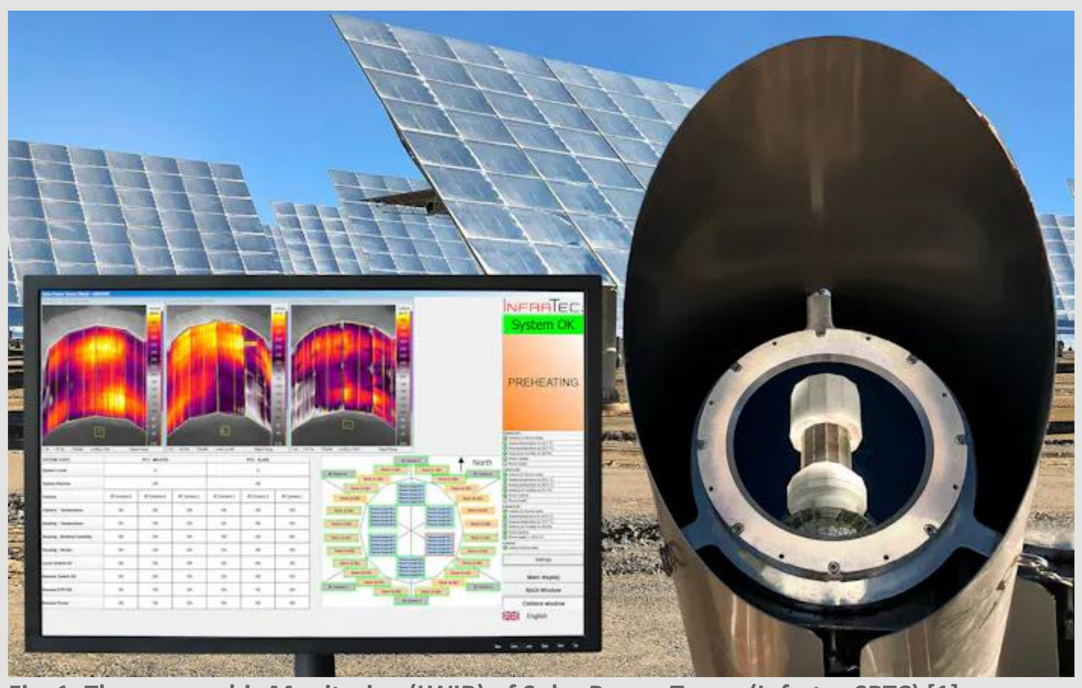

Fig. 1: Thermographic Monitoring (LWIR) of Solar Power Tower (Infratec SPTC) [1]

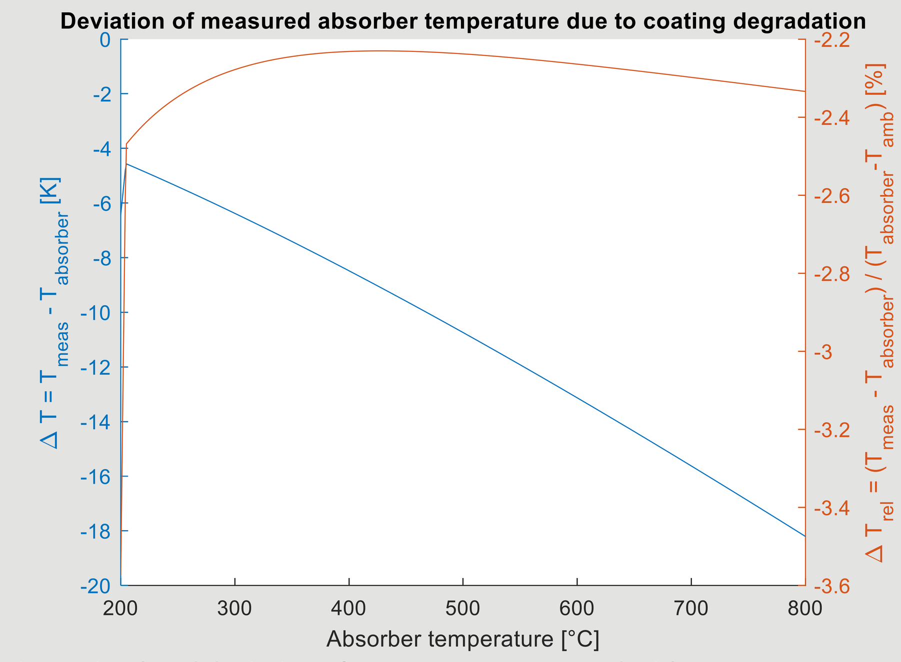

Fig. 2: Simulated deviation of temperature measured with LWIR camera system to true absorber temperature if coating is severely damaged

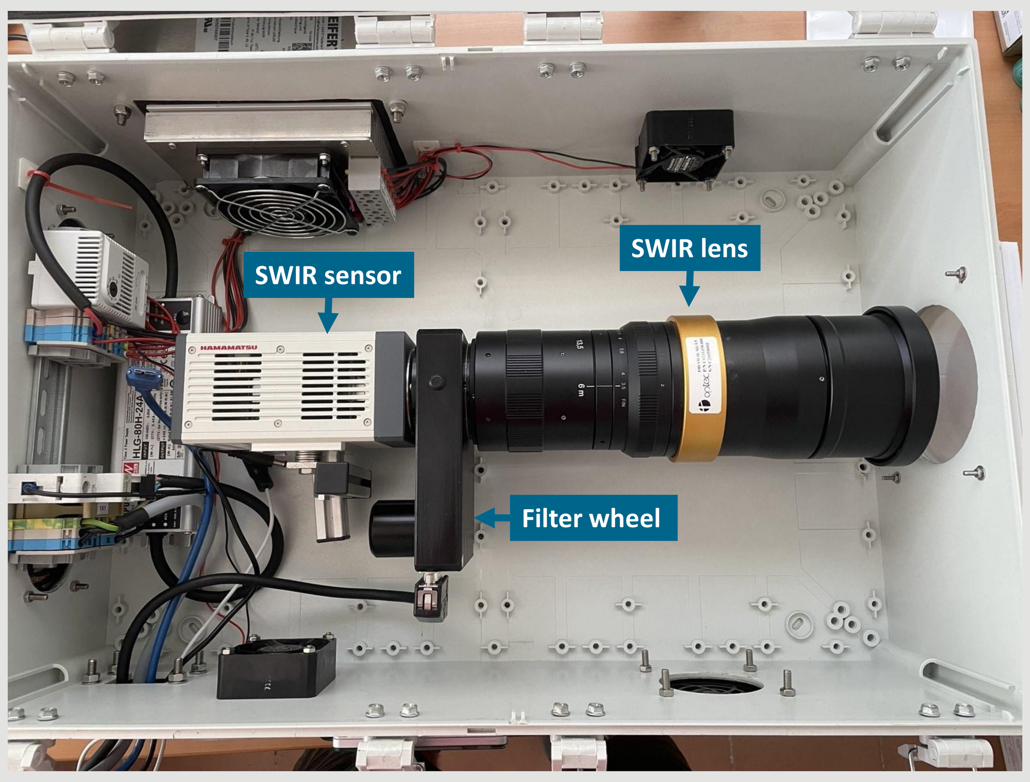

Fig. 3: Picture of the two-color SWIR camera system inside a field case; Details on the components can be derived from Ref. [2]

Two-color SWIR thermometer:

- **Two-color infrared thermometers** enable the **simultaneous measurement** of a surface's **temperature and emittance**.
- Two **short wavelength infrared** (SWIR) thermometers were tested. The first one operates in bandwidths in which water vapor in the atmosphere absorbs radiation. This filter pair is **not affected by reflected (concentrated) solar radiation** and therefore **„solar blind"**.
- The second filter pair is not solar blind, but also less sensitive to atmospheric conditions.
- The effect of radiation extinction in the atmosphere is calculated with the commercial code **MODTRAN® 6** [3] for given ambient conditions.
- The system was calibrated with a blackbody calibrator (Mikron M305) at CIEMAT's Plataforma Solar de Almería (PSA).

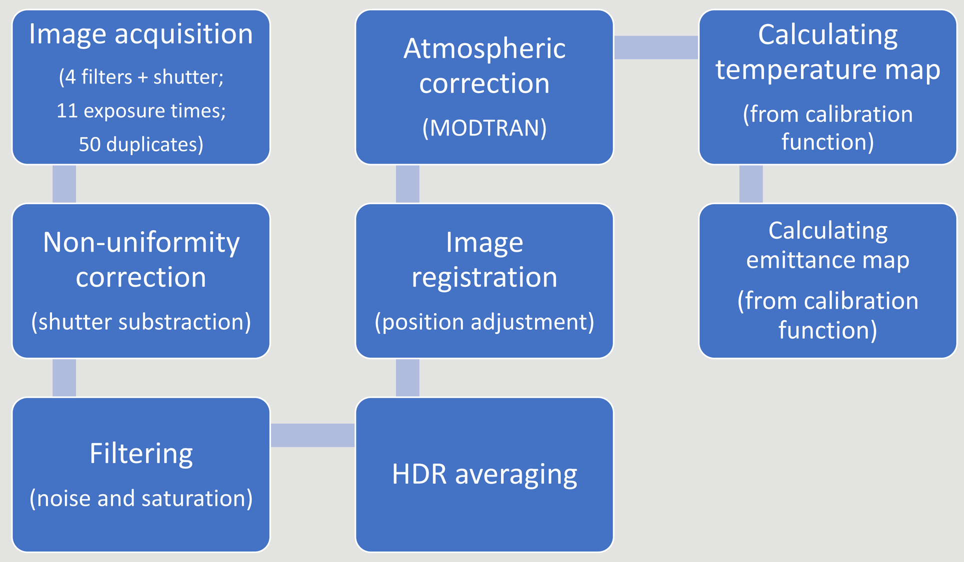

Fig. 4: Schematic of steps in image processing and data analysis for two-color thermometer

Fig. 5: Picture of the muffle furnace setup with mounted sample and thermocouples

Experimental setup:

- A sheet of **oxidized high-temperature alloy** sheet was partially coated with **Pyromark® 2500** paint.
- It was fitted to a **muffle furnace** (Nabertherm) to allow for continuous heating and measurements.
- Two **thermocouples** (TCs) were mounted to each side (coated and uncoated) of the plate (see Fig. 5).
- The oven was heated to above 1000 °C, resulting in TC **measurements of up to 650 °C**.
- The SWIR camera system was positioned 8 m apart from the oven in a **lab environment** at the PSA.
- At each temperature step and for each of the four filters, images were captured for eleven exposure times to create **high-definition ratio** (HDR) images.

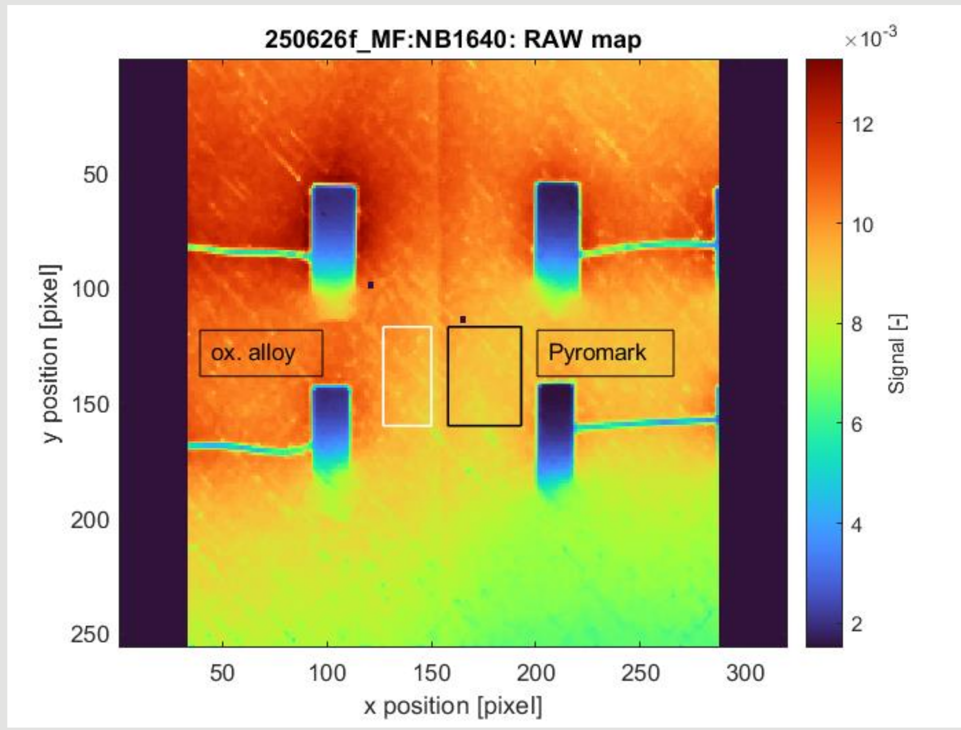

Fig. 6: Raw signal map acquired with Filter NB1640; The white and black rectangles mark the region of interest of the uncoated and coated section, respectively

Results:

- Even for the short distance (8 m) in the lab, **atmospheric extiction for the solar blind filters reaches up to 25 %**. The difficulty in accurately measuring ambient conditions along the radiative path leads to a large uncertainty. In the following, only the results for the second filter pair (for which extinction is close to zero) are presented. In a simulation study, it was further found that the solar blind setup cannot achieve the desired accuracy in a commercial solar tower system [2].
- The temperature distribution over the sample is quite inhomogenious (see Fig. 6).
- The **temperature derived from SWIR measurements agrees well** for the two filters NB1640 and NB2090 as well as for their ratio (Figs. 7 and 8).
- The **standard deviation** within the regions of interest (ROIs) is quite small (**< 5 K**).
- All mean temperatures **are within the estimated uncertainty range of the reference** (TC) measurement. However, this range is large as the TCs are in direct contact with the hot sample and the much colder mounting plates (Fig. 6).
- The calculated values for the **emittance of the coated area vary strongly** over the measurement temperature (Fig. 9). They stabilize above 450 °C and reach a reasonable mean of (95 ± 2) %. The standard deviation, however, is quite high.

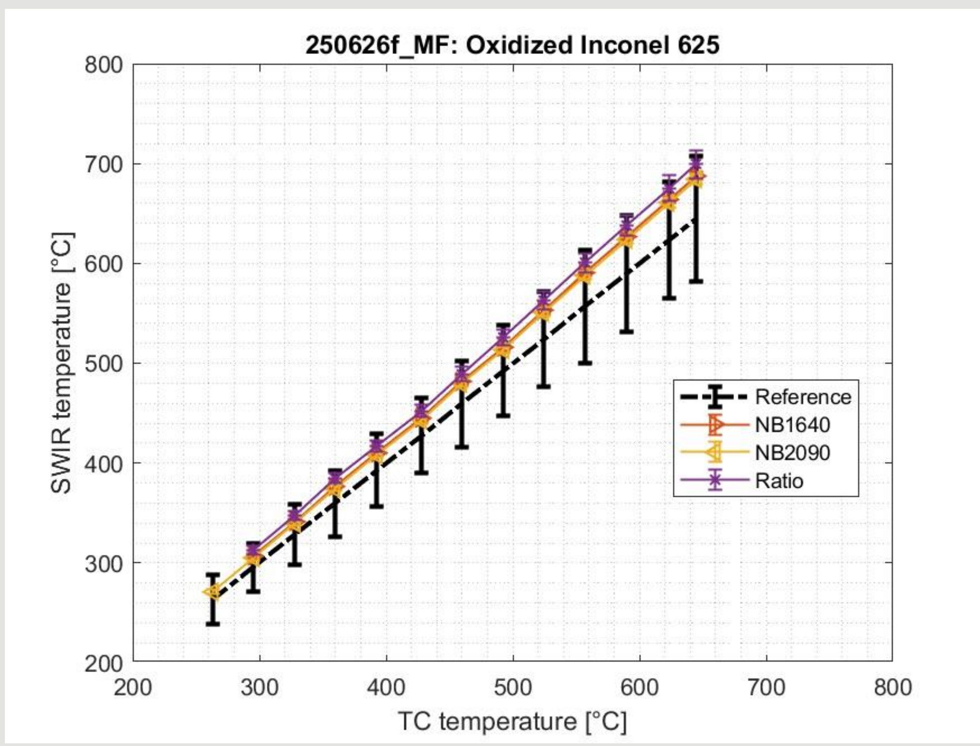

Fig. 7: Temperature determined by SWIR measurements compared with TC reference for uncoated area

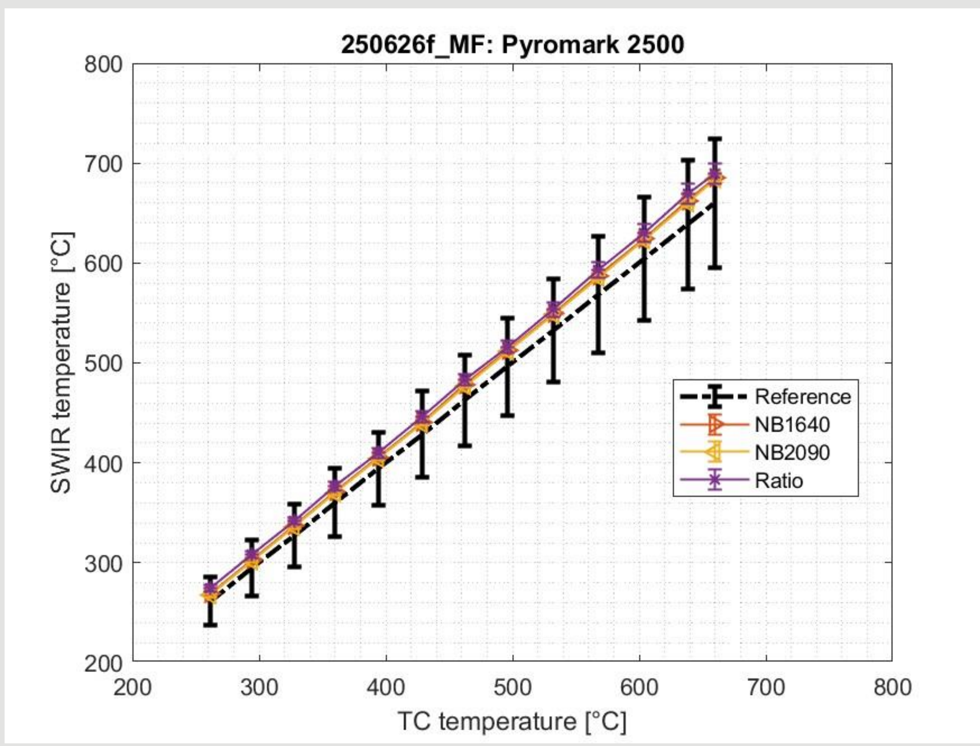

Fig. 8: Temperature determined by SWIR measurements compared with TC reference for coated area

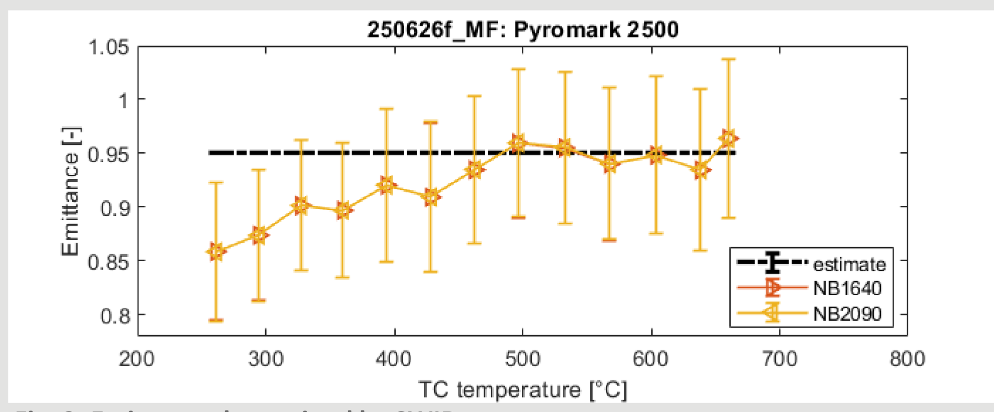

Fig. 9: Emittance determined by SWIR measurements

Conclusions and outlook:

- A SWIR two-color thermometer has been tested on two different surfaces in a lab environment.
- The results of the solar blind thermometer are **highly dependent on ambient conditions**, even at short distances.
- The derived temperatures seem reasonable and have a small standard deviation. However, the **reference measurement has a large uncertainty**, so that the accuracy of the SWIR method could not be quantified.
- Repeating the experiment with more homogeneous temperature profiles on the sample and a different mounting of the thermocouples could lower this uncertainty. This could be achieved by immersing the whole sample in the furnace while only opening the door during image acquisition.
- A **field demonstration** of the thermometer is planned **in a commercial plant** in the upcoming months.

References:
[1] InfraTec GmbH (2025), https://www.infratec.eu/thermography/industrial-automation/solar-power-tower-check-sptc/, Last accessed: 29.08.2025
[2] Caron, S. et al. (2025), Simulation of shortwave infrared ratio thermometers for the remote opto-thermal characterisation of central external receivers, Solar Energy, https://doi.org/10.1016/j.solener.2024.113145
[3] Spectral Sciences Inc. (2025), http://modtran.spectral.com/, Last accessed: 29.08.2025