DEVELOPMENT OF CENTRIFUGAL PARTICLE RECEIVERS

Status Review

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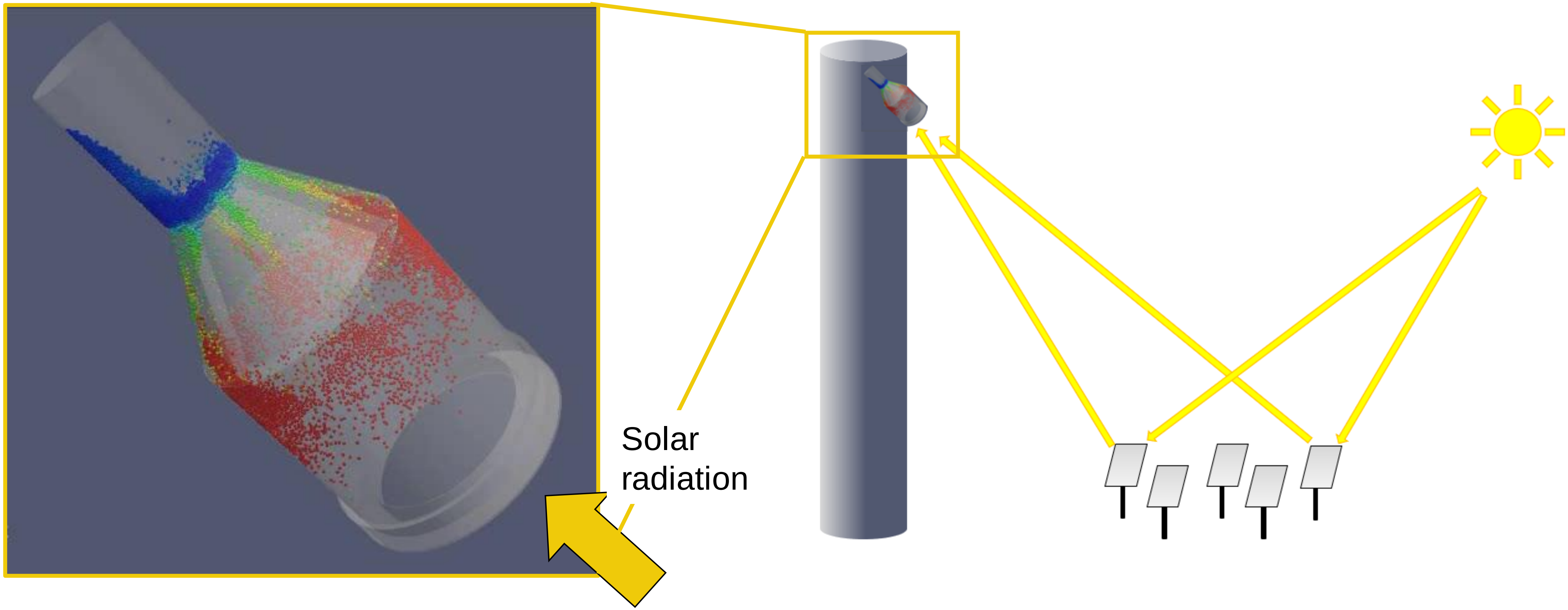
DLR

CentRec® Particle Receiver



- Particle residence time / receiver outlet temperature controlled by adjusting rotational speed
- Thin, optically dense layer for all load conditions

CentRec® timeline

Particle solar centrifugal receiver

2013

First prototype at DLR (15 kW)

2018

CentRec500 demonstration
at solar tower Jülich (500 kW)

2021

PEGASUS-Receiver (CentRec300S)
demonstration in Synlight (300kW)

2023

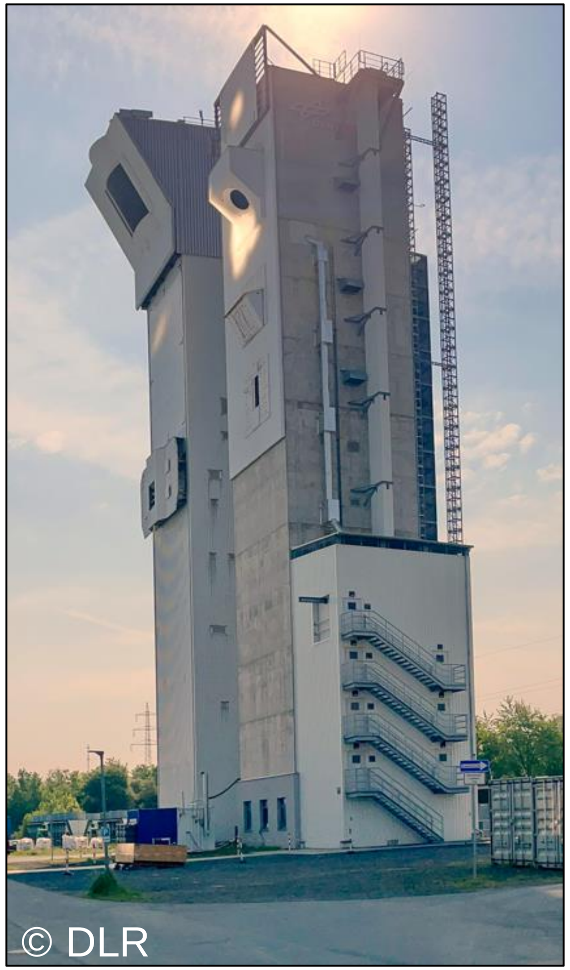
HEHTRES-Project (500 kW)
Long term research facility

2024/25

Future pilot plant project
EU Realize

Multi-focus Tower (MFT) in Jülich, Germany

- Multi-focus tower in Jülich provides a test platform for different CSP technologies under controlled operating conditions
- more than 2‘000 heliostats
- functioning solar tower power plant



Multi-focus tower with fully equipped particle loop system
CentRec on top = HEHTRES receiver

DLR HEHTRES facility in Jülich

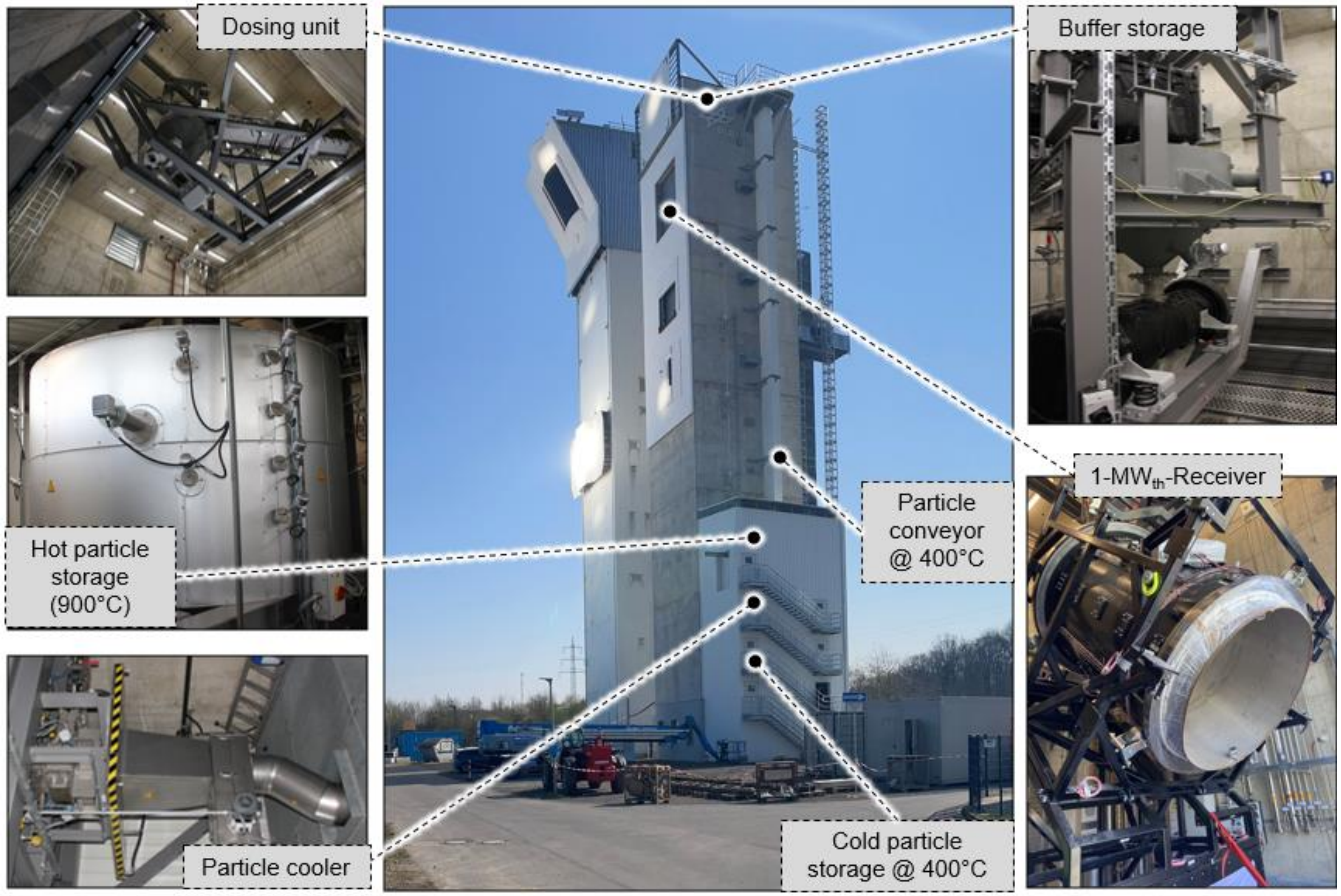
High Efficiency High Temperature REceiver System

Test facility with complete particle loop (Bauxite particles)

- September 2022: Installation of particle transport system completed
- October 2022: Cold commissioning of particle system (transport and control)
- Feb 2023: Delivery of receiver to Jülich
- March 2024: Cold commissioning receiver
- May 2024: Hot commissioning receiver
- June to October: Possible test campaigns

Access to the facility

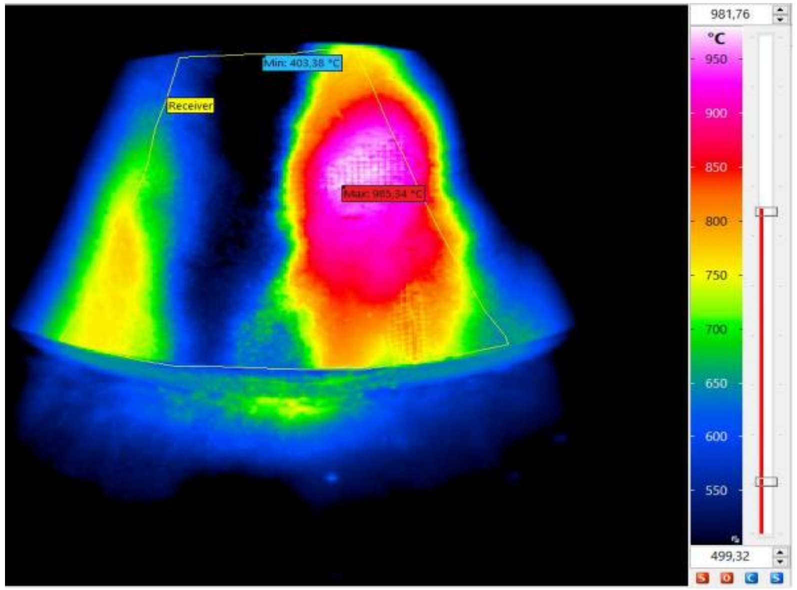
- In summer 2023 four test platforms share one solar field
- Industry can book the test facility to test their components/systems



Particle measurement methods in centrifugal receiver

3D Laser Scan pre-thermal → Film velocity + thickness → 3D Laser Scan post-thermal load → Film velocity + thickness

- Development of measurement methods in centrifugal receivers
    1. **Particle velocity**
    2. **Particle film thickness**
- Understanding the particle film behavior in both states: do thermal deformations influence the particle film velocity or thickness? To which extent?
    - Inhomogeneous temperature distribution in the particle film
    - Several hotspots observed
    - Assumption: Roundness of the particle running surface is crucial
- Correlations between the variables
- Observation of the relevant properties, understand correlations – which property is crucial for film quality?
- Quality control of centrifugal particle receivers



IR measurement of particle film
(view into CentRec-300 receiver)

Measuring film thickness

Measuring principle

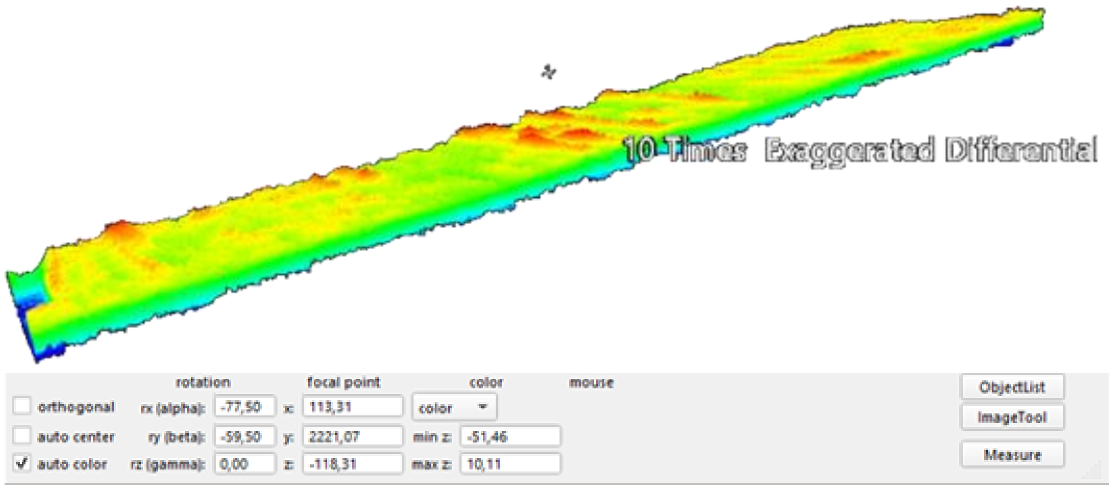
- **Laser scanner** measuring distance to film
- **Scanning a line** in axial direction
- Rotating the receiver

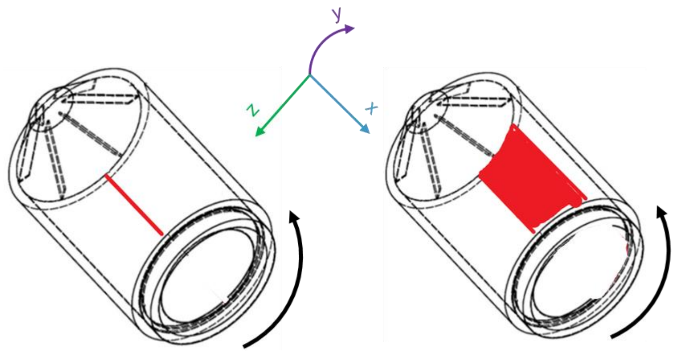
→ 3D-Scan of surface

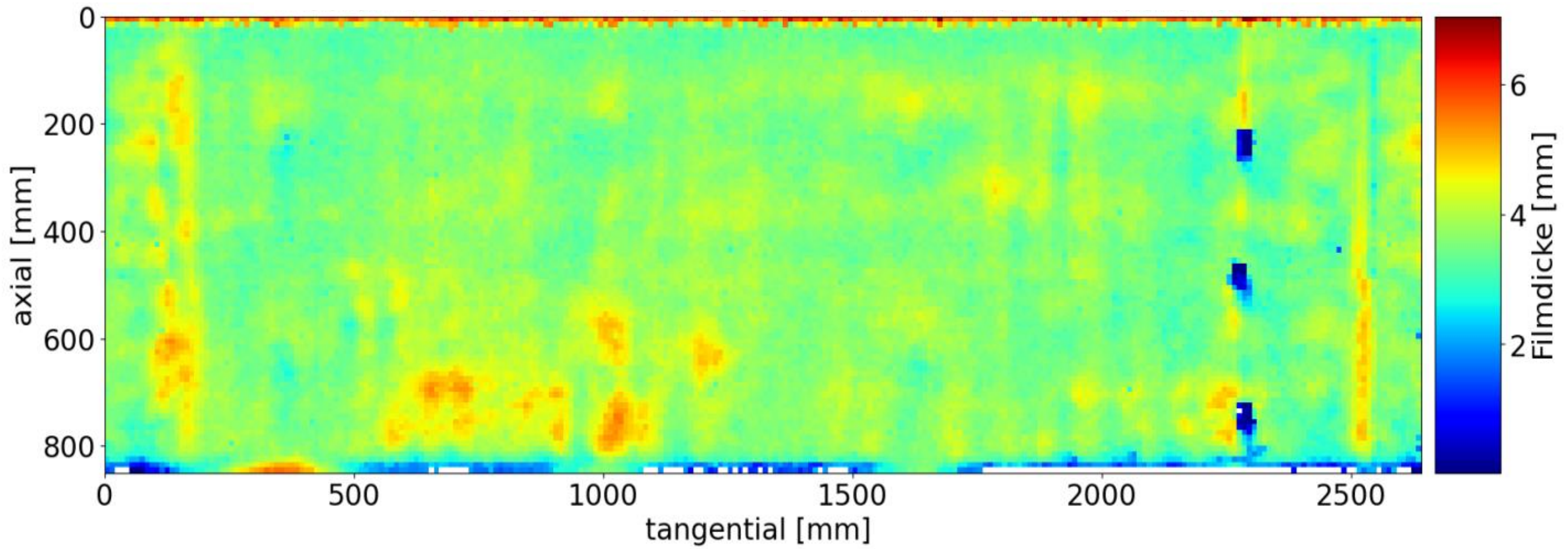
- Reference scan in empty receiver
- scan with particle film

→ **Difference is film thickness**

- Patented



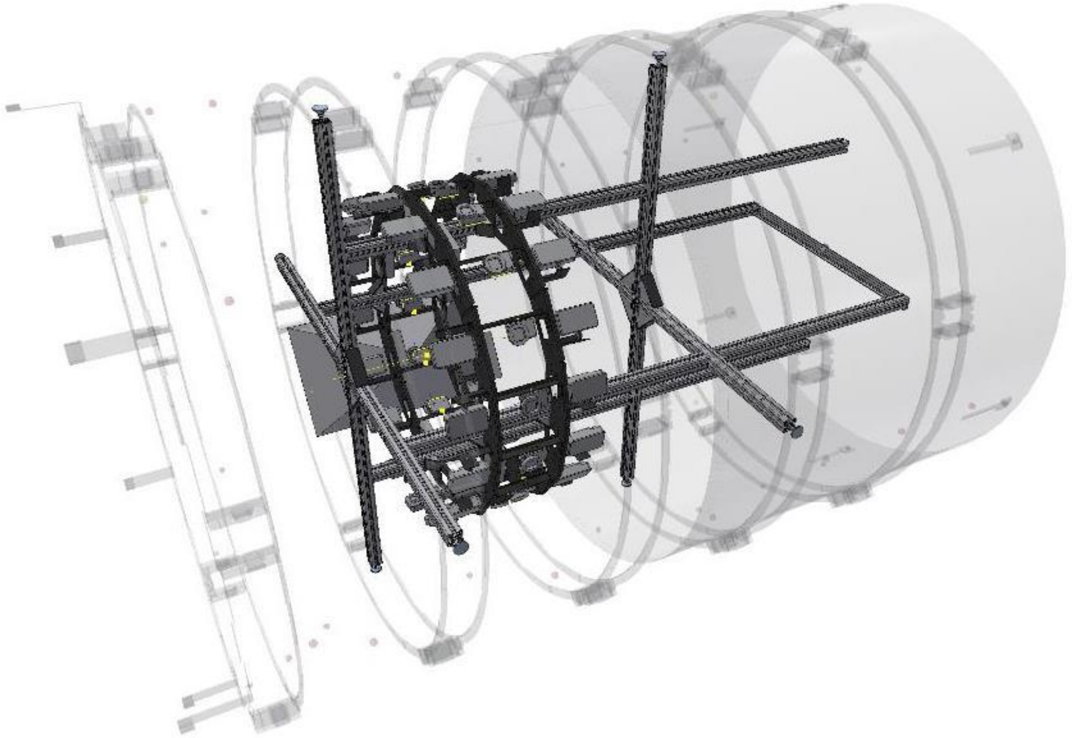




Measuring axial film velocity – Measurement setup

Measurement principle:

- White tracer particles are mixed with the particles
- Tracers are tracked with image processing algorithm
- Velocity of the surface calculated
- New: observing the whole circumference with multiple cameras

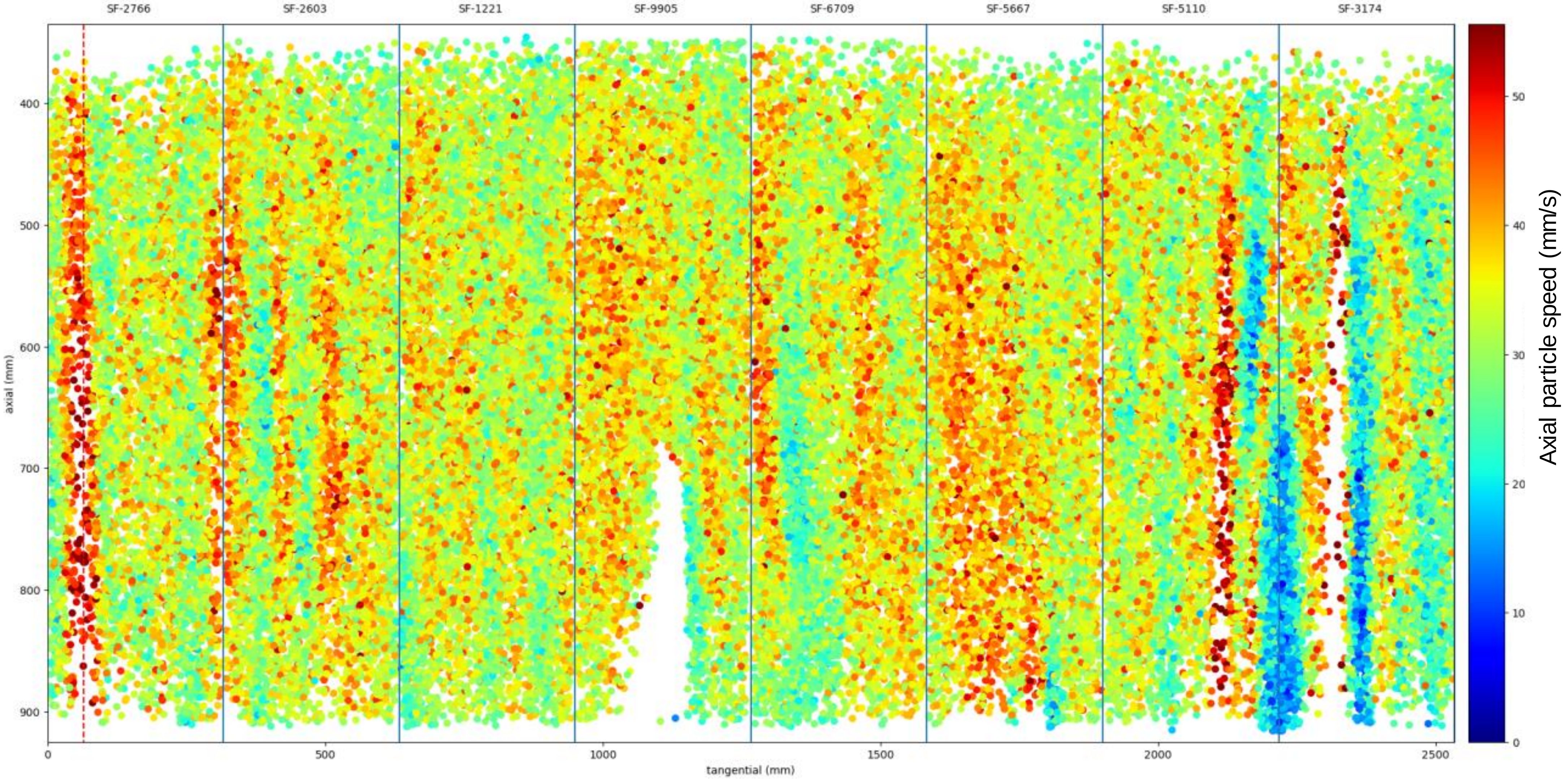


Aspired accuracy

- resolution: minimum 1 cm grid
- accuracy: previous standard deviation $0.04\frac{m}{s} \pm 0.005\frac{m}{s}$

Measuring axial film velocity – Results

Axial particle speed, measured by 8 camera systems using particle imaging velocimetry



Summary of current activities

Concerning the particle film

- Focus on developing the methods for film thickness and film surface velocity in CentRec300 in Stuttgart
- Application of methods in HEHTRES receiver in Jülich
- Understanding the correlations between observed properties
  → relevant for quality check of the particle running surface and for evaluating the receiver performance
- DEM simulations of irregularities on particle running surface

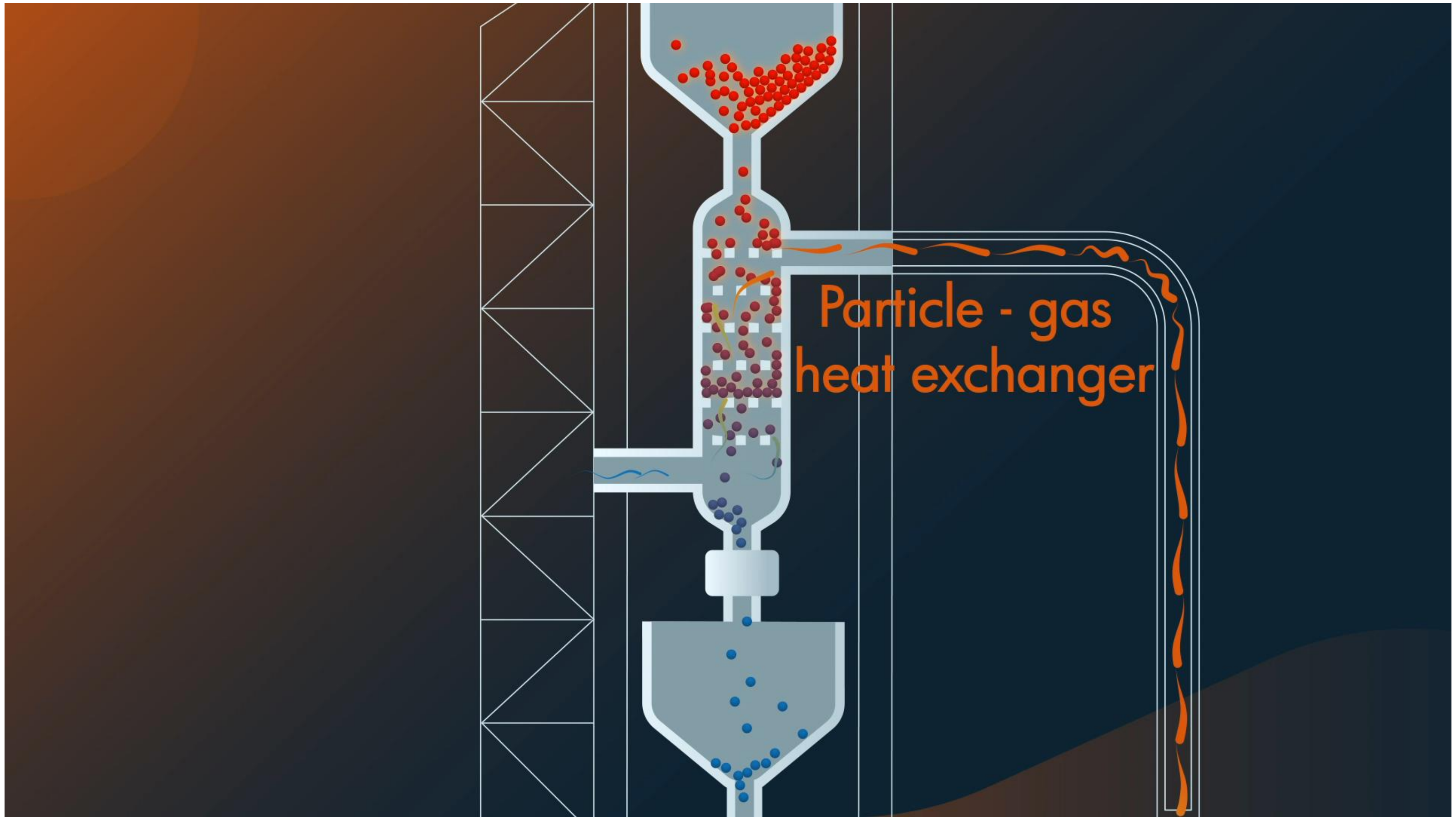
Other measurement methods under development

- Measuring the particle density distribution (2D) in TFHX

Next methods to be developed

- IR method (temperature of the particle film)
- Improvement of outlet temperature measurement

Gas-Particle Trickle-Flow Heat-Exchanger

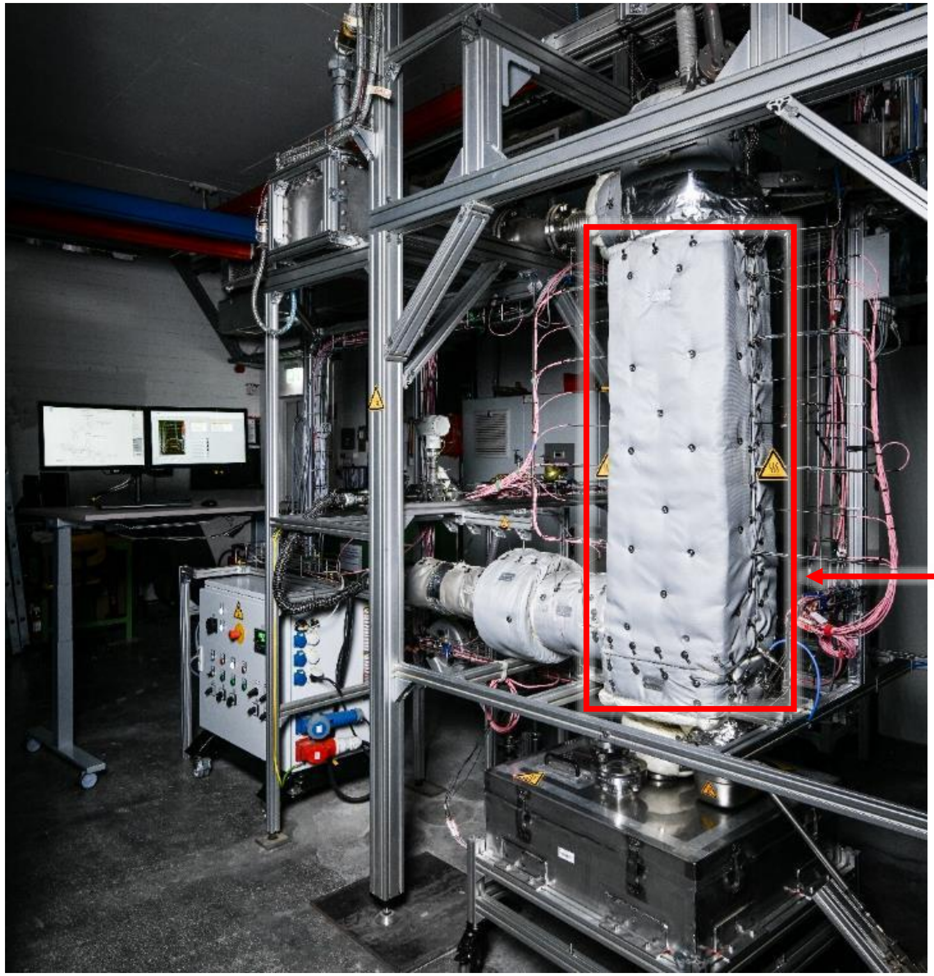


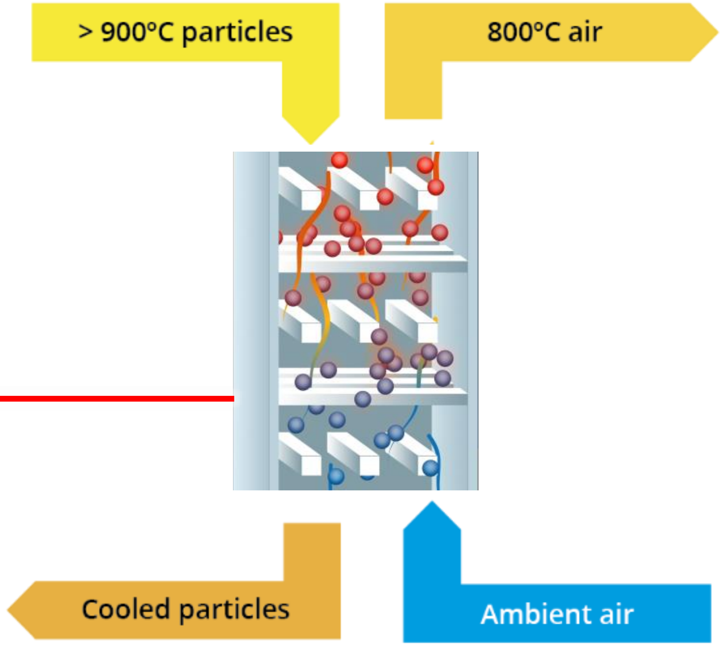
Video Source: https://www.youtube.com/watch?v=DIoTevijQuc

Objectives

- Supply of hot air at 800°C for pre-treatment of manganese ore (EU PreMa Project)
- Reducing the energy- and CO2- demand by 15% in the production of manganese-iron alloys
- Ceramic particles at 930°C from the CentRec receiver
- 5kW$_{th}$ Counter flow direct contract heat exchanger

Gas-Particle Trickle-Flow Heat-Exchanger (TFHX)





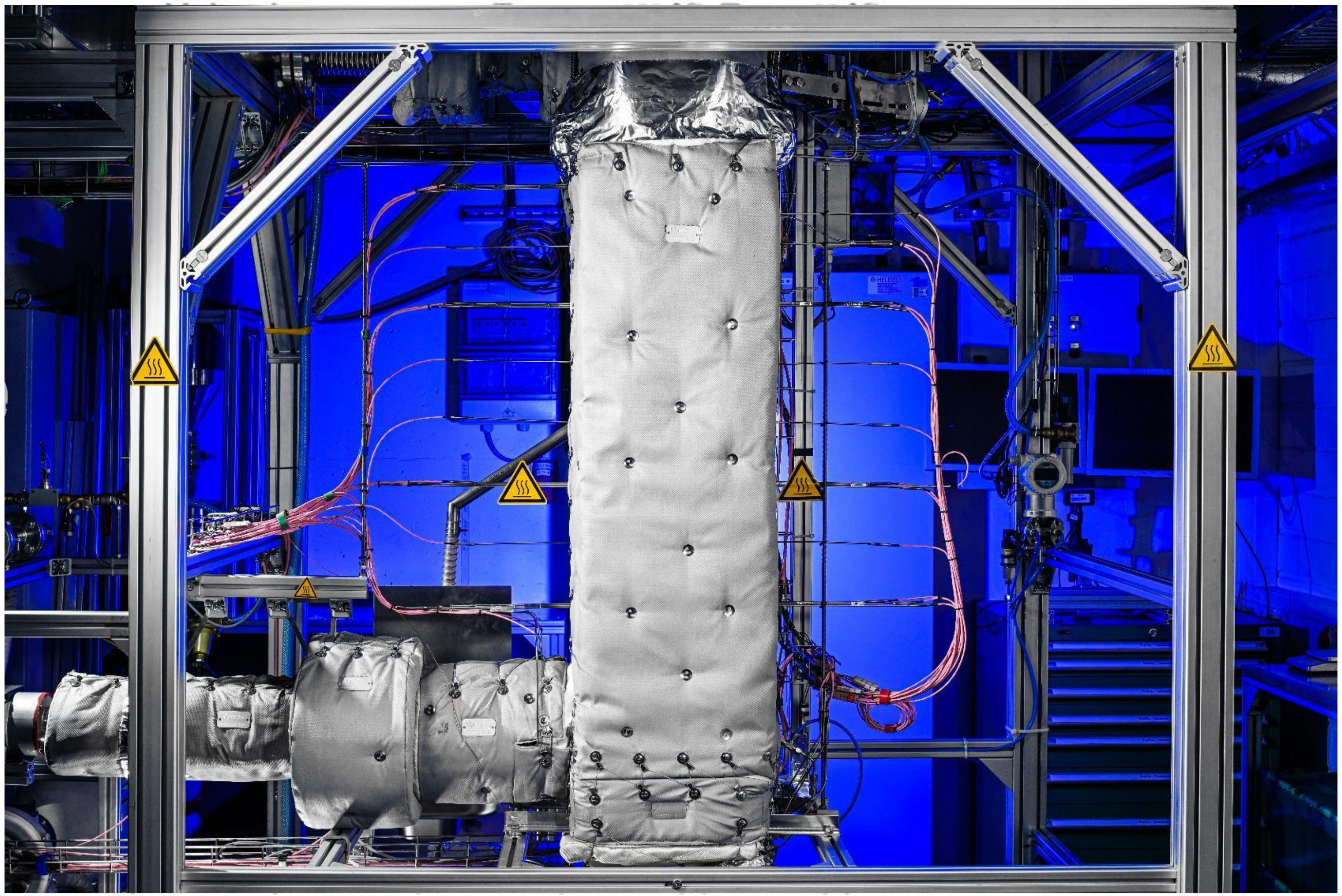
Objectives

- Supply of hot air at 800°C for pre-treatment of manganese ore
- Ceramic particles at 930°C from the CentRec receiver
- Identification of favorable packing structure, providing a high particle surface area of the trickling particles
- Thermal heat transfer performance

Video Source: https://www.youtube.com/watch?v=DIoTevijQuc

First Results

Power Density – specific thermal power transferred from hot air flow to cold particles



$\dot{m}_{\mathrm{p}}^{\#}$ in kg/(s · m^2)

Testing Conditions

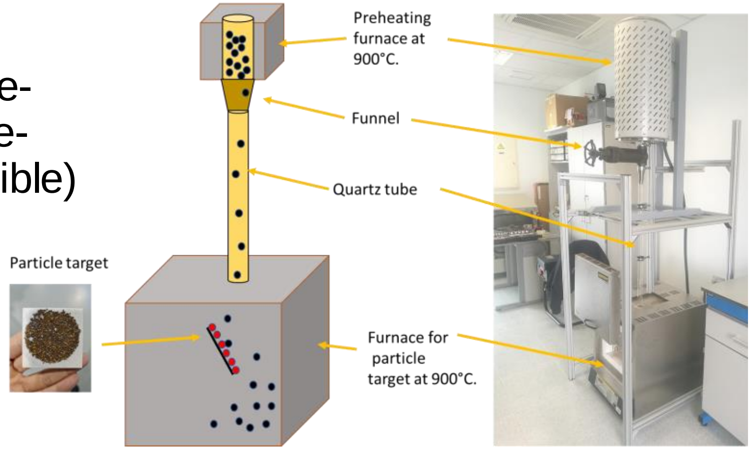
- 1 mm particles
- Packing dimension: 50x50x870mm
- 4 different air inlet temperatures (170°C…638°C)
- Varying media flow rates
- Test conditions chosen to meet equal heat capacity flow rates

Key Findings

- With increasing temperature range, power density increases
- Literature provides measurement data for air temperatures 250°C…350°C, providing power densities up to 350kW/m³. In the same temperature range, the TFHX provides up to 550kW/m³

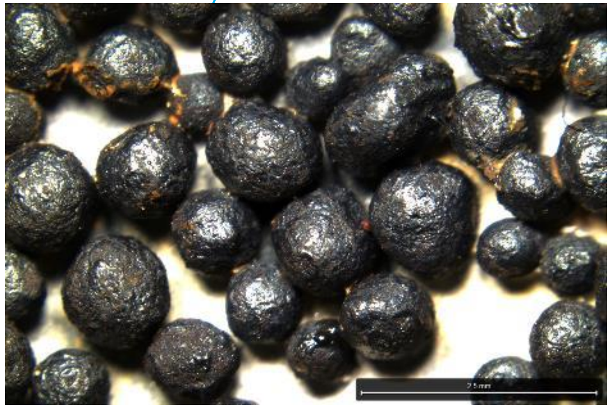
Particle test facilities

- High temperature particle-particle abrasion (particle-alloy abrasion also possible)

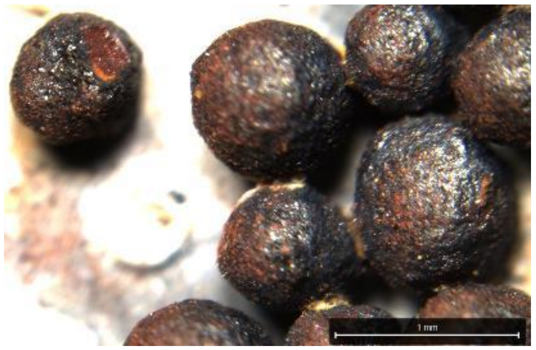


1 cycle ≈ 2.9 years of CENTREC operation

Initial state, coated

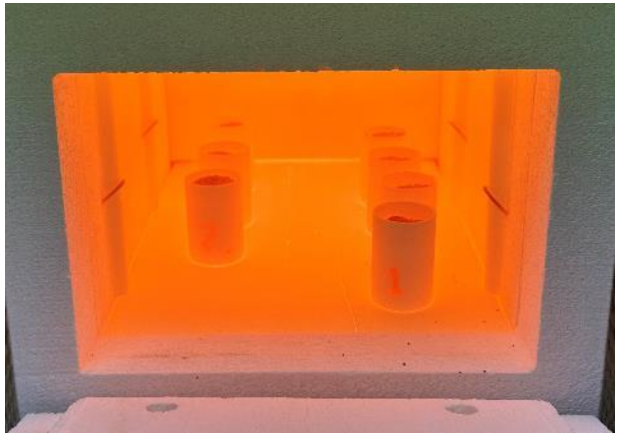


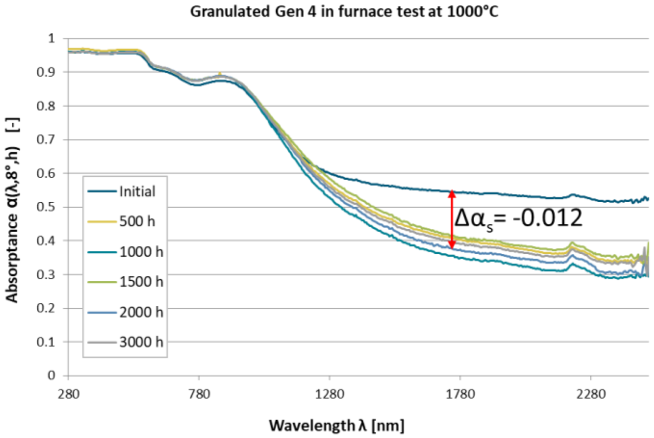
After 3 cycles, partial coating removal and particle breakage



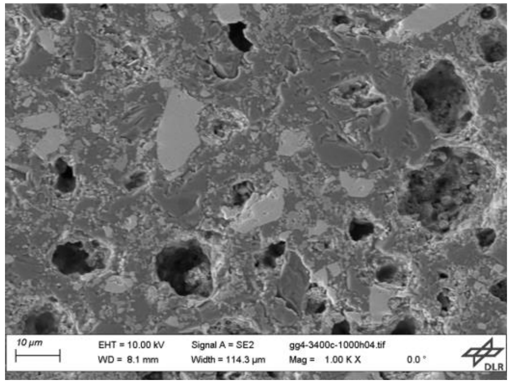
- Thermal stability of particles

- Optical measurement of particles (spectral absorptance/ emittance)





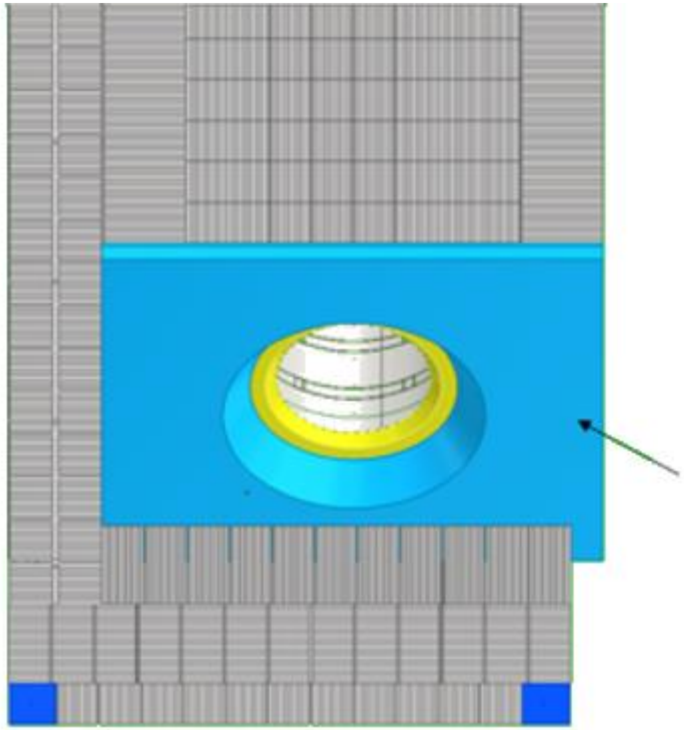
After 3400h at 1000°C

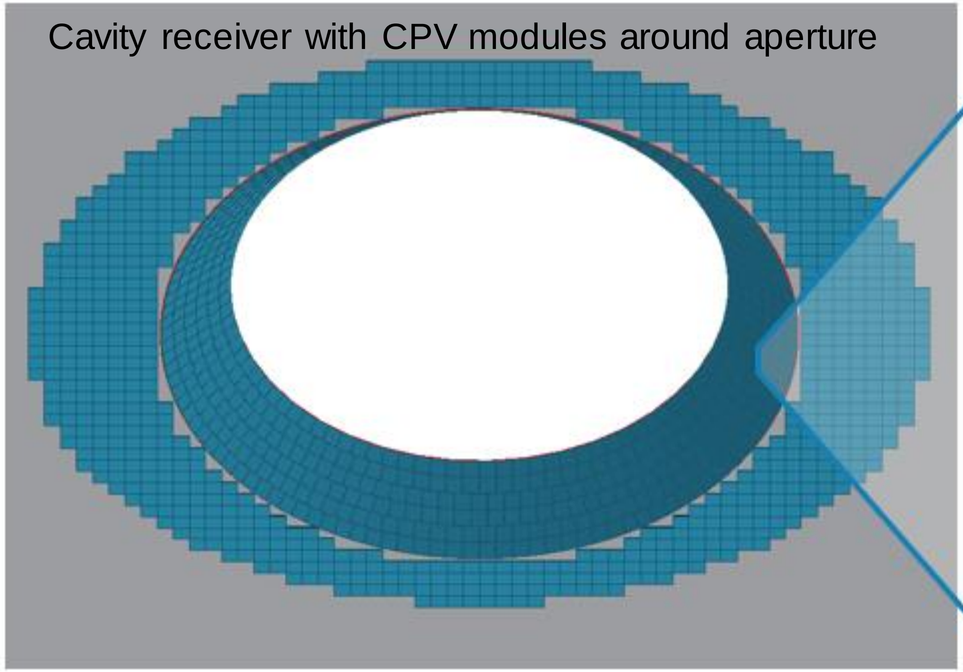


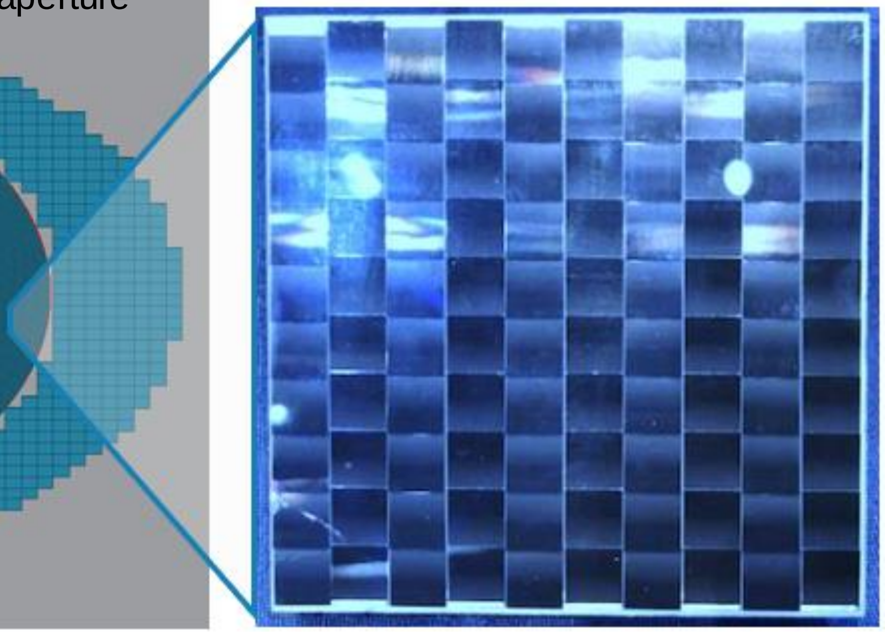
Collaboration with Saint Gobain in HIFLEX project led to the development of a new particle material; commercialization is planned by Saint Gobain under the name “FerOx”

CPV modules to capture spillage radiation

- High temperature receivers show increased spillage losses
- This spillage can be captured and converted directly using high-efficiency CPV modules
- Preliminary results indicate that annual system efficiency can be increased from 16% to more than 20%
- Cost-optimized design will be inbetween (covering only those aperture regions where CPV modules produce power at lower cost than a large stand-alone PV installation)
- SpiCoPV project: 6 CPV modules will be installed around HEHRES receiver aperture







EU HySelect

Efficient water splitting via a flexible solar-powered Hybrid thermochemical-Sulphur dioxide depolarized Electrolysis Cycle

HySelect

Clean Hydrogen Partnership

Co-funded by the European Union

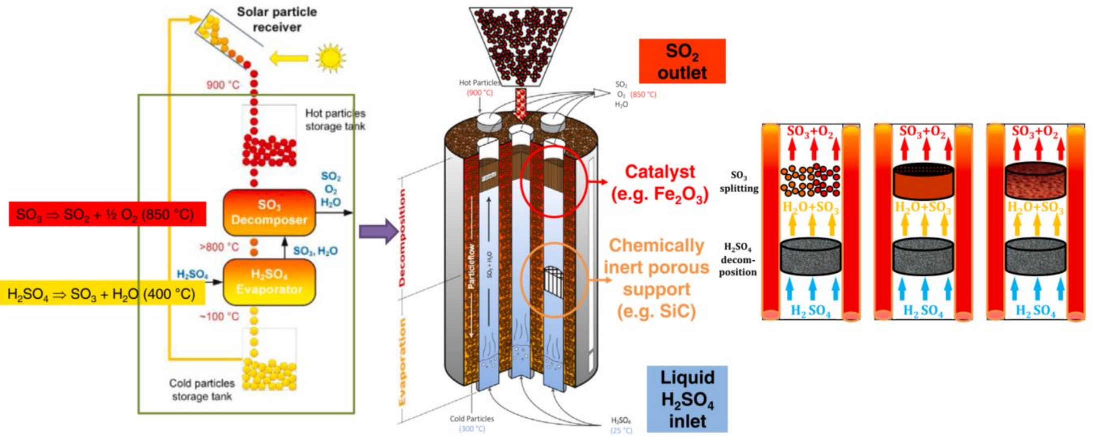
DLR

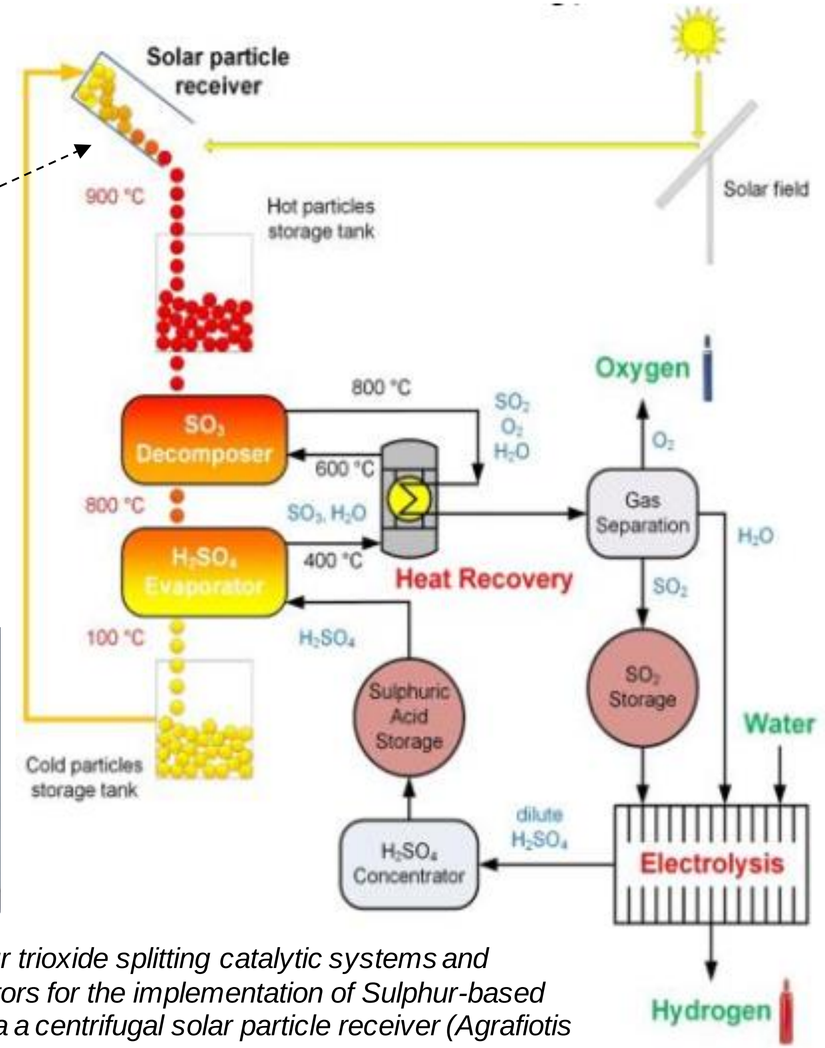
Objective

Production of hydrogen by splitting water using concentrating solar technologies via the hybrid sulfur cycle.

Tasks

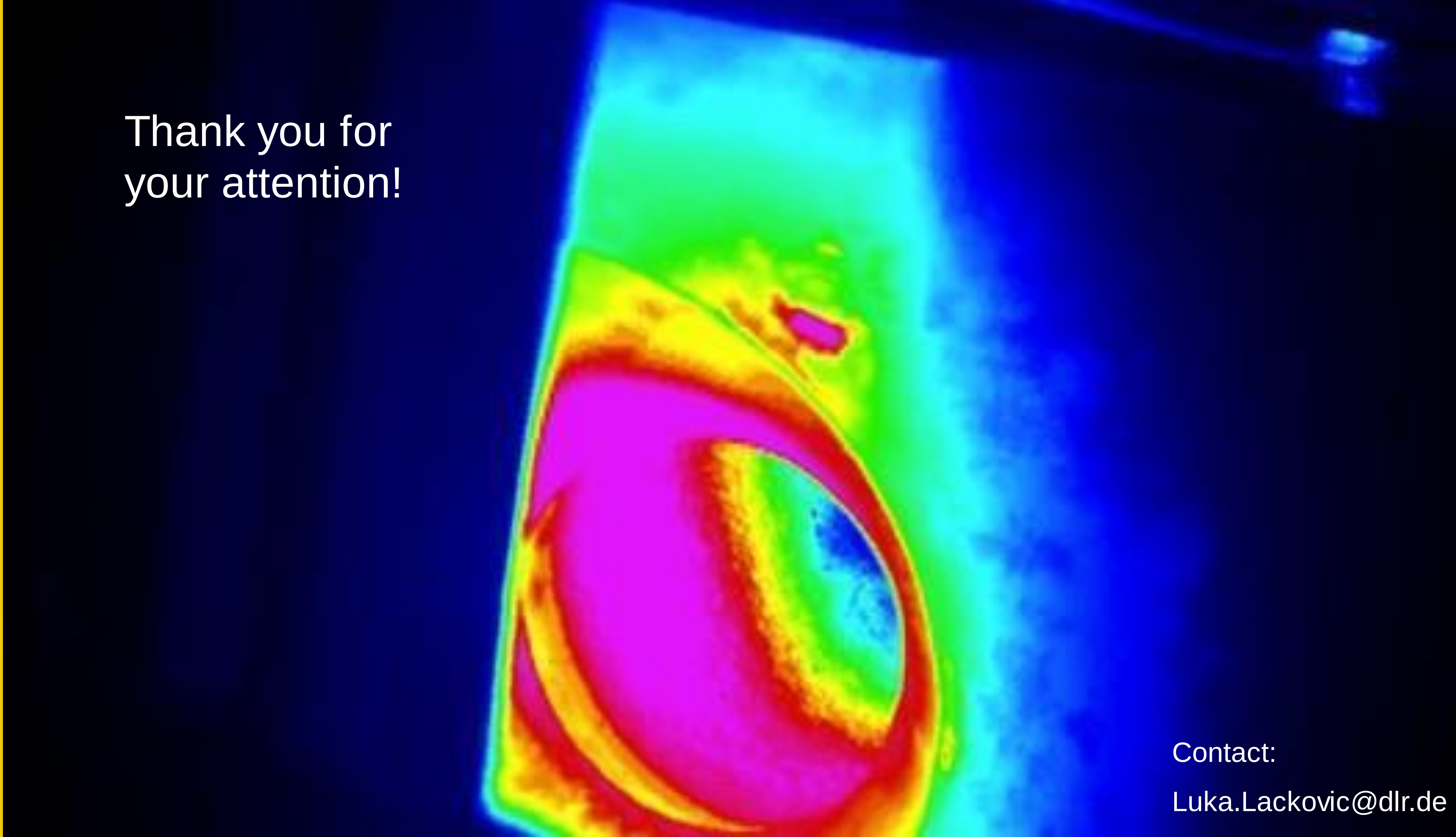
- Support in the development of reasonable operation strategies of the CentRec particle solar receiver
- Demonstrate sustained delivery of 900°C hot particles using the HEHTRES particle system (Jülich, Germany).
- Demonstration of the feasibility of the process with integrated sulfur cycle





Source: *Structured sulphur trioxide splitting catalytic systems and allothermally-heated reactors for the implementation of Sulphur-based thermochemical cycles via a centrifugal solar particle receiver (Agrafiotis et al., 2023, DLR)*

Thank you for
your attention!



Contact:

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BACKUP

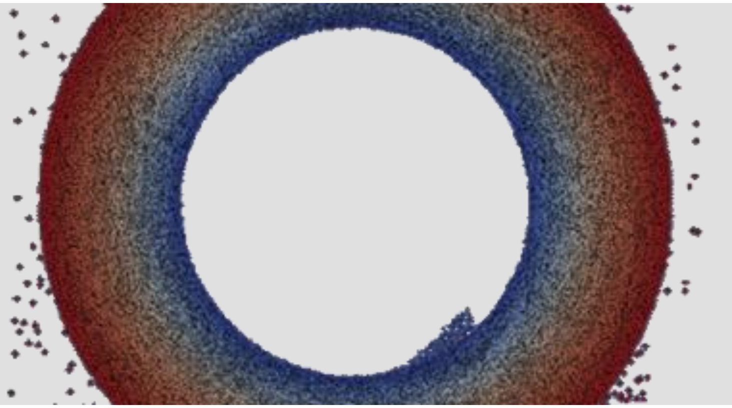
Gliederung (ausgeblendet)

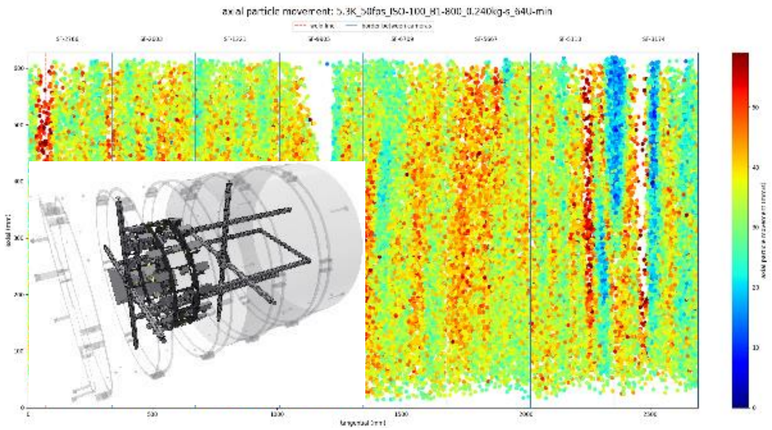
- Prinzip
- Entwicklungsstufen
- Stand:
  - HEHTRES-Receiver
  - Gesamtanlage
  - Messmethoden
  - Nächste Schritte
  - CPV
- DCHX
- Partikelentwicklung

Particle Group
Operation, simulation & measurement methods

Ensuring quality and successful implementation of particle technology

FEM&DEM Simulations (scalability and validation)	Measurement methods Quality of the particle film	Complete particle loop, System operation of HEHTRES facility





- Simulations for upscaling the CentRec receiver and easier implementation of design changes
- Validation of numerical models through measurement methods for particle film quality
- Quality control

Solar Research Infrastructure in Jülich