September 23-26, 2025
Almería, Spain
31st SolarPACES Conference
SolarPACES Concentrating Solar Power, Thermal, and Chemical Energy Systems

AIR-COOLED SECONDARY CONCENTRATOR FOR HIGH FLUX APPLICATIONS

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DLR

Introduction & Motivation

Target: Solar energy supply for thermochemical processes

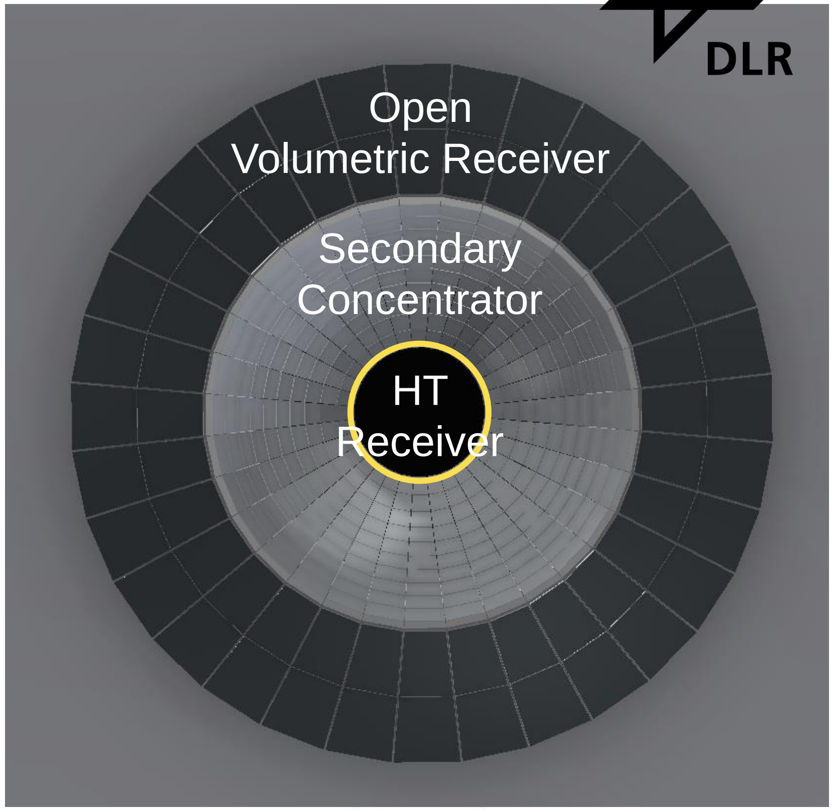
- temperatures 1.000 – 1.500°C + & Industrial scale

➢ No heat pumps / electric heaters for such applications

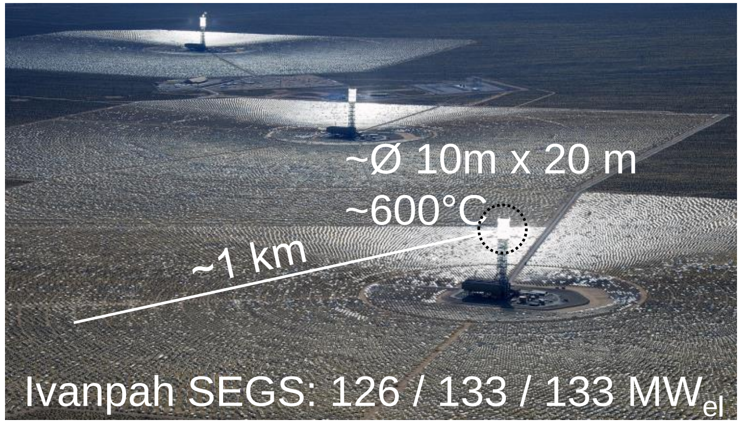
Challenge: High flux densities on small apertures

- Radiation losses (T^4) / production limit for quartz glass windows
- Natural solar radiation broadening 1:100

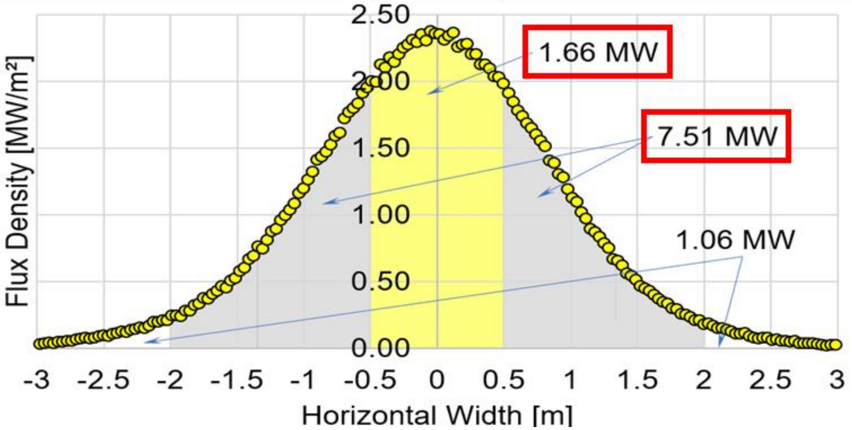
➢ Valuable radiation spillage **used with Combined Receiver**



CSP for power generation



CST for high-temperature heat

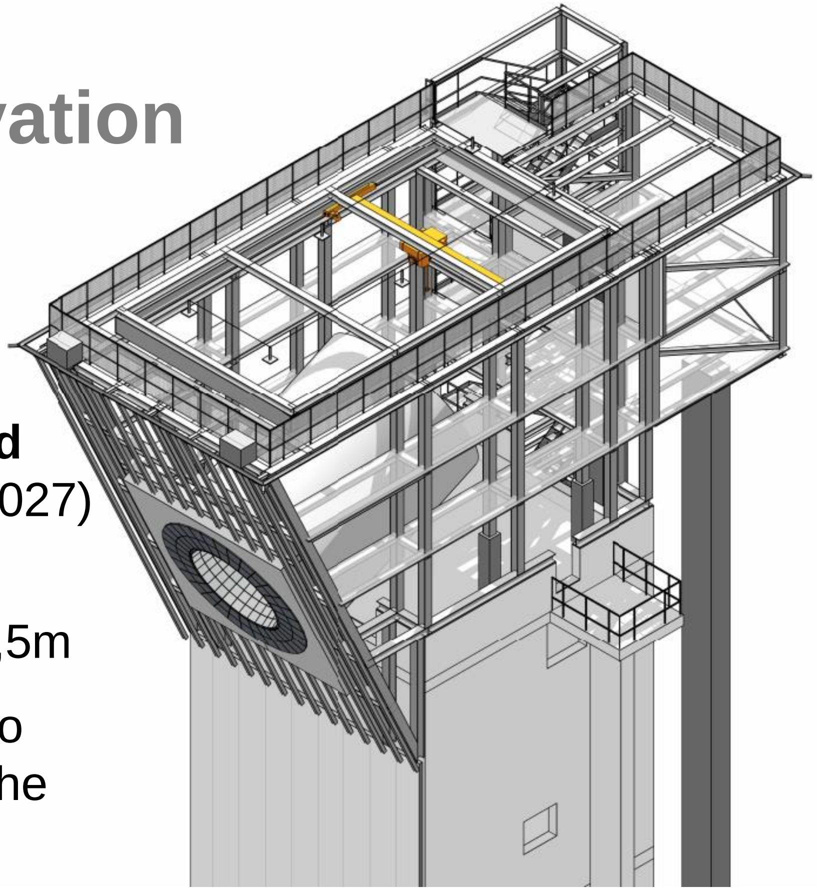


Wieghardt et al. “A combined high-temperature solar receiver”, 30th SolarPACES Nov., 2024, https://elib.dlr.de/209989

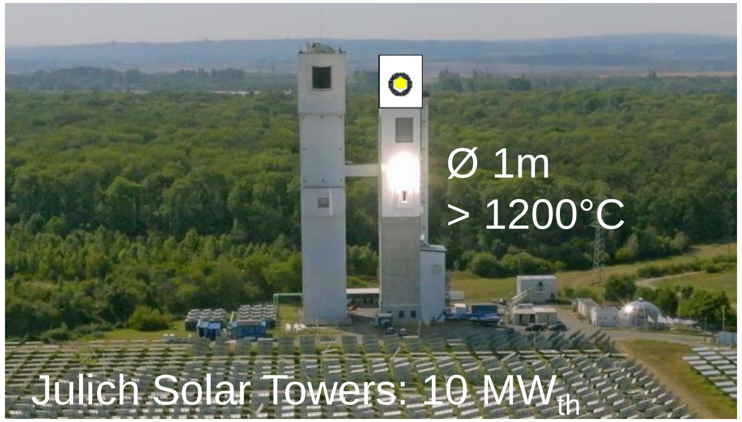
Introduction & Motivation

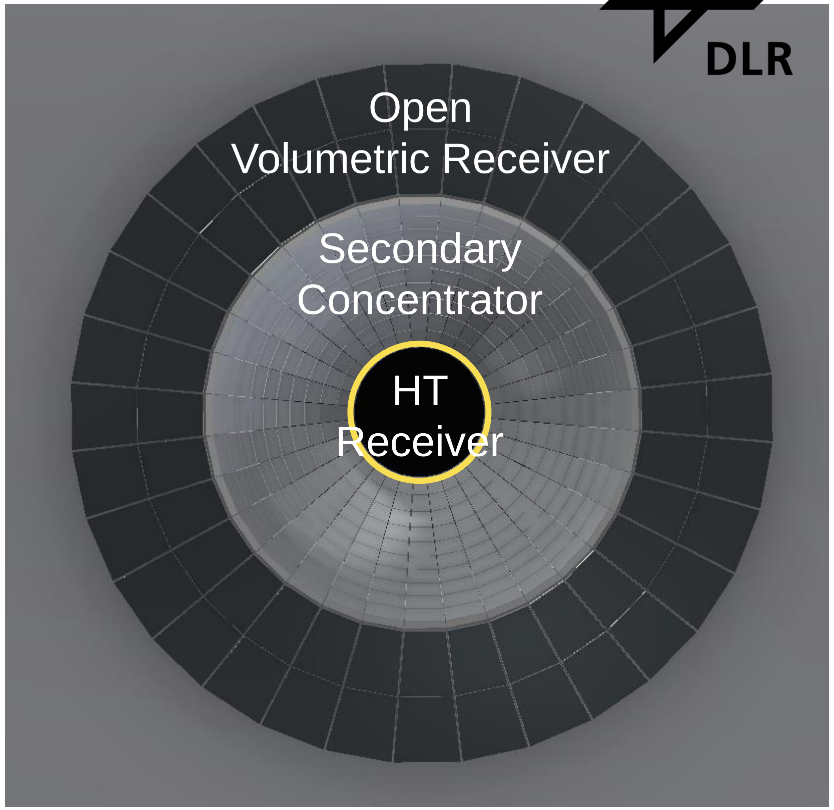
Large-scale secondary concentrator + OVR will be used in 10 MW test facility (planned 2027)

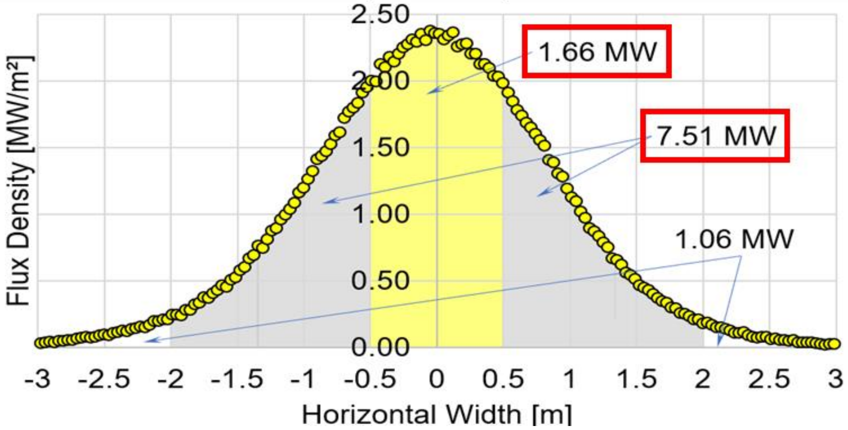
- Test facility for HT receivers with apertures from Ø1m to Ø2,5m
- Secondary concentrator will also serve as geometric adapter to the different HT receiver apertures
- Facility will be used for technology development and demonstration



CST for high-temperature heat







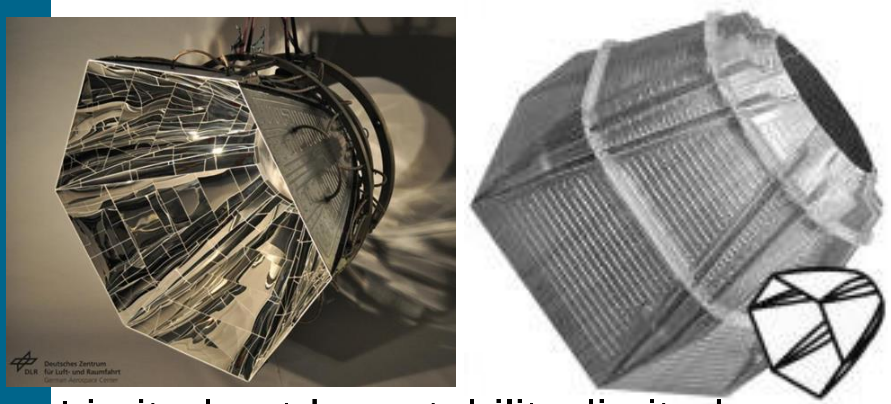
Secondary Receivers: Challenges & Basic Designs

Challenges:

- Sensitivity to soiling: Danger of a progressive self-destruction
- Concentration vs. acceptance angle

Three Basic Designs:

Thin-glass mirrors glued on water-cooled on-piece roll-bond sheets



Limited outdoor stability, limited scalability, waste heat hardly useable

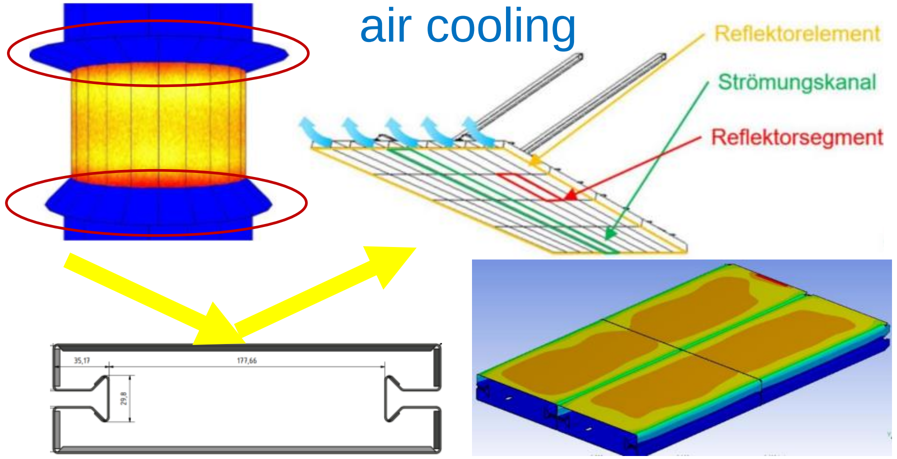
Buck et al. “Solar-hybrid gas turbine-based power tower systems (REFOS). J Sol Energy Eng 2001; 124(1):2–9. https://doi.org/10.1115/1.1445444

Polished Al plates with convection cooling: Final Optical Element, Masdar Institute

100 kW facility, limited to 200°C, low reflectivity <80%

R. Lahlou et al. “Testing of a secondary concentrator integrated with a beam-down tower system under non-liquid cooling strategies” https://doi.org/10.1063/1.5067171

Silver coated metal sheets with forced air cooling

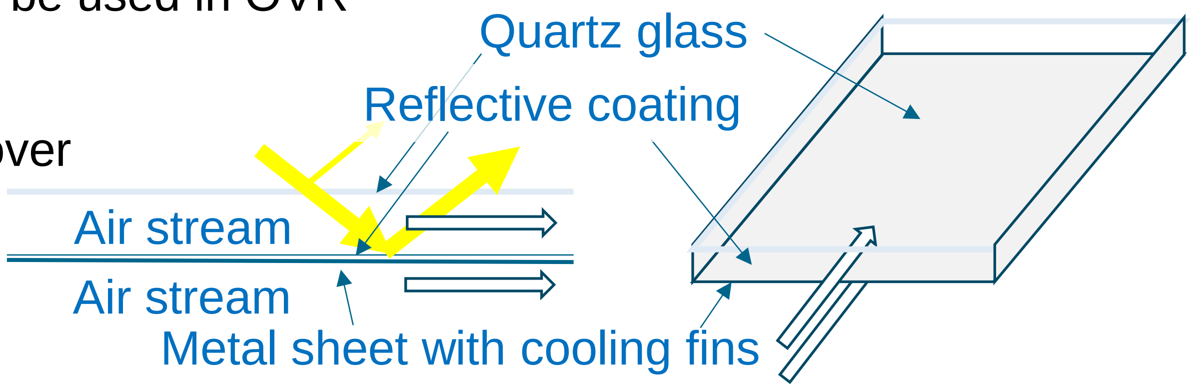


Indoor-test Synlight 16h / 300 kW/m² / 400°C, slight silver layer degradation

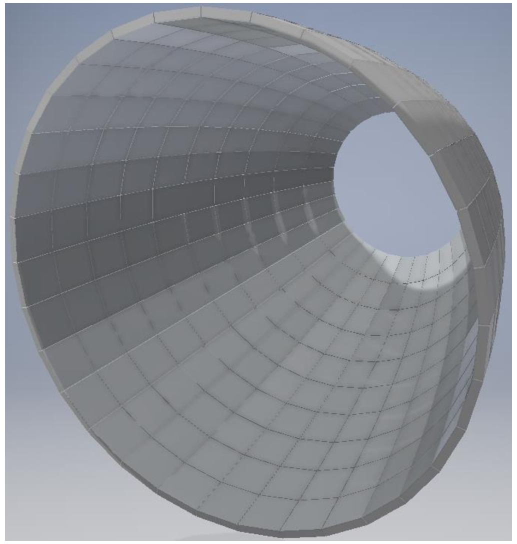
Gledhill et al., „SOLSEC secondary reflectors for tower receivers. Final report, Reporting period: 01.04.2019–31.10.2021 (in German), https://doi.org/10.2314/KXP:1852815426

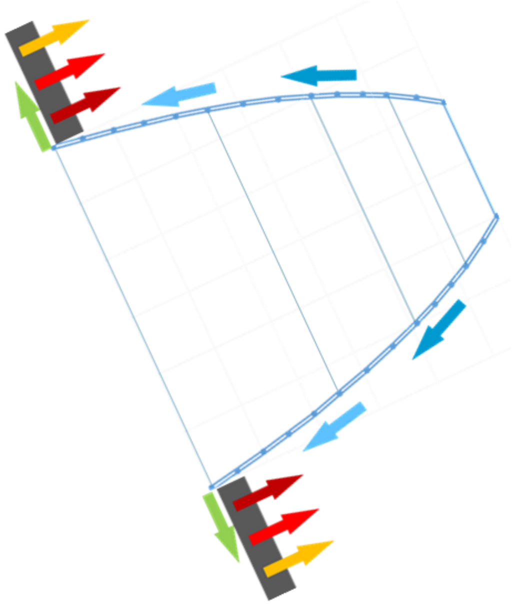
Industrial Scale Secondary Receivers: Our Concept

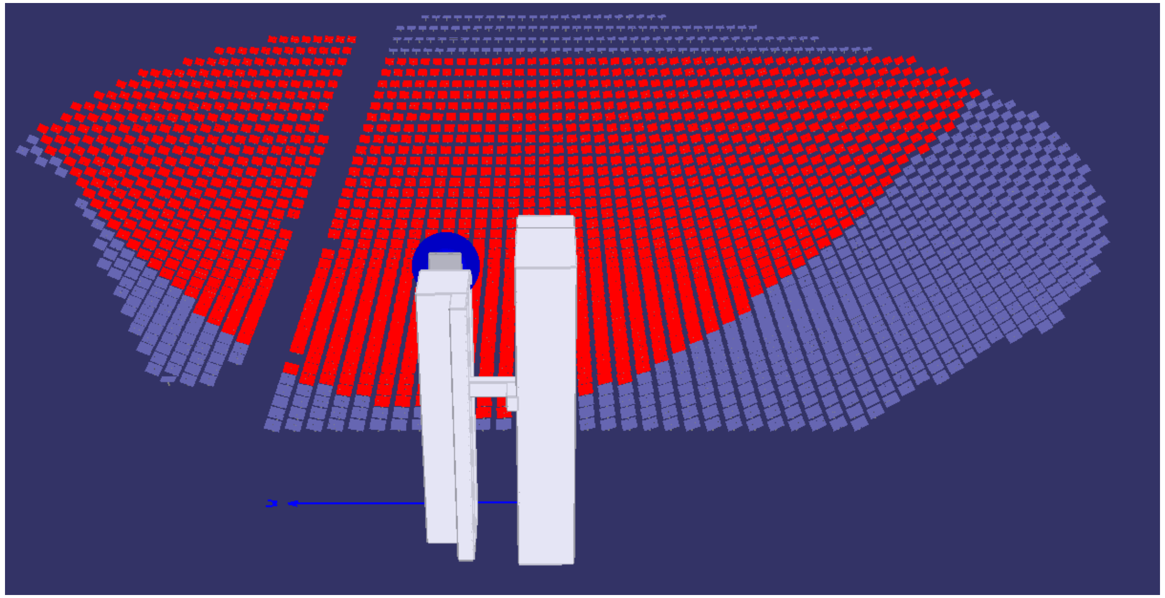
- Repetitive modular design for scalability to larger industrial applications and short development time
- Forced air cooling / no tightness issues, heated air to be used in OVR
- Modules with
  - Soiling degradation protection by quartz glass cover $(\varepsilon = \alpha \cdot \Delta T \; with \; \alpha \sim 0)$
  - Air stream for cooling, insulation and cleaning
  - Reflector with cooling fins in 2^{nd} air stream



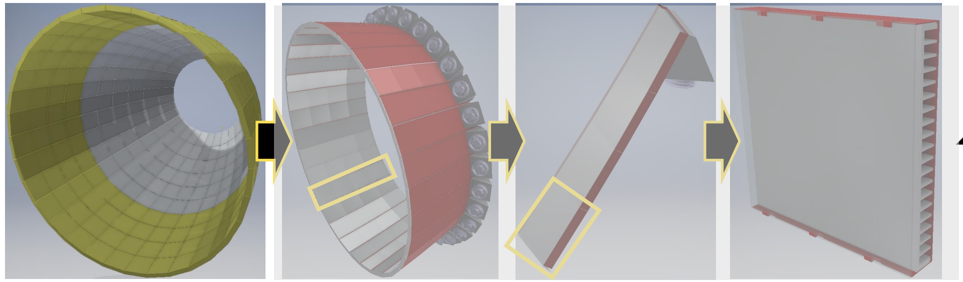
- High concentration & compact heliostat field: Heliostats from outside acceptance angle can aim on OVR

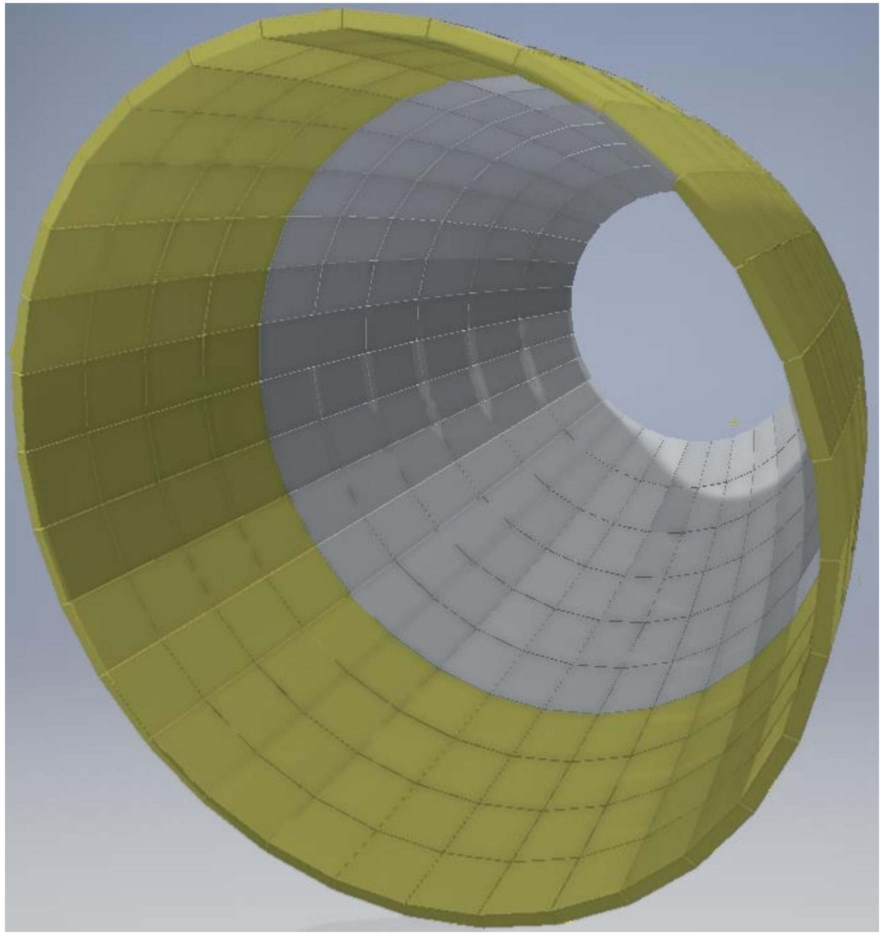




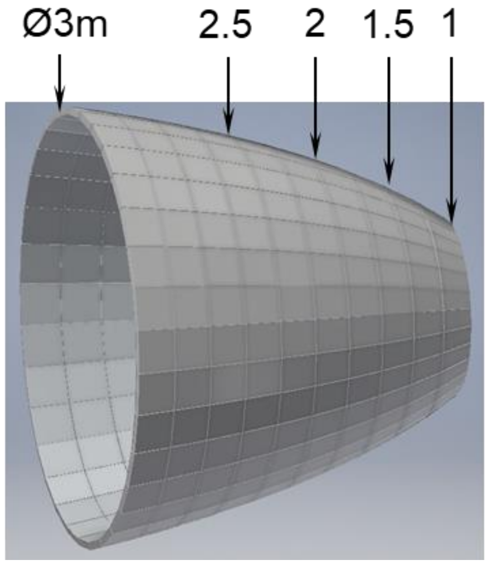


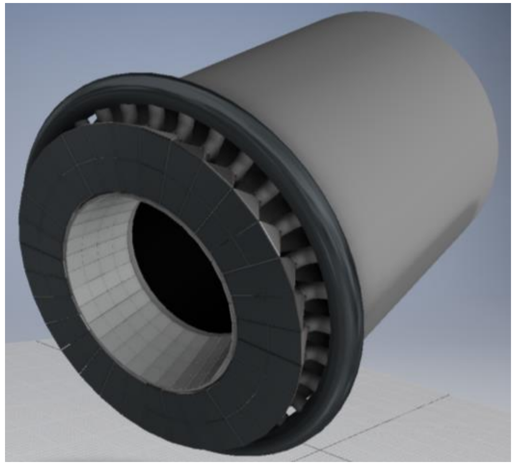
General Design

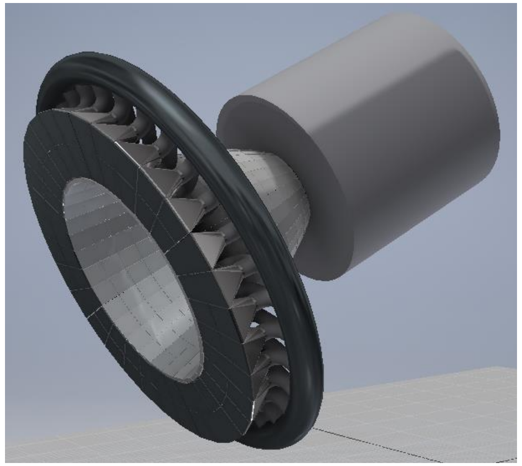




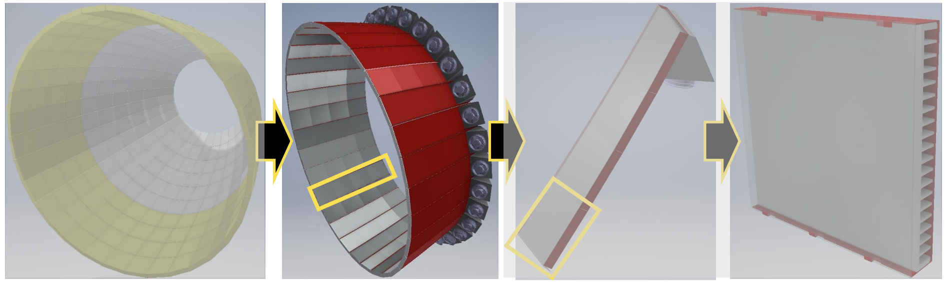
- CPC / Winston cone with different outlet diameters
- Ø 3m → Ø1m, current focus on 1st section

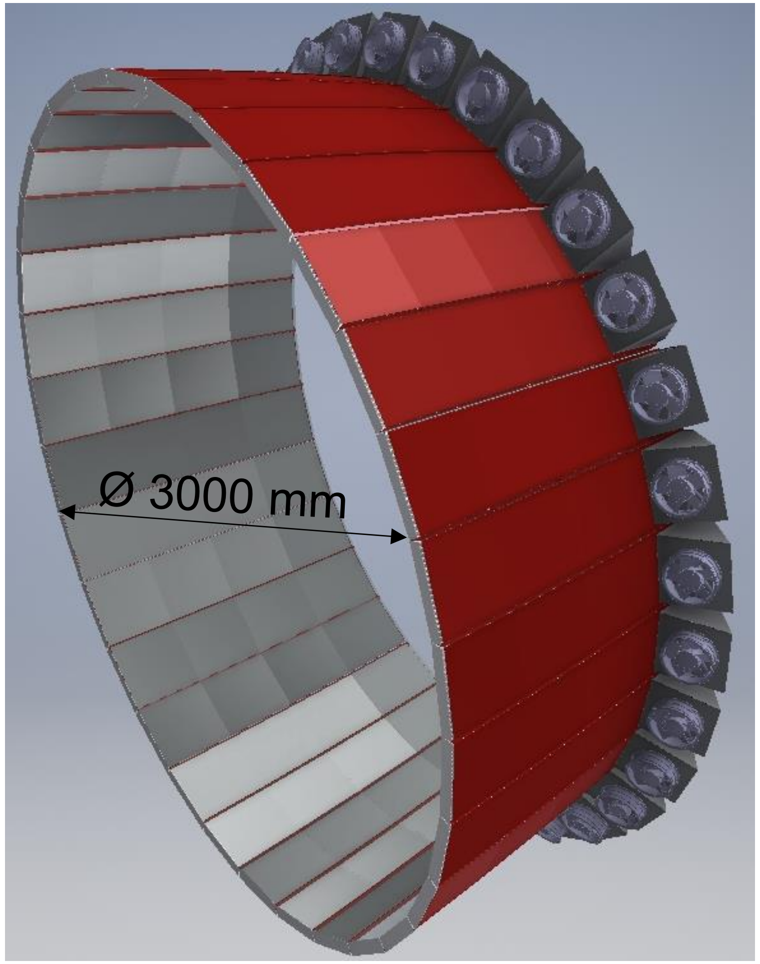






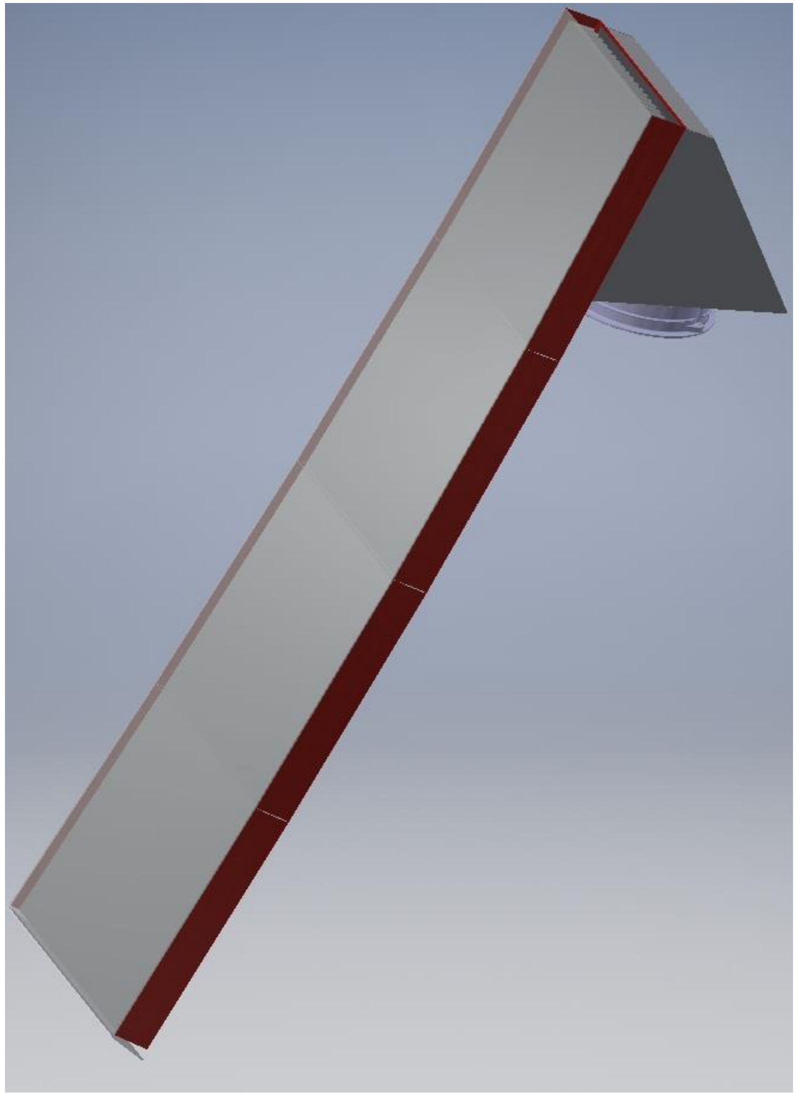
Design of 1st Section

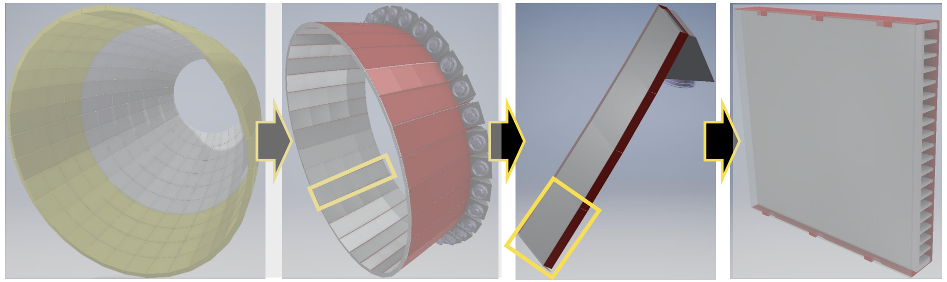




- Ø 3000 mm → Ø 2500 mm
- Modular approach of 32 identical segments
- Each segment: trapezoid, ~240 - 290 mm wide, 1200 mm long
- Air-cooled by axial fans that are locally mounted

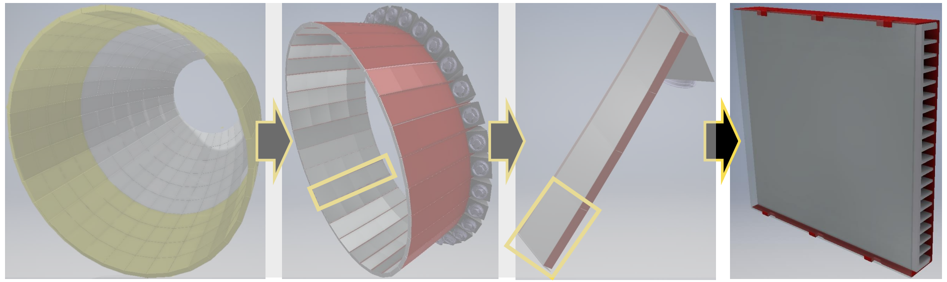
Segment Design



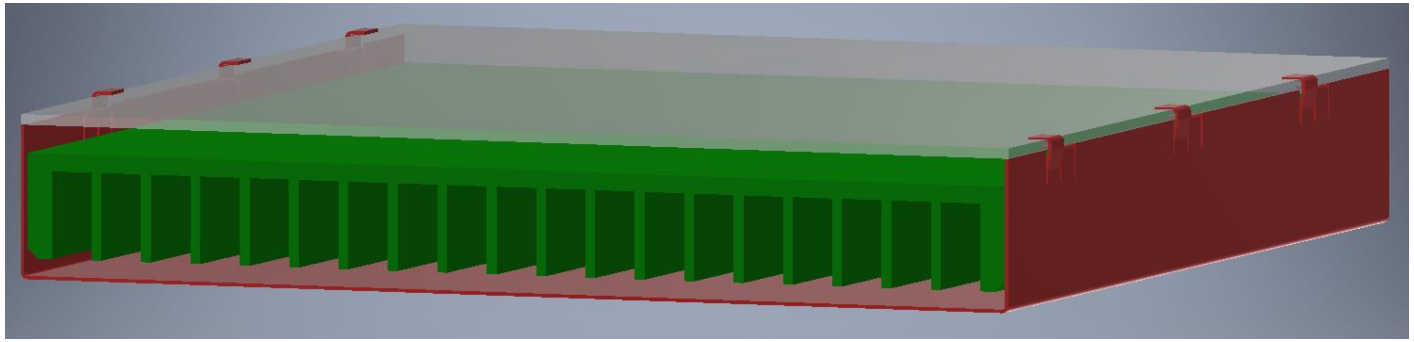


- Ø 3000 mm → 2500 mm
- Modular approach of 32 identical segments
- Each segment: trapezoid, ~240 - 290 mm wide, 1200 mm long
- Air-cooled by axial fans that are locally mounted
- Independently mounted and replaceable

Module Design



- Sputtered silver reflection layer
- Front and back cooling with fins for increased cooling efficiency
- Quarz glass cover for soiling protection



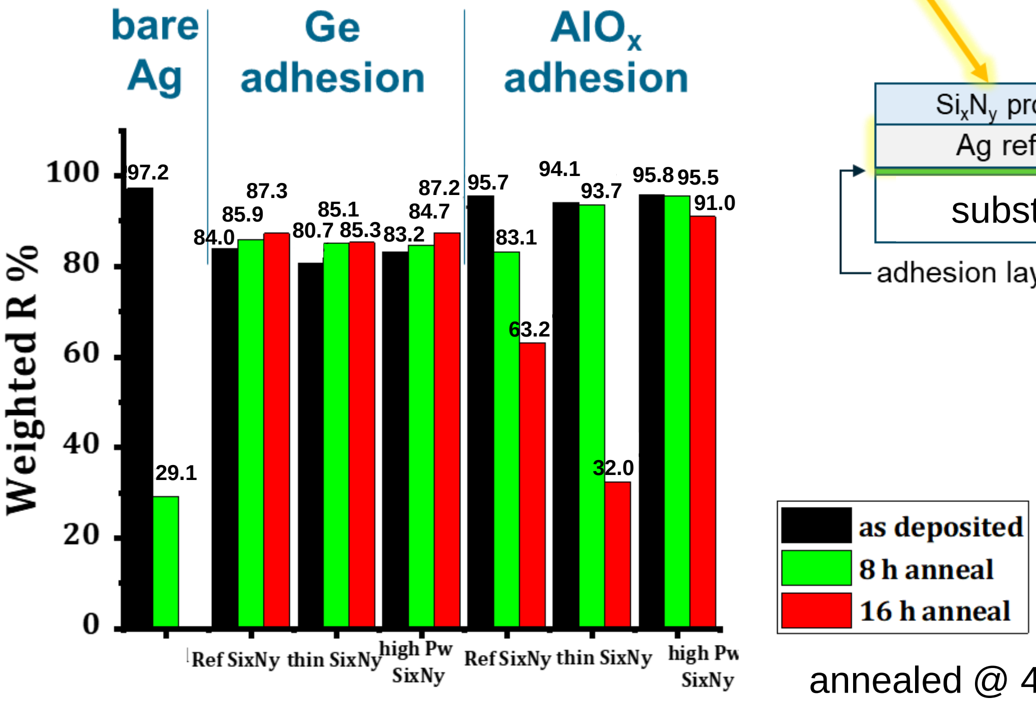
Reflection Layer Design

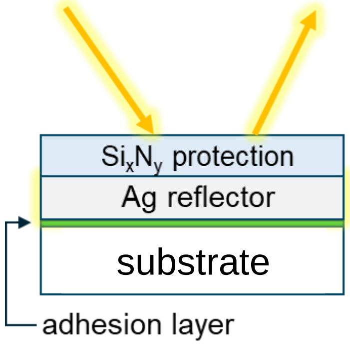
PVD magnetron sputtering

- Singulus *Vistaris 600 LAB* @ DLR Oldenburg
- substrate size up to 300 x 300 mm²
- metal layers, oxides & nitrides

First Tests:

- Impact of adhesion and protection layers on reflection and temperature stability
- Target: ≥93% reflectivity longtime-stable @ 400 °C

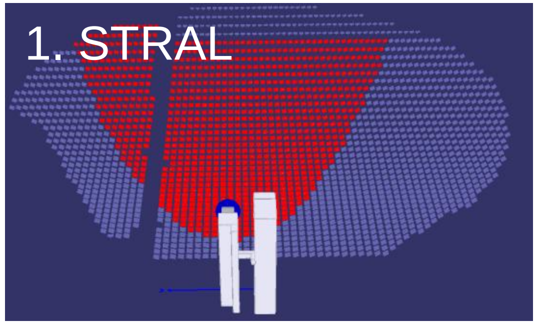


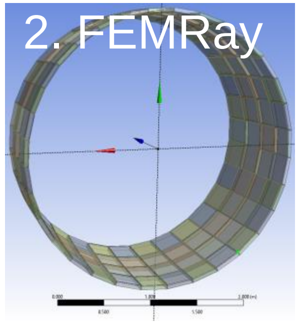


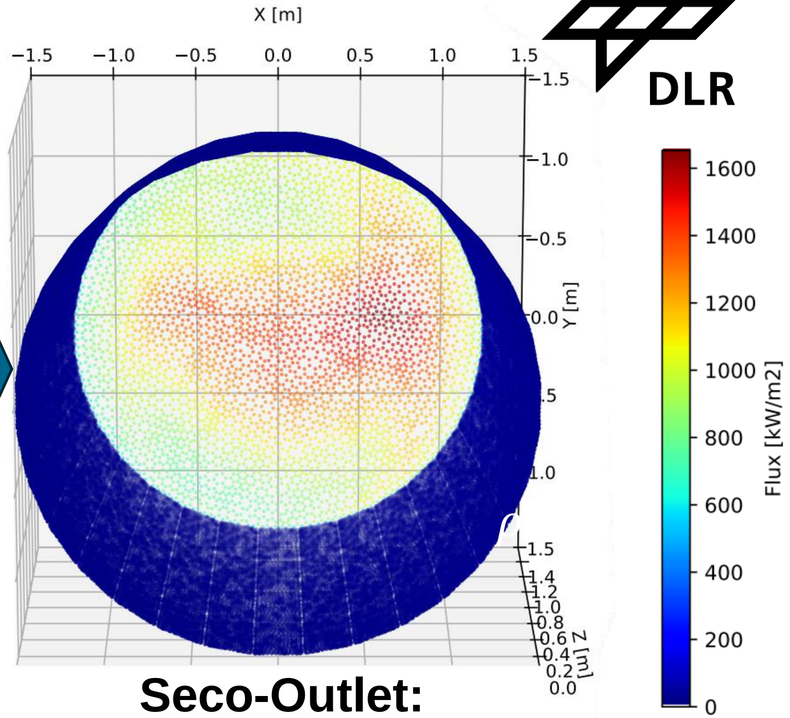
annealed @ 400 °C

Optical Design with STRAL+FEMRay

Raytracing:
1. Heliostat field → Seco Aperture
2. FEMRay Inside the geometry with local optical properties



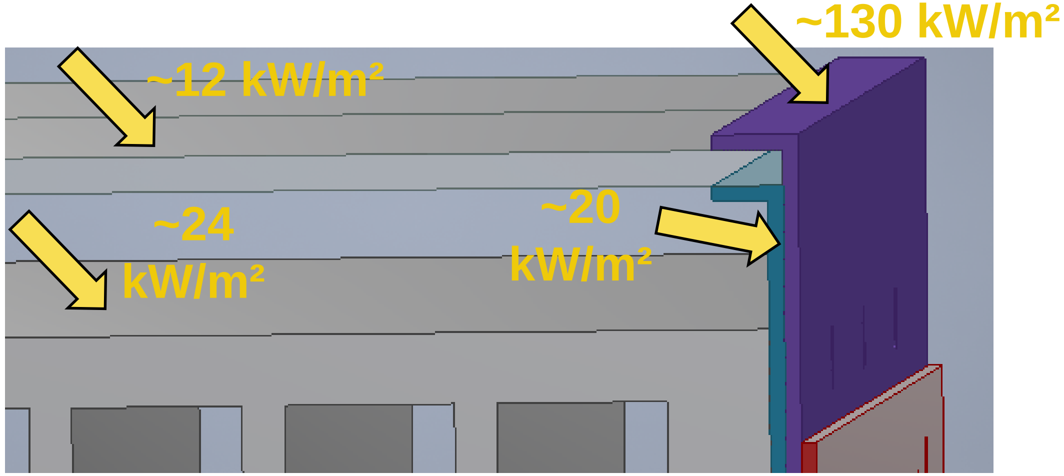




Seco-Outlet:
Peak: 1.6 MW/m2
Sum: 5.2 MW

Detailled, absorbed local solar radiation

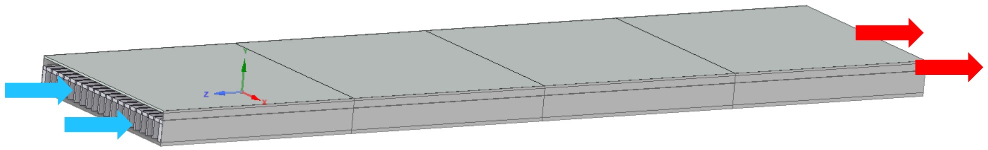
Effective flux density: 300-600 kW/m²

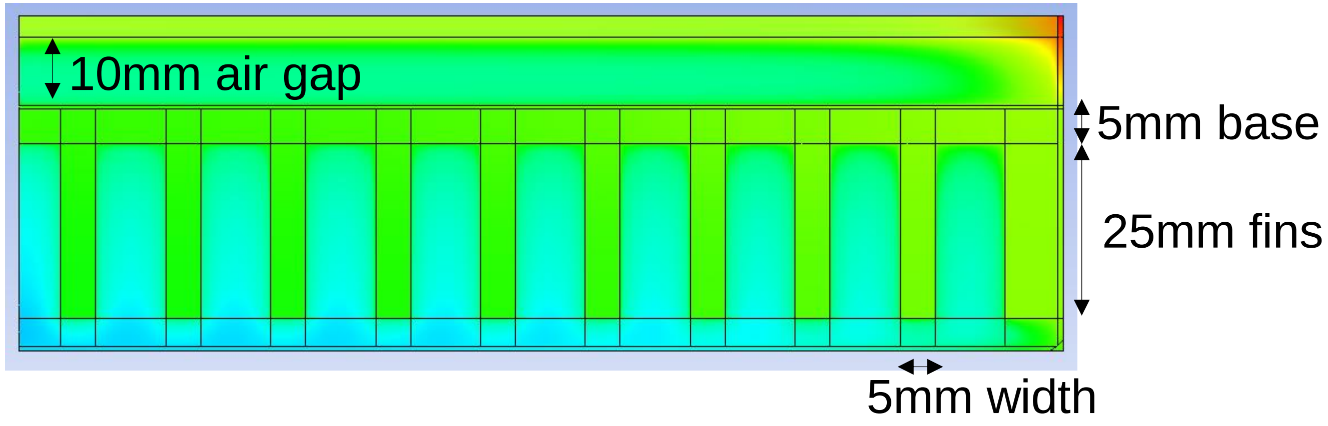


Thermal load for
- CFD cooling analysis ✓
- Testing parameters ✓

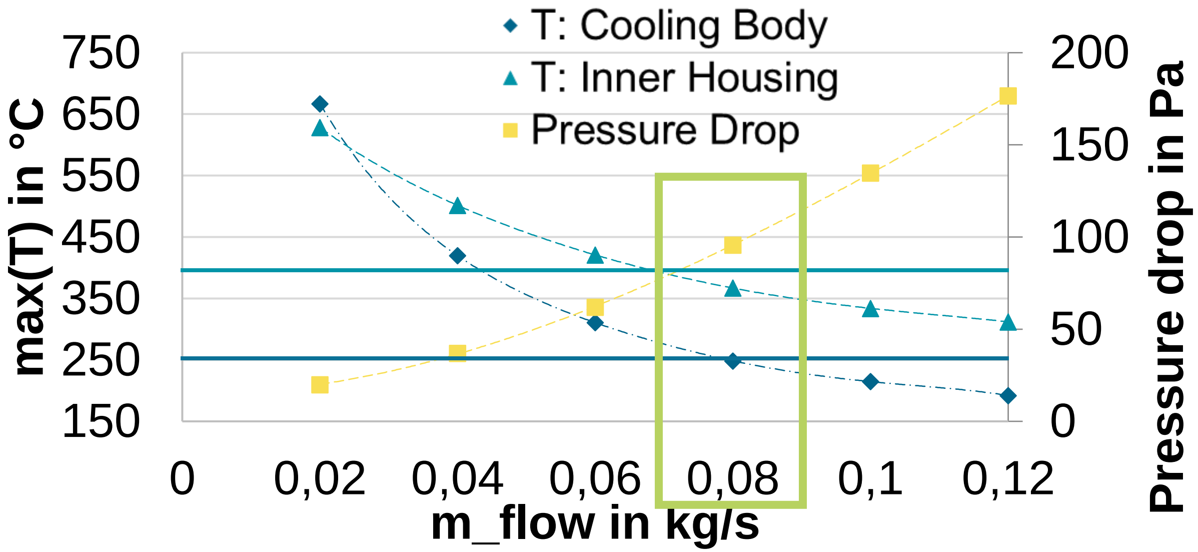
Cooling and Structural Analysis

DOE for Optimal Fin Design





Maximum Temperature vs. Pressure Drop

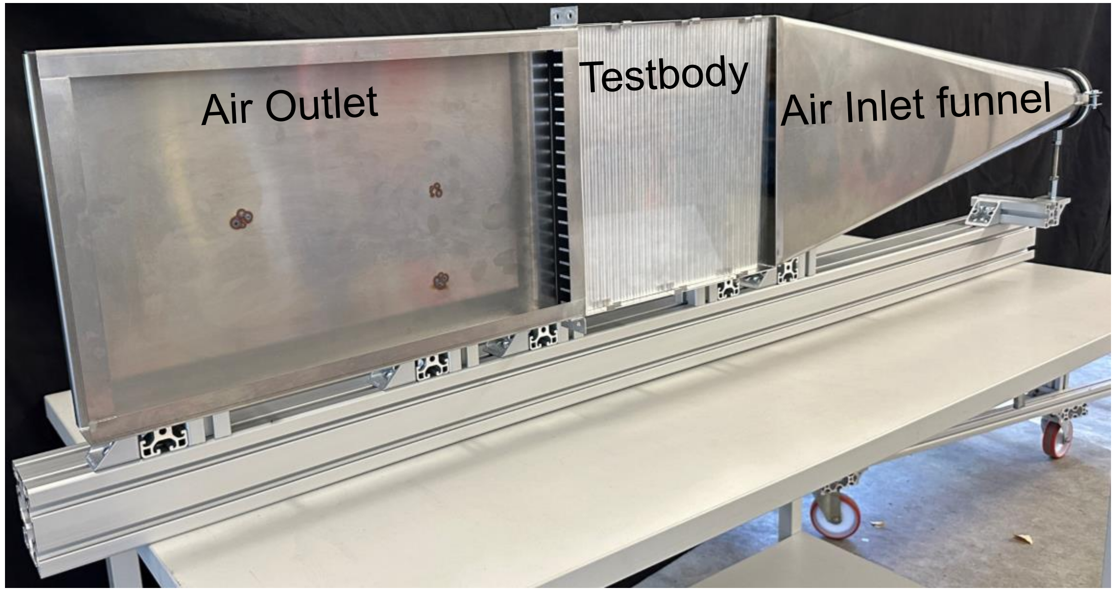


Inner Housing: T<= 400 °C (reflection layer limit)
Cooling Body: T<= 250 °C (material limit)

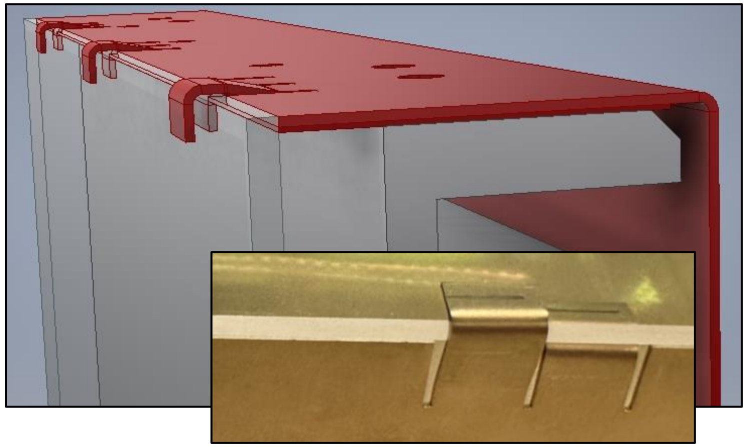
Design point @ 0.08 kg/s
& 96 Pa pressure drop

Upcoming Tests 2025 / 2026 for Full-Size Test Module

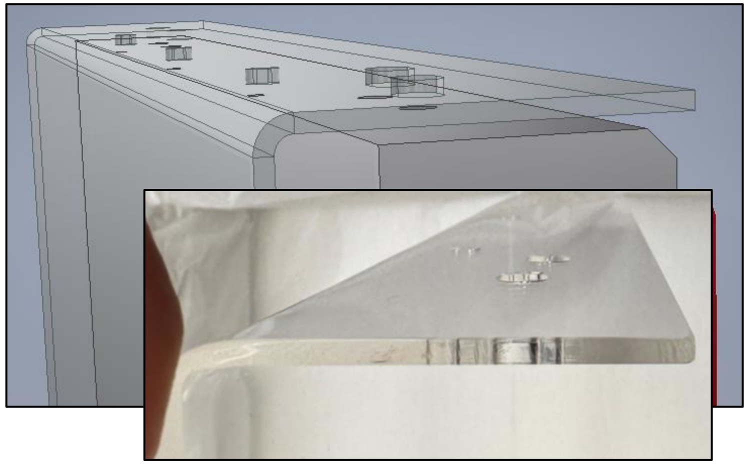
- Synlight Tests @ 300 - 600 kW/m² - planned for Oct – Dec, 2025
  - Qualification of cooling concept
  - CFD Model validation
  - Evaluation of three different designs
  - Test of various reflective coatings
- Outdoor tests in Solar Tower in 2026



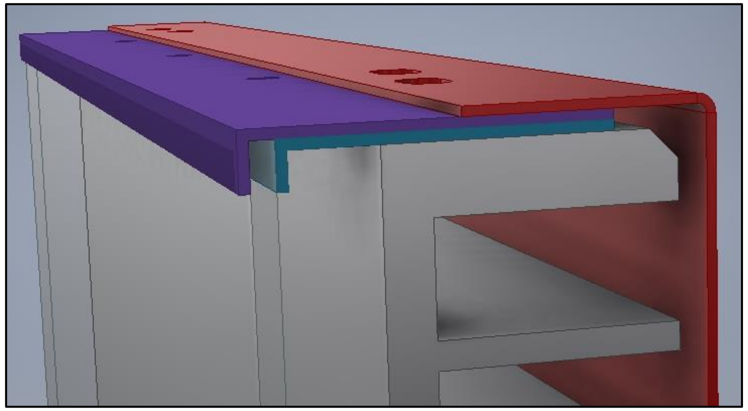
Stainless Steel Brackets



Bended Glass Cover



Oxide Ceramic Fiber Composite Sheets



Outlook: Further development and qualification in GFE test facility

10.000

Solar radiation power [kW]

1000

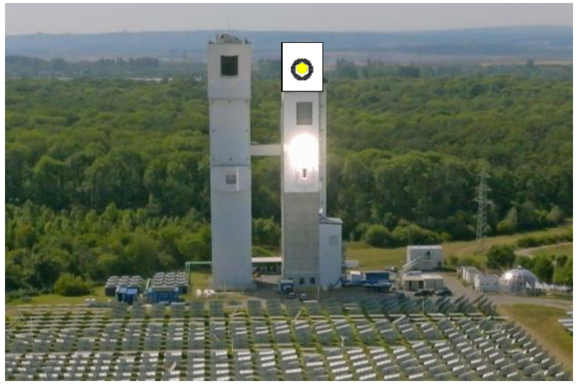
100

10

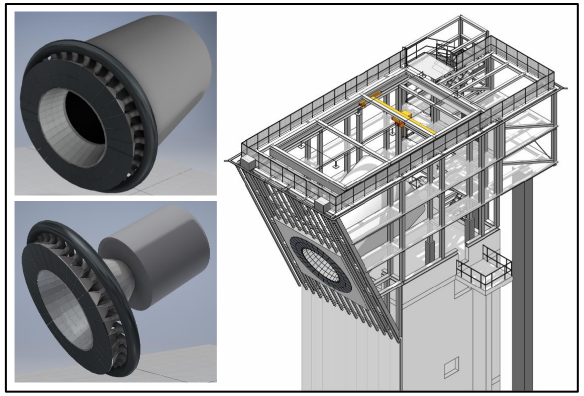
1

High-Flux Solar Simulator & Solar Furnace, Cologne

Synlight, Jülich



Jülich Solar Tower & Multifocal Tower



GFE on Multifocal Tower
- Commissioning 07/2026
- Secondary concentrator & OVR planned for 2027

Summary

- Large, robust and highly loaded secondary concentrators appear to be absolutely essential for solar thermochemical processes on an industrial scale
- Operating experience shows that there is still a lot of work to be done in this field
- A new type of modular air-cooled secondary concentrator with quartz glass protection is under development
- Such a secondary concentrator with an inlet diameter of 3 m will become part of DLRs new 10 MW GFE test facility. Its commissioning is planned for 2027.
- With this facility, the secondary concentrators will be successively improved and validated for higher flux densities and temperatures.
- Visit us in Jülich / Germany and plan your projects with DLR's unique solar research infrastructure!