Thermal Evaluation of a Novel External Receiver Concept

Cathy Frantz[1], Ralf Uhlig[1], Michael Puppe[1], Fritsch Andreas[1], Dr. Barbara Waldmann[2], Dr. Christian Storm[2] , Thomas Dressel[2], Stefan Schmalz[2]

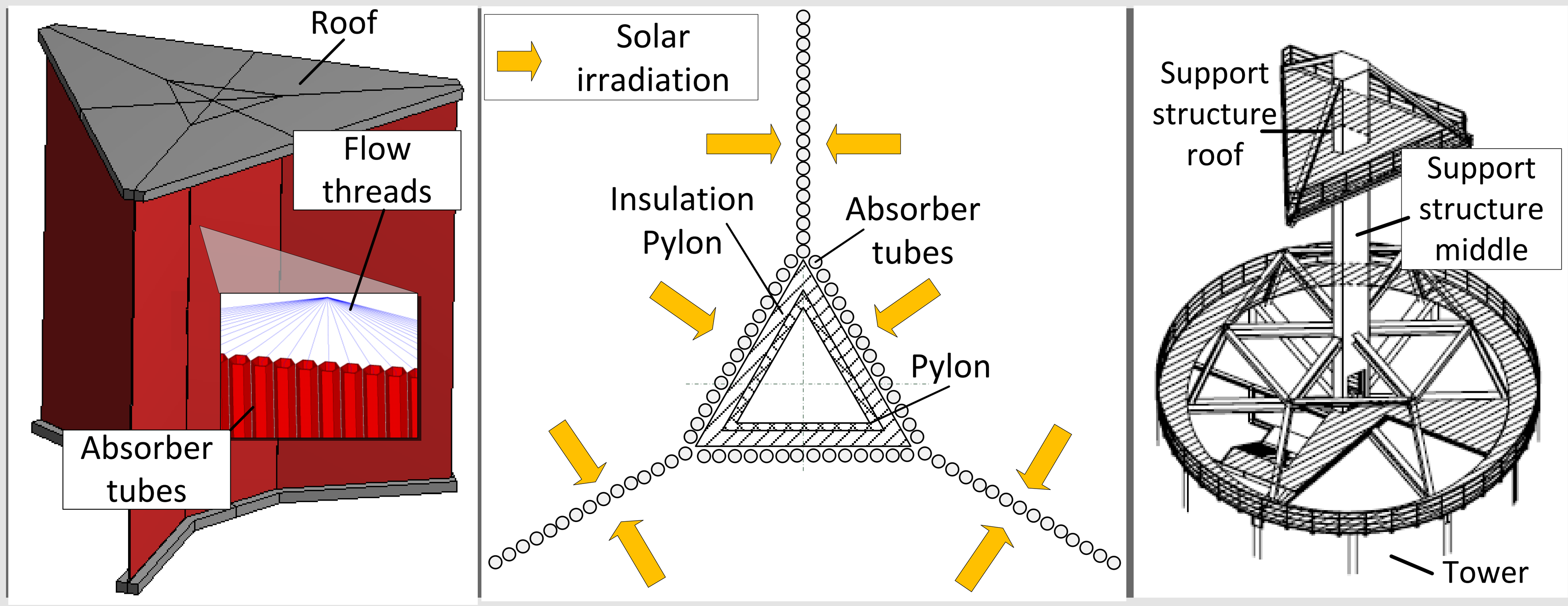

Fig. 1: schematic representation of the STAR receiver concept (left: 3D view absorbers, middle: plan view; right: 3D view support structure

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The economic viability of central receiver systems using tubular absorbers to maintain the heat transfer fluid is mostly influenced by the following three aspects:

- a large aperture to minimize spillage losses
- High flux densities, and thus a small absorber surface to maximize the receiver efficiency while respecting material limits
- Low receiver costs

One design option, which addresses all three aspects is the use of panels which are irradiated from both sides. This work presents a receiver concept using the concept of two-side-irradiated panels and the thermo-optical evaluation of the concept.

Novel receiver concept

In the “STAR”-receiver concept, a middle pylon supports the absorber panel structure. Conventional panels, which are supported and irradiated conventionally, surround the pylon. Three additional sections are arranged in a star-shaped fashion (Fig. 1): this configuration enables a two-sided irradiation. On these panels the flux density is doubled without increasing common flux density limits. By limiting the number of extension sections to three, the decrease of aperture circumference compared to external receivers is minimized.

Thermo-optical modeling

The thermal analysis has been performed on a molten salt receiver system. For the thermal analysis of this novel receiver, the ASTRID© approach is used [Frantz, 2016]. This includes deducing an initial heliostat field design, optimizing the thermo-hydraulic design of the receiver, computation of aiming points and simulation of the thermal efficiency using an FEM model, which is coupled to a raytracing model. The heat transfer to the fluid is modeled using Nusselt correlations. The thermal radiative exchange between all surfaces is modeled using the radiosity method. The natural and forced convection losses are modeled by local heat transfer coefficients issued from CFD simulations. A parametrized Gaussian distribution assigns aim points in order to adhere to flux limits issued from thermal stress [Vant-Hull, 2002] and to meet a maximum film temperature of 600°C. (Fig. 2) The same procedure has been followed to deduce the thermo-optical efficiency for an external receiver. the following performance criteria have been used to evaluate the performance:

$$\eta_{thermal} = \frac{P_{absorbed\ by\ fluid}\ (W)}{P_{incident\ on\ aperture\ with\ aiming}\ (W)}$$

$$\eta_{thermal\ \&\ aiming} = \frac{P_{absorbed\ by\ fluid}\ (W)}{P_{incident\ on\ aperture\ with\ central\ aiming}\ (W)}$$

Results

The detailed thermo-optical simulation shows that the thermal efficiency of the STAR receiver can be increased by up to 1.3% while the amount of absorber material has been reduced by 36% and the aperture is only reduced by 10%. The increase of the thermal efficiency is caused by the cavity effect of the STAR receiver. Current work focuses on the optimization of the spillage losses due to aiming, which are higher than the ones achieved for the external receiver.

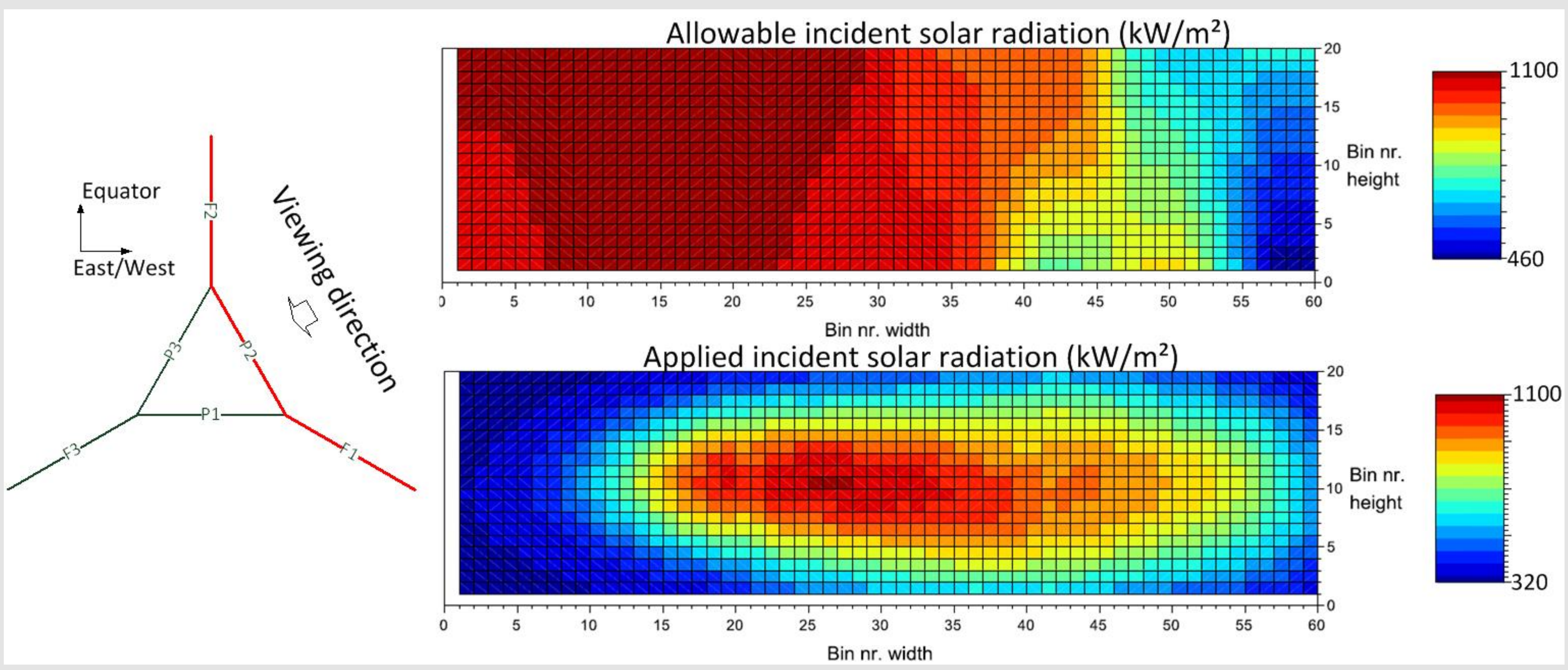

Fig. 2: Allowable and applied incident solar radiation at design point for the East/West section

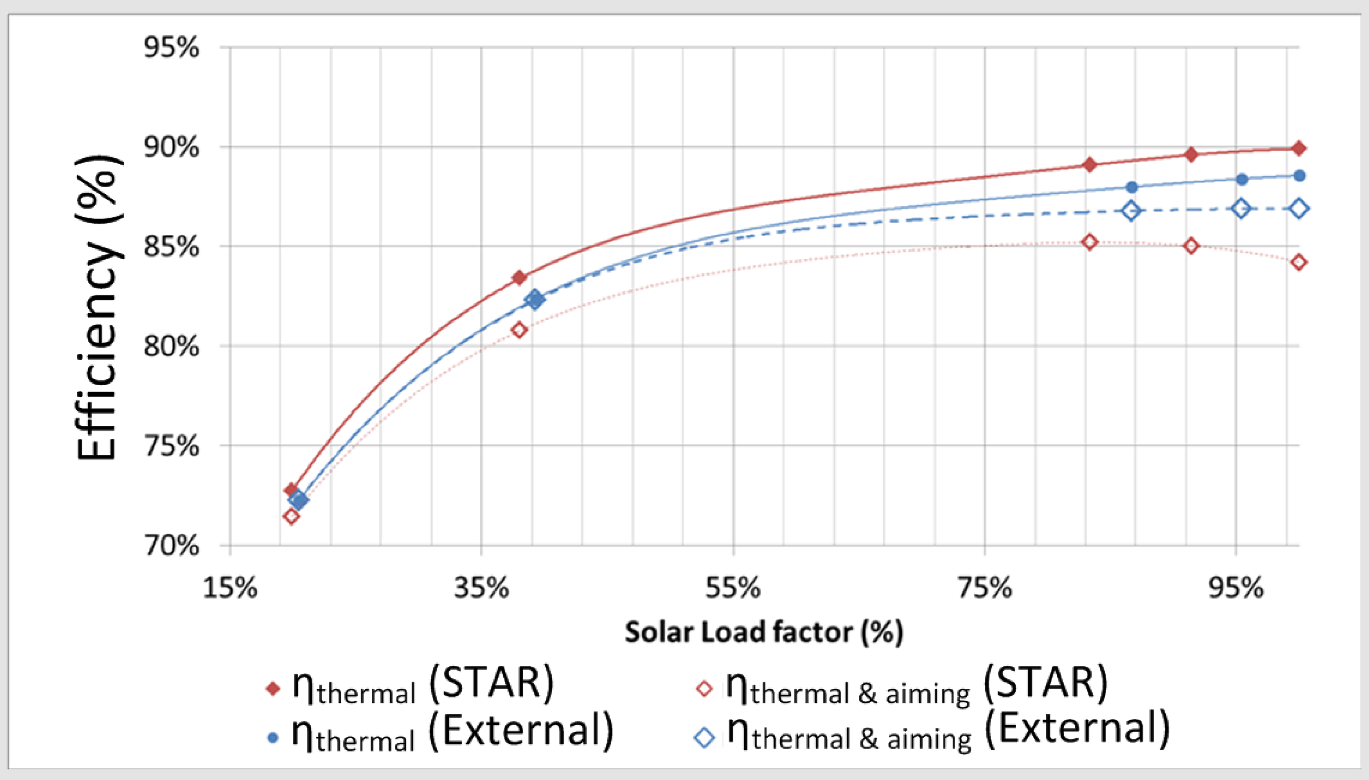

Fig. 3: thermal and thermo-optical efficiency STAR receiver compared to external receiver

[1]DLR – Institute of Solar Research | Point Focus Systems | Stuttgart |
Cathy Frantz | telephone: +49 711 6862 645 | E-Mail: cathy.frantz@dlr.de

[2] BBS GmbH – Babcock Borsig Steinmüller GmbH
| Europaallee 1 | Oberhausen

Deutsches Zentrum für Luft- und Raumfahrt
DLR
BILFINGER