Euromat 2009
Glasgow, 7-10 September

Porous Materials for Solar Thermal and Spin-off Applications: Characterization of Thermophysical and Permeability Behaviour

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- The Volumetric Air Receiver
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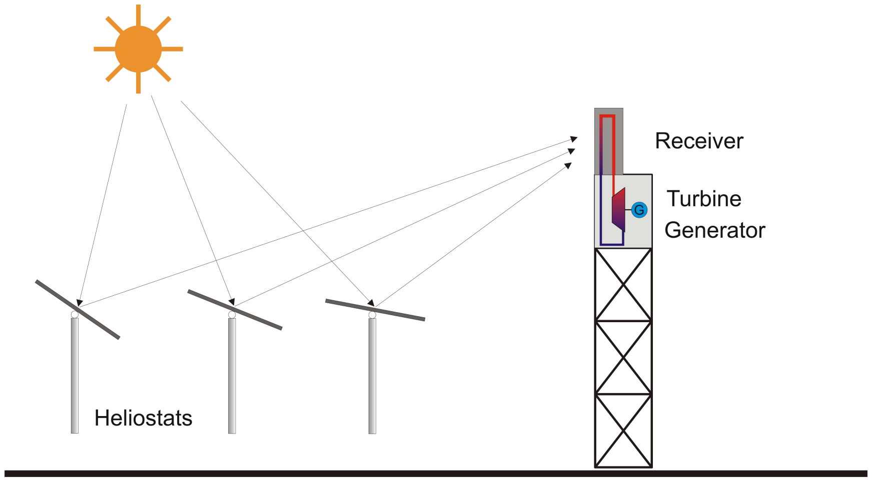
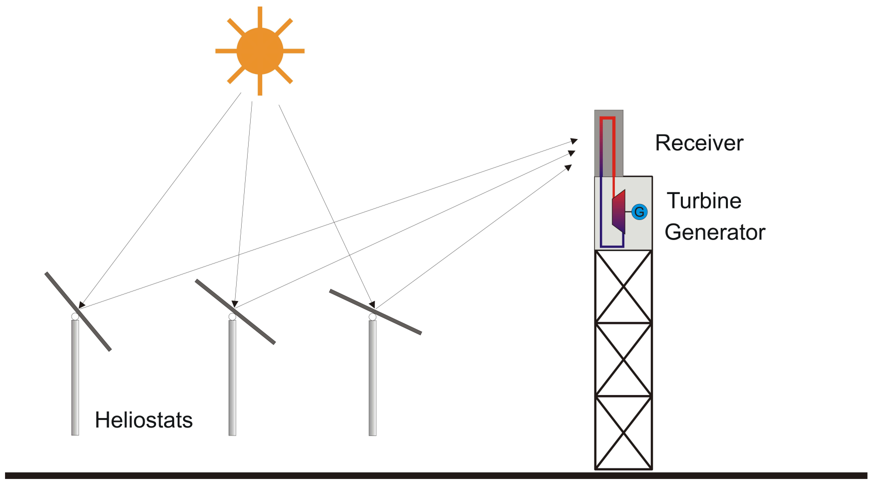
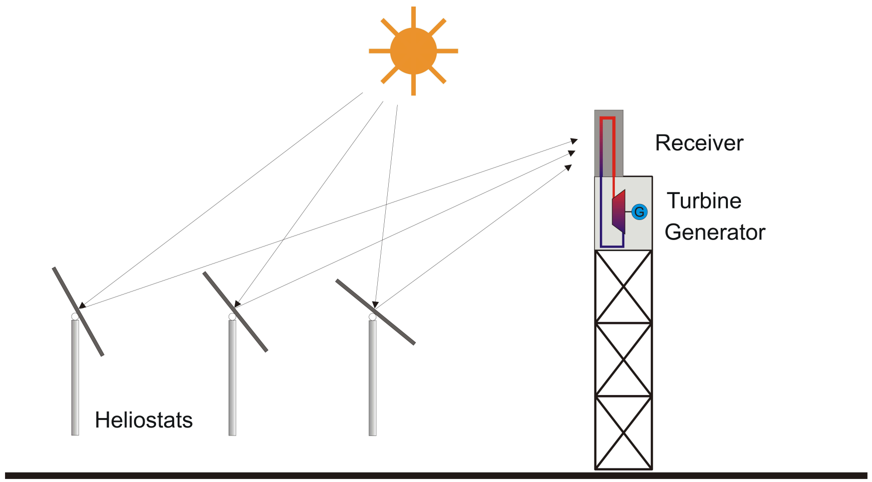
Solar Tower Technology



Solar Tower Technology



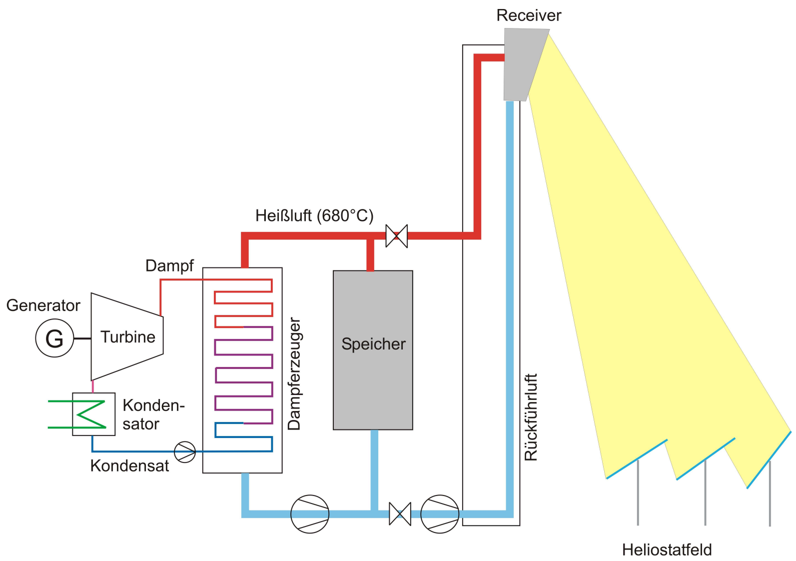
Solar Tower Technology



Solar Tower Technology

objective: Generation of high temperature heat

⇒ Power process (gas or steam turbine)
⇒ Central electricity generation
⇒ long term LEC ≈ 0,13 – 0,20 €/kWh



The Volumetric Air Receiver

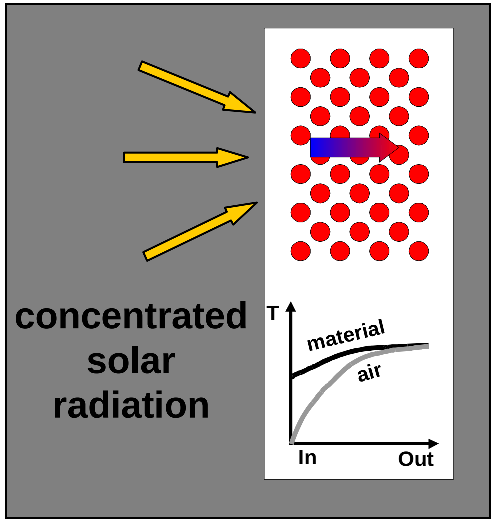
function: *absorption* of radiation *heat transfer* to a fluid
solar receiver = absorber + heat exchanger

optical - thermophysical requirements

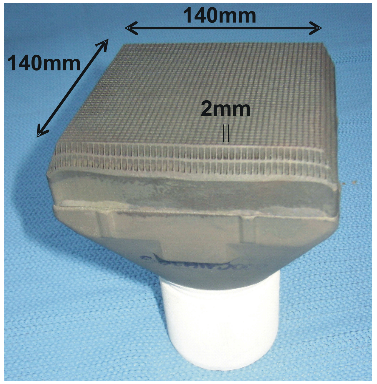
- absorption
- optical extinction
- heat transfer surface
- high fluxes
- radial heat transport
- char. permeability

material requirements

- dark
- high porosity
- high cell density
- temp. resistance
- thermal conductivity
- 3D-Structure

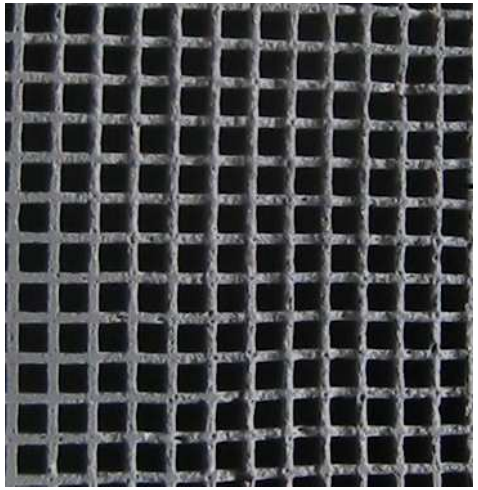


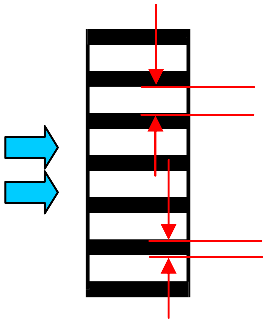
Volumetric Receiver: Examples

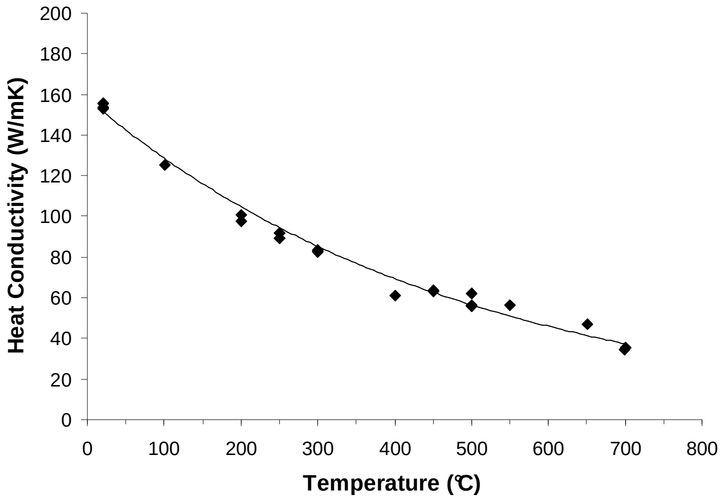


SiSiC honeycomb structure

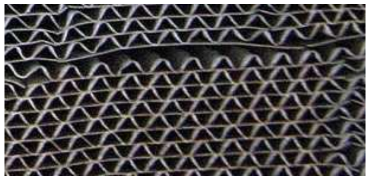
+ thermal conductivity
+ strength at high temperatures
- cell density (≈ 1000 m^2/m^3)
- porosity (≈ 50%)

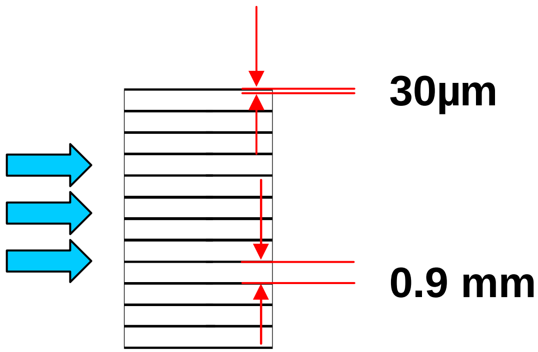






Volumetric Receiver: Further Examples



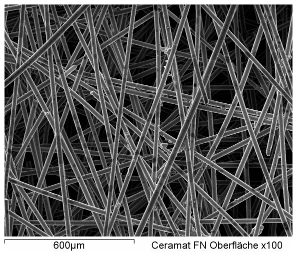


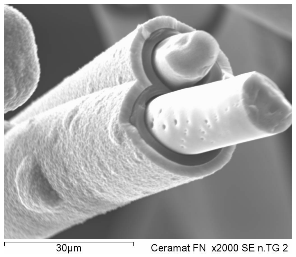
coiled corrugated metal foil
(iron based)

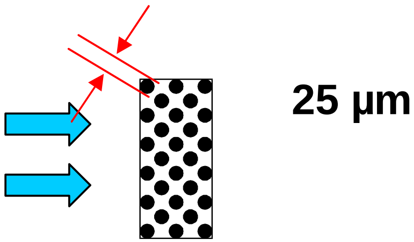
+ cell density (up to 6000 1/m)

- limited to 900℃

Volumetric Receiver: Further Examples





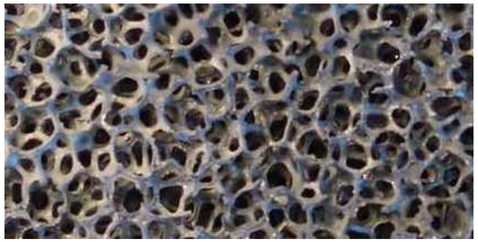


SiC fiber mesh (Schott Ceramat)

+ cell density (>8000 1/m)

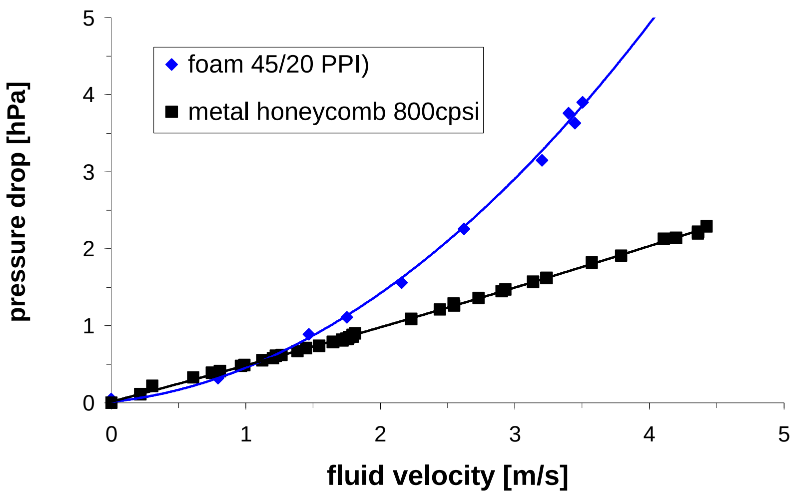
- strength at high temperatures

Volumetric Receiver: Further Examples

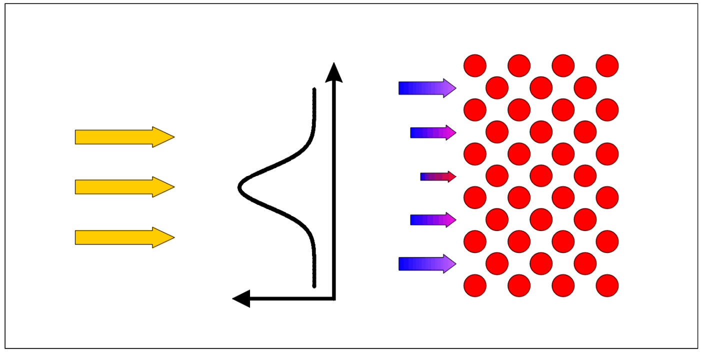


ceramic foams 30-80 ppi
(siliconized Silicon Carbide)

+ cell density (up to 6000 1/m)
+ permeability characteristics



Physical Problems and Constraints



- viscosity increases with increasing temperature
- hot zones are badly cooled

- local hot spots
- → instable flow at
  - high temperatures
  - linear pressure drop characteristics
  - low thermal conductivity

Modeling: which basic mechanisms are involved

k: permeability
λ: effectice heat conductivity
αAv: vol. heat transfer coeff.
a: absorption
e: extinction

- heat conduction in the solid grid
- solid to fluid heat transfer
- fluid flow through the network of open porosity

$$\lambda_{eff} \nabla^2 T_S = 0$$

heat conduction law

$$\lambda_{eff} \nabla^2 T_S - \alpha A_v (T_S - T_F) = 0$$

$$\dot{m} C_P \frac{dT_F}{dx} - \alpha A_v (T_S - T_F) = 0$$

energy conservation

$$\frac{\Delta p}{l} = \frac{\eta_{DYN}}{K_1} v - \frac{\rho}{K_2} v^2$$

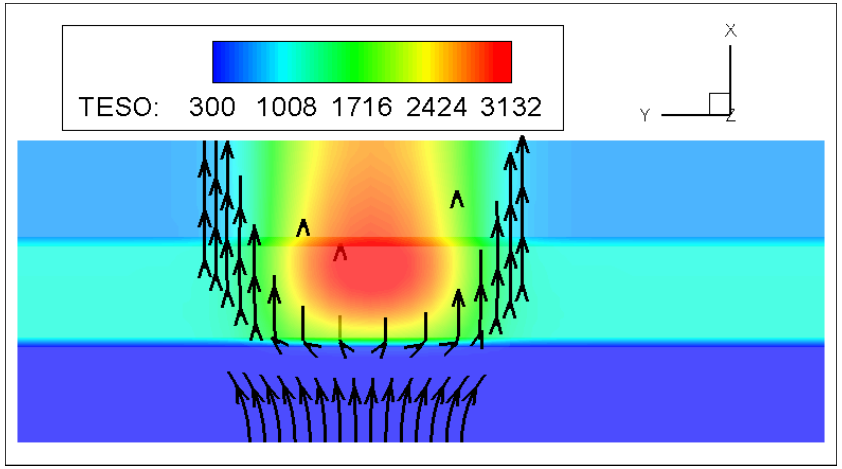
extended Darcy Law

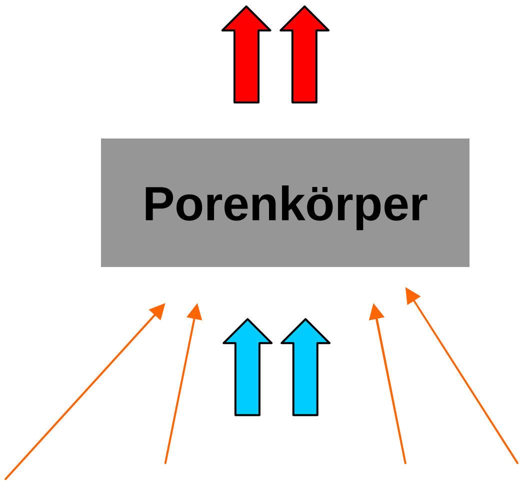
- quantities to be determined experimentally
- effective quantities/homogeneous material

Determination of Material Properties

- **permeability**
  - simple pressure loss measurement
- **extinction**
  - modeling the absorber material
  - optical measurements
- **absorption**
  - UV-VIS-NIR Spectrometer
- **effective thermal conductivity**
  - Transient Plane Source technique
- **volumetric convective heat transfer**
  - transient flow technique after Younis/Viskanta

Results of numerical approach





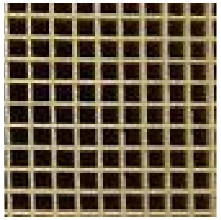
air out

air in

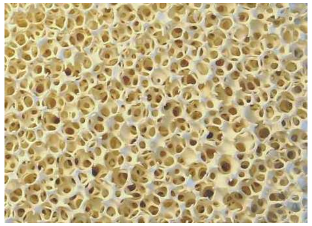
(Results by LSTM/Uni Erlangen within SOLPOR)

Results: at which Parameters Hot Spots May Occur?

- temperature distribution at cross section 2mm behind inlet (I = 1 MW/m²)



pressure drop
characteristics b/a [10^{-6}m]

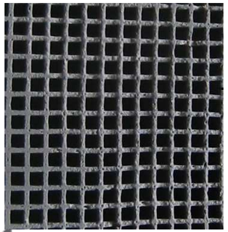


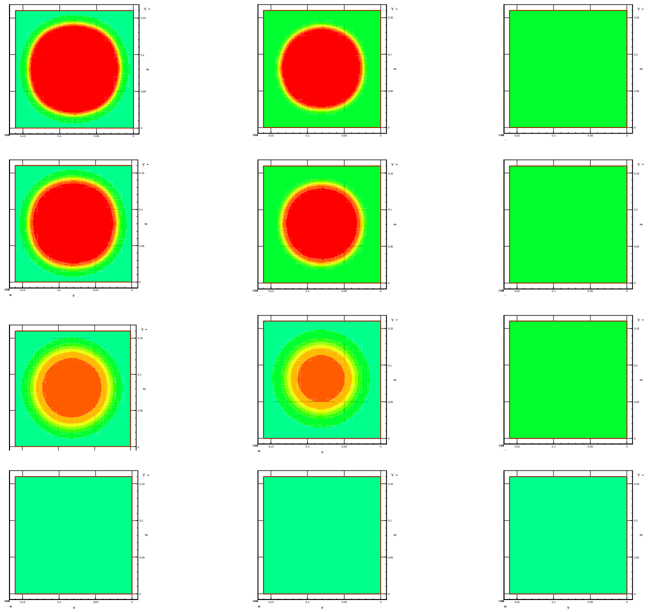
b/a = 0 *b/a* = 1 *b/a* =10

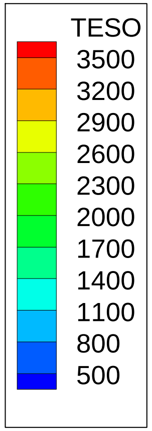
λ=0.01

heat
conductivity λ
[W/mK]

λ=10



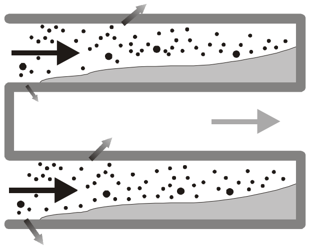


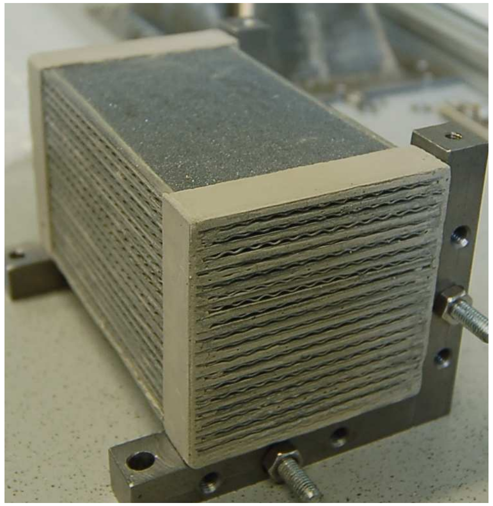


(Results by LSTM/Uni Erlangen within SOLPOR)

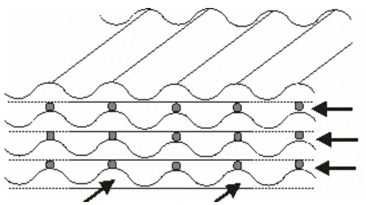
Spin-off Applications

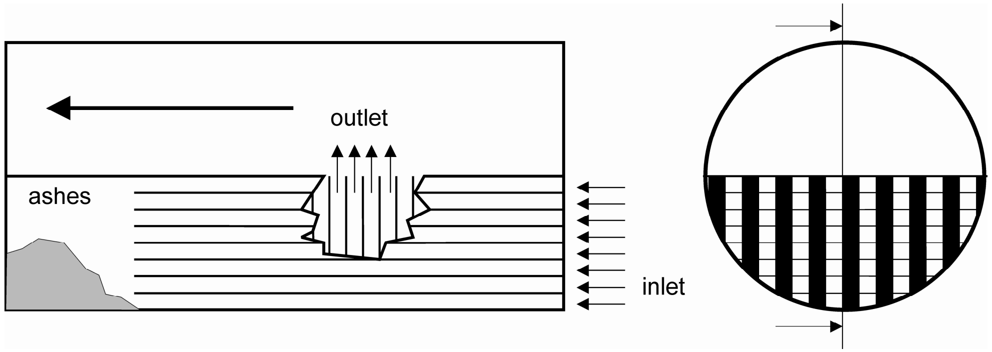
- cross flow particle filter





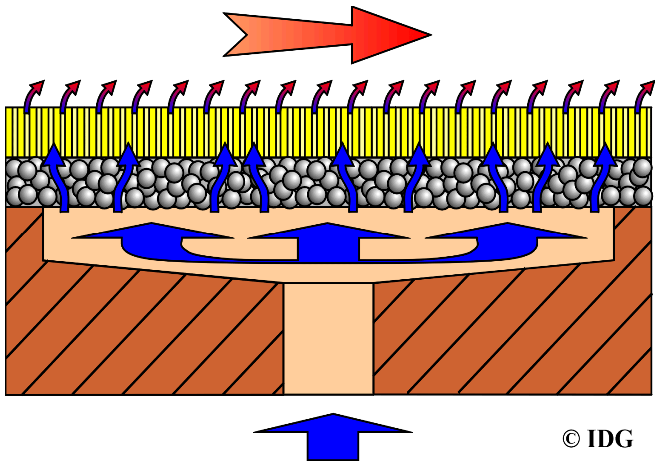
state-of-the-art

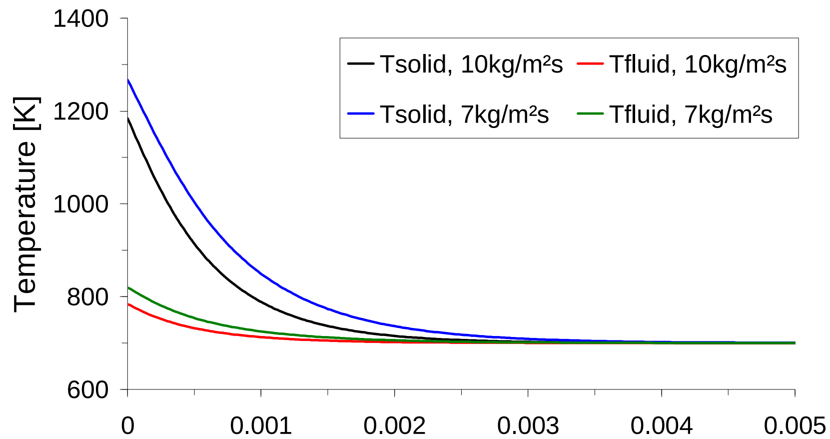


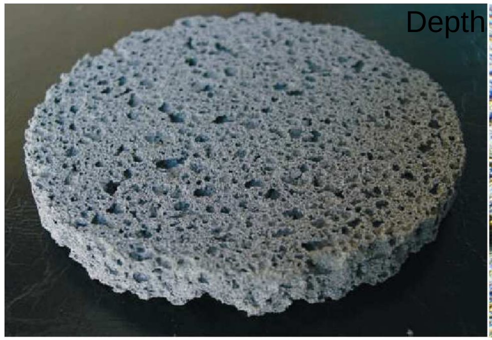


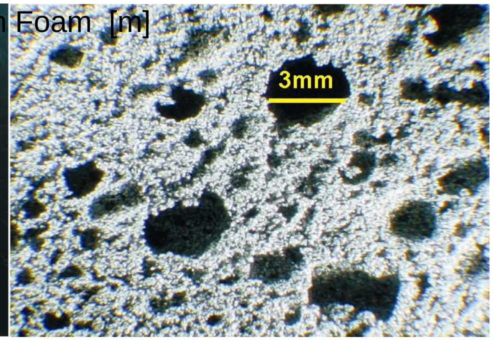
Metallic foam as porous combustion chamber wall element: effusion cooling

- characterization of flow and heat transfer



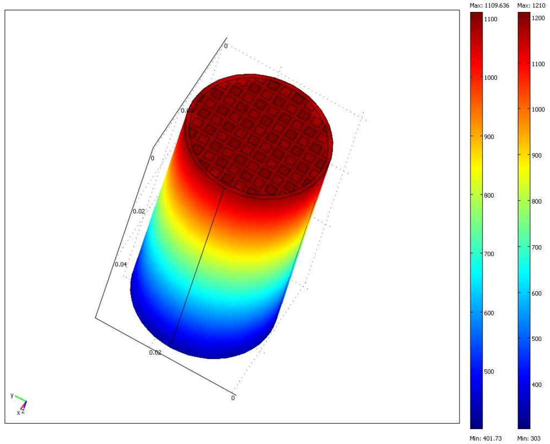


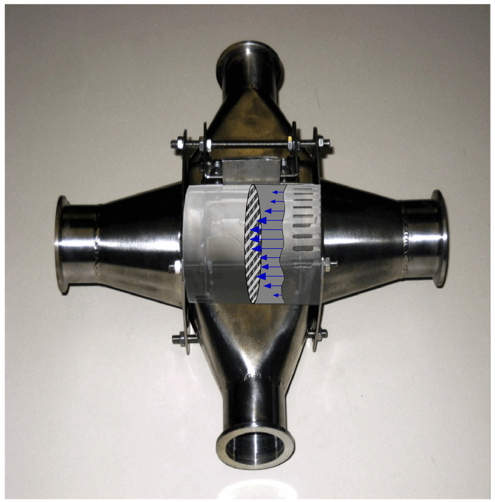


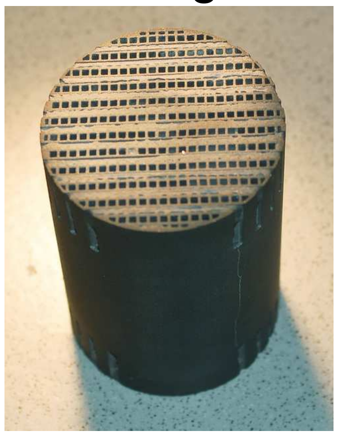


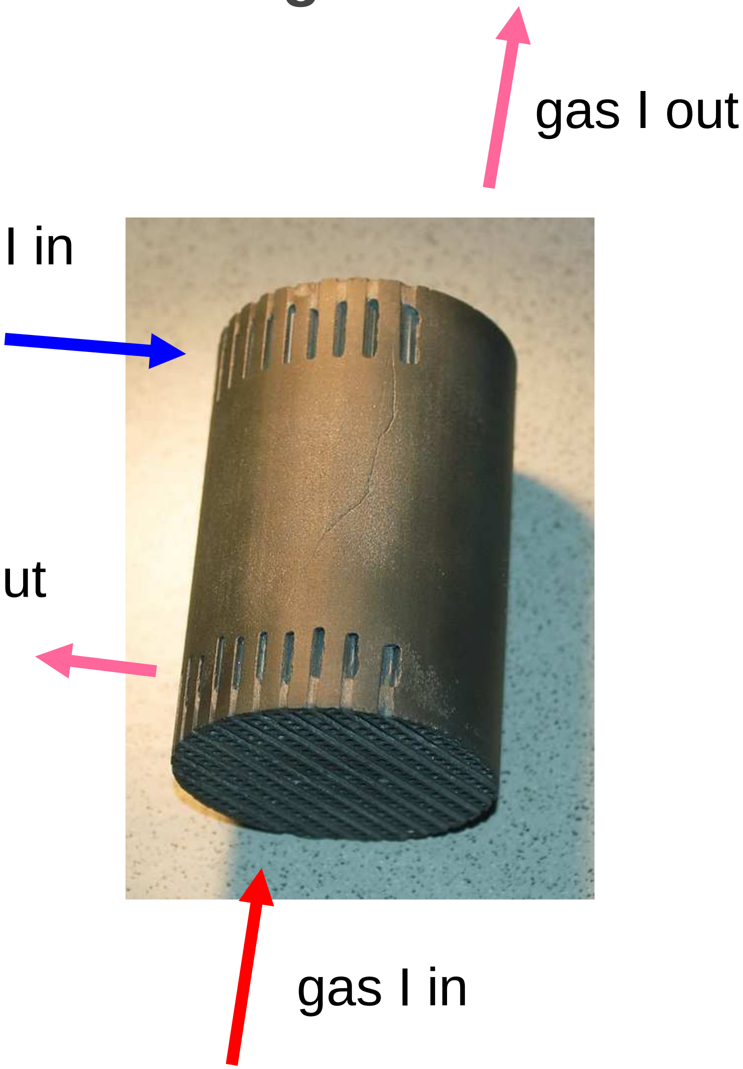
Foams manufactured via SFRS-technology by University of Aachen, Institute of Ferrous Metalurgy
project co-ordinated by University of Aachen, Institute of Steam and Gasturbines

Cross-flow/Counterflow Heat-exchanger

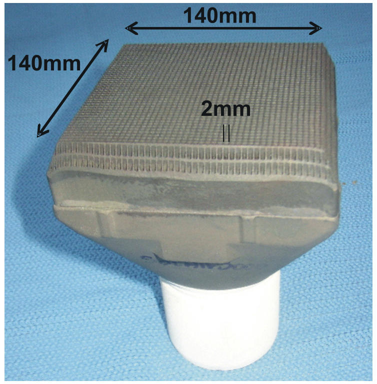








Solar Tower Jülich



- 1.5 MW electrical power
- hot air fired steam turbine process
- air cooled receiver
- ca. 20 m² absorber surface
- ca. 20 000 m² mirror area

Conclusions and Prospects

Acknowledgements

Solar tower Jülich August 31, 2009

http://www.solarturm-juelich.de/de