Dynamic Sorption Characteristics as Key for Reliable Performance Predictions of Adsorption Chillers

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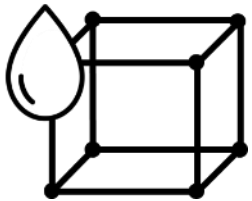
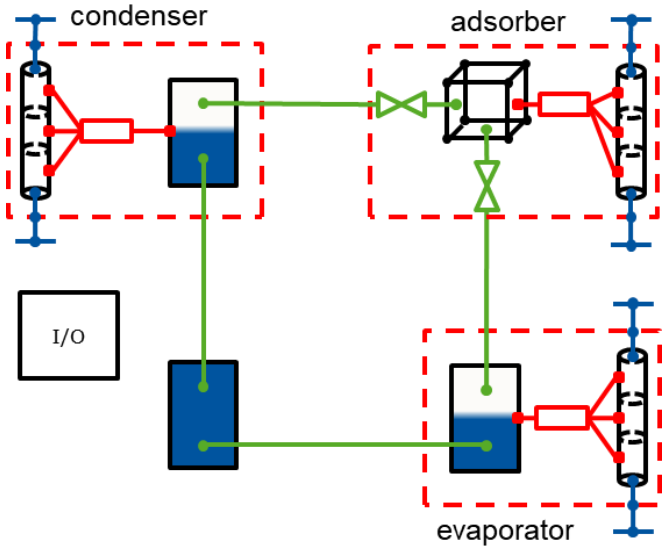
Lehrstuhl für Technische Thermodynamik
RWTH AACHEN UNIVERSITY

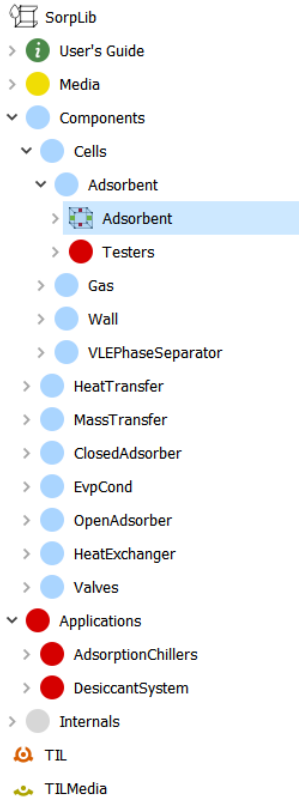
Modelling of Adsorption Systems

SorpLib

- Open Source Modelica Library https://git.rwth-aachen.de/ltt_public/SorpLib
- Cells: Adsorbent, Gas, Wall, ...
- Components
  - Adsorber
  - Condenser
  - Evaporator
  - Valves
- Examples
  - Adsorption Chillers
  - Desiccant Systems

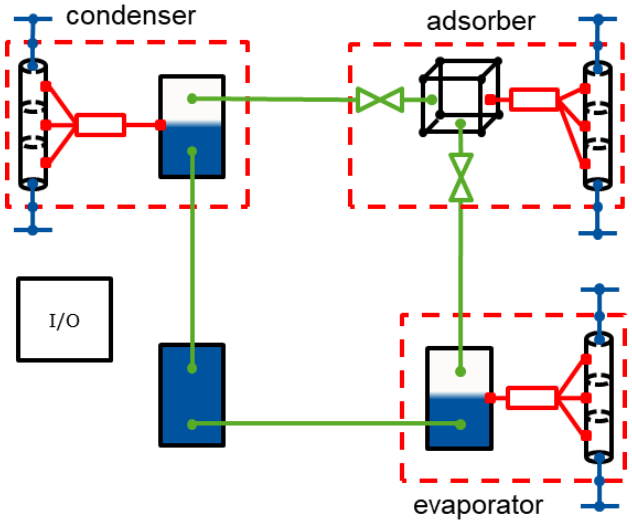






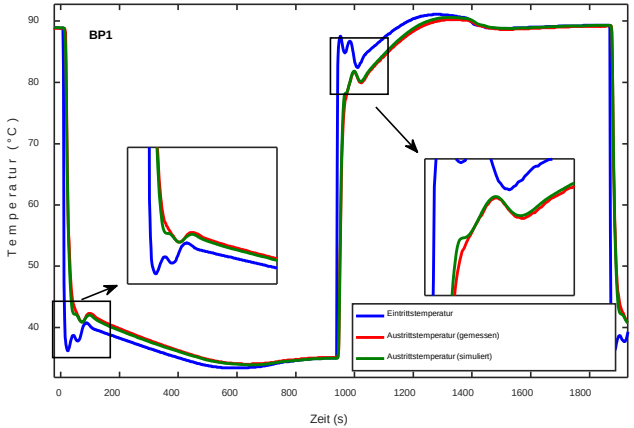
Performance Prediction: Simulations

model



simulations
@
different
operating
conditions

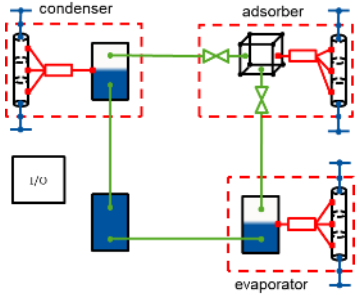
performance figures:
temperatures, heat flows,
COP, SCP, …



how do I know that my model is reliable?

Model Calibration & Validation

model



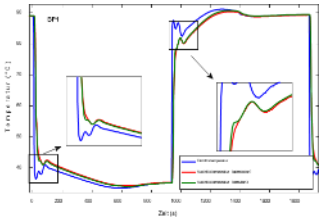
adsorption chiller test stand

many simulations @ different operating conditions

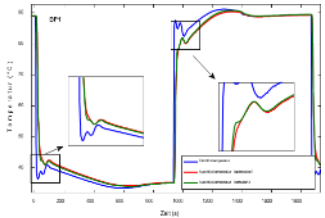
+

many experiments @ different operating conditions

simulation data sets



experimental data sets



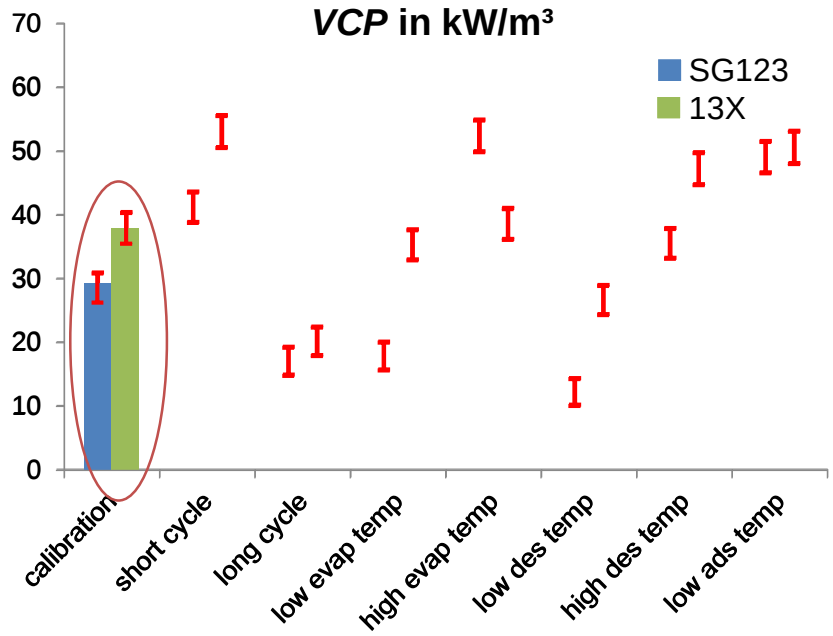
parameter identification + validation

reliable performance predictions for the calibrated system

State of the Art Performance Predictions

model calibration and validation with full-size adsorber

- one bed adsorption chiller
- lab scale ~ 1kg sorbent material
- silica gel 123 and zeolite 13X

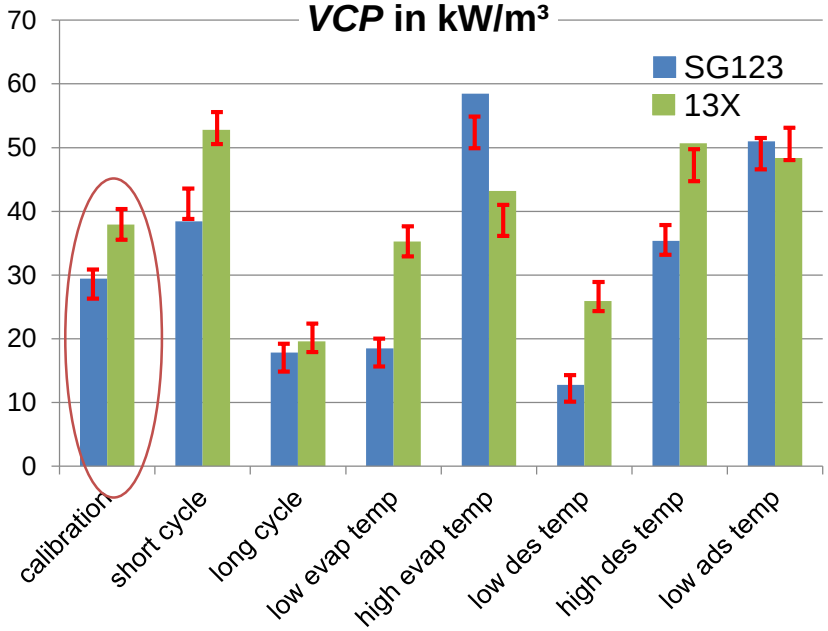


not transferable to other adsorber configurations (hx design, adsorbent)

State of the Art Performance Predictions

model calibration and validation with full-size adsorber

- one bed adsorption chiller
- lab scale ~ 1kg sorbent material
- silica gel 123 and zeolite 13X

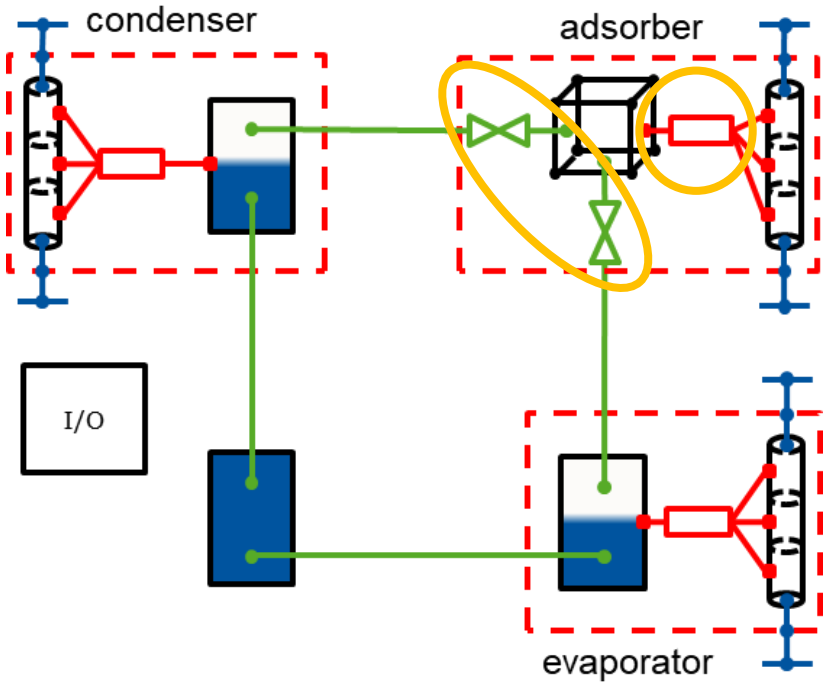


reliable performance predictions, but high effort for a single configuration

How to shrink the sorption lab?

1. What are the important parameters?
2. How do we determine these parameters?
3. How to setup the model?
4. Does it work?

Important Parameters



<u>known</u>

- geometry
  - hx, isolation, volumes, …
- material properties
  - sorption equilibrium, thermal conductivity, heat capacities, …
- evaporator and condenser
  - mass, UA-values, …

<u>unknown / uncertain</u>

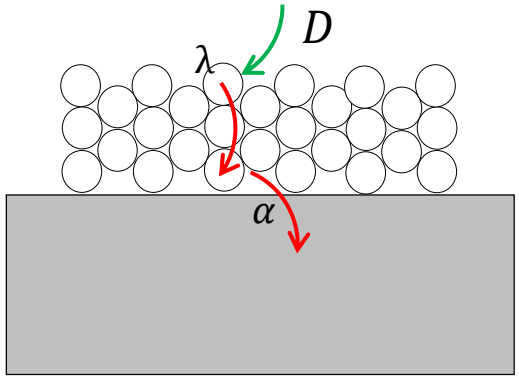
- heat and mass transfer coefficients of adsorber

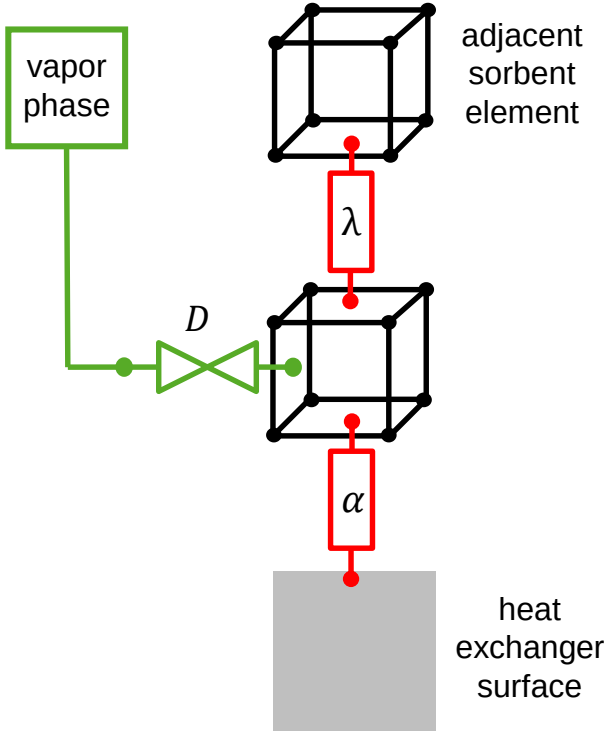
Important Unknown Parameters

vapor phase

sorption material

heat exchanger





Effective heat and mass transfer coefficients

λ: conductivity in sorbent material
α: heat transfer coefficient to hx surface
D: diffusion coefficient

How to shrink the sorption lab?

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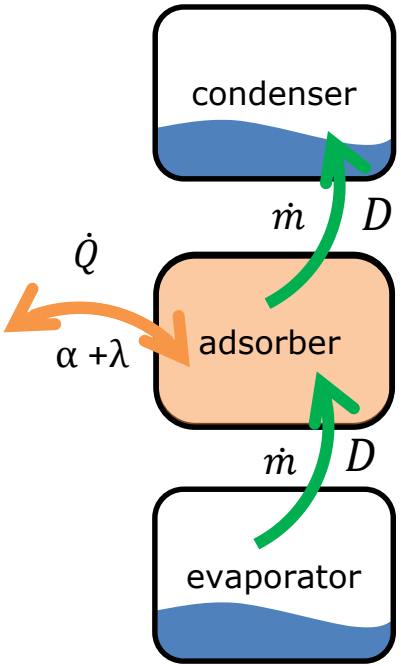
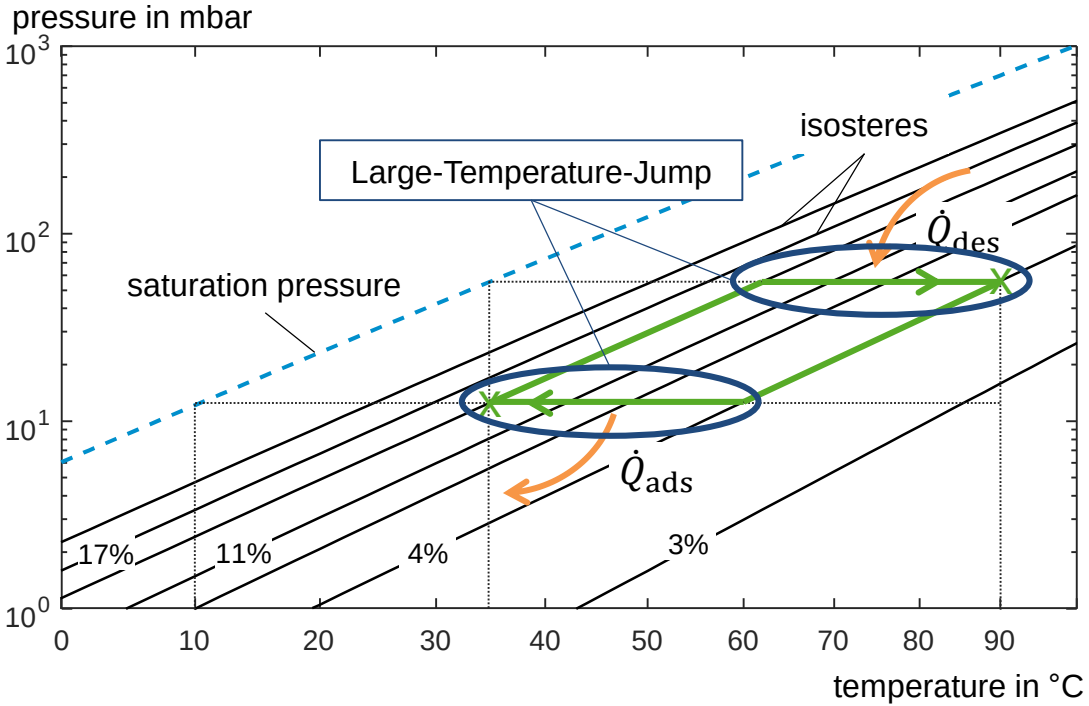
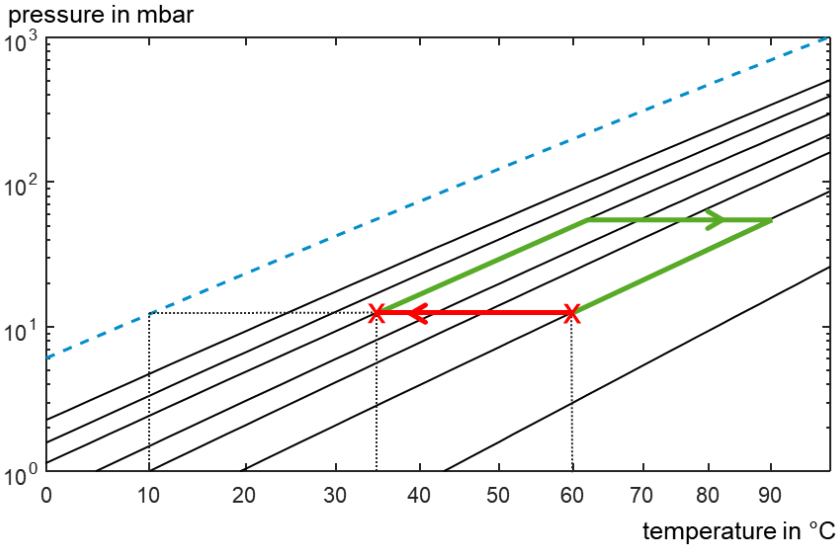
Adsorption Chiller Process

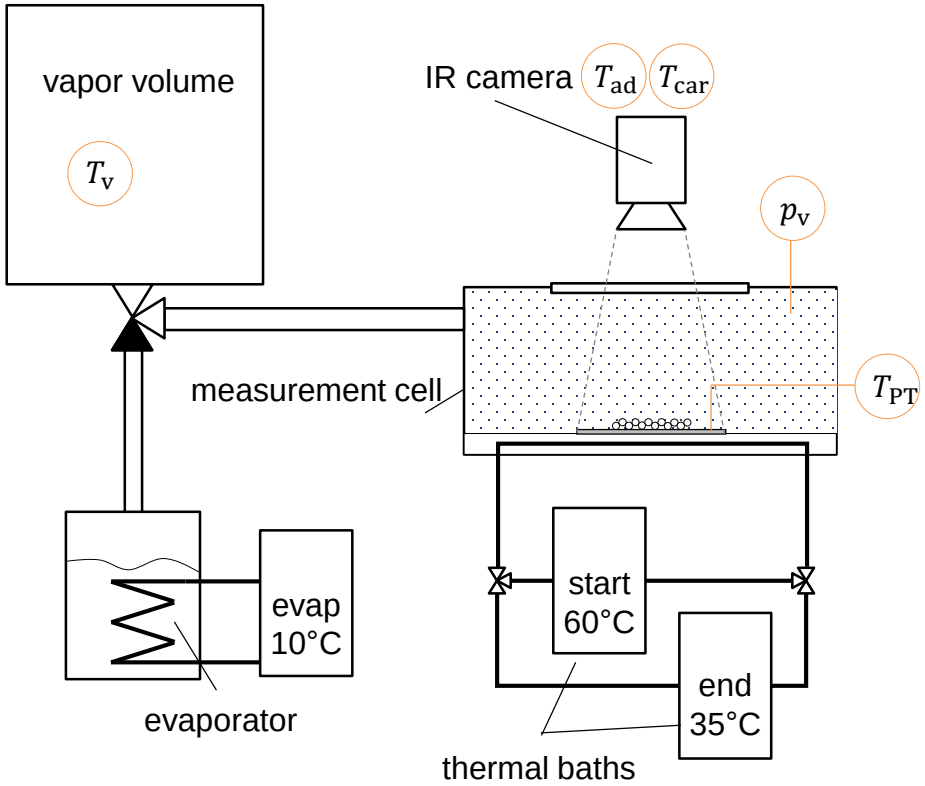




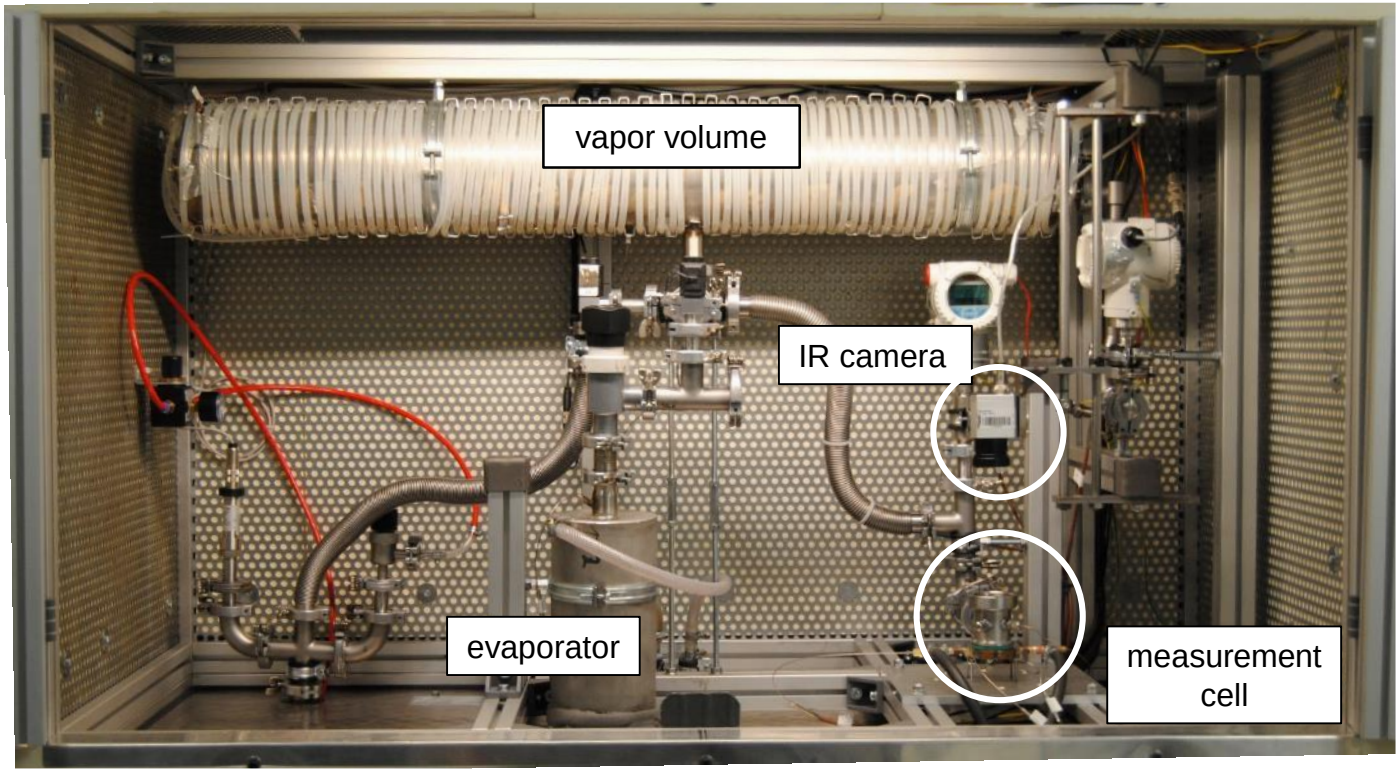
InfraRed - Large Temperature Jump (Adsorption)



measurement of temperatures and pressures during LTJ



Experimental Setup of IR-LTJ

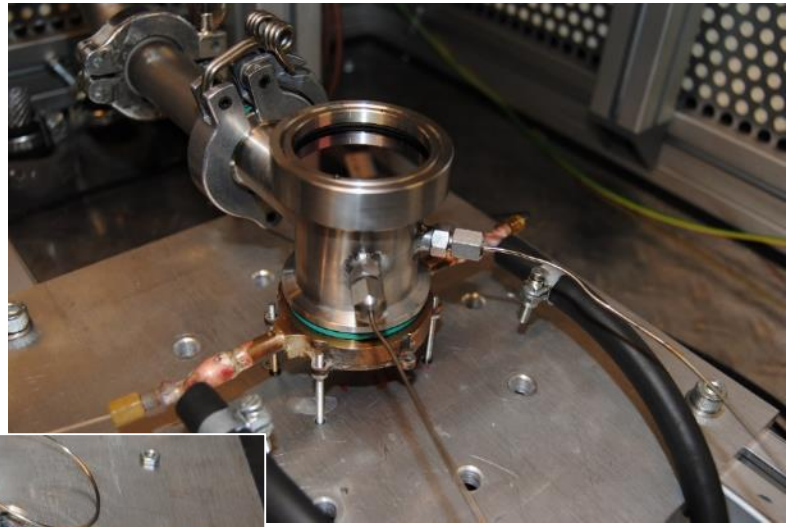


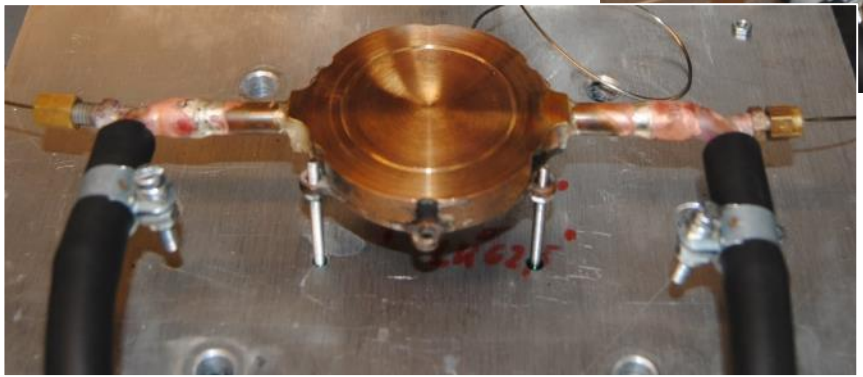
Measurement Cell

small heat exchanger

→ low heat capacity: fast temperature jumps

→ oil circuit: high temperatures, up to 200°C





IR-LTJ Measurement Conditions

sample material

- Silica Gel 123
- total mass: ~ 450 mg
- pellet size: 0,9 mm

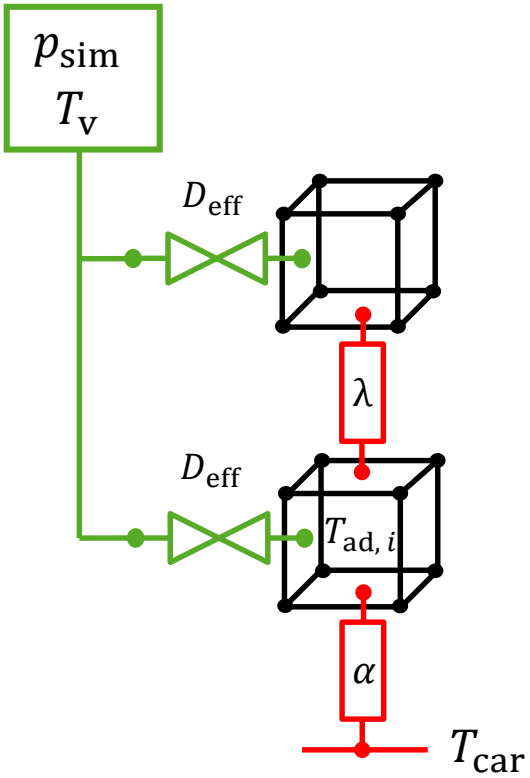
temperatures

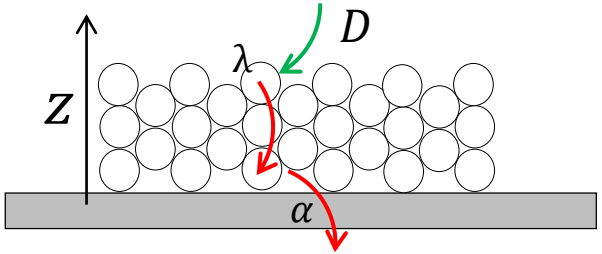
- evaporation: 10°C
- condensation: 35°C
- adsorption: 35°C
- desorption: 90°C

results

- temperature and pressure curves
  - characteristic times τ
  - cannot be used in model directly
- employing dynamic model of IR-LTJ
  - determine λ, α and D

Discretized IR-LTJ Model



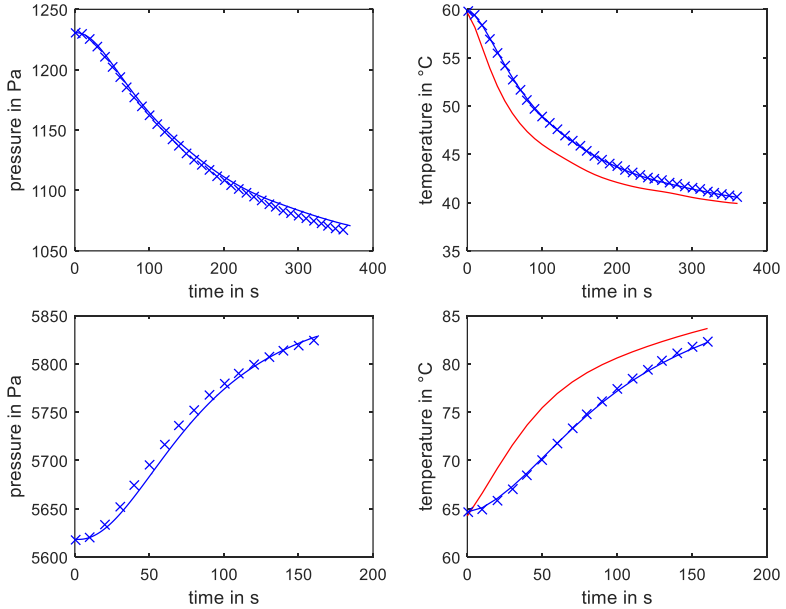


- simple geometry
- model discretized in z-direction
- no pressure loss in sorbent layer
- measurements with different layer thicknesses
  → distinguish λ and α
- minimizing RMSD for pressure and temperature
  → determine λ, α and D by

IR-LTJ Results

	Adsorption
α	245 W/m²K
λ	0.278 W/mK
D	1.32 x 10^{-9} m/s²

	Desorption
α	370 W/m²K
λ	0.355 W/mK
D	6.16 x 10^{-10} m/s²

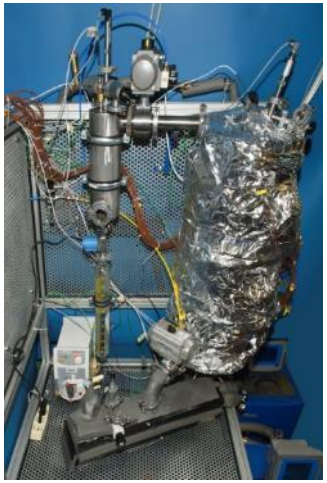


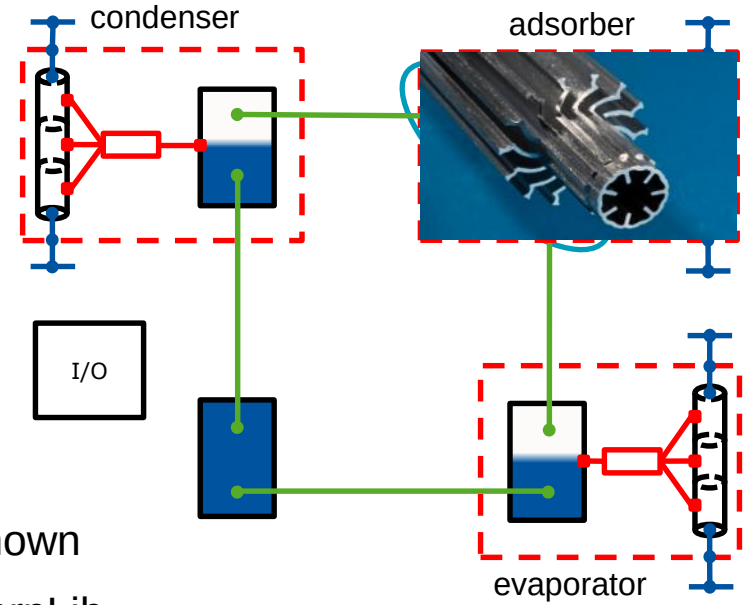
- Good agreement of measurement and simulation
- Deviation smaller than measurement uncertainty
- Coefficients dependent on temperature, pressure and loading

How to shrink the sorption lab?

1. What are the important parameters? λ, α and D ✓
2. How do we determine these parameters? IR-LTJ measurements ✓
3. How to setup the model?
4. Does it work?

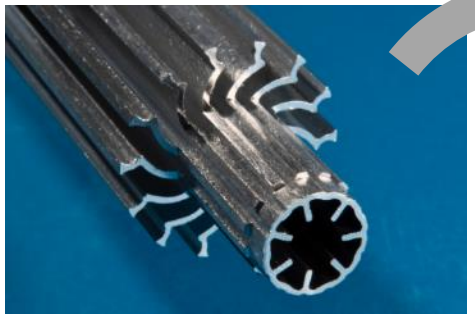
Setup of full-size adsorption chiller model

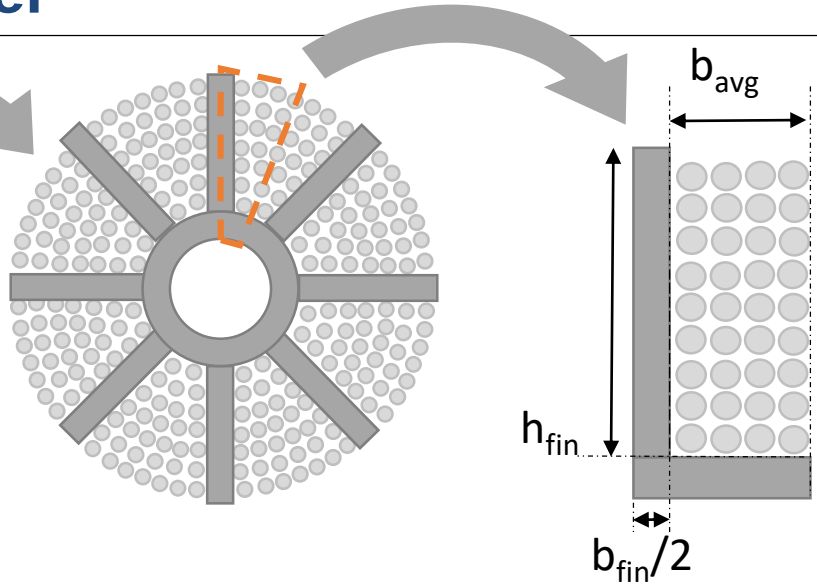


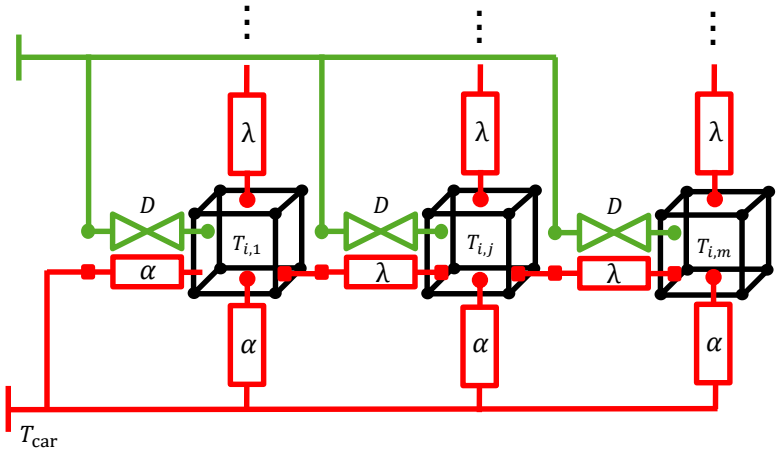


- geometries, material data, ... are known
- setup component models → e.g. SorpLib
- use heat and mass transfer coefficients from IR-LTJ
- complex adsorber hx → discretized model necessary

Discretized Model of Adsorber





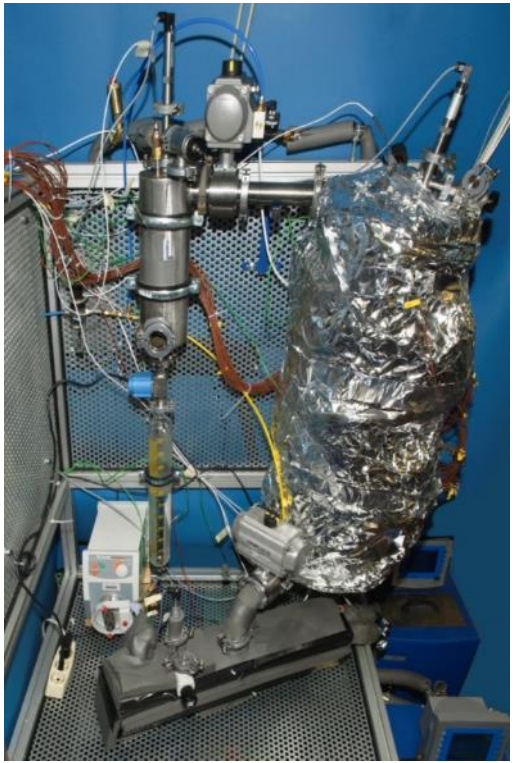


	Adsorption	Desorption
α	245 W/m²K	370 W/m²K
λ	0.278 W/mK	0.355 W/mK
D	1.32 x 10^{-9} m/s²	6.16 x 10^{-10} m/s²

How to shrink the sorption lab?

1. What are the important parameters? λ, α and D ✓
2. How do we determine these parameters? IR-LTJ measurements ✓
3. How to setup the model? Using discretized adsorber model + λ, α and D ✓
4. Does it work?

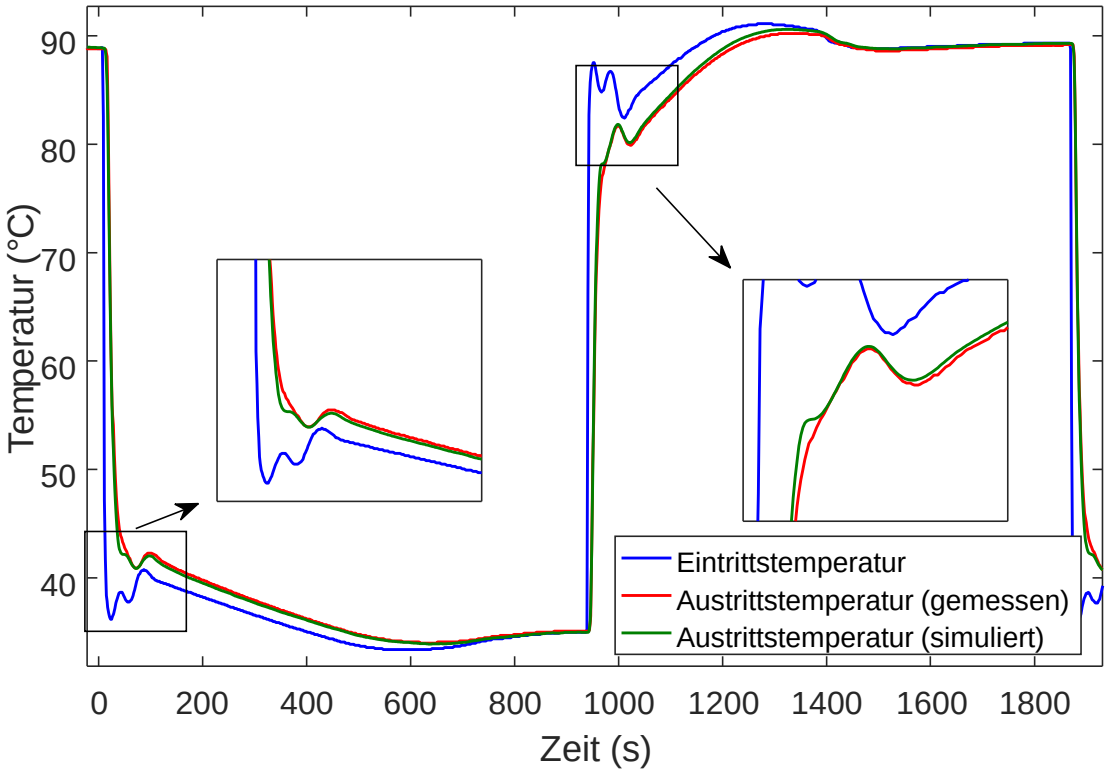
Validation with full-size adsorption chiller setup



<u>experiments</u>

- silica gel 123
- temperatures 10 / 30 / 95 °C
- cycle times
  - 450 s
  - 900 s
  - 1800 s

Experiment vs Simulation Ads 450s / Des 300s; 10/30/95°C

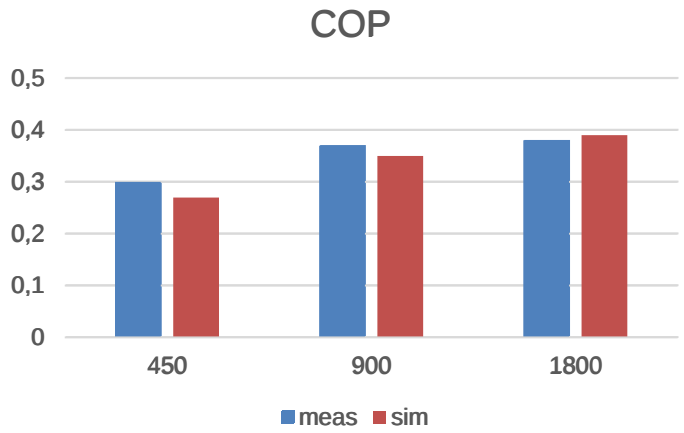


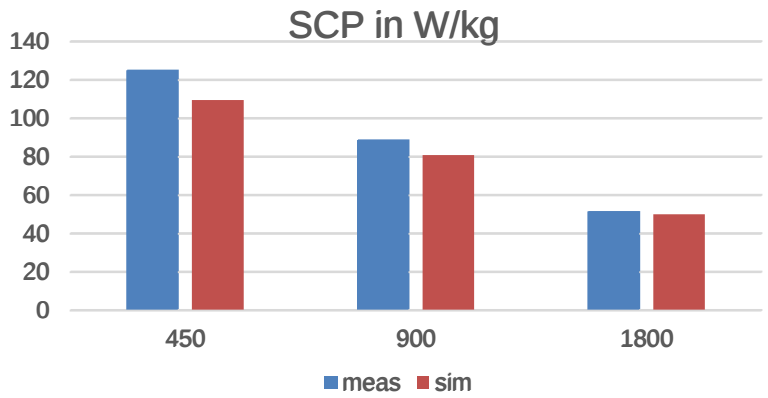
- model parameters
  - λ, α and D
  - geometry, …
- model inputs
  - measured inlet temperatures
  - volume flows
- model outputs
  - outlet temperatures

→ heat flows, COP, SCP

prediction almost perfectly describes the characteristics of the full-scale adsorption chiller

Results of Performance Prediction





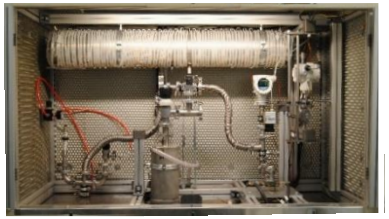
- COP and SCP are accurately predicted for various cycle times
- model is based only on coefficients from small and fast IR-LTJ experiments
- accuracy is close to full-scale calibrated model

How to shrink the sorption lab?

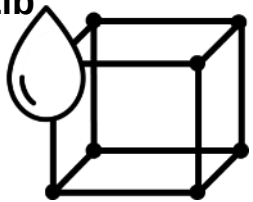
1. What are the important parameters? λ, α and D ✓
2. How do we determine these parameters? IR-LTJ measurements ✓
3. How to setup the model? Using discretized adsorber model + λ, α and D ✓
4. Does it work? Yes, it does! ✓

LTT‘s Guide on how to shrink your sorption lab

1. **Determine heat and mass transfer coefficients with IR-LTJ**
   for your specific sorbent – hxc material combination

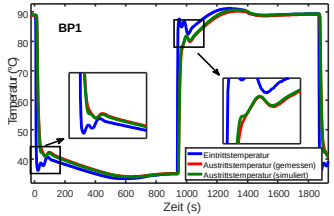


2. **Setup your adsorption chiller model with SorpLib**
   https://git.rwth-aachen.de/ltt_public/SorpLib



3. **Implement specific adsorber hxc geometry**
   discretized model for adsorber

4. **Carry out simulations for performance prediction**
   and enjoy reliable results



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