

CONNECTING
EXPERTS.

CHILLVENTA eSPECIAL

Refrigeration | AC & Ventilation | Heat Pumps

13.–15.10.2020

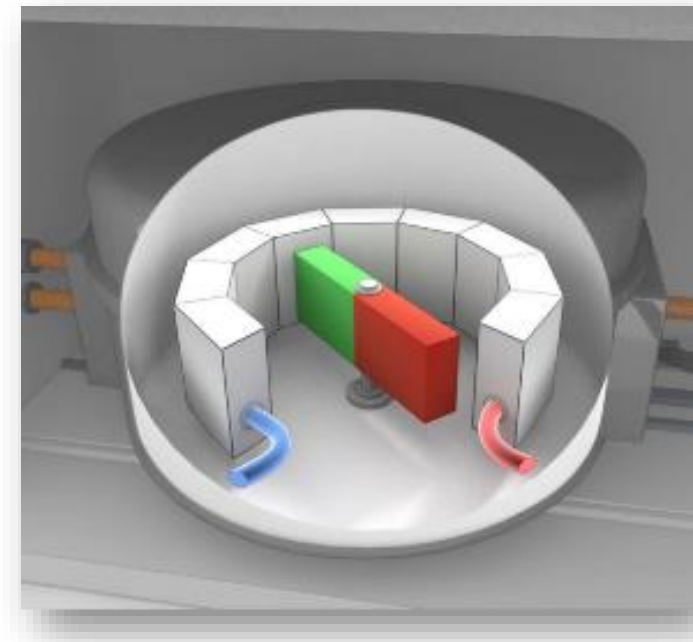
NÜRNBERG MESSE

Caloric Materials for Thermal Compression

15.10.2020 Chillventa eSpecial

K. Bartholomé, D. Bach, L.M. Maier, N. Bachmann, A. Fitger, O. Schäfer-Welsen

- Motivation
- »Active Magnetocaloric Heat Pipe« as Thermal Compressor
- Other caloric effects
- Summary



Motivation

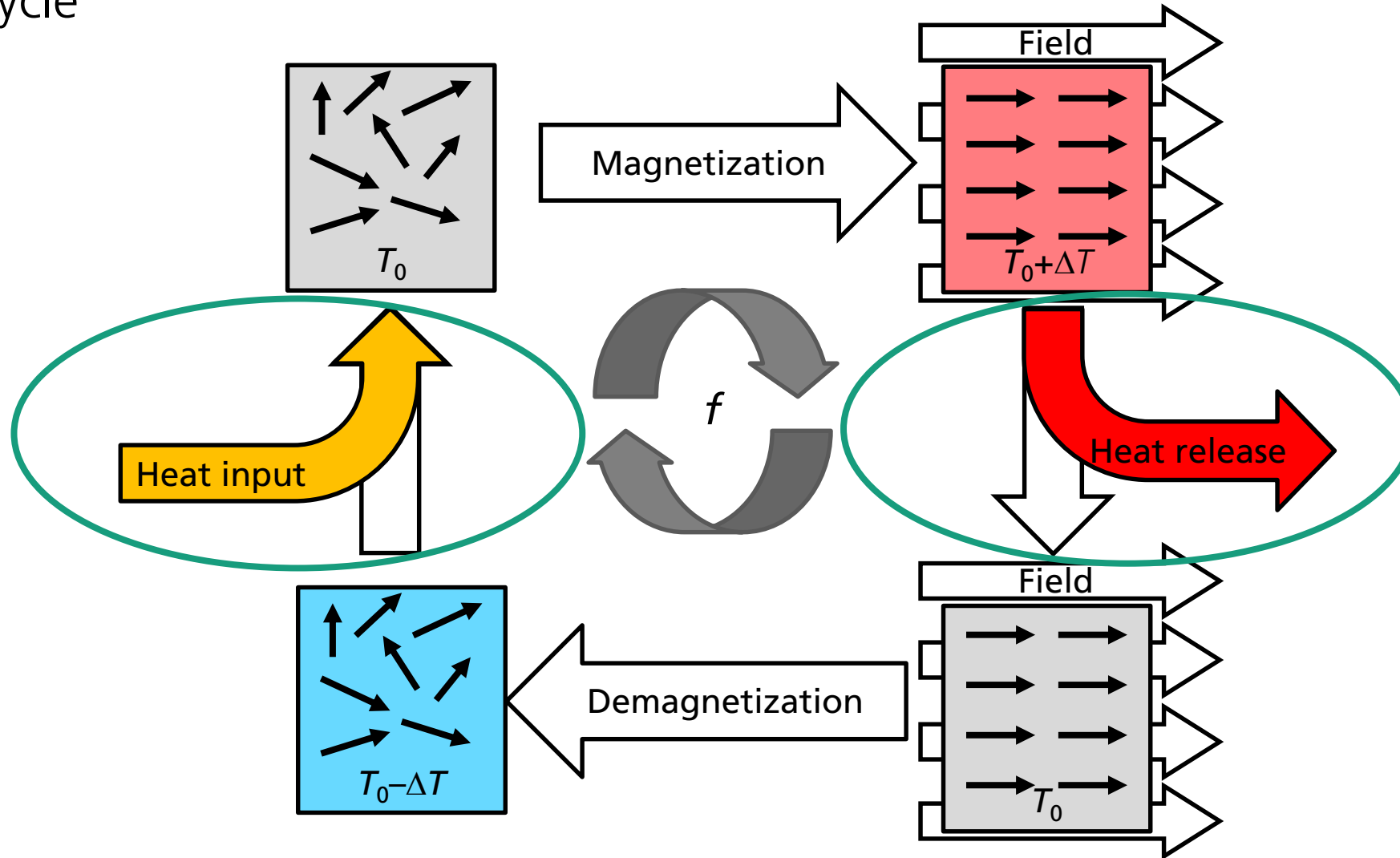
Why to deal with calorics?

1. Environmentally friendly:
No harmful refrigerants
2. Large efficiency!
3. Silent and easy-maintenance technology



Motivation

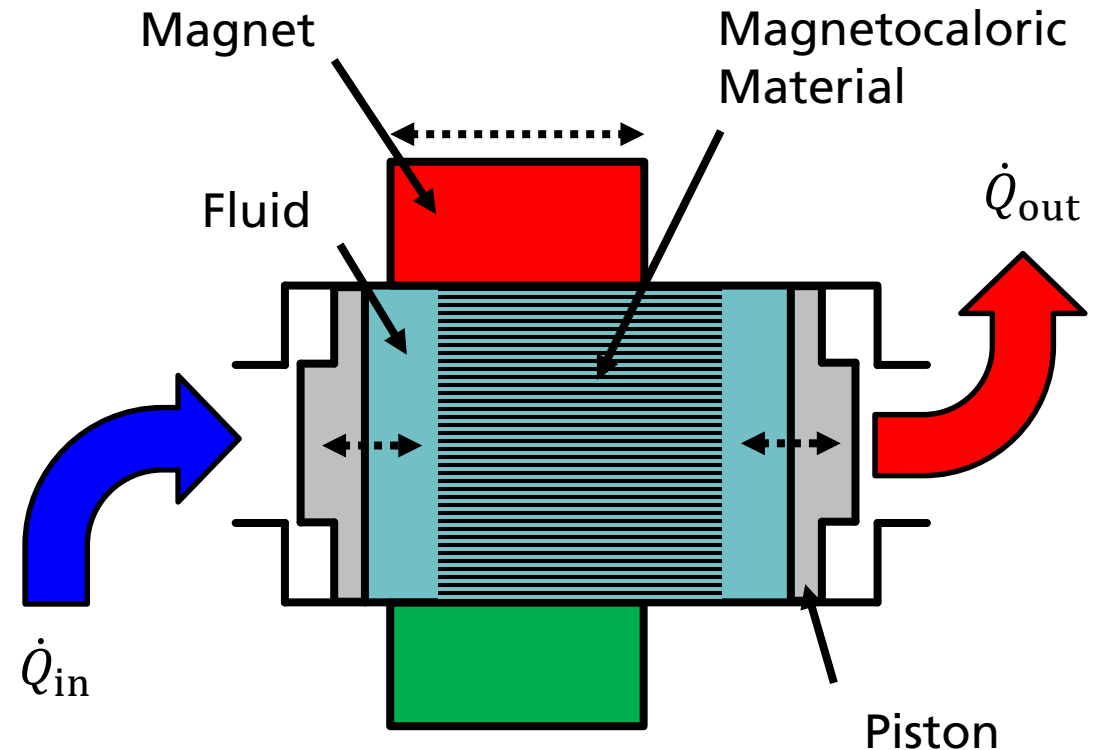
Caloric Cycle



Motivation

Active magnetocaloric regeneration (AMR)

- Several Demonstrators built based on AMR concept
- Showing good performance regarding temperature span and cooling power
- Challenge:
Realization of large cycle frequency and cooling power density!

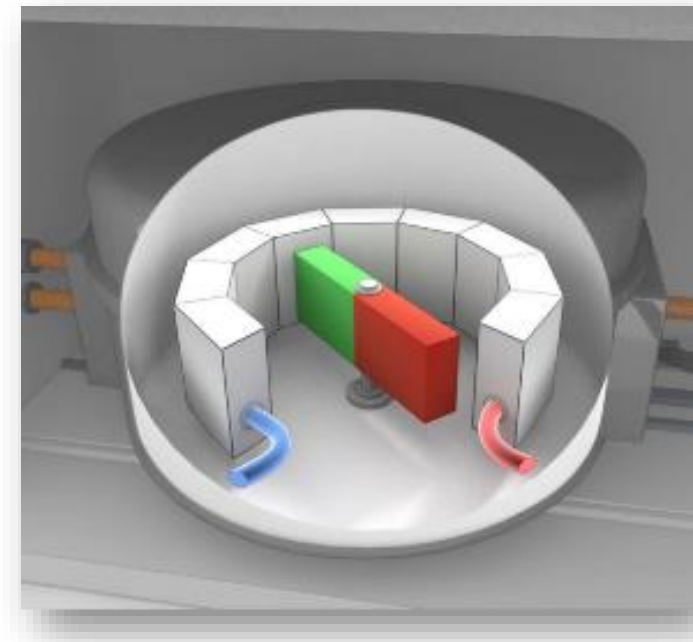


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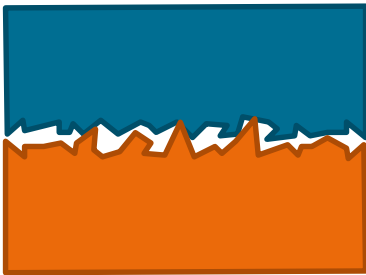
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Active Magnetocaloric Heat Pipe as Thermal Compressor

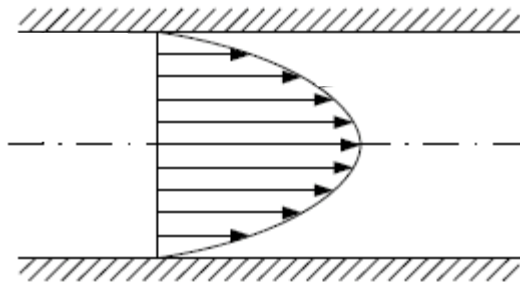
Fast heat transfer for larger cooling capacity

Solid-State Heat Transfer



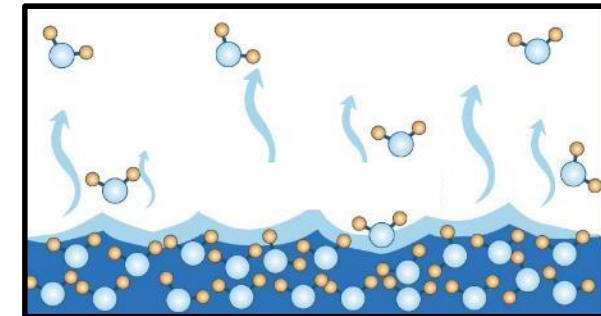
$$h = 10 \dots 10.000 \frac{W}{m^2 K}$$

Convection



$$h = 100 \dots 10.000 \frac{W}{m^2 K}$$

Evaporation / Kondensation



$$h = 10.000 \dots 100.000 \frac{W}{m^2 K}$$

Active Magnetocaloric Heat Pipe as Thermal Compressor

New concept for heat transfer in caloric systems

Alternative system approach

Fast and efficient heat transfer by combining

- Latent heat transfer:
Evaporation and condensation
- Thermal diode:
Passive, uni-directional heat transfer

Magneto-/ Electrocalorics: Patent DE10 2014 010 476

Elastocalorics: Patent pending

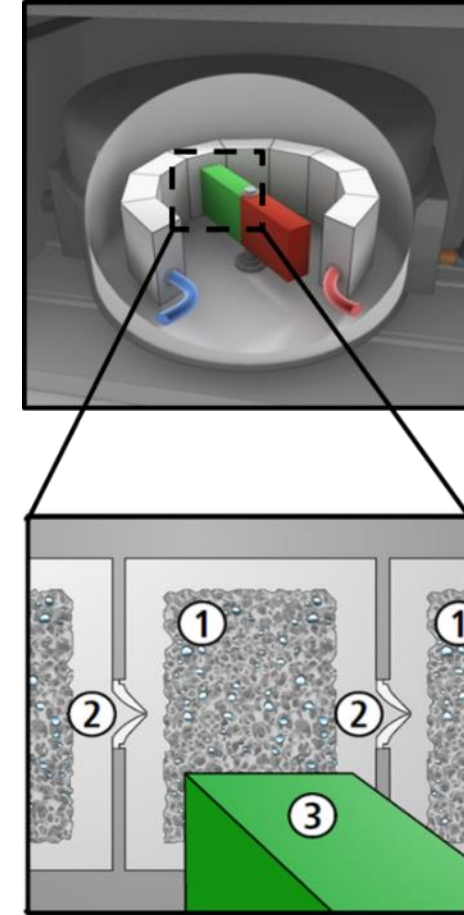


Active Magnetocaloric Heat Pipe as Thermal Compressor

New concept for heat transfer in caloric systems

Advantages

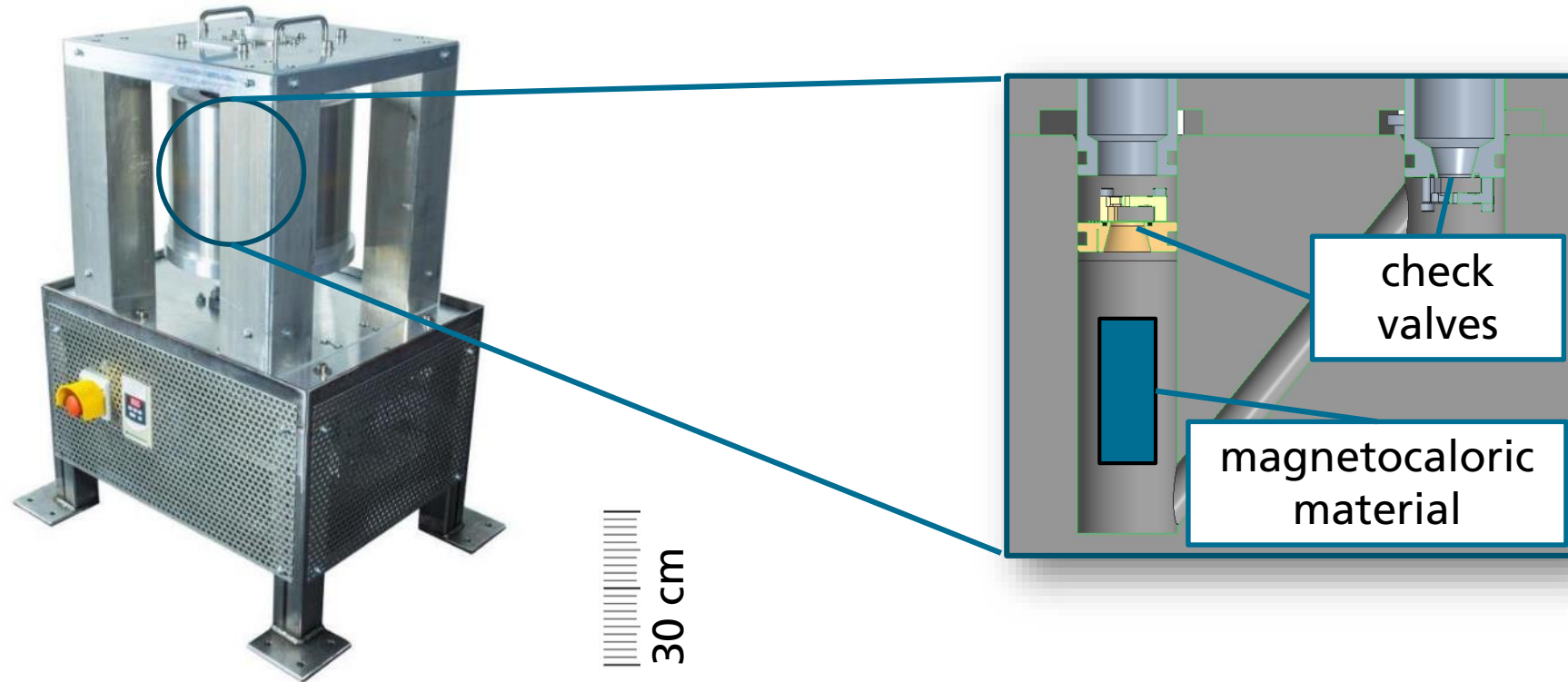
- Better heat transfer using latent heat:
 - Higher frequencies
 - Higher cooling power density
 - Less permanent magnet required
- Passive heat transfer:
 - No pumps required
 - Higher system efficiency
 - Reduced system complexity



Patent DE10 2014 010 476

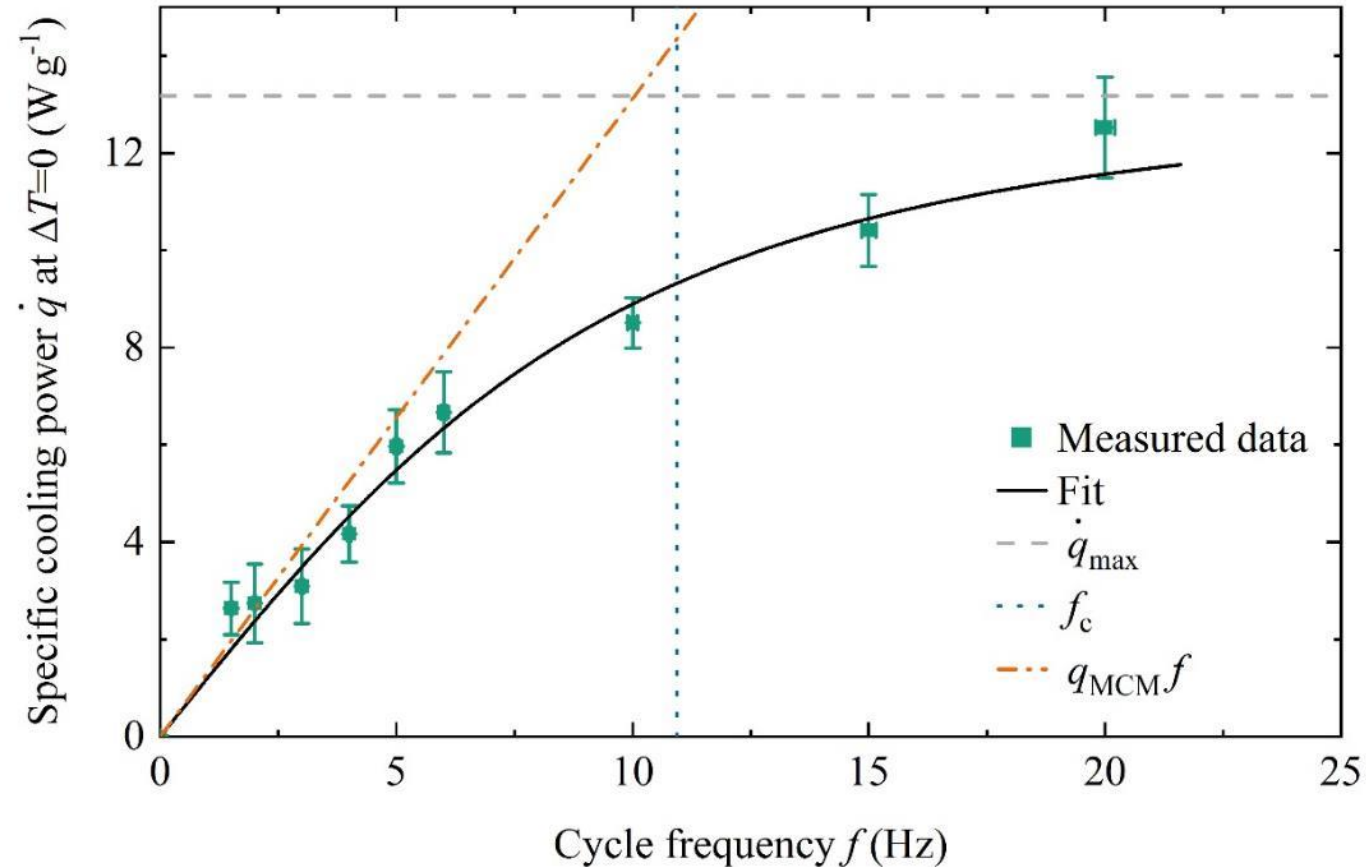
Active Magnetocaloric Heat Pipe as Thermal Compressor

Experimental Setup



Active Magnetocaloric Heat Pipe as Thermal Compressor

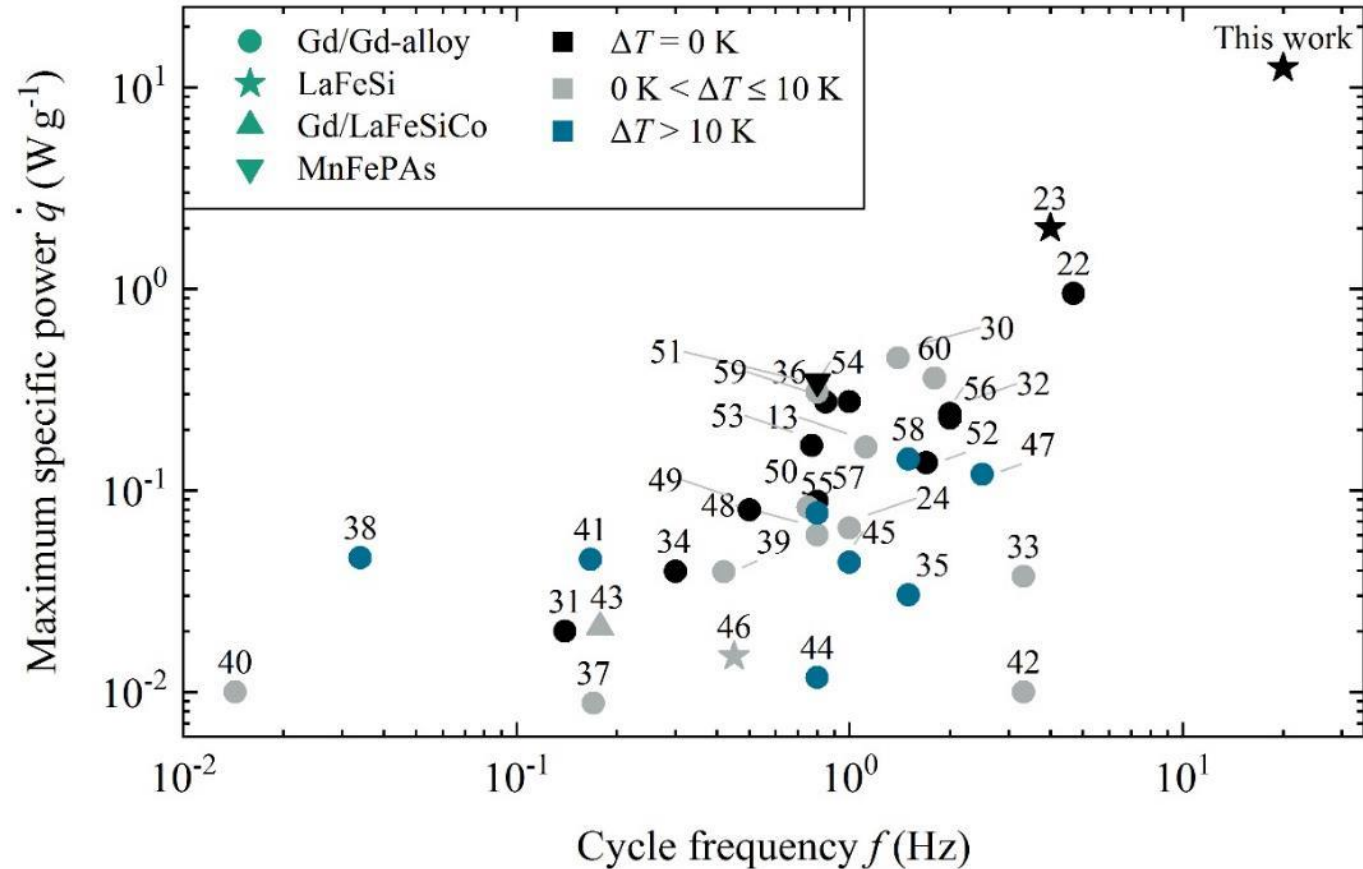
Experimental Data



L. M. Maier et al. „Active magnetocaloric heat pipes provide enhanced specific power of caloric refrigeration“, Nature Communication Physics, accepted

Active Magnetocaloric Heat Pipe as Thermal Compressor

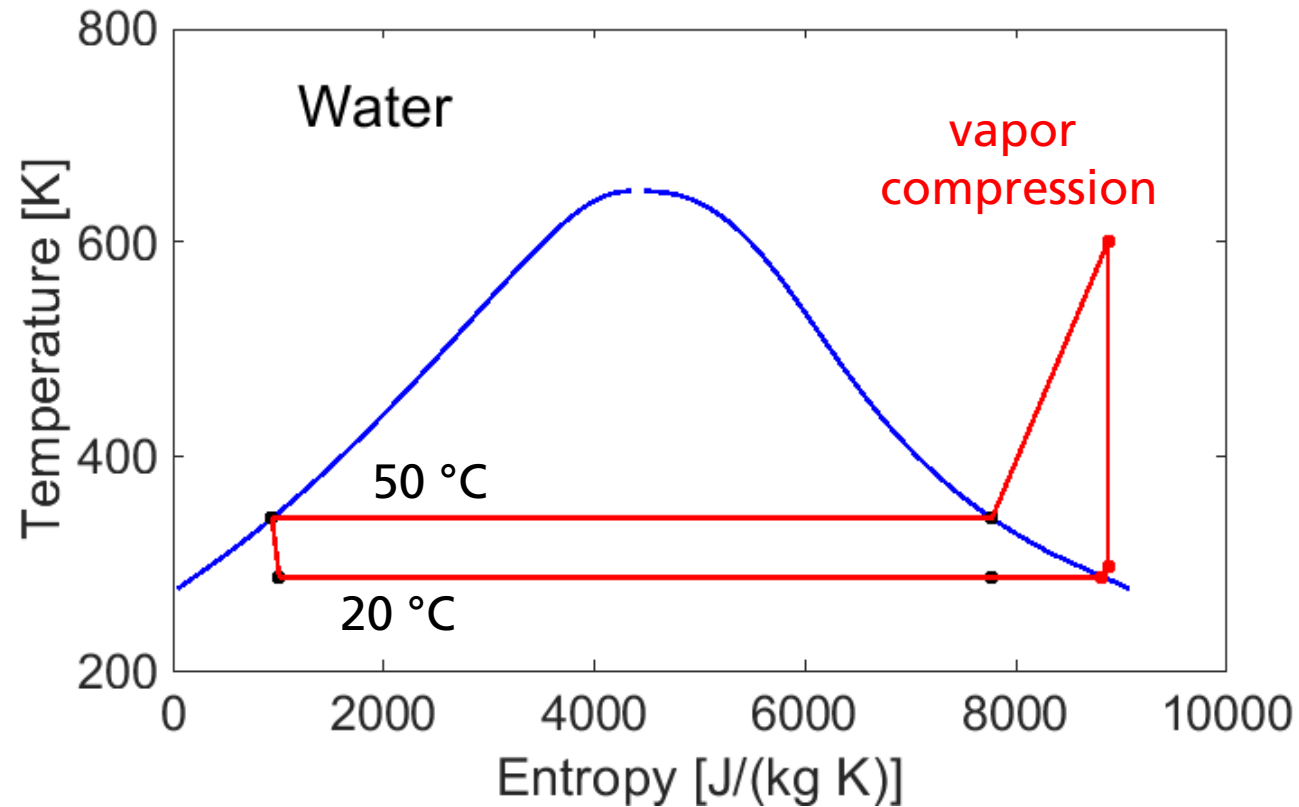
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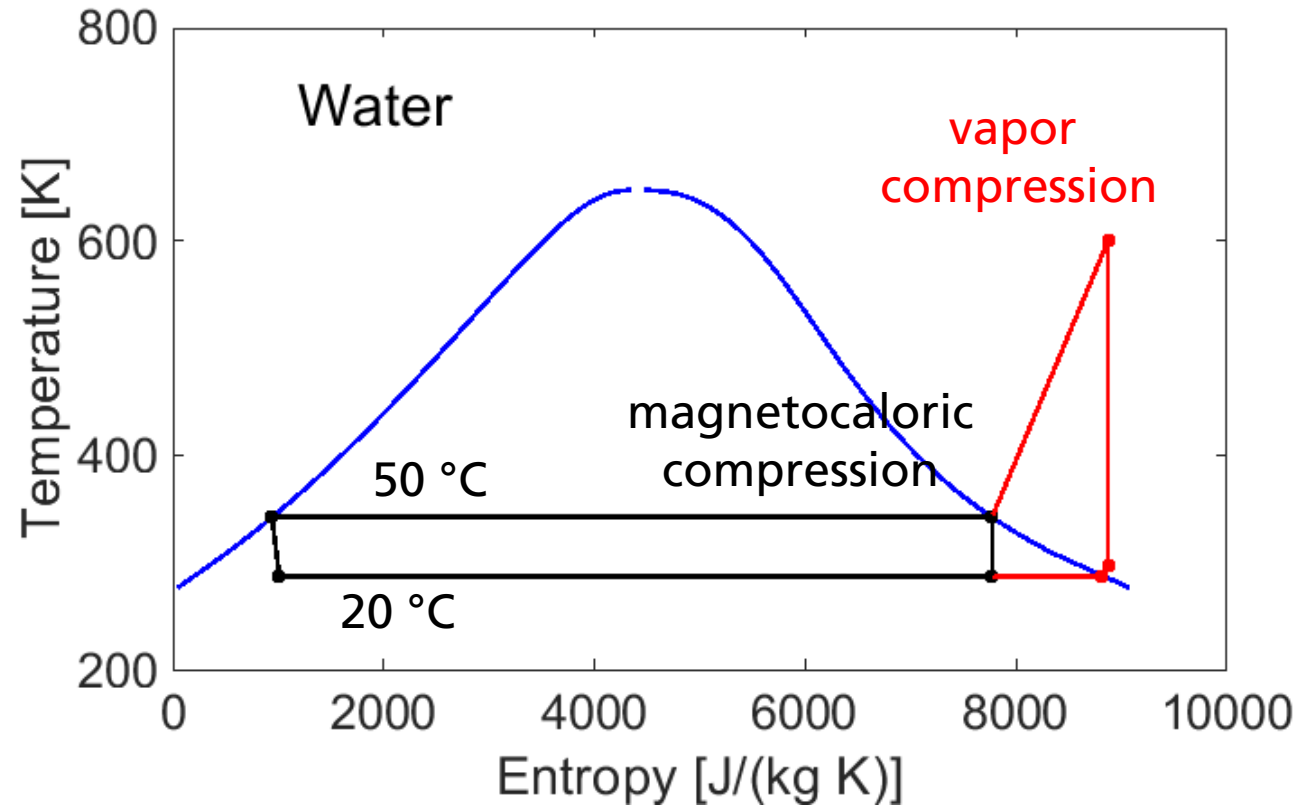
Active Magnetocaloric Heat Pipe as Thermal Compressor

Efficiency Potential: Comparison to Vapor-Compression



Active Magnetocaloric Heat Pipe as Thermal Compressor

Efficiency Potential: Comparison to Vapor-Compression



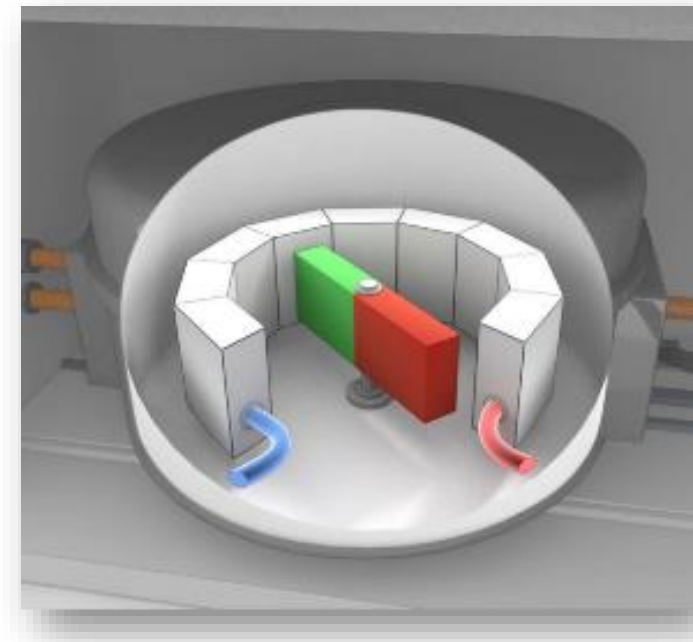
High efficiency possible – also for „wet“ fluids!

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Other caloric effects

Elastocalorics

Background

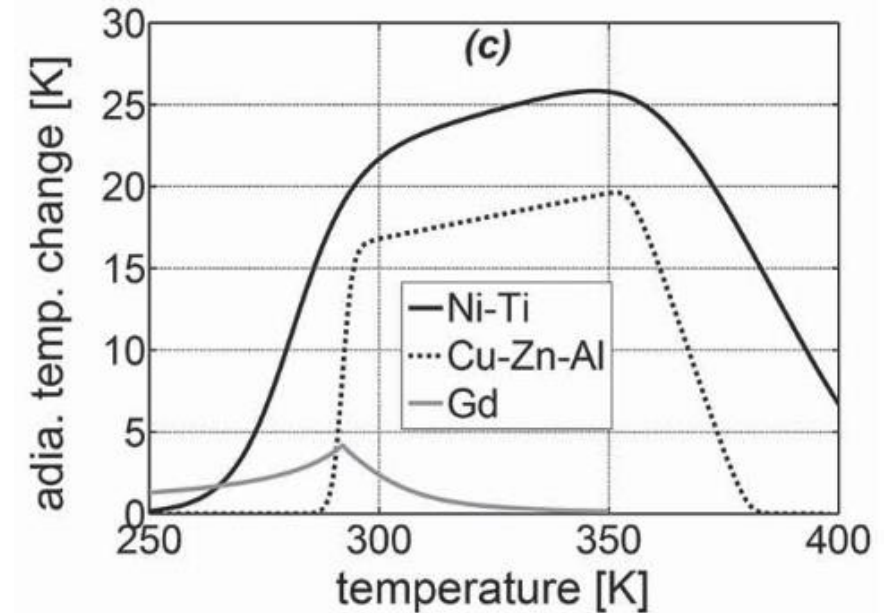
- Materials: Shape memory alloys (e. g. Nitinol)
- Phase change induction by mechanical force

Advantages

- Large adiabatic temperature and entropy changes

Challenges

- Long-term stability
- Material efficiency



Tusek, J. *et al.* The Elastocaloric Effect. A Way to Cool Efficiently. *Advanced Energy Materials* 5, 1500361 (2015)

Other caloric effects

Electrocalorics

Background

- Adiabatic temperature change in capacitor-like components
- Induction of phase change by electrical field

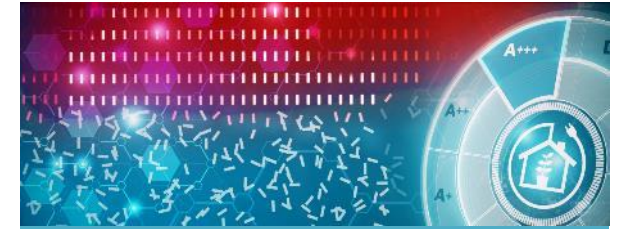
Advantages

- No magnetic field or large forces required for effect
→ system possible (almost) completely without moving parts!

Challenges

- Breakthrough voltage, stability
- Transfer material properties → system

www.elkawe.org



Project Information

Start: 01.10.2019

Duration: 4 Jahre

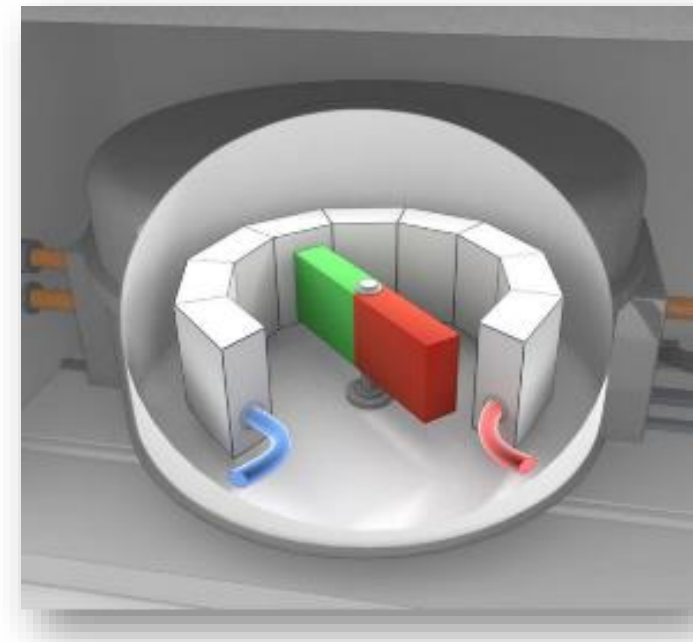
- Fraunhofer IPM (Coordinator)
- Fraunhofer FEP
- Fraunhofer IAF
- Fraunhofer IAP
- Fraunhofer IKTS
- Fraunhofer LBF

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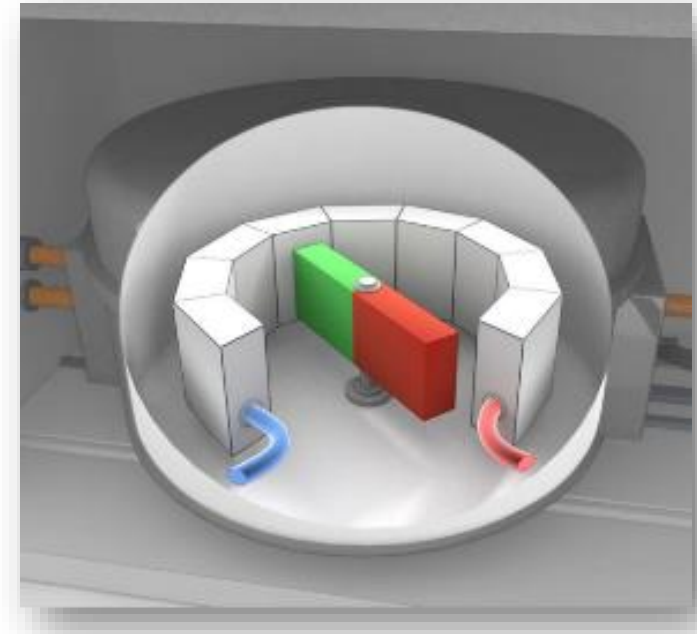
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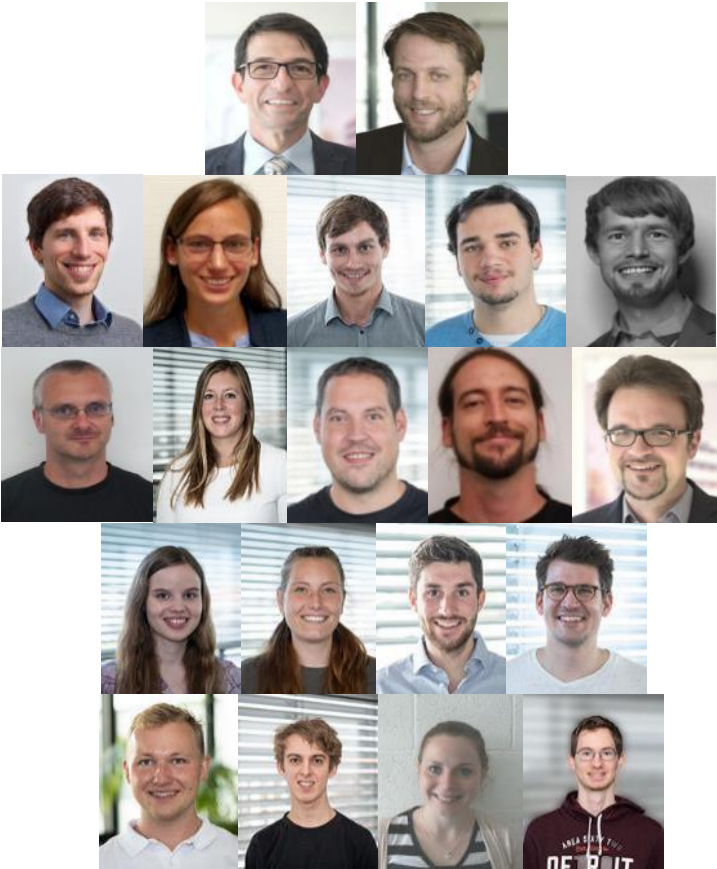
Summary

- Integration of caloric materials into heat pipes enables thermal compression!
- Hereby large system efficiencies and high cooling capacities are possible – even with water as coolant!
- Proof-of-Concept experimentally shown
- Next steps:
 - Increase temperature difference
 - Experimental quantification of efficiency



Danksagung

Project Team



Project Partners



Project Funding



Bundesministerium
für Wirtschaft
und Energie



Bundesministerium
für Bildung
und Forschung



Baden-Württemberg



InnoCool

Konsortialstudie Kalorik

Kältetechnik | Klimatechnik | Wärmepumpen



Thank you for your attention.

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