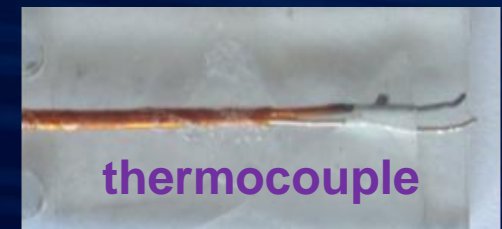
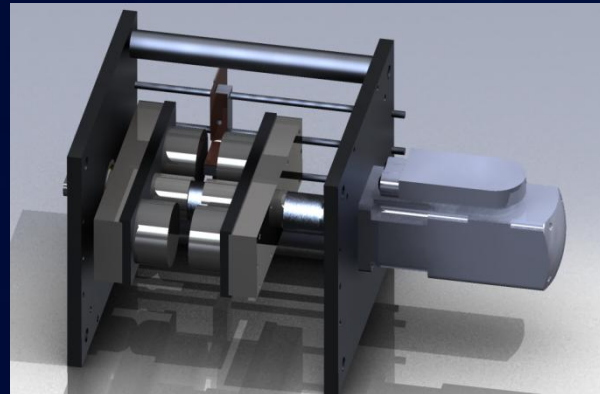
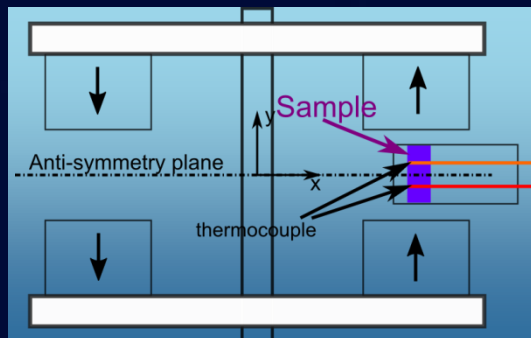


Dynamic measurement of temperature change for magnetocaloric materials

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Dynamic measurement of temperature change for magnetocaloric materials

Introduction

- Magnetocaloric effect and Magnetic refrigeration
- Way of improvement

Experimental Setup

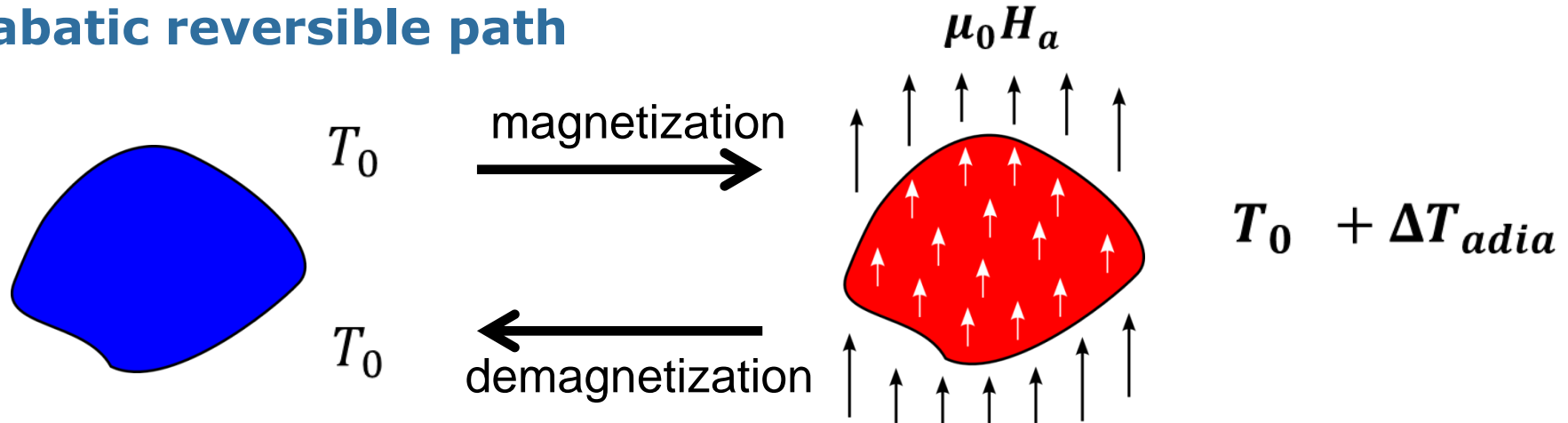
- Magnetic source
- Temperature measurement
- Result and difficulties met

Conclusion

Magnetocaloric effect

I. Introduction

■ Adiabatic reversible path



■ Second law of thermodynamics

$$\frac{\delta Q}{T} = dS(T, H) - \delta S_{produced}^{mat}(T, H) \geq 0$$

Case of reversible material: **NO LOSSES**

$$\delta S_{produced}^{mat} = 0$$

● In adiabatic and reversible path

$$dS(H, T) = 0 \quad \Rightarrow \quad dT = -\frac{\partial S}{\partial H} / \frac{\partial S}{\partial T} dH$$

Measurement

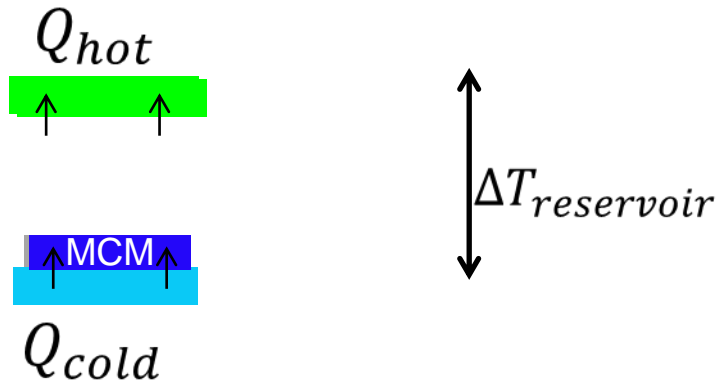
Magnetometry

Calorimetry

Temperature change

Example of cooling system

I. Introduction

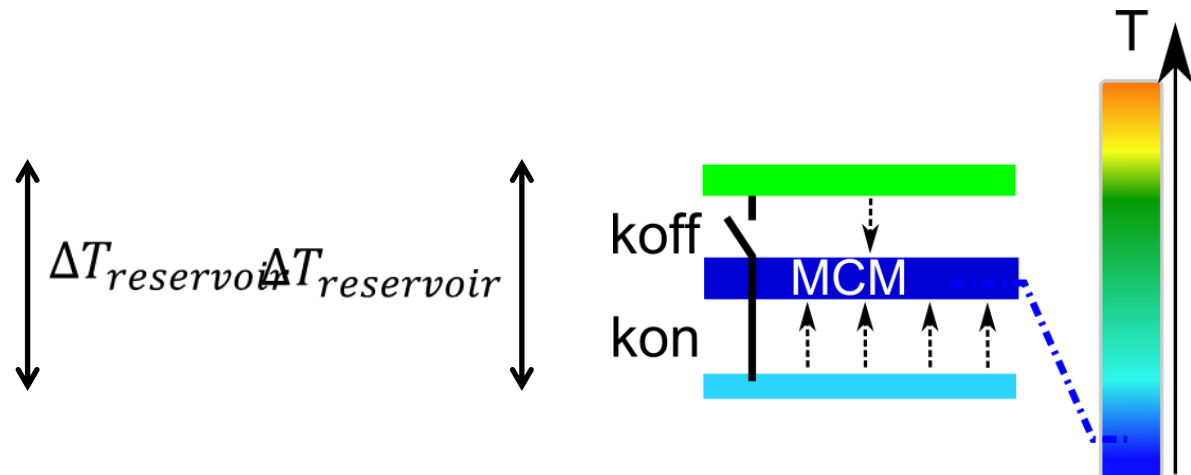


1) Adiabatic Magnetization

2) Heat exchange at constant field with the hot reservoir

3) Adiabatic demagnetization

4) Heat exchange at constant field with the cold reservoir

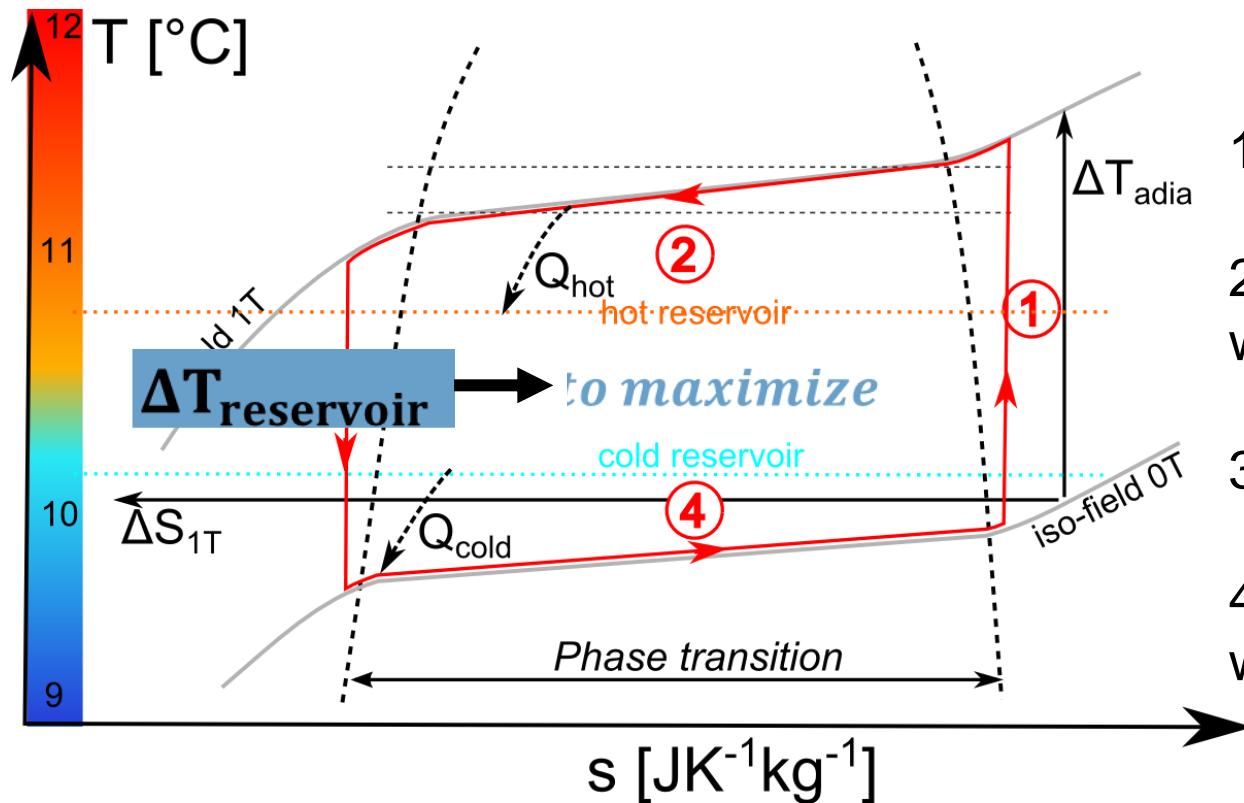


Magnetic refrigeration: Objectives

I. Introduction

Brayton Cycle

1. Adiabatic magnetization
2. Heat exchange at constant field with hot reservoir
3. Adiabatic demagnetization
4. Heat exchange at constant field with cold reservoir



$\frac{Q_{\text{cold}}}{\Gamma_{\text{periode}}}$ first order phase transition material \rightarrow to maximize

Magnetic refrigeration: Objectives

I. Introduction

■ Coefficient of performance

$$COP = Q_{cold} / W_{mag}$$

to maximize

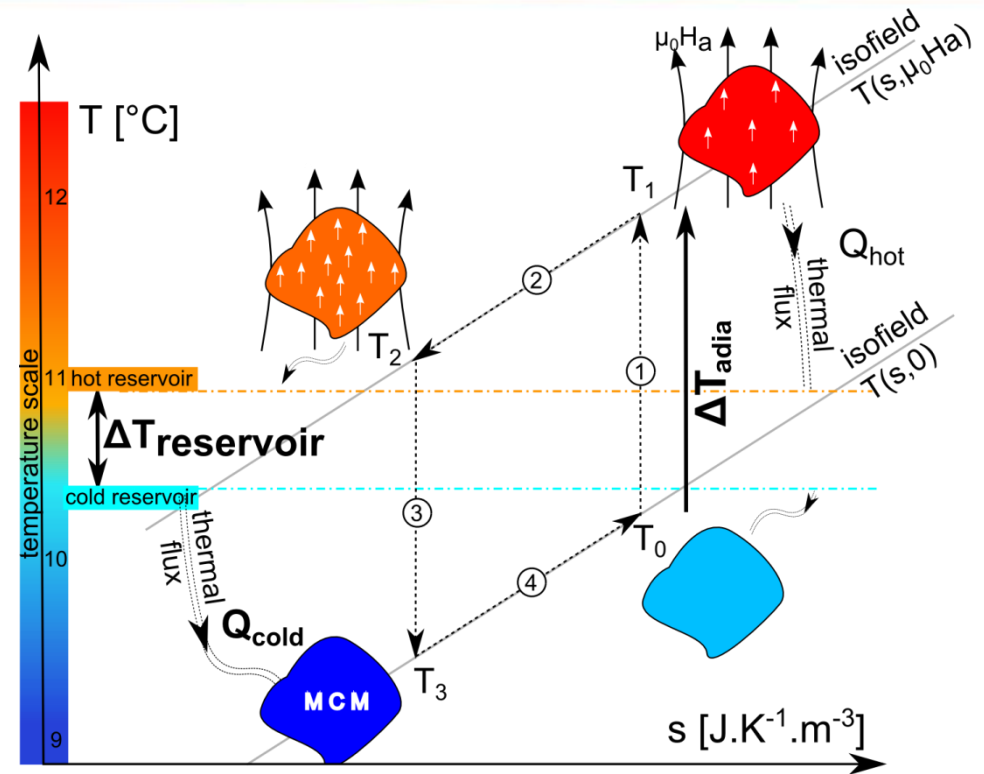
■ Heat exchange (2 & 4)

$$\delta Q = TdS - T\delta S_{\text{exchange produced}}$$

Q_{cold} ↘
 W_{mag} ↗ to minimize

■ Improve heat transfer

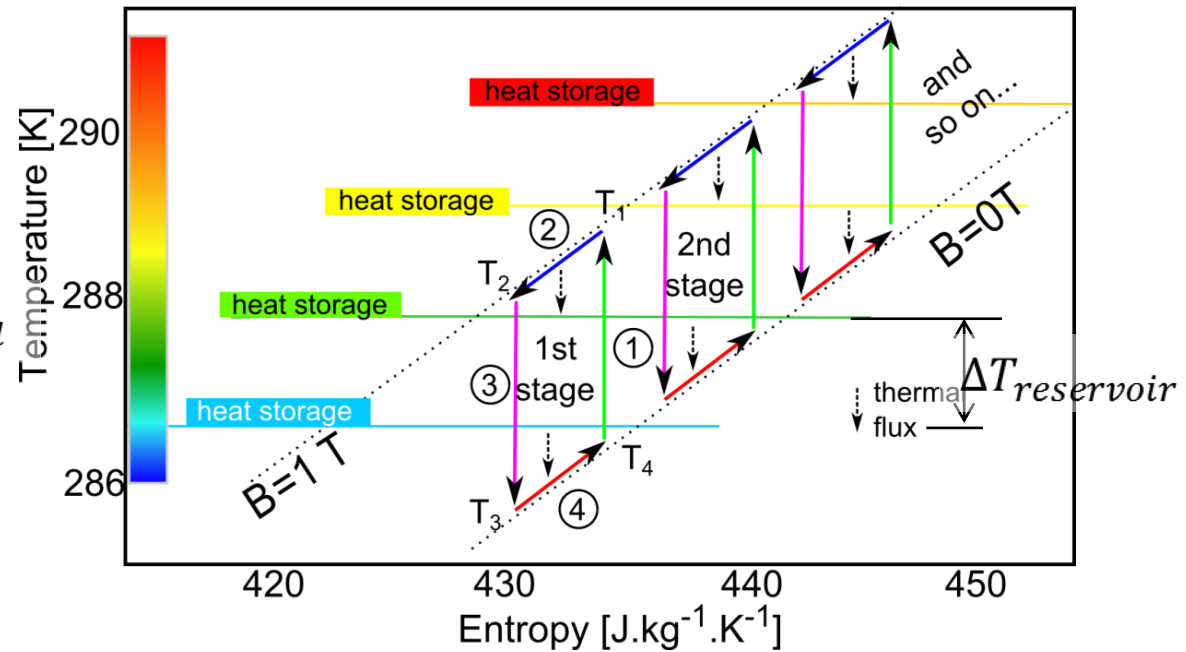
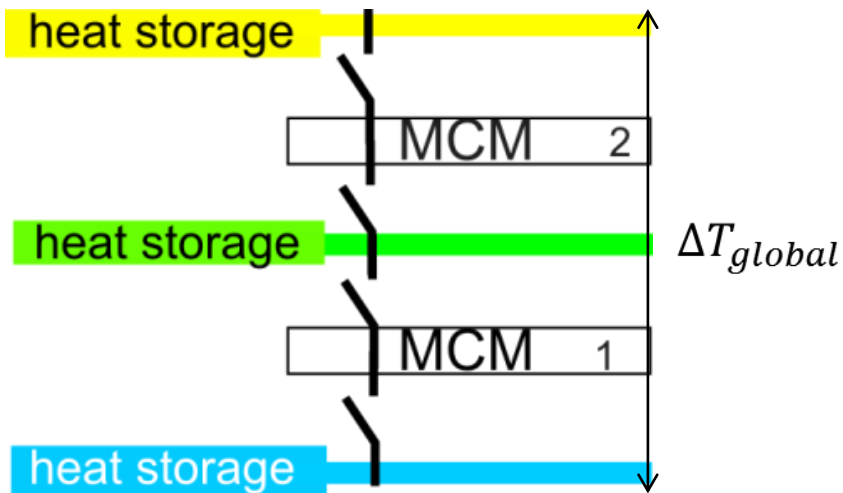
- Increase COP
- Increase power density



Way of improvement

I. Introduction

Temperature span increases by cascade



N Cascades \Rightarrow **Power density / N**
 $\Delta T_{global} = N \Delta T_{reservoir}$

Introduction

■ Increase the power density & COP

- Improve material performance
- Increase the magnetic field available
- Increase the cycle frequency



■ Increase the cycle frequency

- Capability to increase the heat transfer
- Assume the same behavior of the material at higher frequency



Validation of the material behavior at high frequency

Dynamic measurement of temperature change for magnetocaloric materials

Introduction

- Magnetocaloric effect and Magnetic refrigeration
- Way of improvement

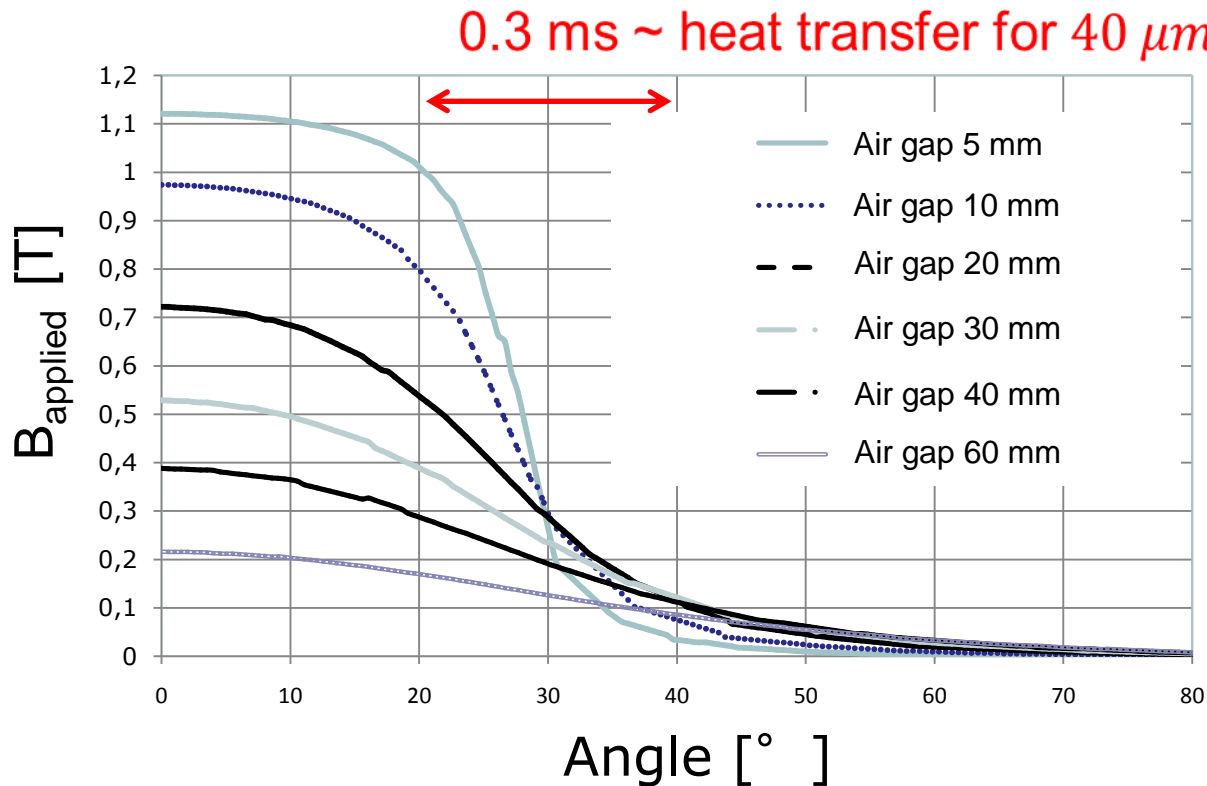
Experimental Setup

- Magnetic source
- Temperature measurement
- Result and difficulties met

Conclusion

Control

- Field through the air gap \Rightarrow 0.2 to 1.1 T
- Field variation with the speed of the rotor \Rightarrow 0 to 1000 T/s

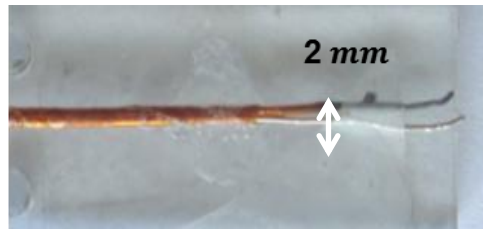


Temperature measurement

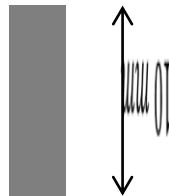
I. Introduction > II. Experimental setup

Possible methods

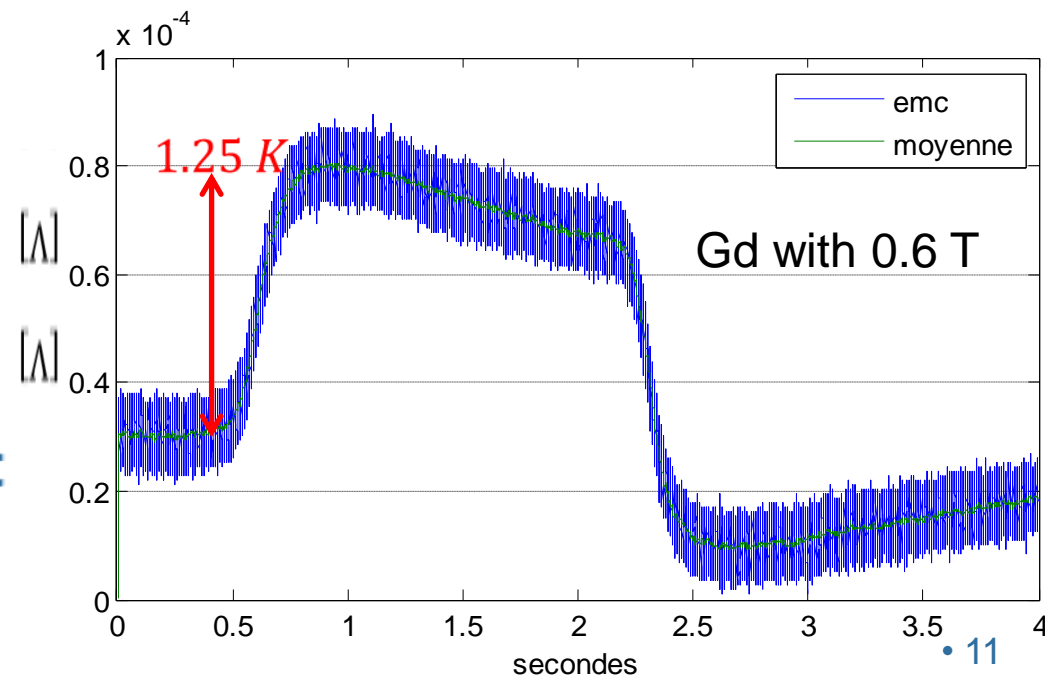
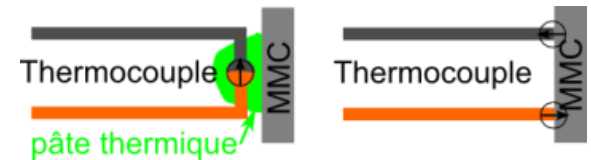
- Thermal imaging – Pyrometer => Cost
- Thermo-Reflectance => Accessibility
- **Thermocouple (type T) with open junction**



thickness 1 mm



3 mm

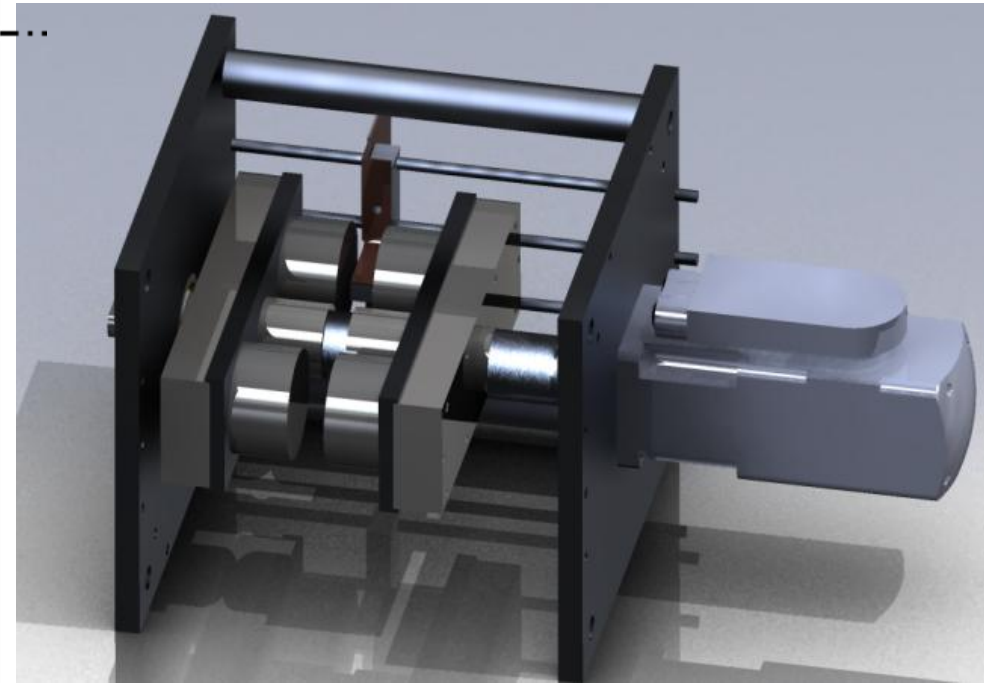
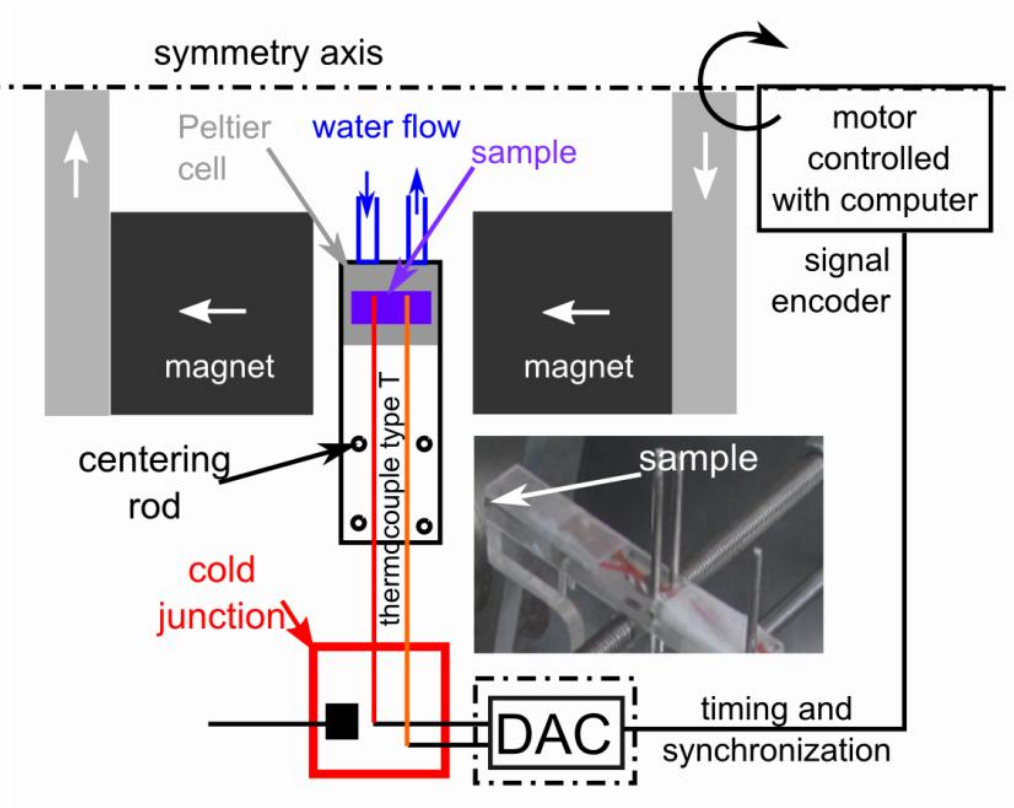


Temperature measurement

- 40 $\mu V/K$ low sensibility & noise

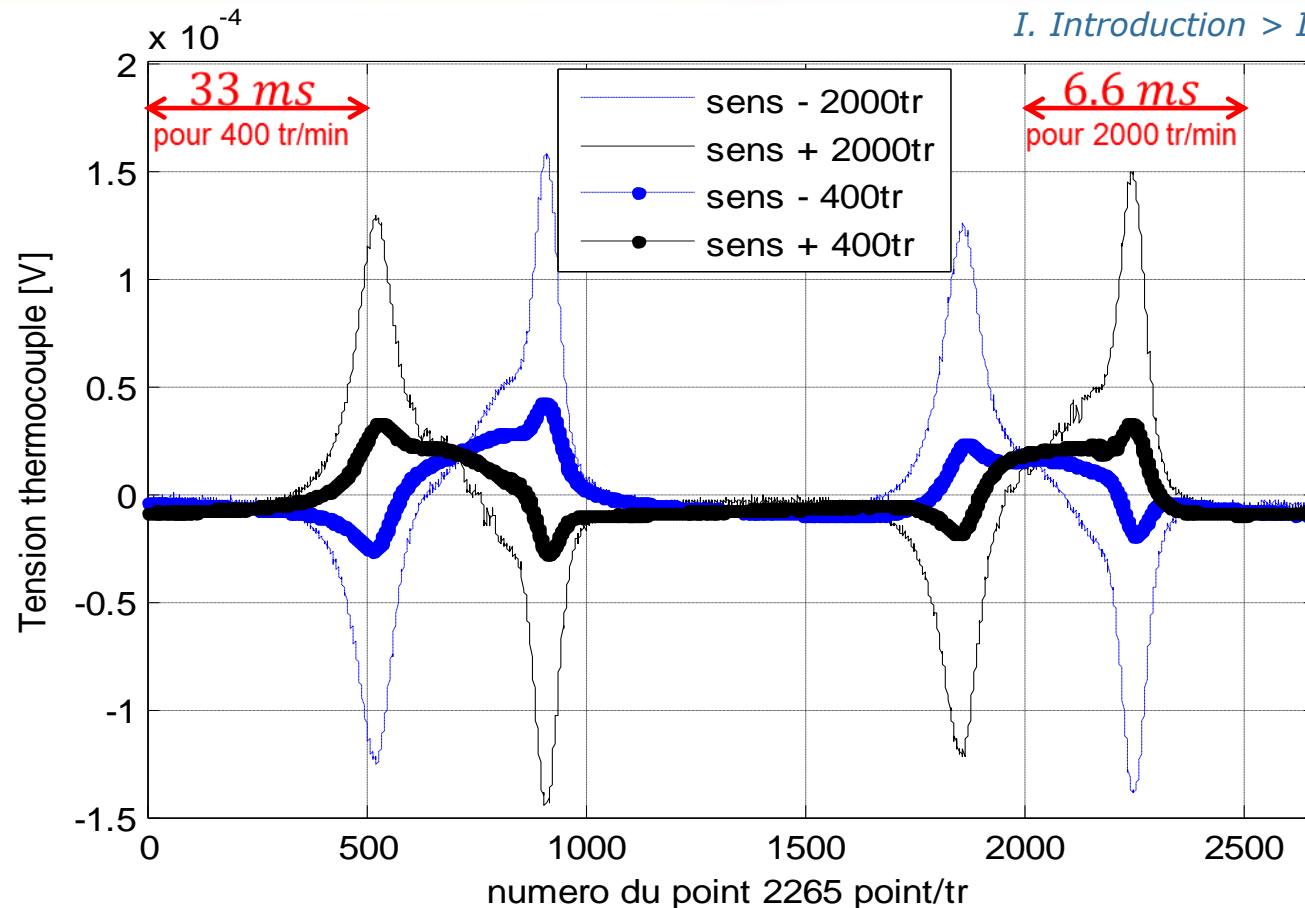
I. Introduction > II. Experimental setup

High dynamic measurement of the temperature change



Difficulties in high frequency

- Temperature measurement
- Applied field



Induced voltage in the wires and in the sample

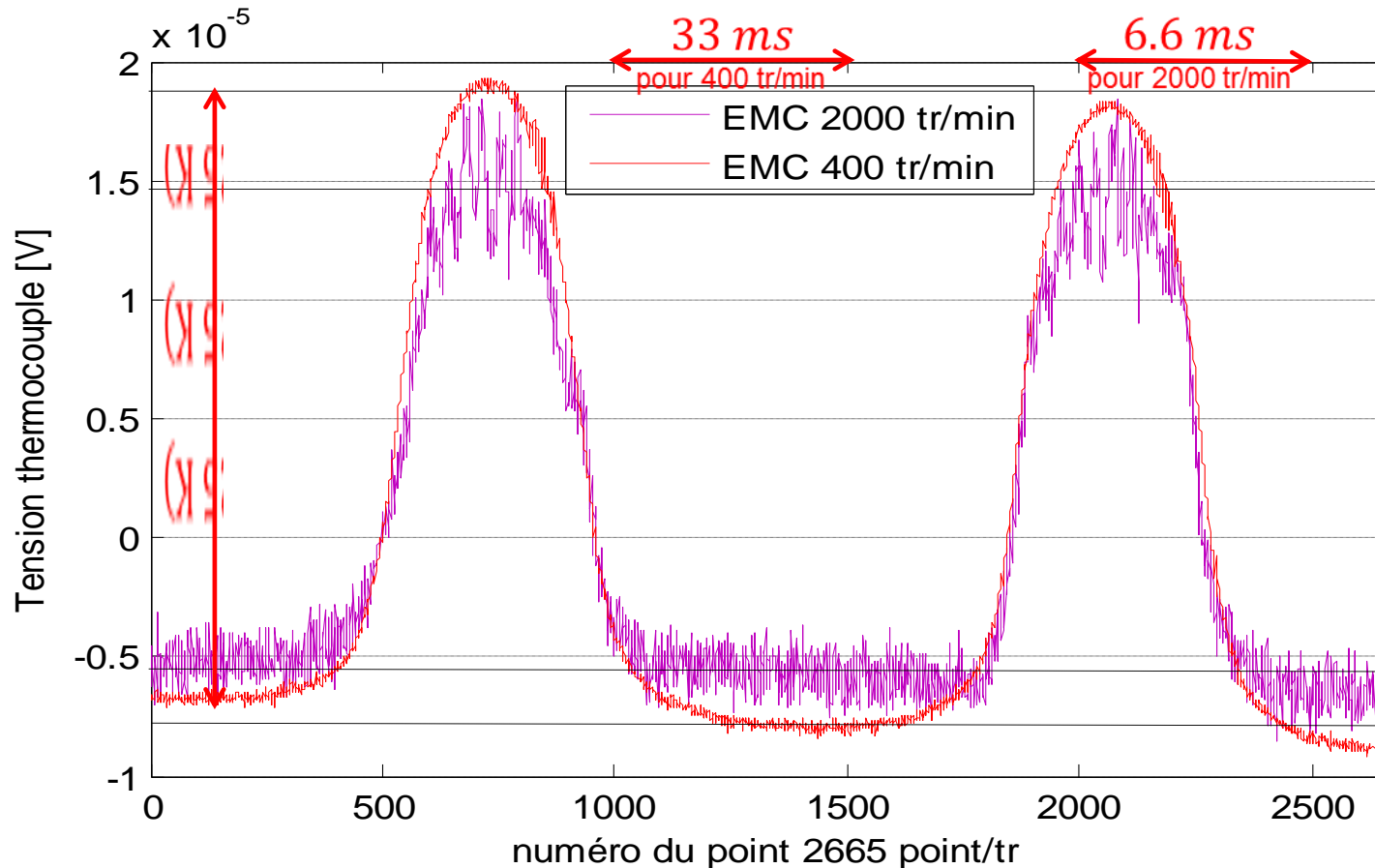
- Use of symmetry properties
 - Induce Voltage (dB/dt) is an odd function
 - $MCE(dB/dt)$ is an even function

Symmetry cancel induced voltage

I. Introduction > II. Experimental setup

Use of symmetry

- Reliable is the sensor of position and the speed are sufficiently accurate



I. Introduction > II. Experimental setup > III. Conclusion

■ Adiabatic temperature change

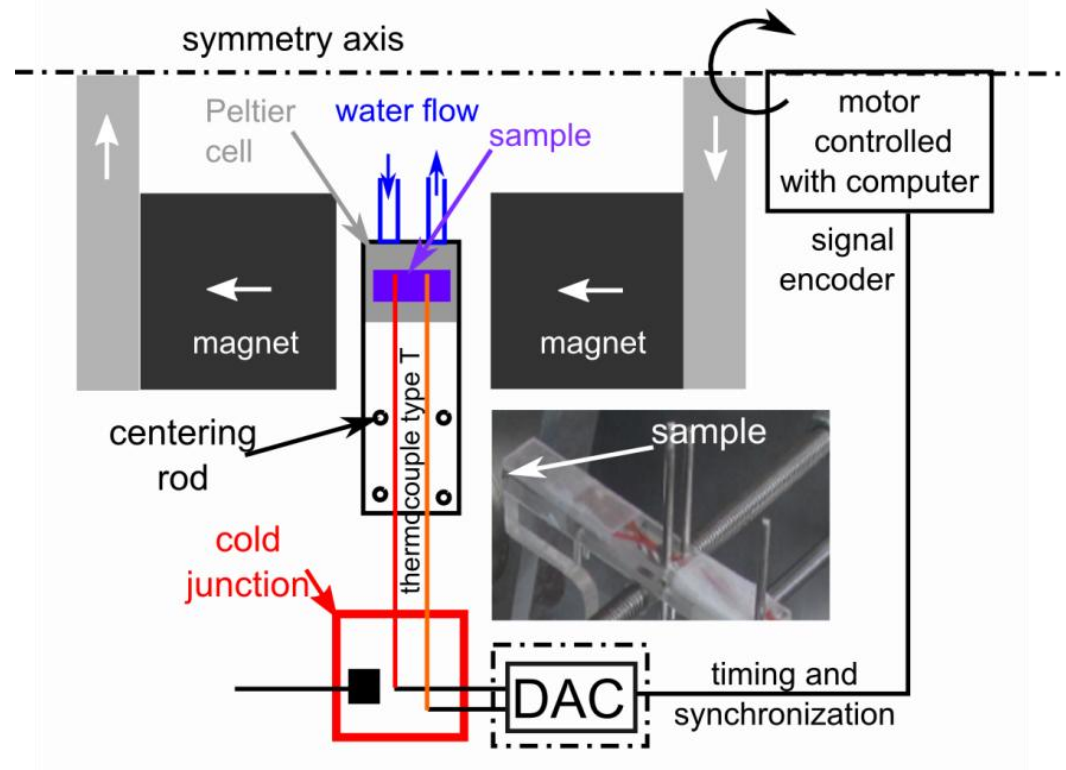
- Affected by the field speed change?

■ Or problem with :

- the temperature measurement
- the internal field

■ Estimation of the heat exchange function of

- the interface
- the material
- the surface finishing



I. Introduction > II. Experimental setup > III. Conclusion

Thanks for your attention

