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# Study of the Laser-Assisted Thermal Hysteresis in FeRh Films

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► **To cite this version:**

Alexis Pecheux, Morgan Almanza, Daniele Fournier, Laura Thevenard, Catherine Gourdon, et al.. Study of the Laser-Assisted Thermal Hysteresis in FeRh Films. Dresden Days on Magnetocalorics 2023, Nov 2023, Dresden, Germany. hal-04287214

**HAL Id: hal-04287214**

**<https://hal.science/hal-04287214>**

Submitted on 15 Nov 2023

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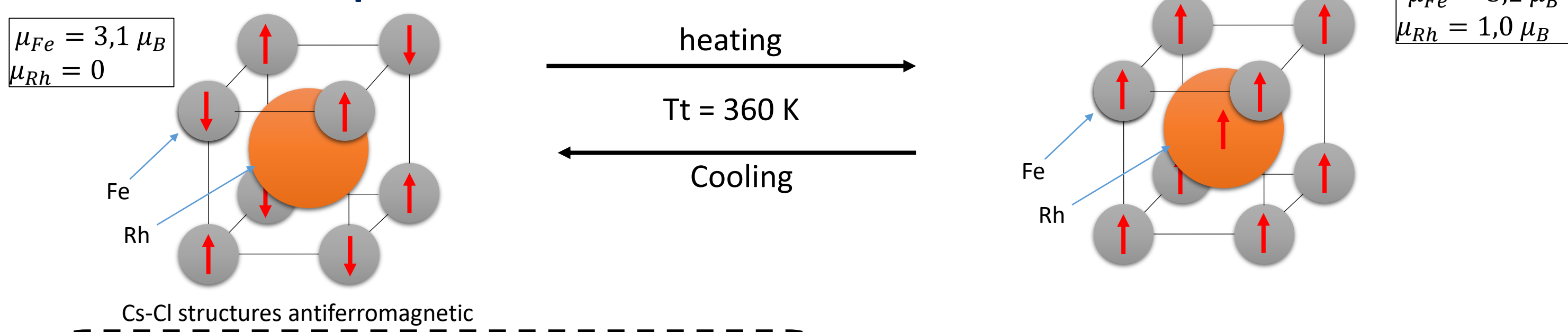
## Abstract

Near equiatomic FeRh alloys, with their close to room temperature antiferromagnetic (AF) to ferromagnetic (FM) magnetostructural transition, have been studied in bulk, and in thin film form. The complex interplay between optical, electronic, magnetic, and structural properties underlying the phase transition makes FeRh a promising multifunctional material with possible applications in fields as different as spintronics, nanomagnetism, and magnetic cooling [1]. Whatever the aimed application, understanding FeRh phase change mechanism, and tackling the associated thermal hysteresis, is one of the key challenge for harnessing its functional properties. Here we study the AF-FM transition using a modulated reflectance experiment [2] with a laser driven phase change taking place at a rather long timescale ( $\mu\text{s}$  range) where only thermal

effects are at play. An optical microscopy setup where a pump and a probe beam (532 nm laser with square modulation at 100 kHz, and 488 nm laser respectively), are focused on a  $2\ \mu\text{m}$  radius spot, is used to measure the material's reflectance. The DC component ( $f=0$ ), and the AC component ( $f=100\text{Hz}$ ) of the reflectance are measured while the temperature of the sample is slowly varied across the transition. The average transition temperature shifts by  $2.2^\circ\text{C}$  per mW of the laser pump and, while the DC component under cooling is unaffected by the pump power, the one under heating merge with the cooling curve when pump power gets above 4 mW. On the other hand, the AC signal, rather weak at low pump power, increases (two orders of magnitude) when pump power gets above 2 mW.

## Introduction

### The first-order phase transition in the FeRh



### Interesting Properties

- Giant Magnetoresistance [3]
- Giant Magnetostriction [4]
- Giant Magnetocaloric effect [4]
- Antiferromagnetic/Ferromagnetic phase transition leading to Heat-Assisted magnetic recording application [5]

### How to study the metamagnetic phase transition?

- We need an order parameter that is a relevant image of the two phase proportion
- We know that there is a difference of reflectance between the two FeRh phase  $R_{AF} > R_{FM}$
- The reflectance is measured over a spot of  $2\ \mu\text{m}$  of Gaussian radius and at each temperature  $T$ , we can extrapolate  $x(T)$  from the following equation:  $R = x R_{FM} + (1 - x) R_{AF}$
- Where  $R$  is the reflectance,  $x$  the surface phase fraction,  $R_{FM}$  and  $R_{AF}$  are the reflectance of FM and AFM phases
- This allows to study the phase transition kinetics at local scale and the related thermal hysteresis

### Sample Preparation [6]

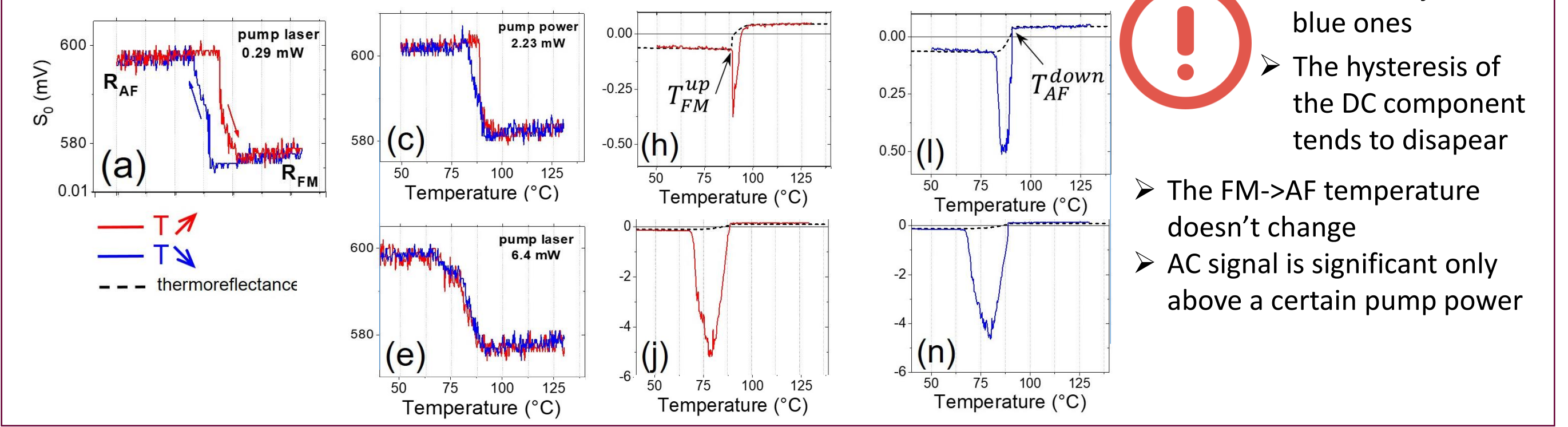
- Growth of FeRh at  $430^\circ\text{C}$  after pre-heating the substrate with magnetron sputtering
- The sample is annealed in the vacuum at  $780^\circ\text{C}$  during 80 min
- Thin protection layer in Pt of 2 nm has been sputtered below  $120^\circ\text{C}$

### Advantage of optical methods

- High spatial resolution that allow local probing of the thermal hysteresis
- High band-pass limited only by the photodiode that allow to study high dynamic behavior
- Possibility for fast heating and cooling by mean of pump laser

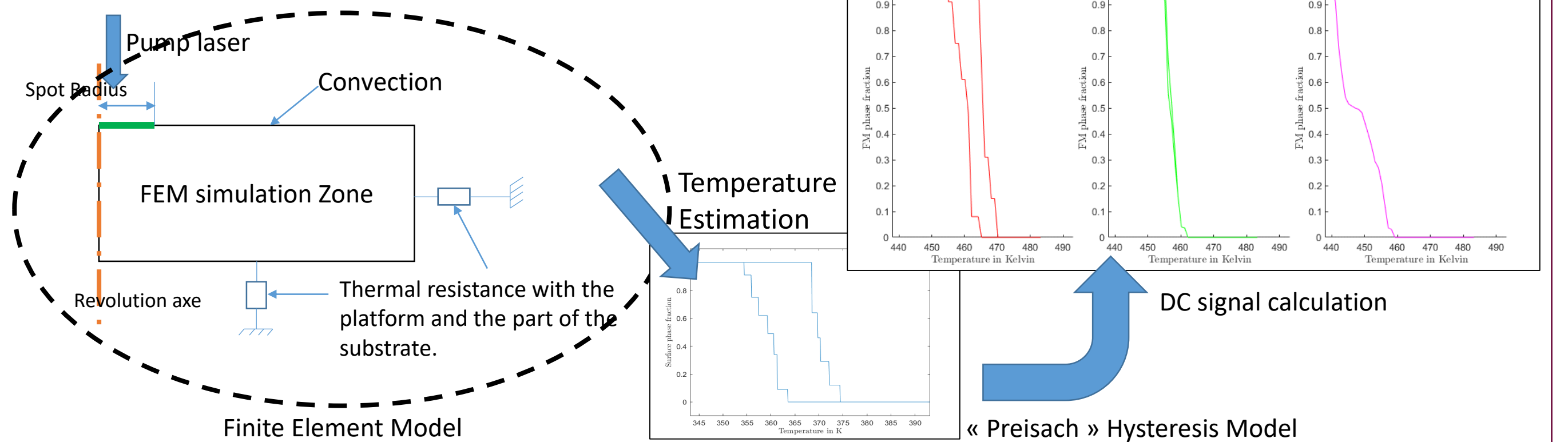
## Laser-assisted thermal hysteresis

### Thermal Hysteresis with modulated pump at 100 kHz



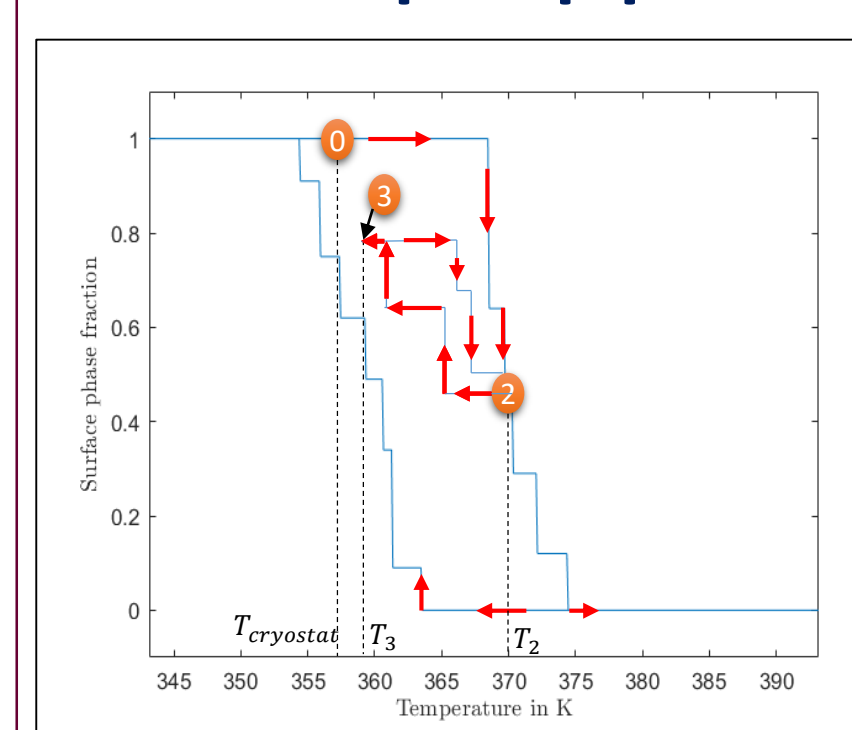
## Thermal hysteresis modeling

### Are we observing hysteresis features?

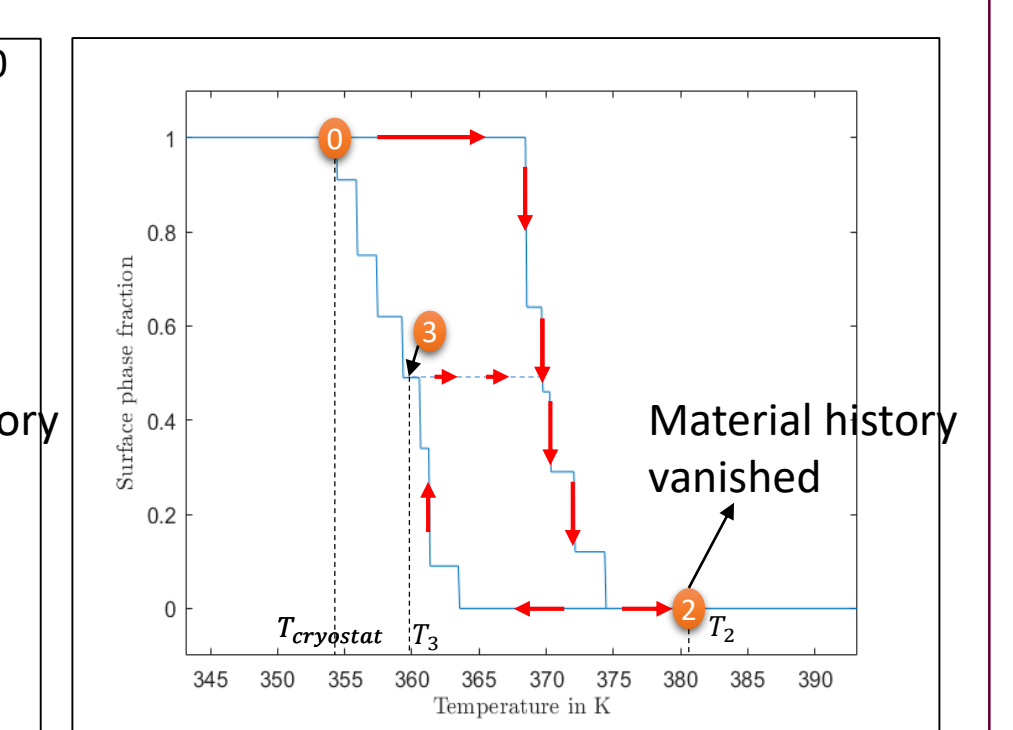


## Interpretation

### For low pump power

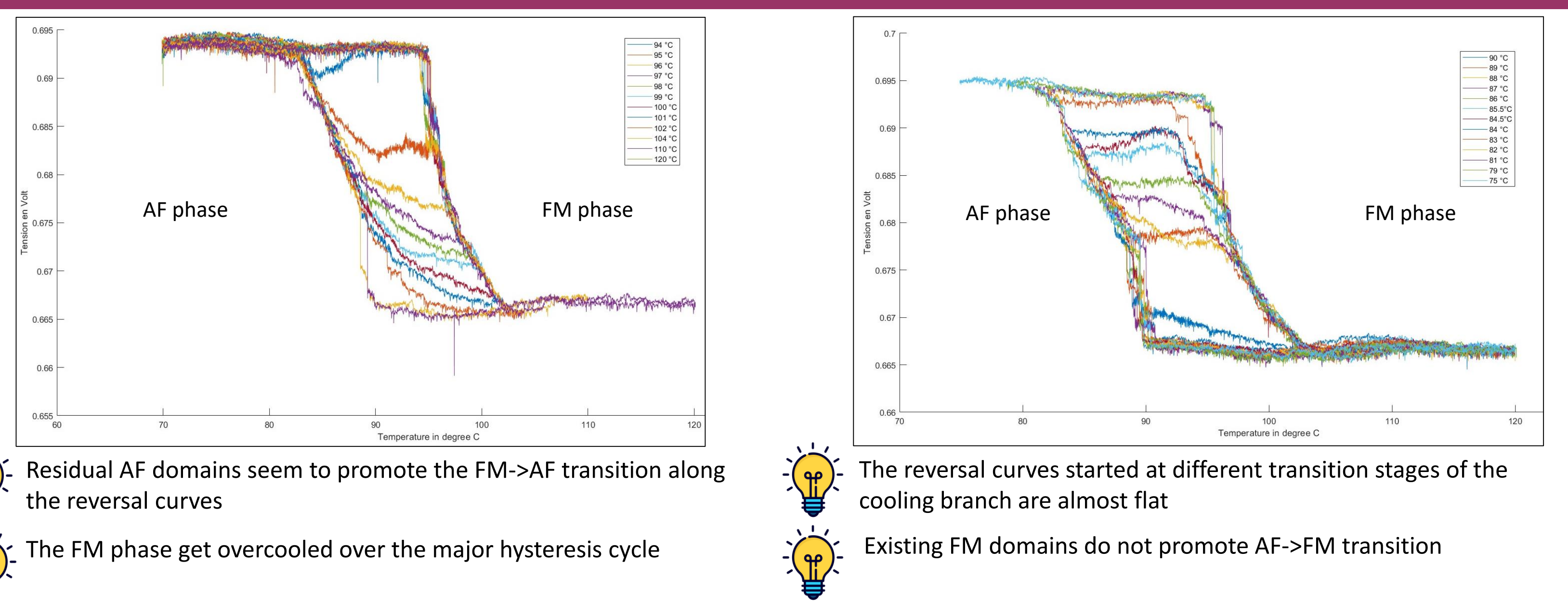


### For high pump power

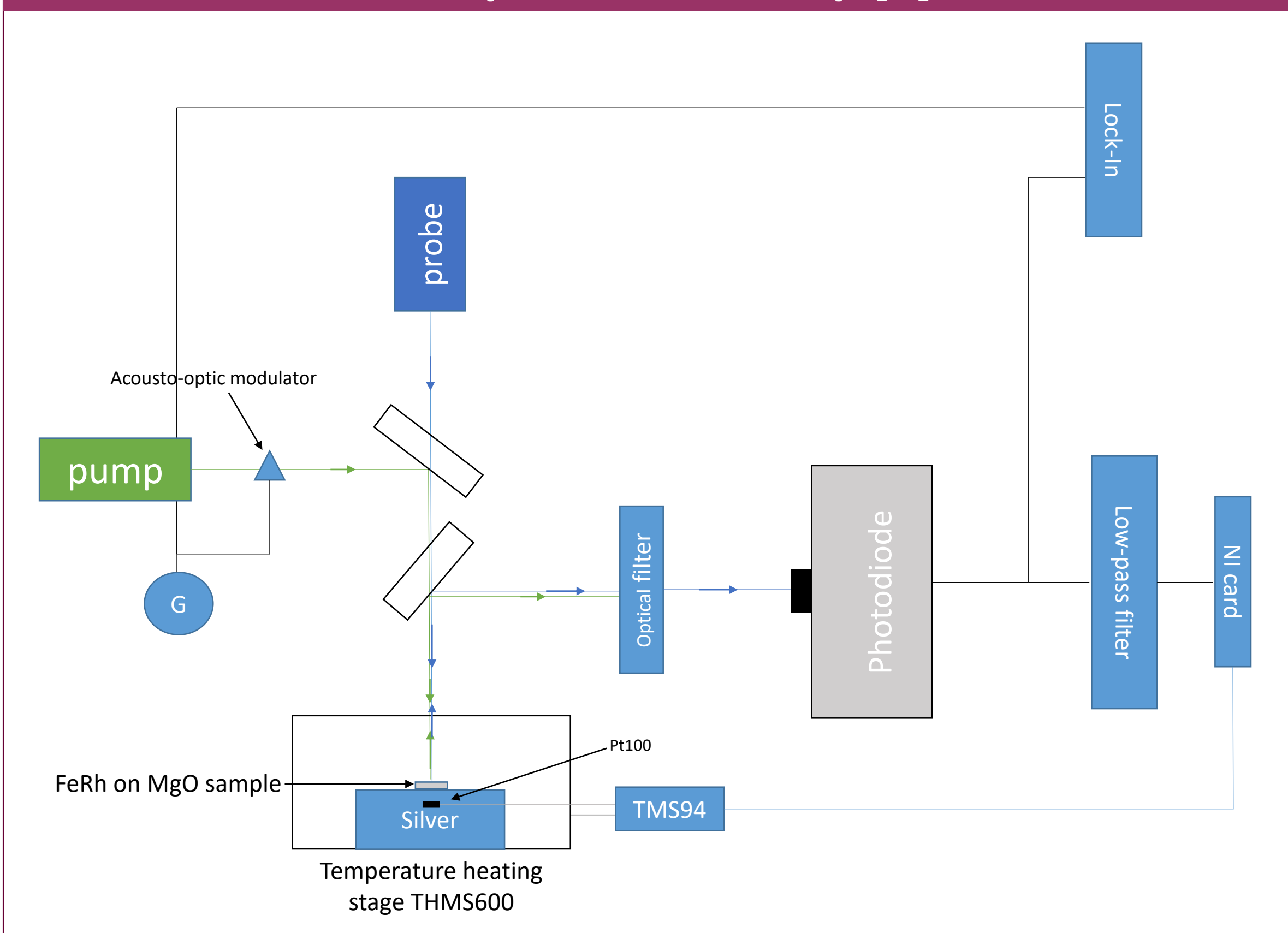


Those curves are based on our Preisach model guided by the first and second order reversal curves

## Laser-free thermal reversal and hysteresis



## Experimental Setup [2]



## Perspectives

- Study the phase transition on the entire surface and in the film volume to probe the hysteresis properties at multiples scale to have a better understanding of the coupling involves inside the phase transition
- Further investigation without the lock-in
- Introduce a magnetic field in order to probe the impact of magnetic field on the phase transition kinetics

## References

- [1] : L. Lewis, et al., J.Phys. D: App. Phys. 49, 323002 (2016)  
 [2] : D. Fournier, M. Marangolo, and C. Fretigny, J. Appl. Phys., 128, 241101 (2020)  
 [3] : Uhlíř, V., Arregi, J. A., and Fullerton, E. E. (2016) Nat.Com, 7(1), 13113

[4] : Stern-Taulats, et al. Phys Rev B, 89(21), 214105.

[5] : Jan-Ulrich Thiele, Stefan Maat, Eric E. Fullerton, Appl. Phys. Lett. 28 April 2003; 82 (17): 2859–2861.

[6] : Arregi, J. A., Caha, O., and Uhlíř, V. (2020). Phys Rev B, 101(17), 174413.

## Acknowledgments

We want to thanks Mathieu Bernard and Maxime Vabre of the INSP for their technical help This research has been carried out thanks to LabEx LaSIPS (ANR-10-LABX-0032-LaSIPS) FLIGHTPATH in the « Investissement d'avenir » program and the Agence Nationale de la recherche (contract ANR ACAF 20-CE30-0027). We also want to thanks the Czech-NanoLab support by MEYSCR(LM202351) for the growth and the sample preparation