

# DESENVOLVIMENTO DE SENSORES DE CAMPO MAGNÉTICO NANOESTRUTURADOS DE ALTA PERFORMANCE

Paulo Davi Borges Esteves

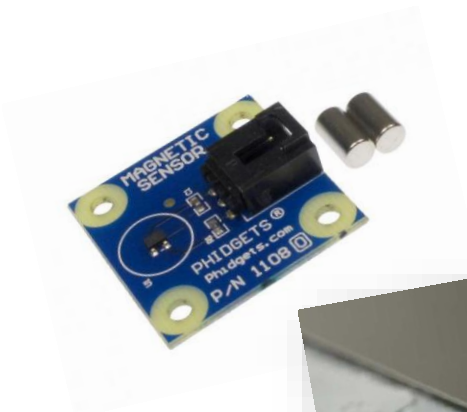
Orientador: Rubem Luís Sommer

Co-orientador: Bruno Gomes da Silva



# MOTIVAÇÃO

- Atuação dos sensores magnéticos em diversos temas tecnológicos:
  - Indústrias aeronáutica, aeroespacial, automobilística
  - Eletrônica: Gravação e leitura magnética



# MAGNETORRESISTÊNCIA E MAGNETOIMPEDÂNCIA

Variação de resistência (impedância) ao ser aplicado um campo magnético externo.

Tem por formulação:

$$MR(\%) = \frac{R(H) - R(H_s)}{R(H_s)} \times 100\%$$

$$MI(\%) = \frac{Z(H) - Z(H_s)}{Z(H_s)} \times 100\%$$



# Métodos – Preparação de amostras

## *Magnetron Sputtering*

### Parâmetros:

$$P_{trabalho} = 5 \text{ mtorr}$$

$$P_{base} = 1 \times 10^{-7} \text{ torr}$$

$$\Phi_{argônio} = 50 \text{ sccm}$$

$$H_{aplicado} \sim 200 \text{ Oe}$$

### Amostras produzidas

1.  $[\text{Ti}(2.5\text{nm})/\text{Py}(10\text{nm})]_{10}$
2.  $[\text{Ti}(2.5\text{nm})/\text{Py}(10\text{nm})]_{50}$
3.  $[\text{Pt}(2.5\text{nm})/\text{Py}(10\text{nm})]_{10}$
4.  $[\text{Pt}(2.5\text{nm})/\text{Py}(10\text{nm})]_{50}$
5.  $[\text{Pt}(1.25\text{nm})/\text{Ti}(1.25\text{nm})/\text{Py}(10\text{nm})]_{10}$
6.  $[\text{Pt}(1.25\text{nm})/\text{Ti}(1.25\text{nm})/\text{Py}(10\text{nm})]_{50}$

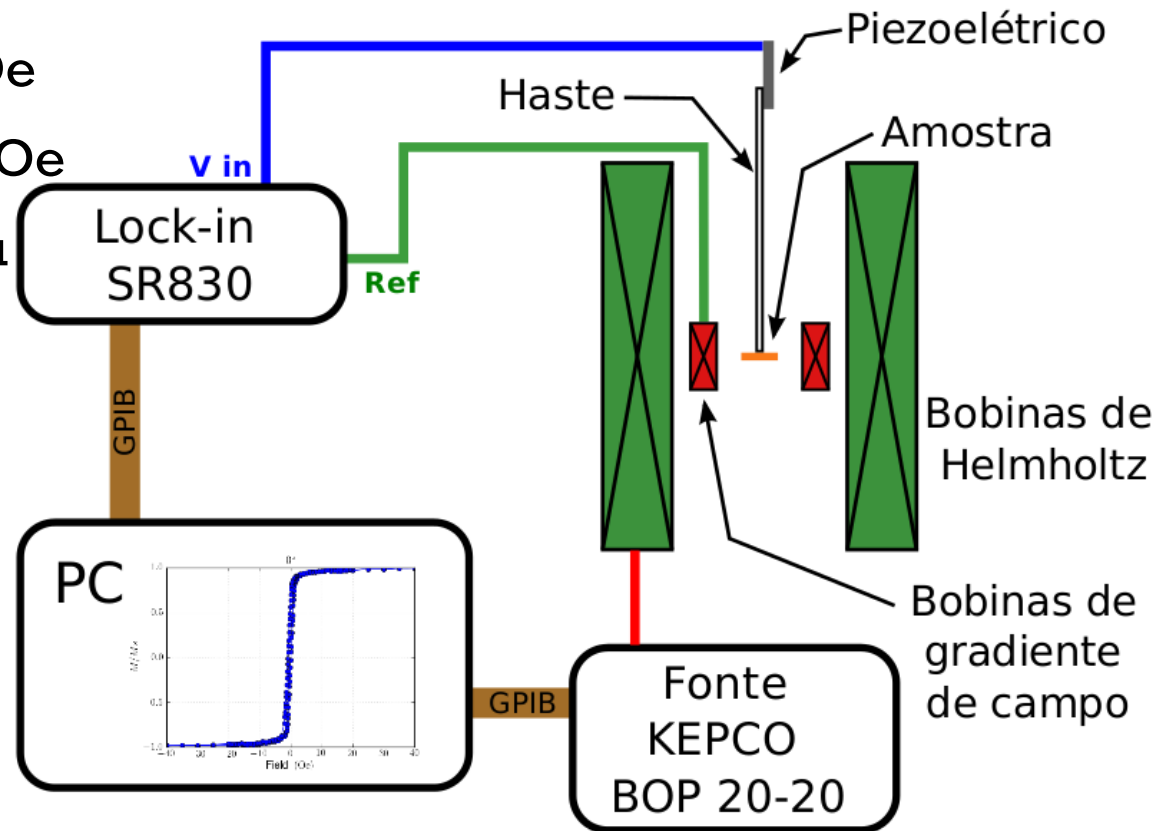
$$\text{Py} = \text{Ni}_{81}\text{Fe}_{19}$$



# Métodos – Curvas de magnetização

## Magnetômetro de gradiente de campo alternado (AGFM)

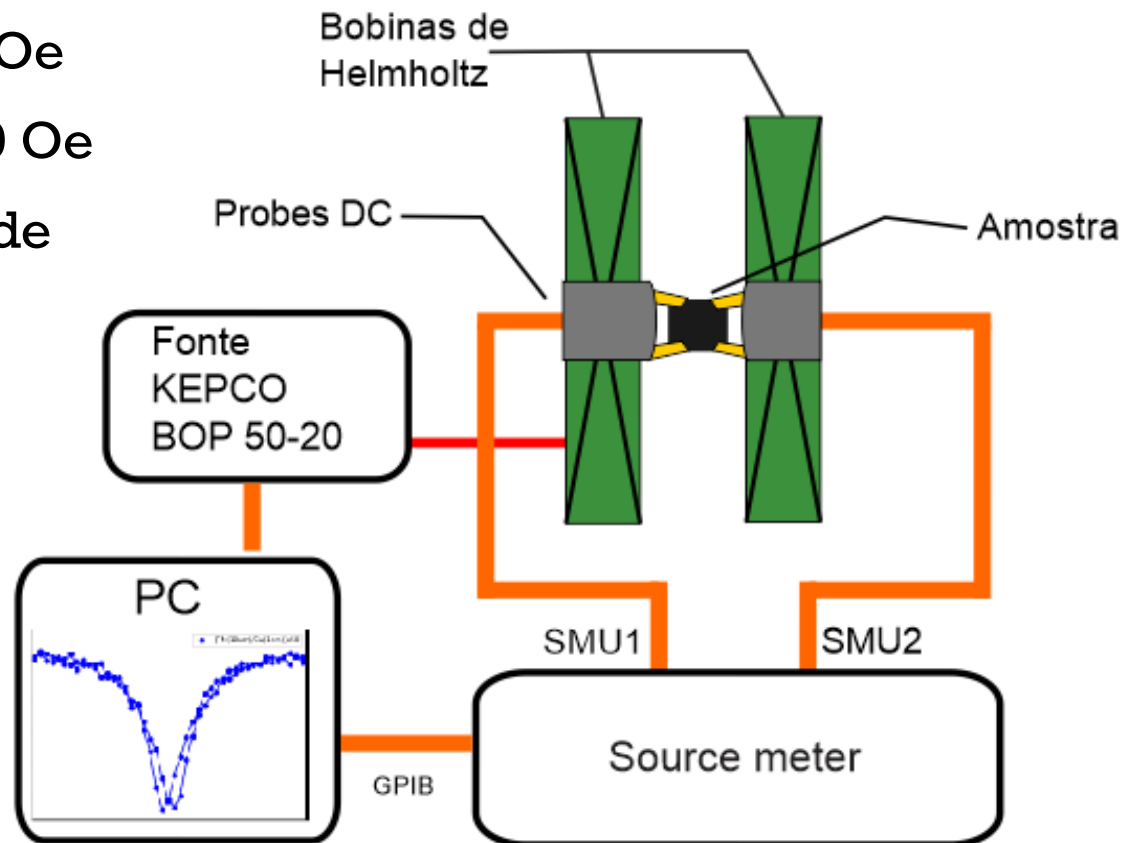
- ❖  $M \times H$
- ❖ Resolução de campo – 0,01 Oe
- ❖ Amplitude de campo de 600 Oe
- ❖ Sensibilidade de até  $10^{-7}$  emu



# Métodos – Medidas de magnetorresistência

## Sistemas de MR por quatro pontas

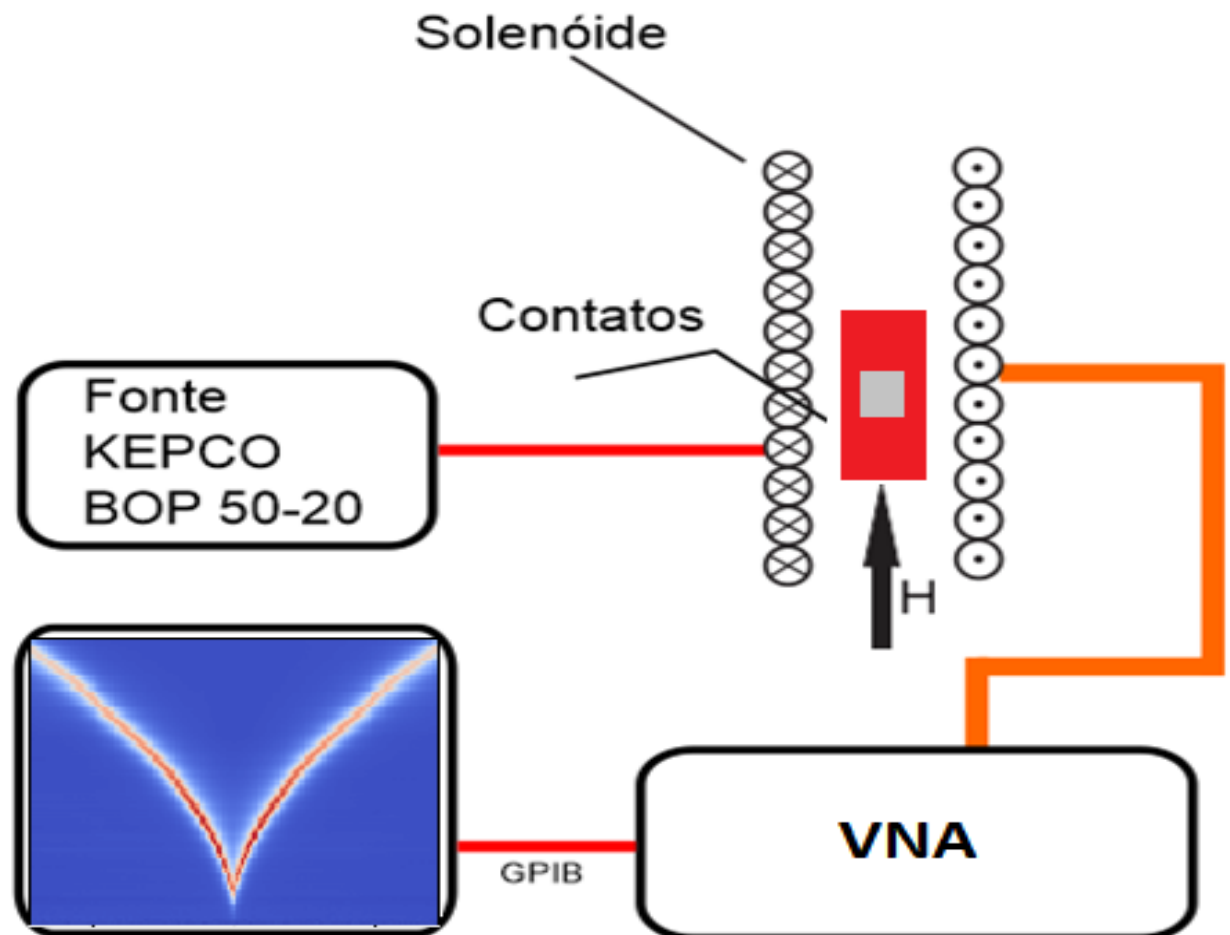
- ❖  $R \times H$
- ❖ Resolução de campo – 0,01 Oe
- ❖ Amplitude de campo de 350 Oe
- ❖ Medidas de alta sensibilidade



# Métodos – Ressonância Ferromagnética

## Analizador Vetorial de Rede

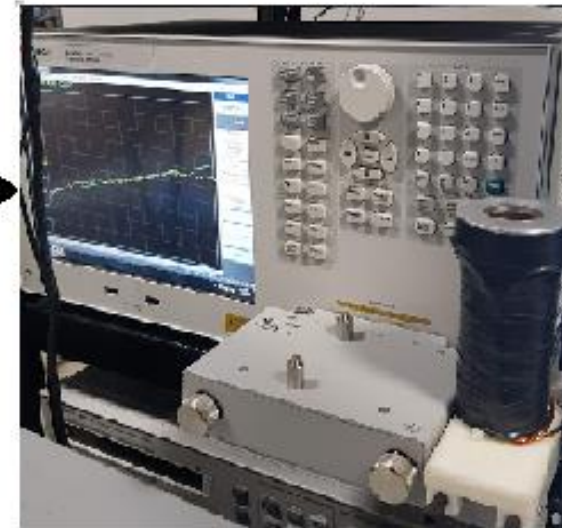
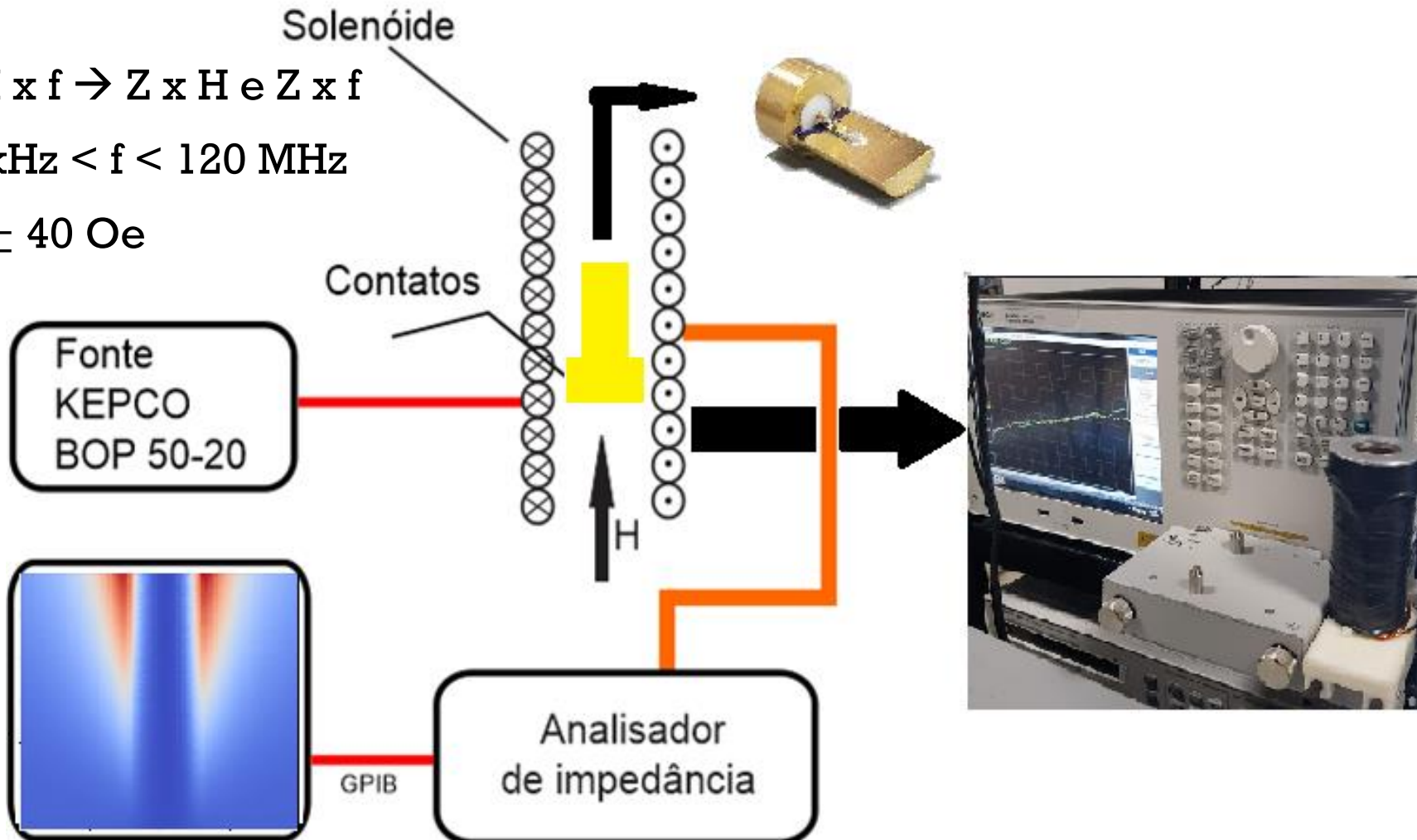
- ❖  $Z \times H \times f \rightarrow Z \times H \text{ e } Z \times f$
- ❖  $100 \text{ MHz} < f < 10 \text{ GHz}$
- ❖  $H = \pm 720 \text{ Oe}$



# Métodos – Medidas de magnetoimpedância

## Sistema de medida MI por analisador de impedância

- ❖  $Z \times H \times f \rightarrow Z \times H \text{ e } Z \times f$
- ❖  $100 \text{ kHz} < f < 120 \text{ MHz}$
- ❖  $H = \pm 40 \text{ Oe}$



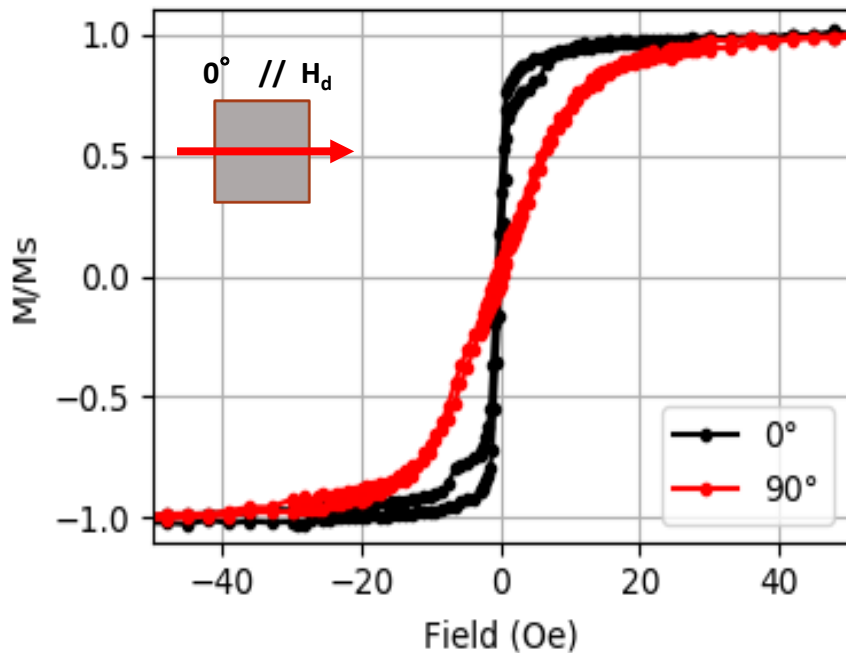


# RESULTADOS

[ Ti / Py ] x 50

Curva de magnetização:

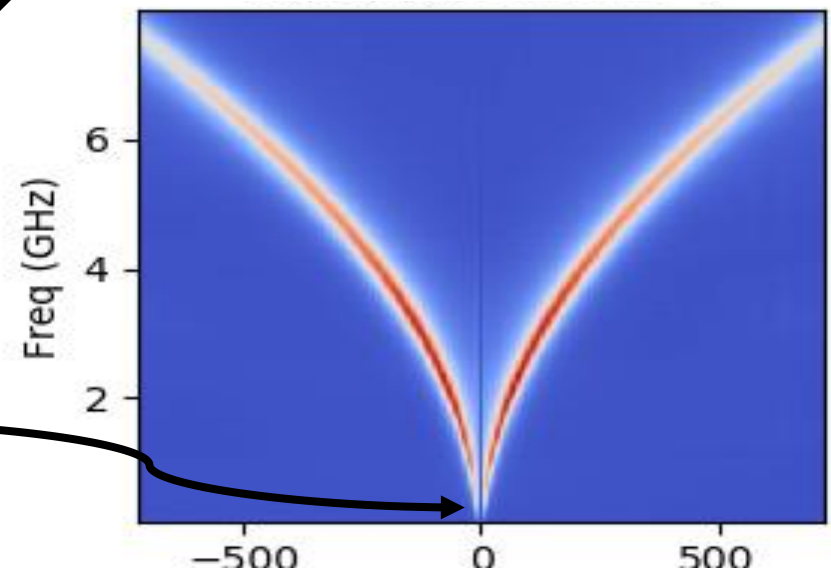
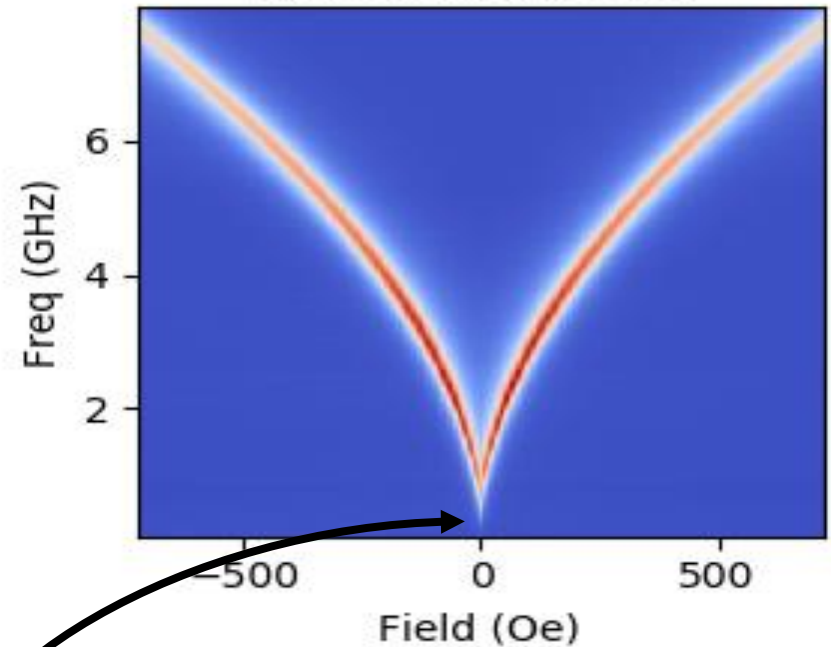
[Ti(2.5)/Py(10)]x50



As medidas em  $90^\circ$  possuem resultados em frequências menores

FMR

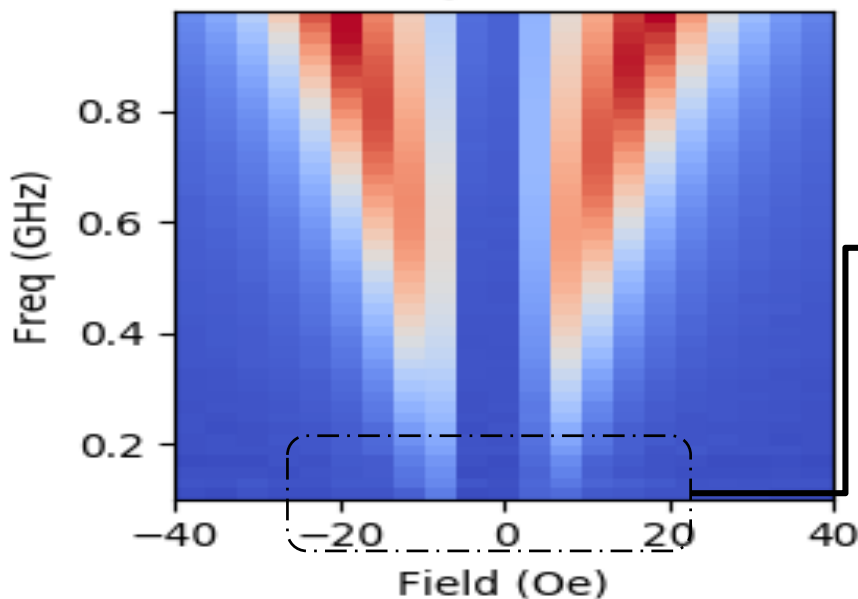
[Ti(2.5)/Py(10)]x50 ( $0^\circ$ )



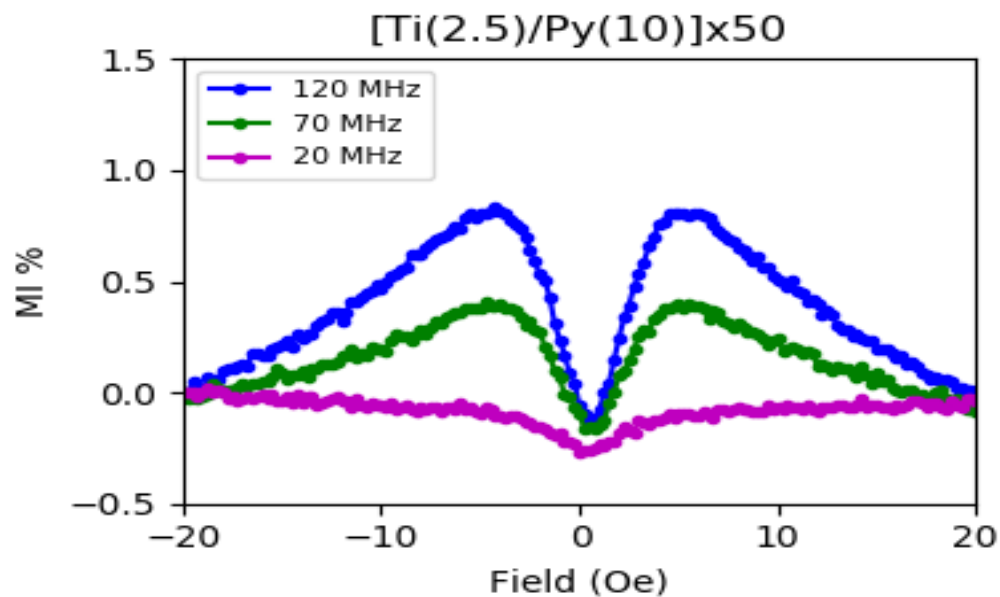
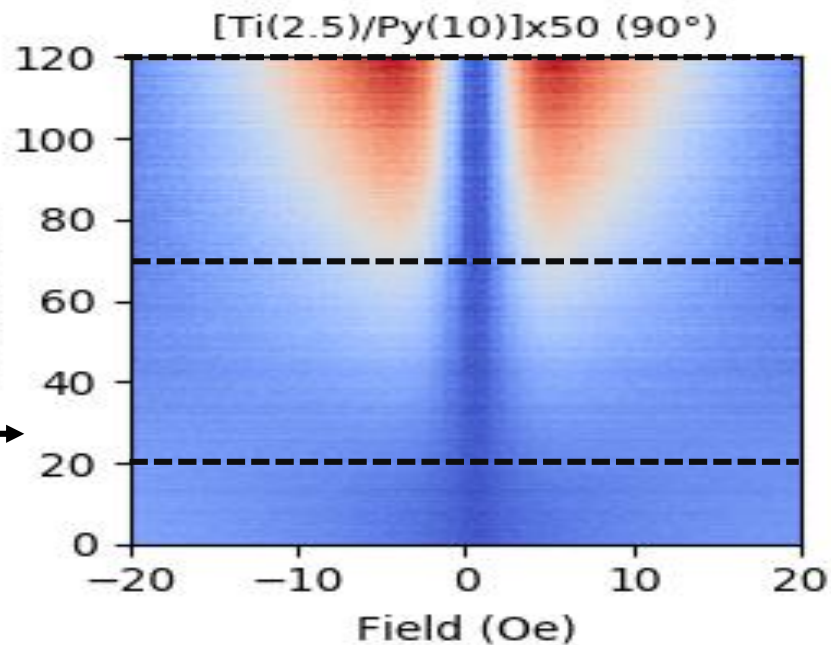
# RESULTADOS

Aplicando um Zoom:

[Ti(2.5)/Py(10)]x50 (90°)



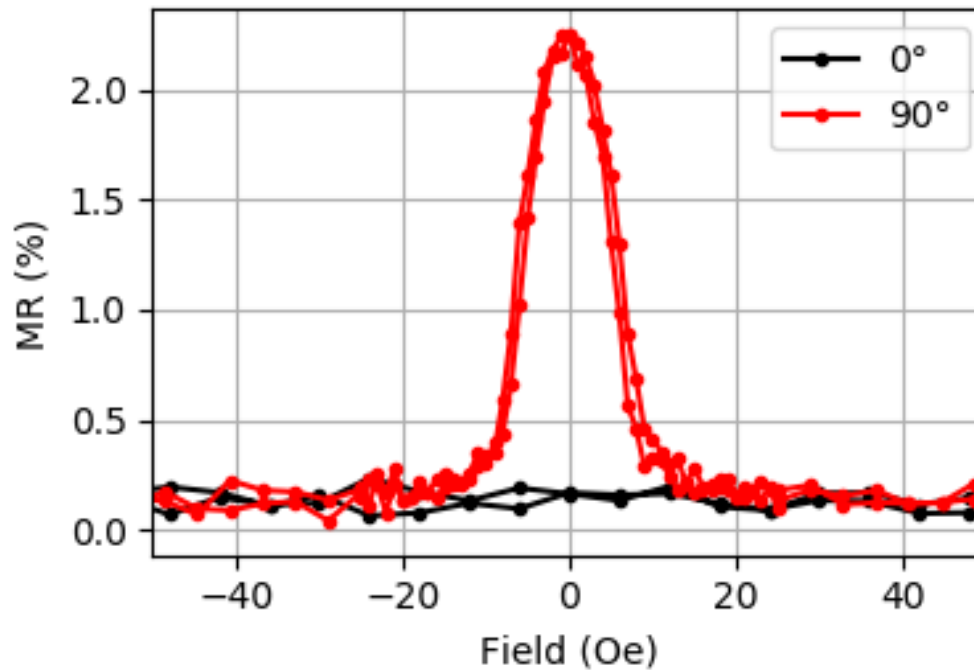
Freq (MHz)



# RESULTADOS

Magnetorresistência

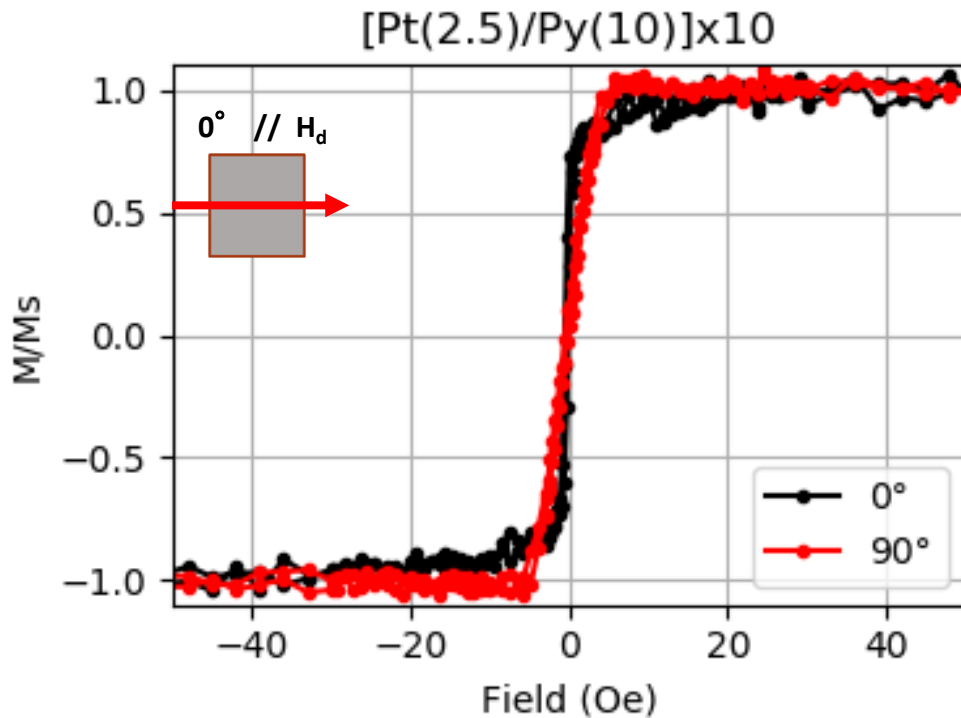
[Ti(2.5)/Py(10)]x50



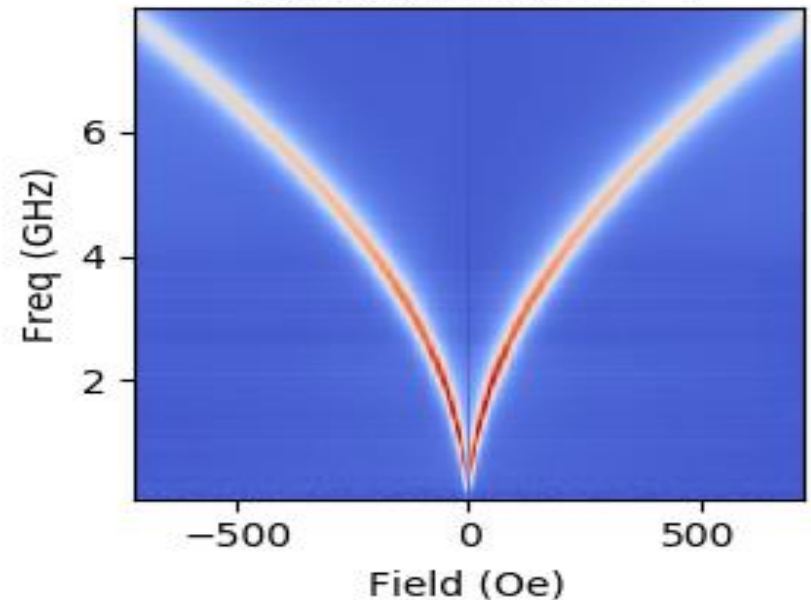
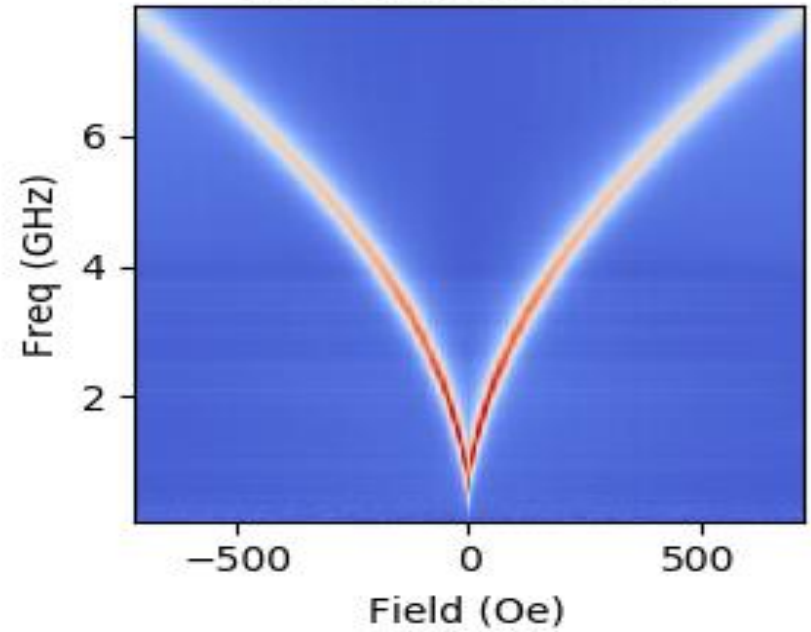
# RESULTADOS

[ Pt / Py ] x 10

Curva de magnetização:



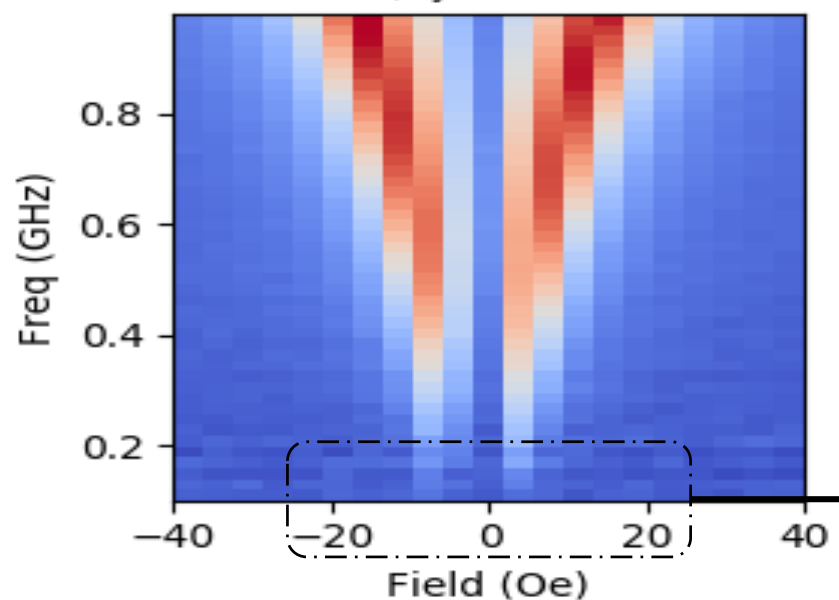
FMR  
[Pt(2.5)/Py(10)]x10 (0°)



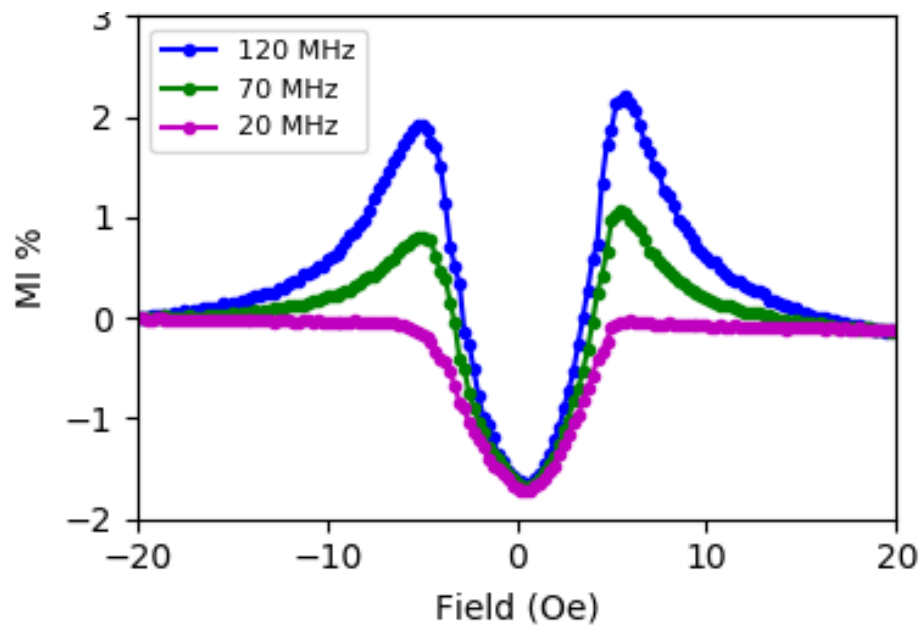
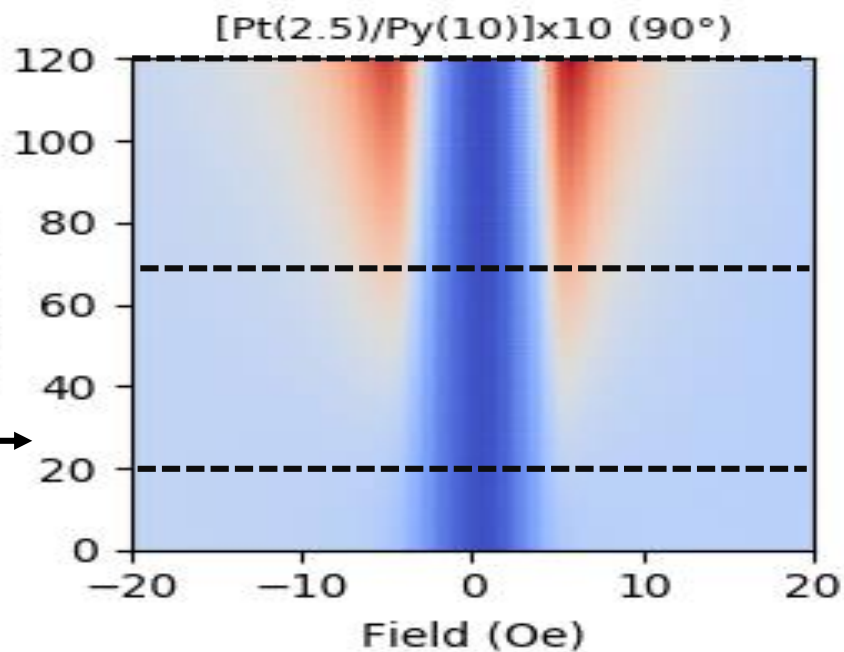
# RESULTADOS

Aplicando um Zoom:

[Pt(2.5)/Py(10)]x10 (90°)

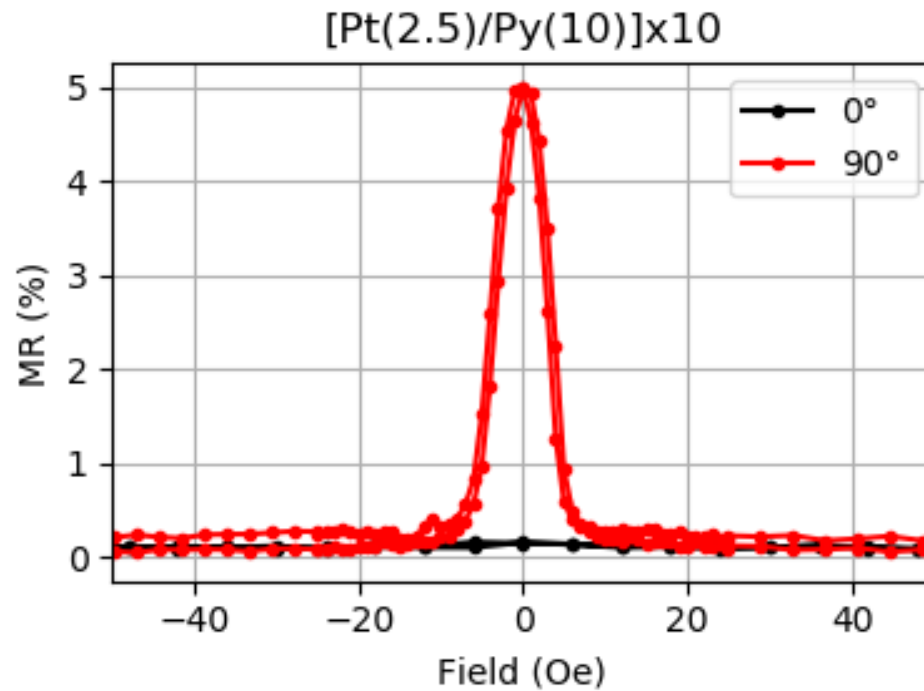


Freq (MHz)



# RESULTADOS

## Magnetorresistência



# CONCLUSÕES

- Conseguiu-se alcançar bons sinais em baixas frequências, com amostras de diferentes construções
- Testou-se o projeto do sistema de análise de impedância com sucesso

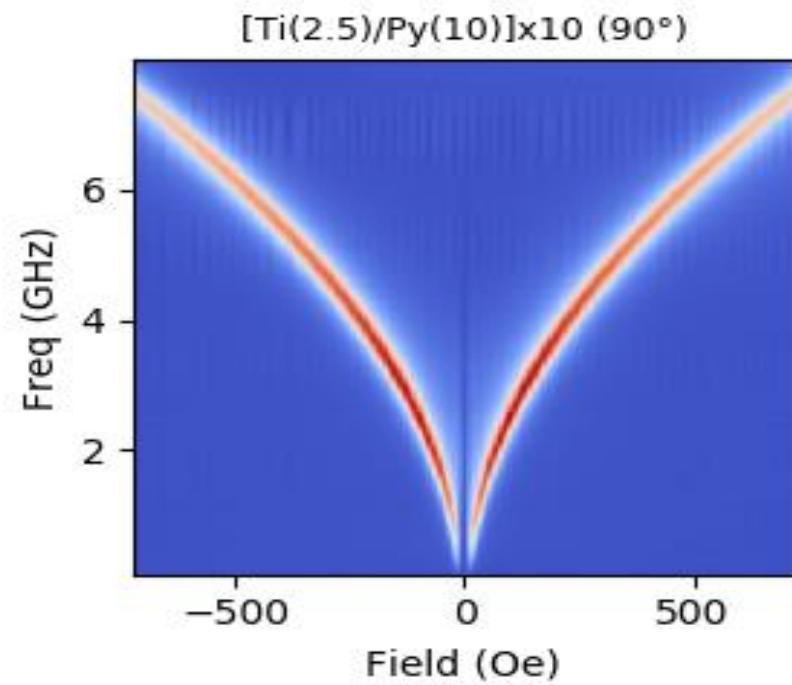
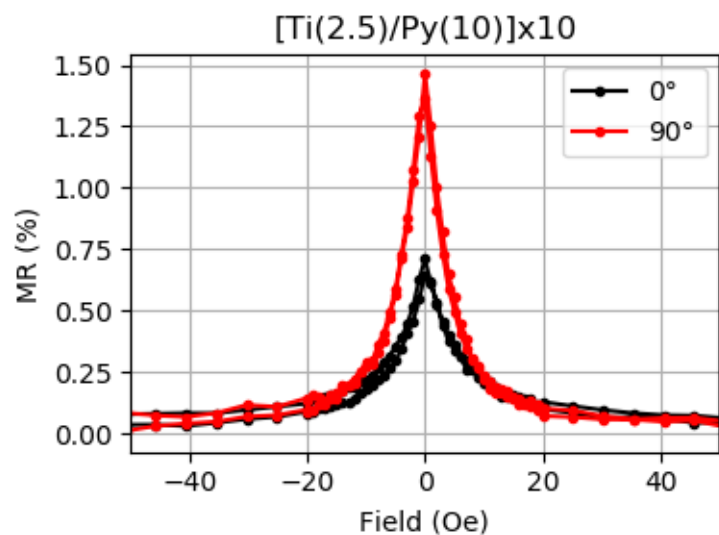
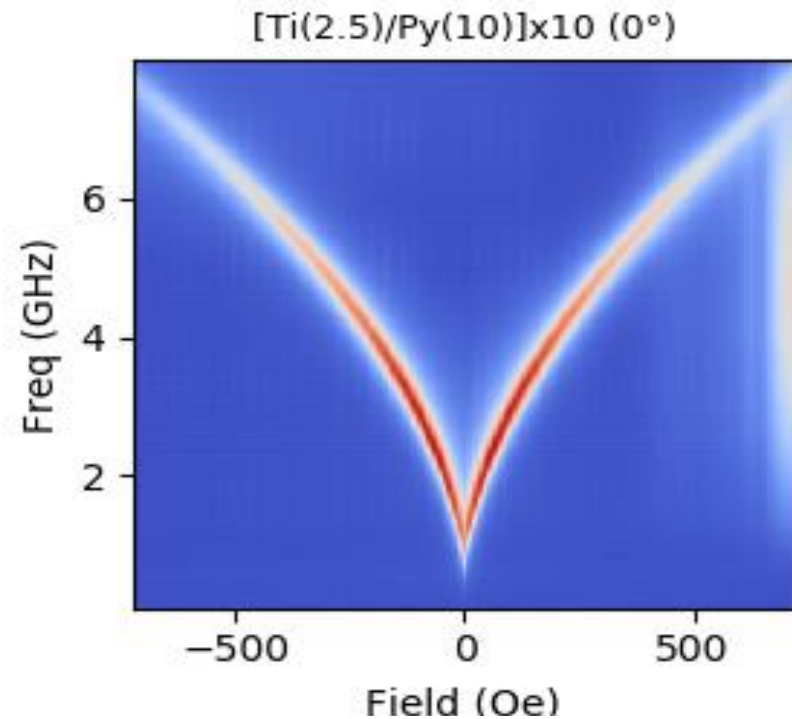
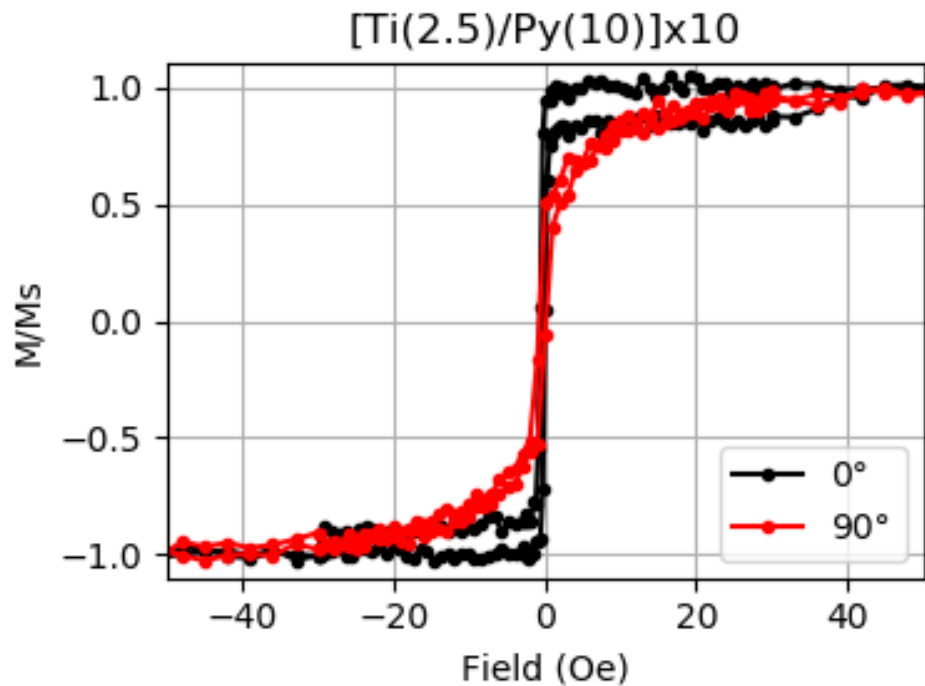
## Agradecimentos



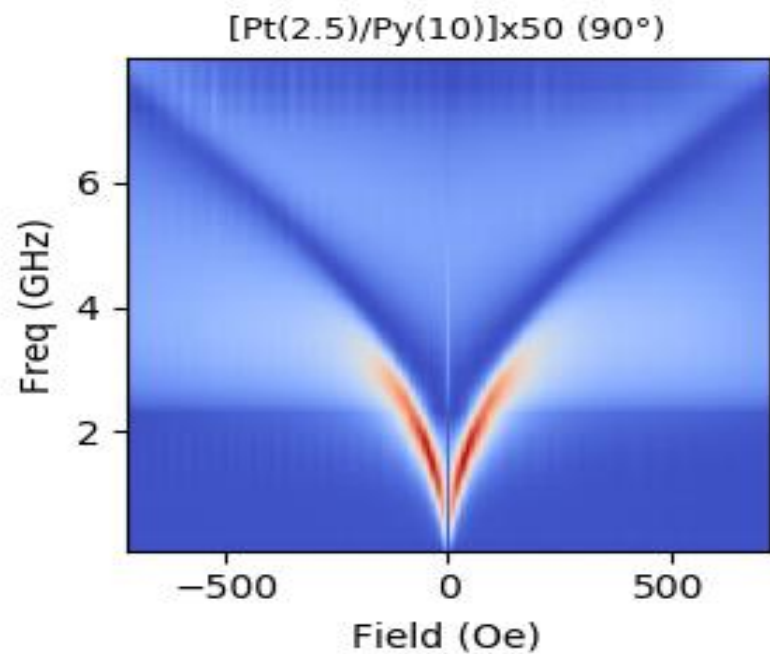
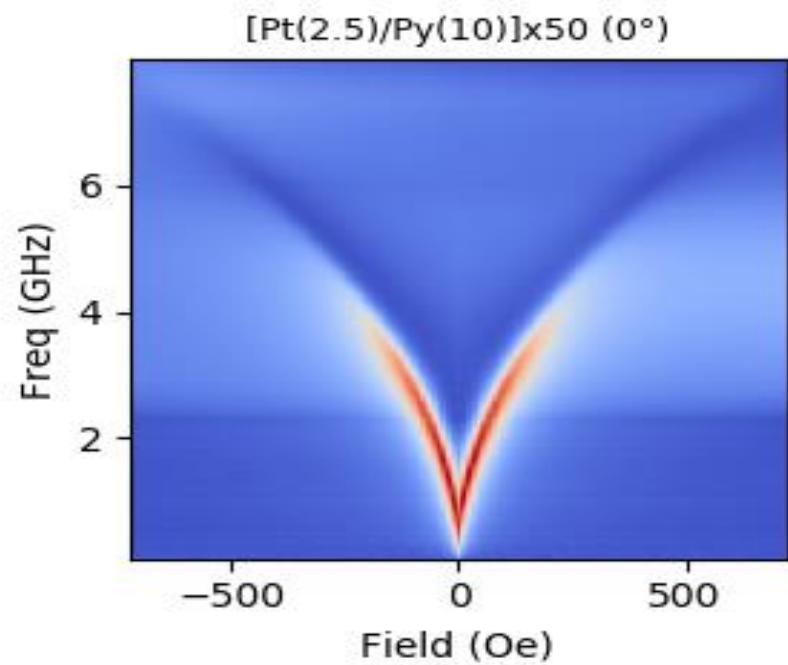
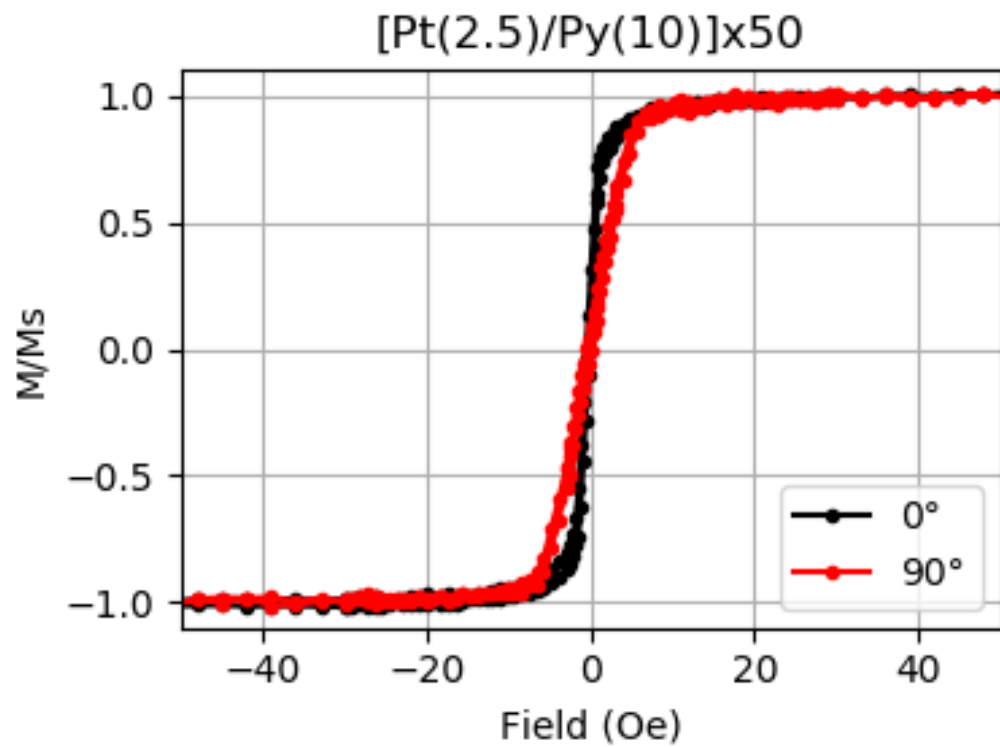


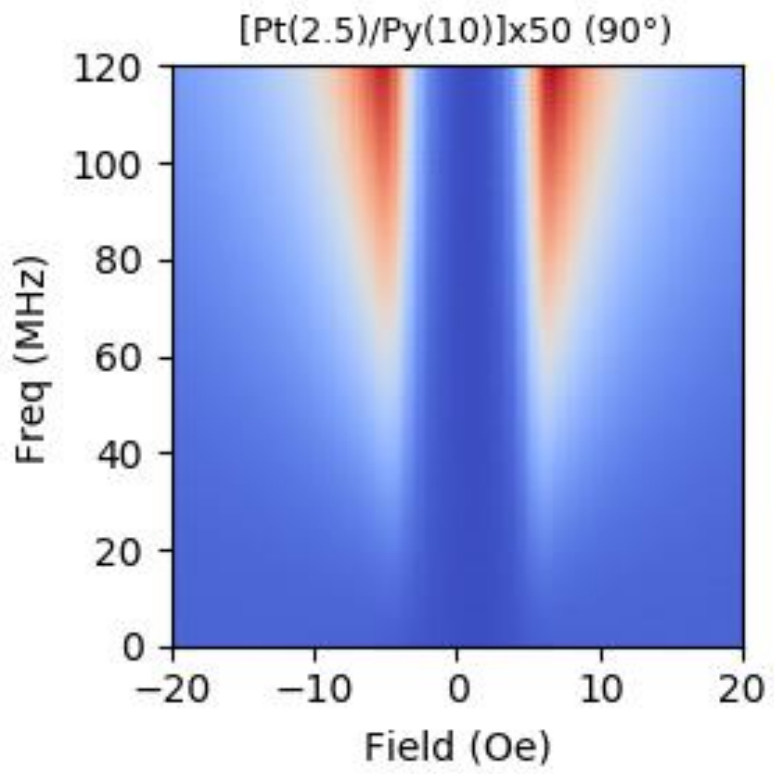


# [Ti / Py] x 10

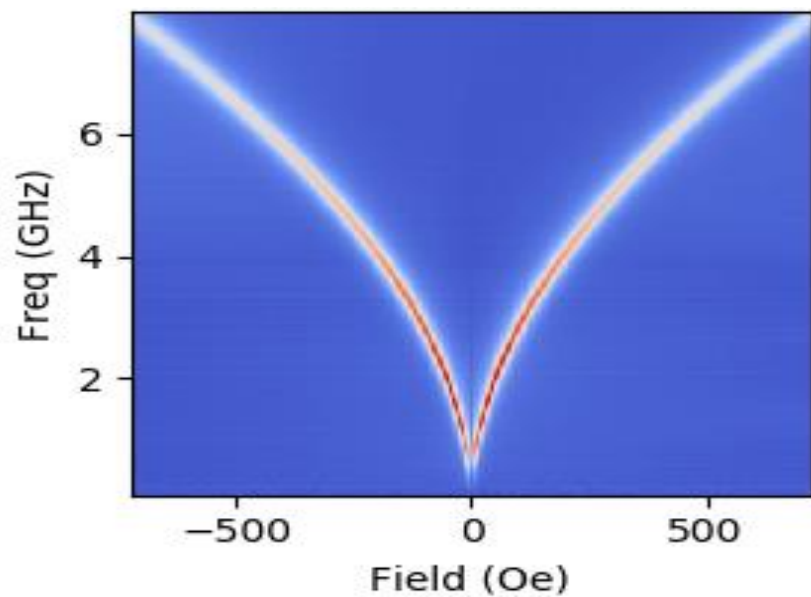
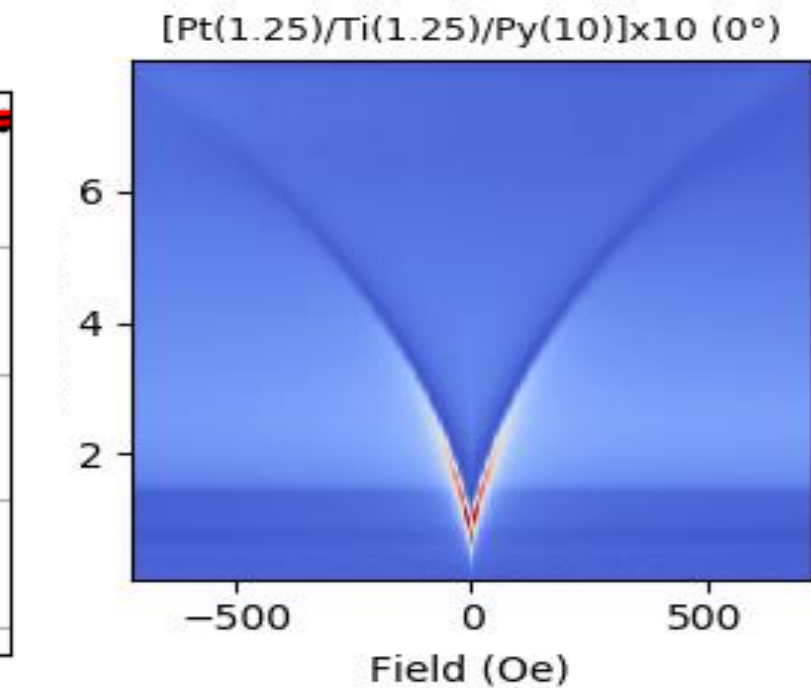
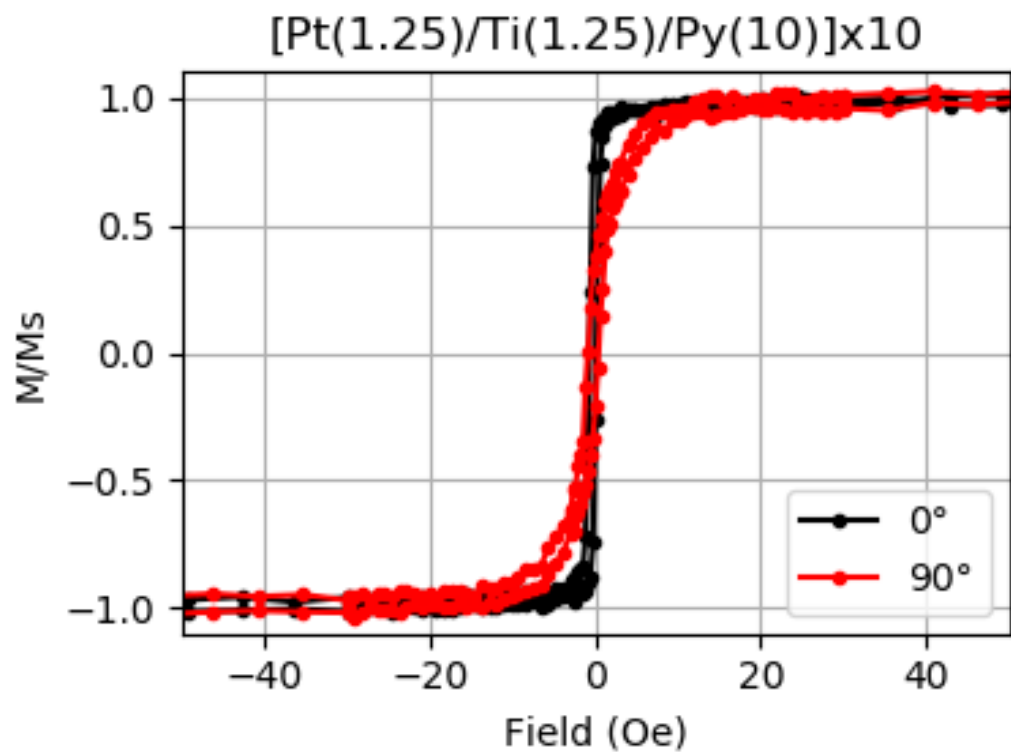


**[ Pt / Py ] x 50**

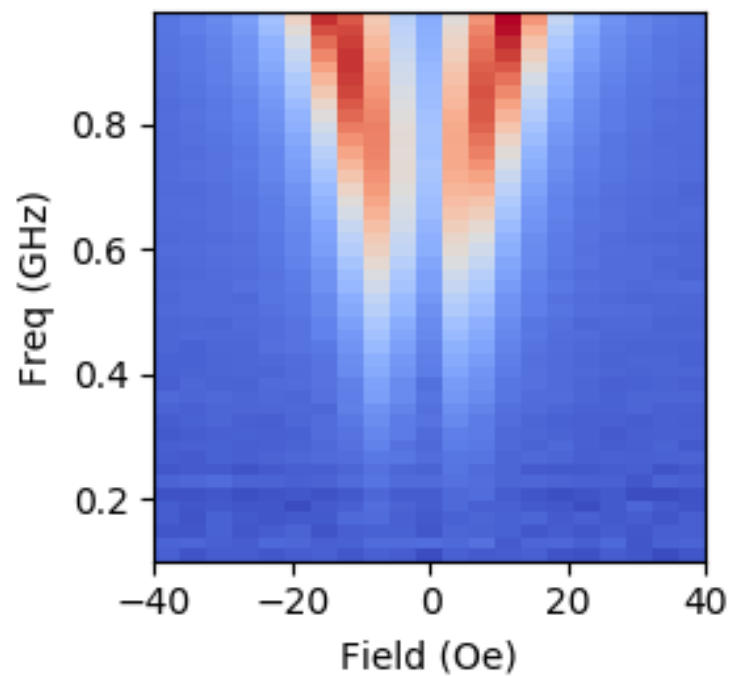




**[ Pt / Ti / Py ] x 10**



[Pt(1.25)/Ti(1.25)/Py(10)]x10 (90°)



# [ Pt / Ti / Py ] x 50

