

# Giant anisotropic Gilbert damping in single crystal CoFeB(001) films



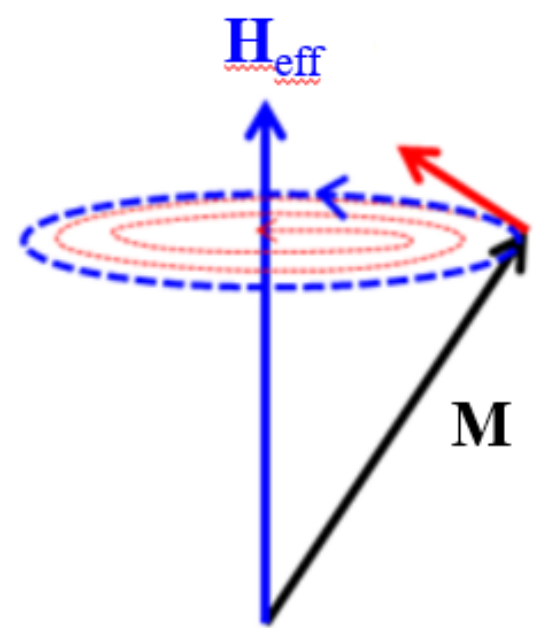
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## Introduction

### 1. Gilbert damping

**Damping**  $\Rightarrow$  a key parameter for spin dynamics



Landau-Lifshits-Gilbert equation:

$$\frac{d\mathbf{M}}{dt} = -\gamma \mathbf{M} \times \mu_0 \mathbf{H}_{\text{eff}} + \frac{\alpha}{|\mathbf{M}|} \mathbf{M} \times \frac{d\mathbf{M}}{dt}$$

$\alpha$ - Gilbert damping

- ✓ Magnetization switching
- ✓ Domain wall motion
- ✓ Spin wave propagation

### 2. Anisotropic Gilbert damping

BCC-structure single crystal CoFe(001)

◆ Giant damping anisotropy

$$\alpha_{(100)}/\alpha_{(110)} = 440\%$$

Calculation: Interface Rashba effect

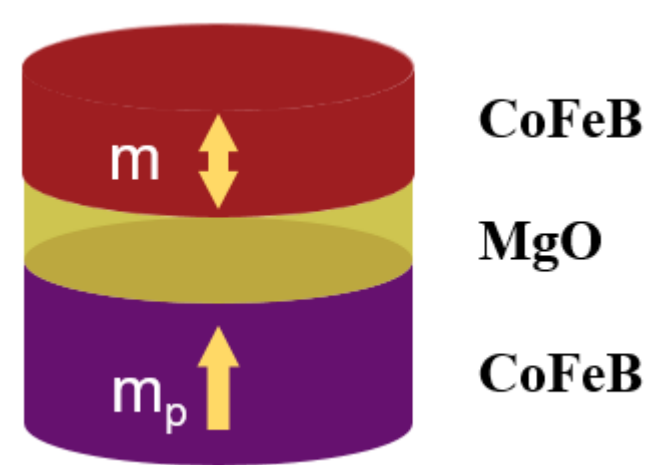
➤ More magnetic systems with anisotropic damping

### 3. CoFeB

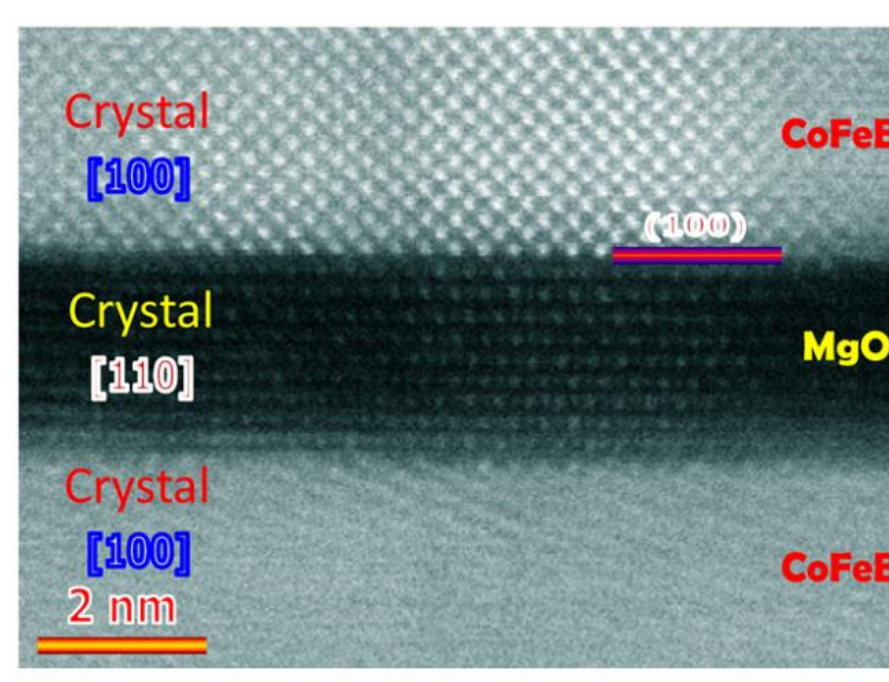
**CoFeB**  $\Rightarrow$  a promising ferromagnetic material

■ Magnetic tunnel junction

■ STEM image:



CoFeB Structure after annealing:  
**Textured or Single Crystal**



Z. C. Wang et al., Nano Lett. 16, 1530 (2016)

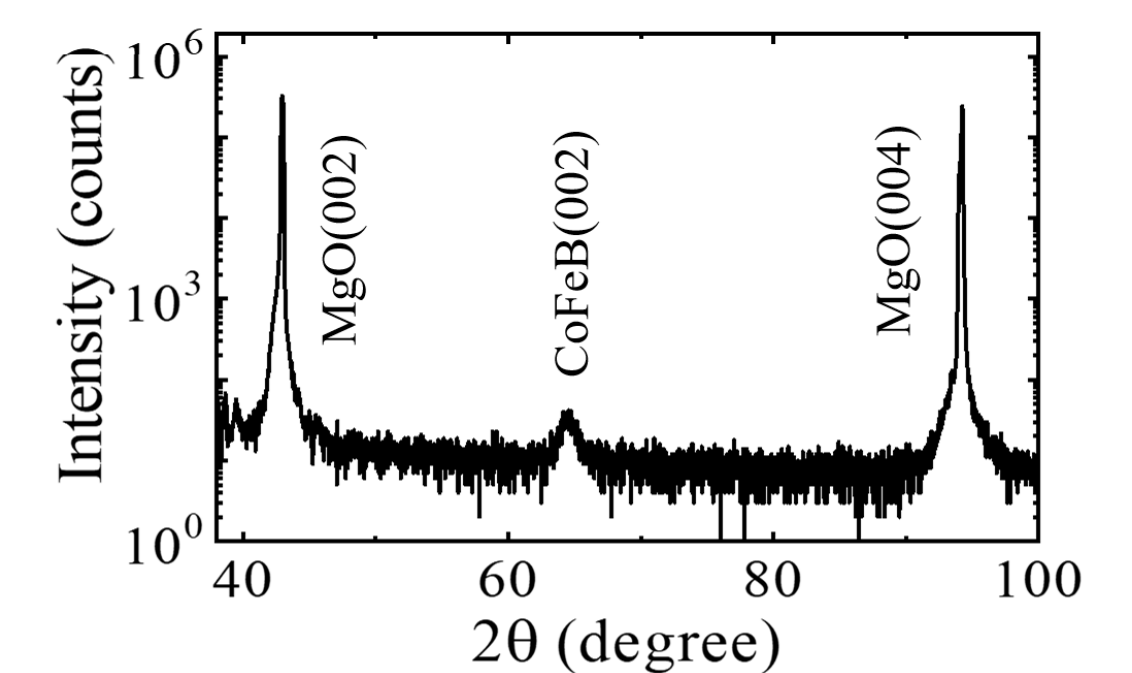
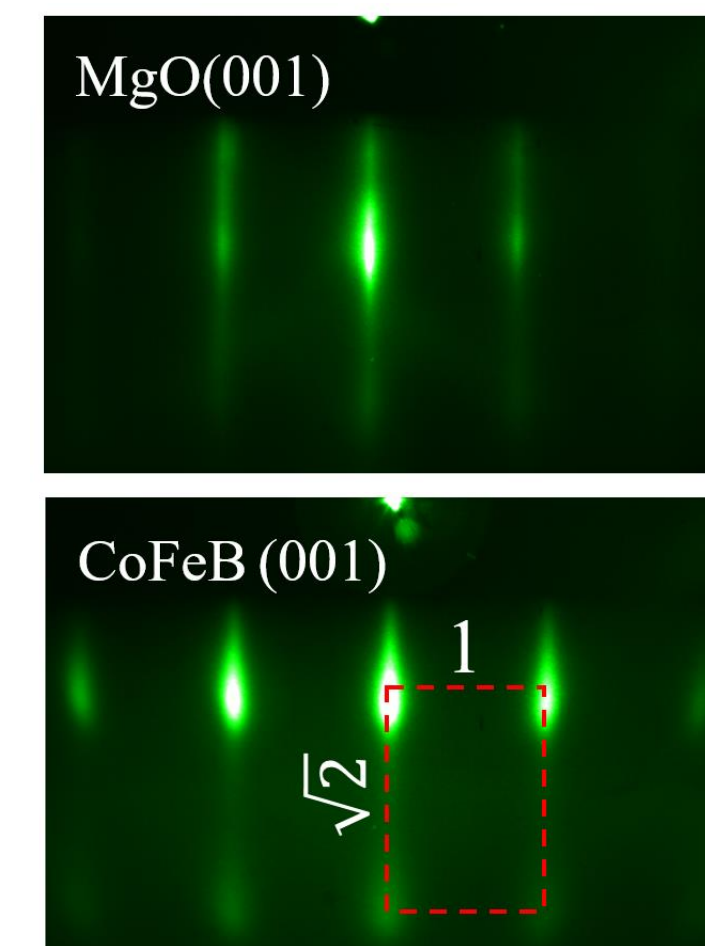
➤ Anisotropic damping in CoFeB?

## Experiment

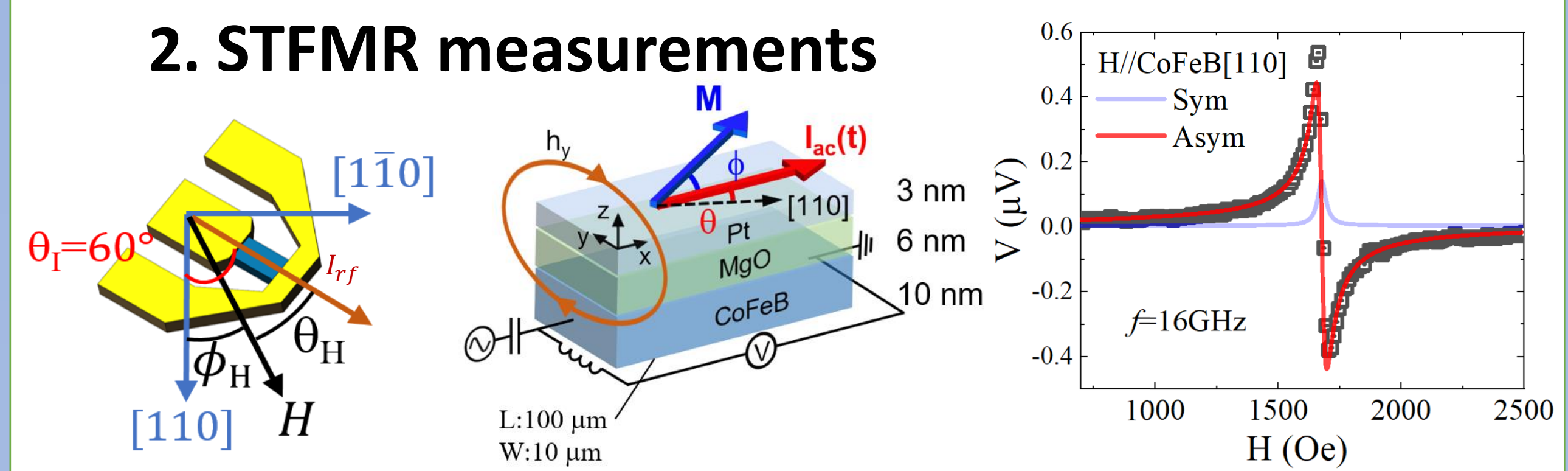
### 1. Films growth

Co<sub>40</sub>Fe<sub>40</sub>B<sub>20</sub> (10 nm)/MgO(001)

**BCC CoFeB (001) film**



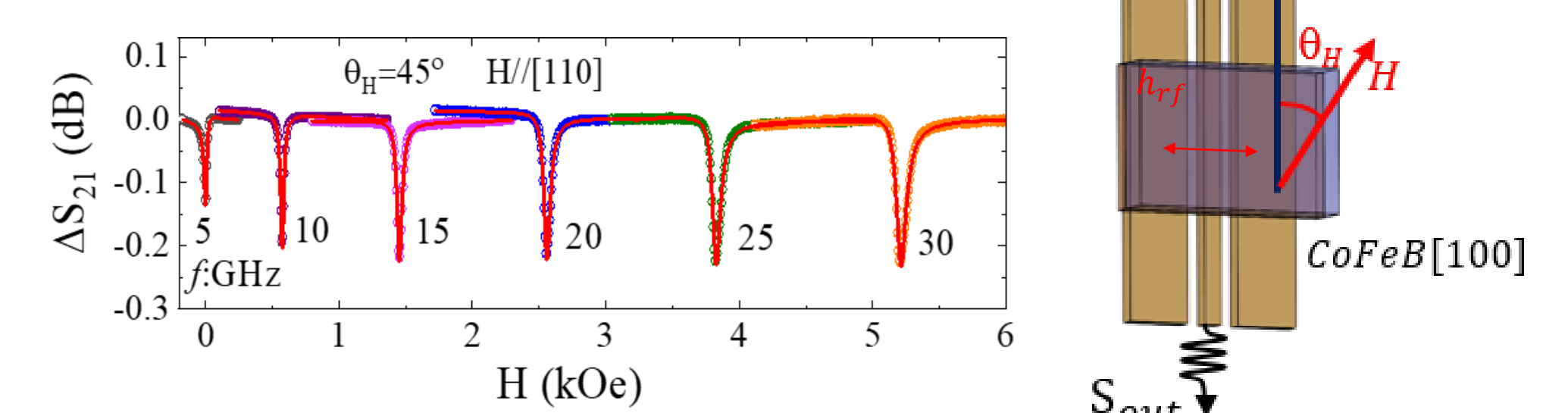
### 2. STFMRF measurements



$$U = A_{\text{sym}} \frac{\Delta H^2}{(H-H_T)^2 + \Delta H^2} + A_{\text{asym}} \frac{\Delta H(H-H_T)}{(H-H_T)^2 + \Delta H^2}$$

$$\Delta H = \Delta H_0 + \frac{\alpha_G \omega}{\gamma}$$

### 3. VNA-FMR measurements



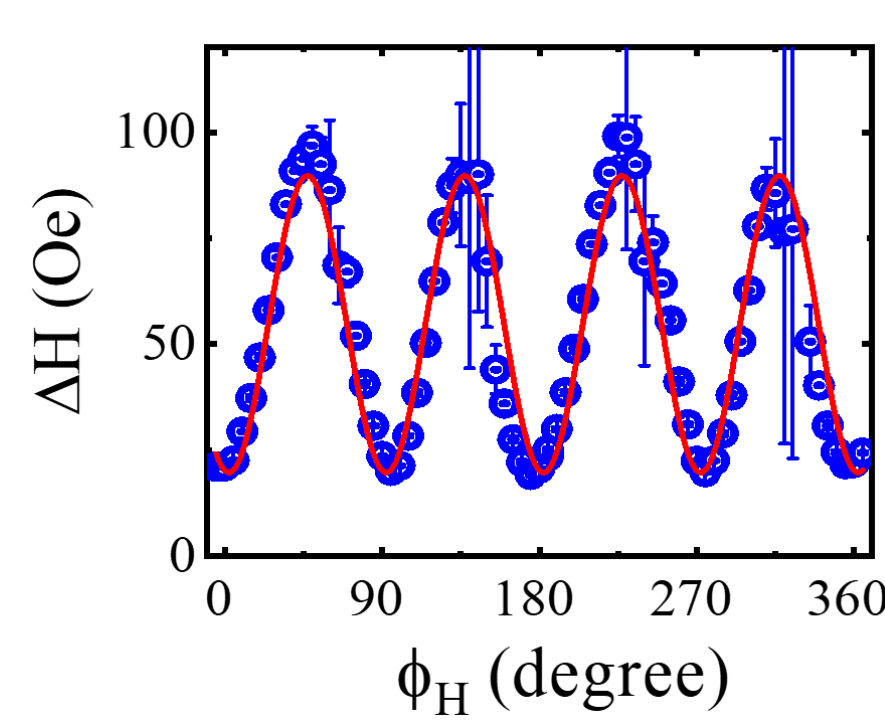
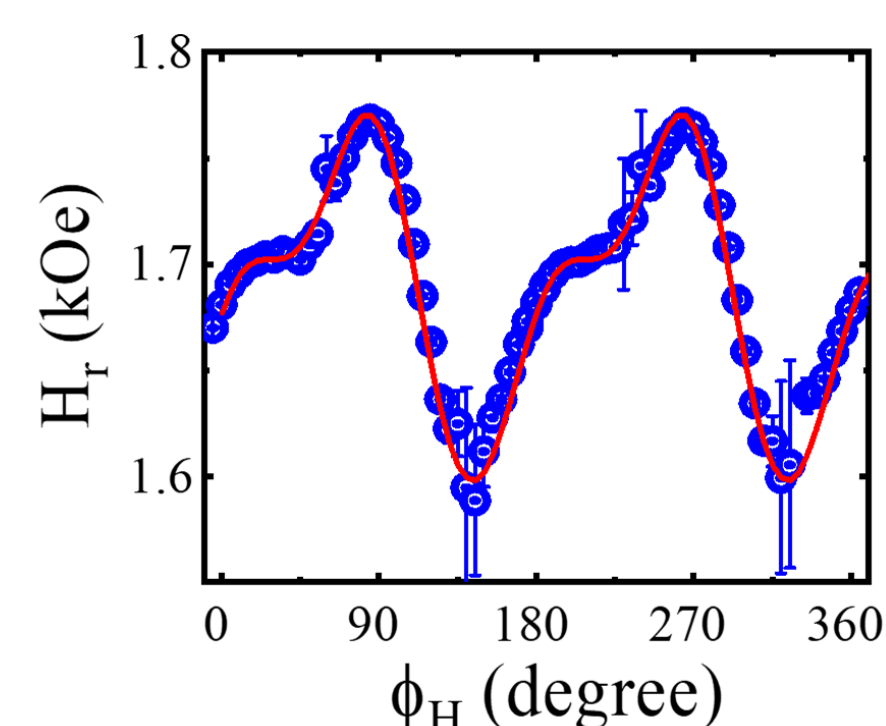
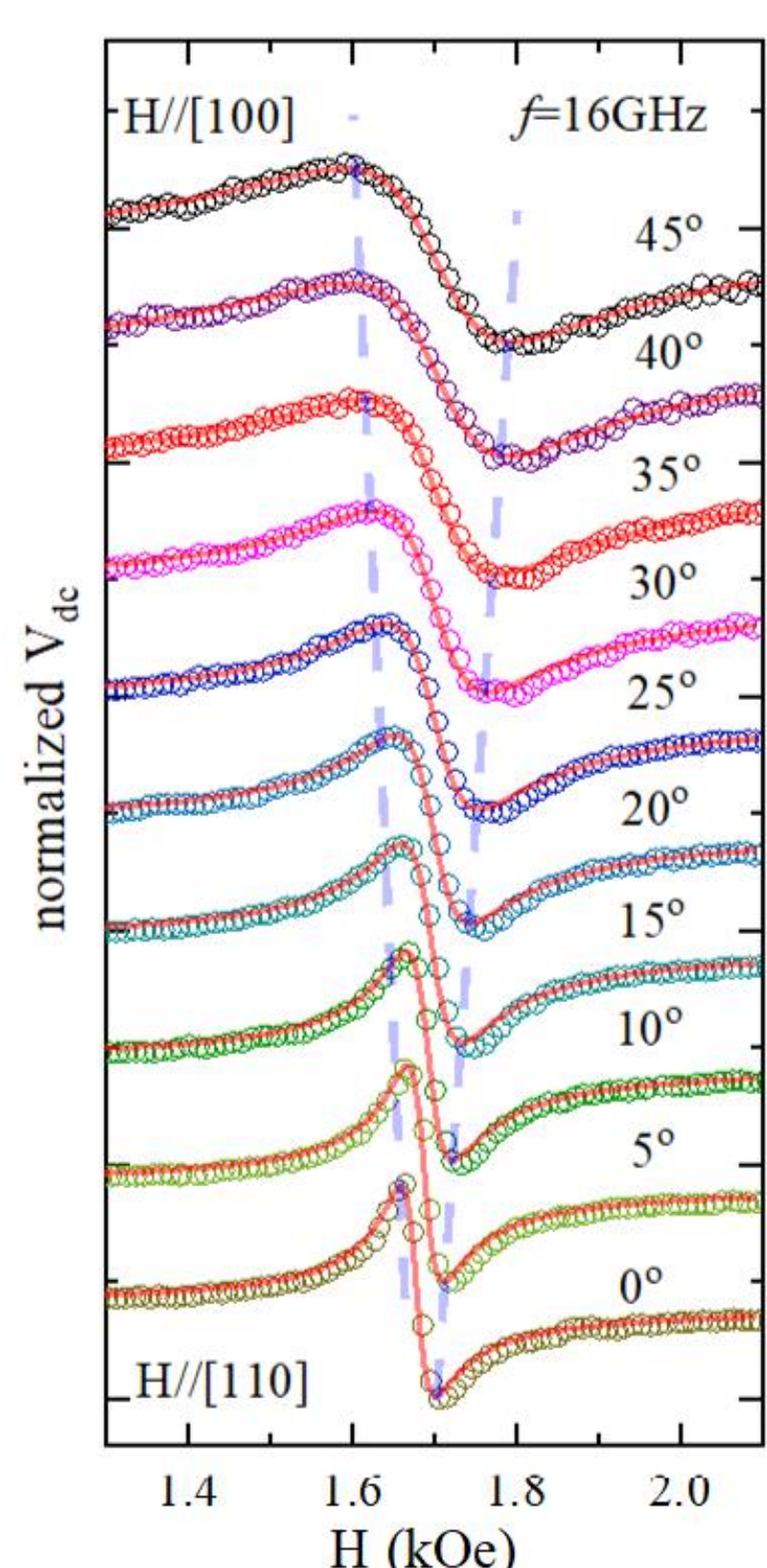
## Anisotropic Damping

### 1. STFMRF Measurement

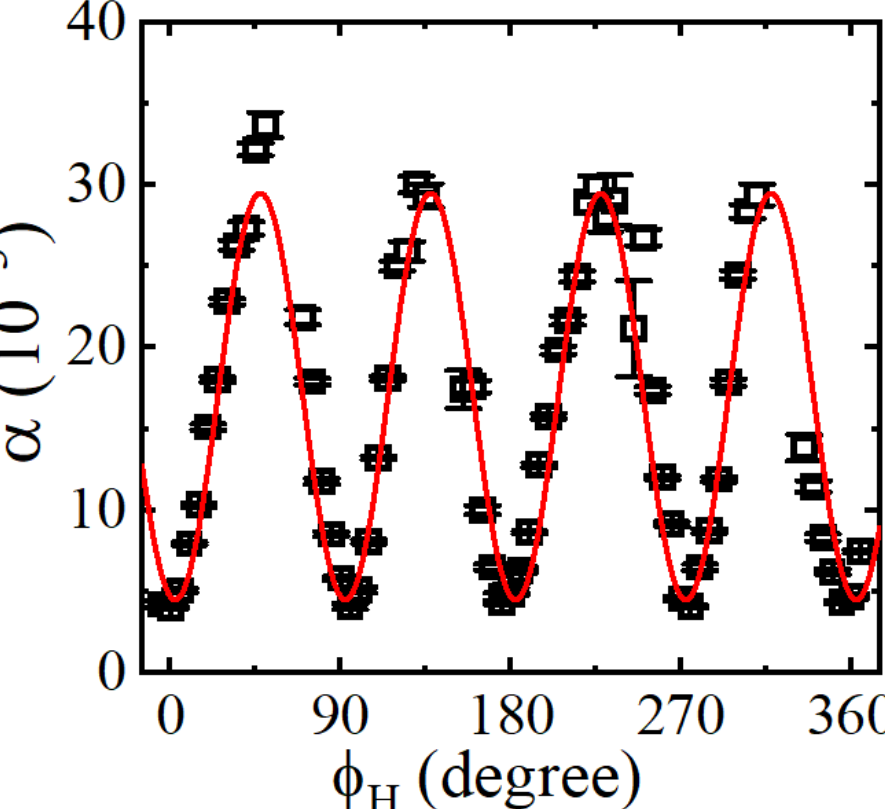
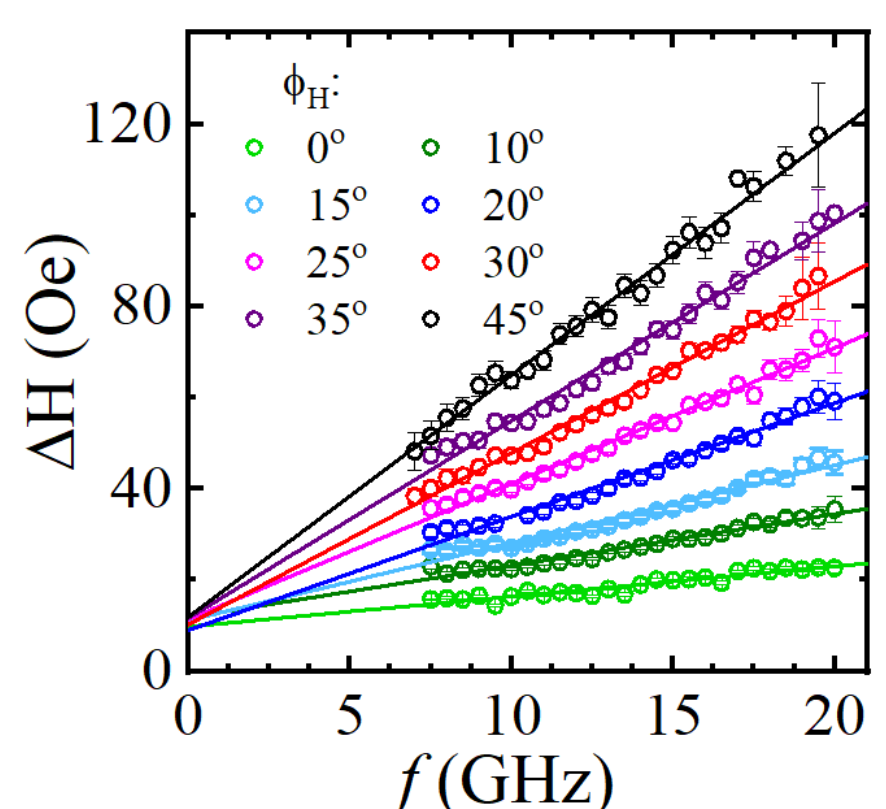
■ FMR spectra

■ Resonance field  $H_T$

■ Linewidth  $\Delta H$



■ Damping anisotropy



$$\alpha_{[100]} = 0.0322 \pm 0.0004$$

$$\alpha_{[110]} = 0.0040 \pm 0.0001$$

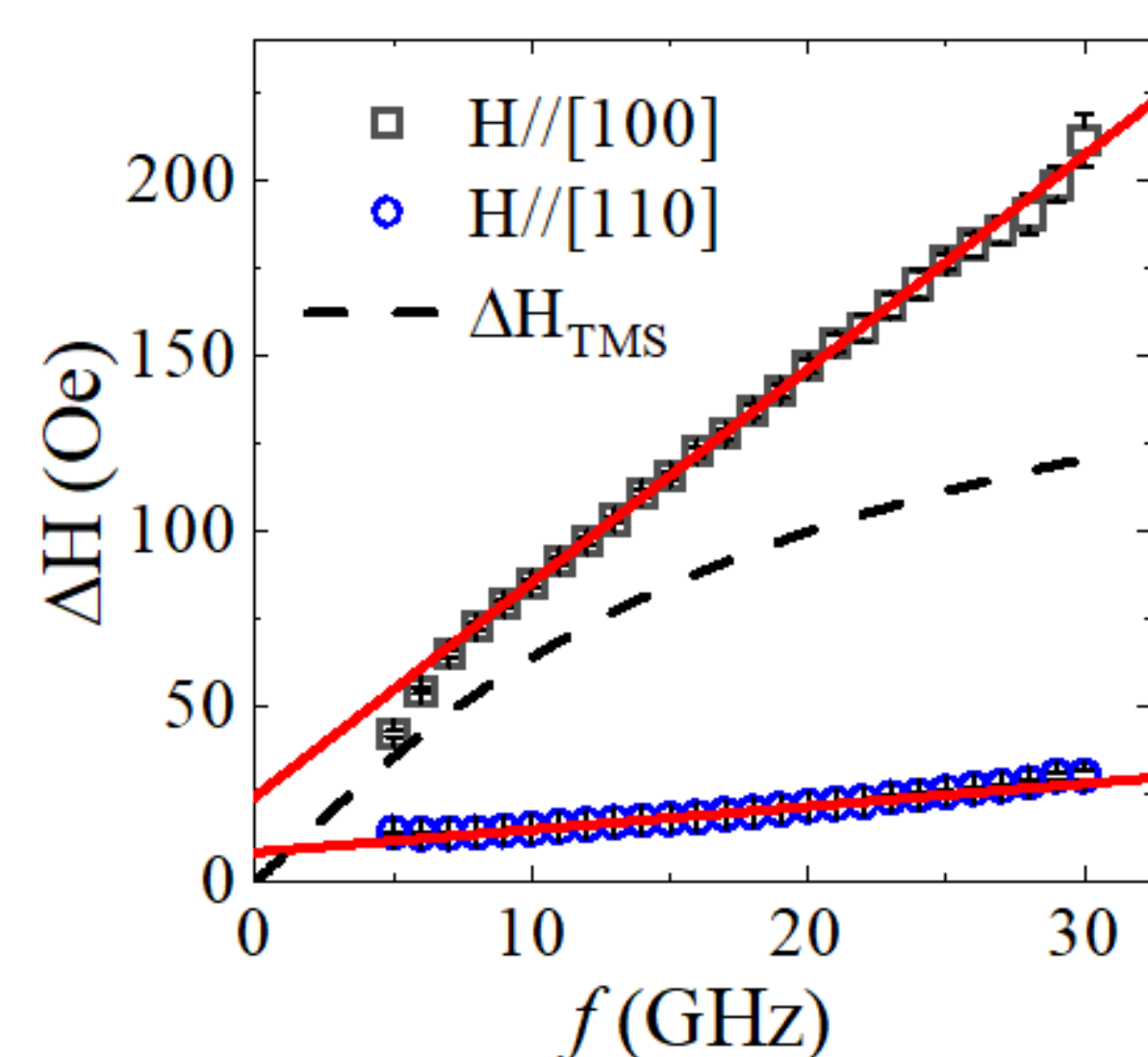
$$\alpha_{(100)}/\alpha_{(110)} = 800\%$$

### 2. VNA-FMR Measurement

$$\alpha_{[100]} = 0.0368 \pm 0.0001$$

$$\alpha_{[110]} = 0.0039 \pm 0.0002$$

$$\alpha_{(100)}/\alpha_{(110)} = 940\%$$

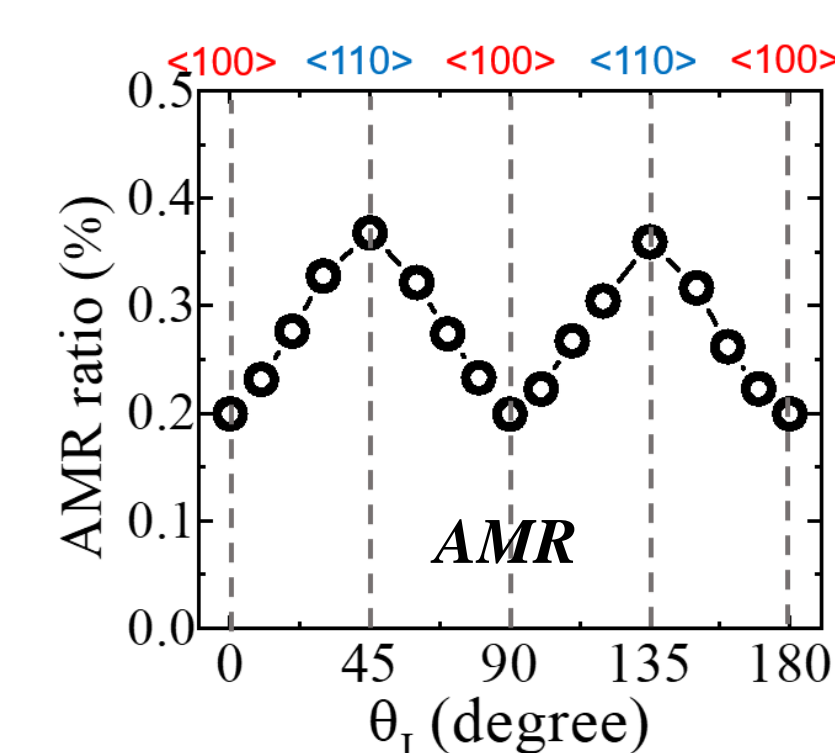


## Discussion

◆ CoFe(001):  $\alpha_{(100)}/\alpha_{(110)} = 4.4$   $\text{AMR}_{(100)}/\text{AMR}_{(110)} = 23$

**Strong damping anisotropy**  $\leftrightarrow$  **Strong AMR anisotropy**

◆ CoFeB(001):  $\alpha_{(100)}/\alpha_{(110)} = 9.4$   $\text{AMR}_{(100)}/\text{AMR}_{(110)} = 1.8$



**Strong damping anisotropy**

**Weak AMR anisotropy**

➤ Anisotropic damping mechanism in CoFeB?

## Conclusion

- BCC-structure single-crystal CoFeB(001) prepared.
- 900% anisotropic Gilbert damping observed.
- Damping anisotropy has weak correlation with AMR.