



Static and Dynamic Magnetic Characterization of CoFeB/ IrMn/ CoFeB Trilayers

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ABSTRACT

- ✓ **Ferromagnetic coupling** occurs in between two CoFeB layers for **IrMn thickness** up to **6nm** above which the two layers get decoupled
- ✓ Interfacial coupling is evidenced by:
 - **Negative exchange bias (H_{eb})** at 10K after positive field cooling (+FC)
 - **Positive H_{eb}** at 10K after negative field cooling (-FC)
 - Under zero field cooling (ZFC) separate reversal of top and bottom CoFeB layer occurs that signifies antiferromagnetic coupling between the two layers
- ✓ Damping α is **increased** due to **interfacial effect**, which is ascertained by large increase in damping and resonance field for lower CoFeB thickness

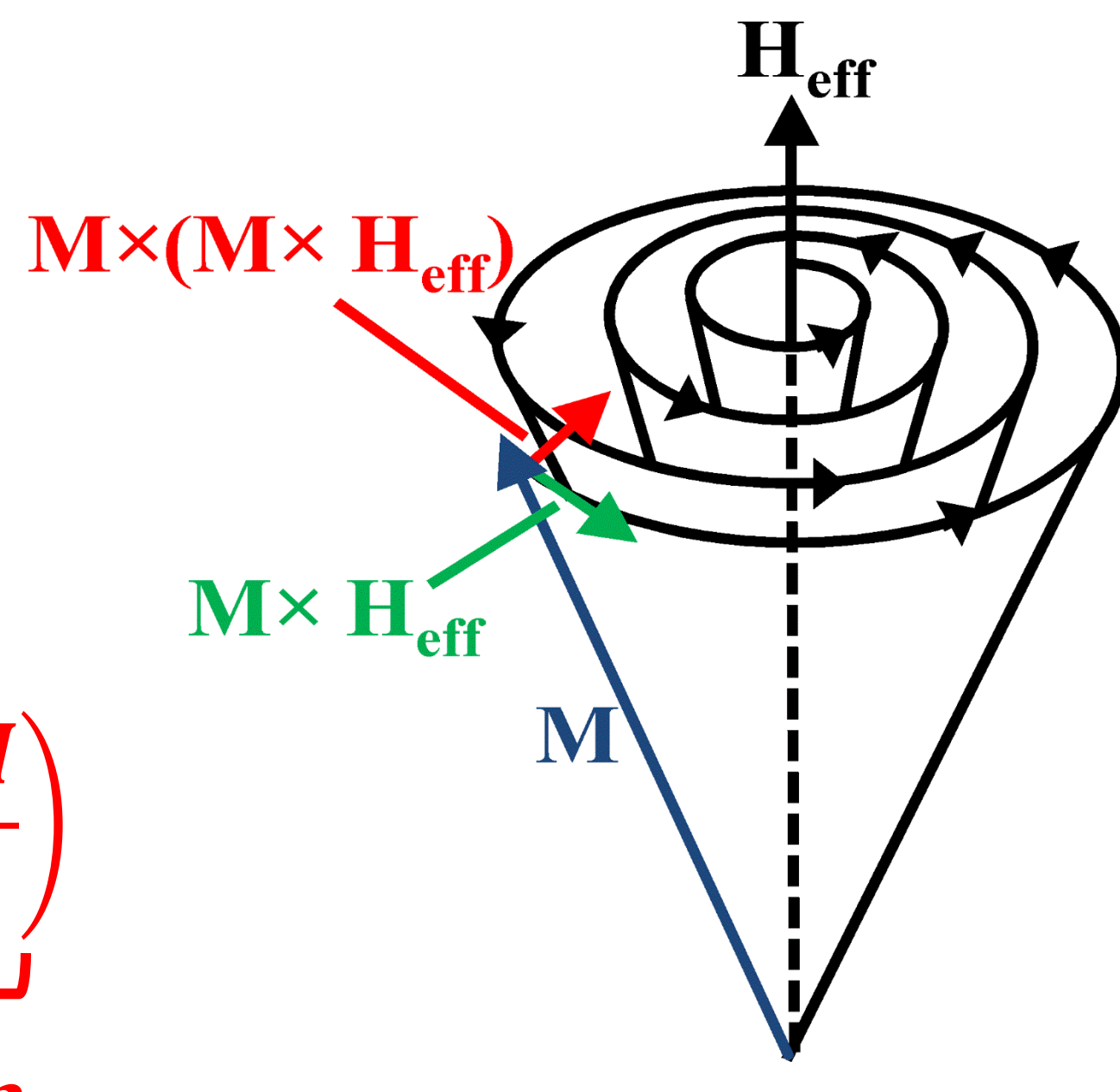
Introduction

Magnetization Dynamics

The magnetization dynamics of a ferromagnet is given in terms of LLG equation:

Landau-Lifshitz-Gilbert (LLG) equation

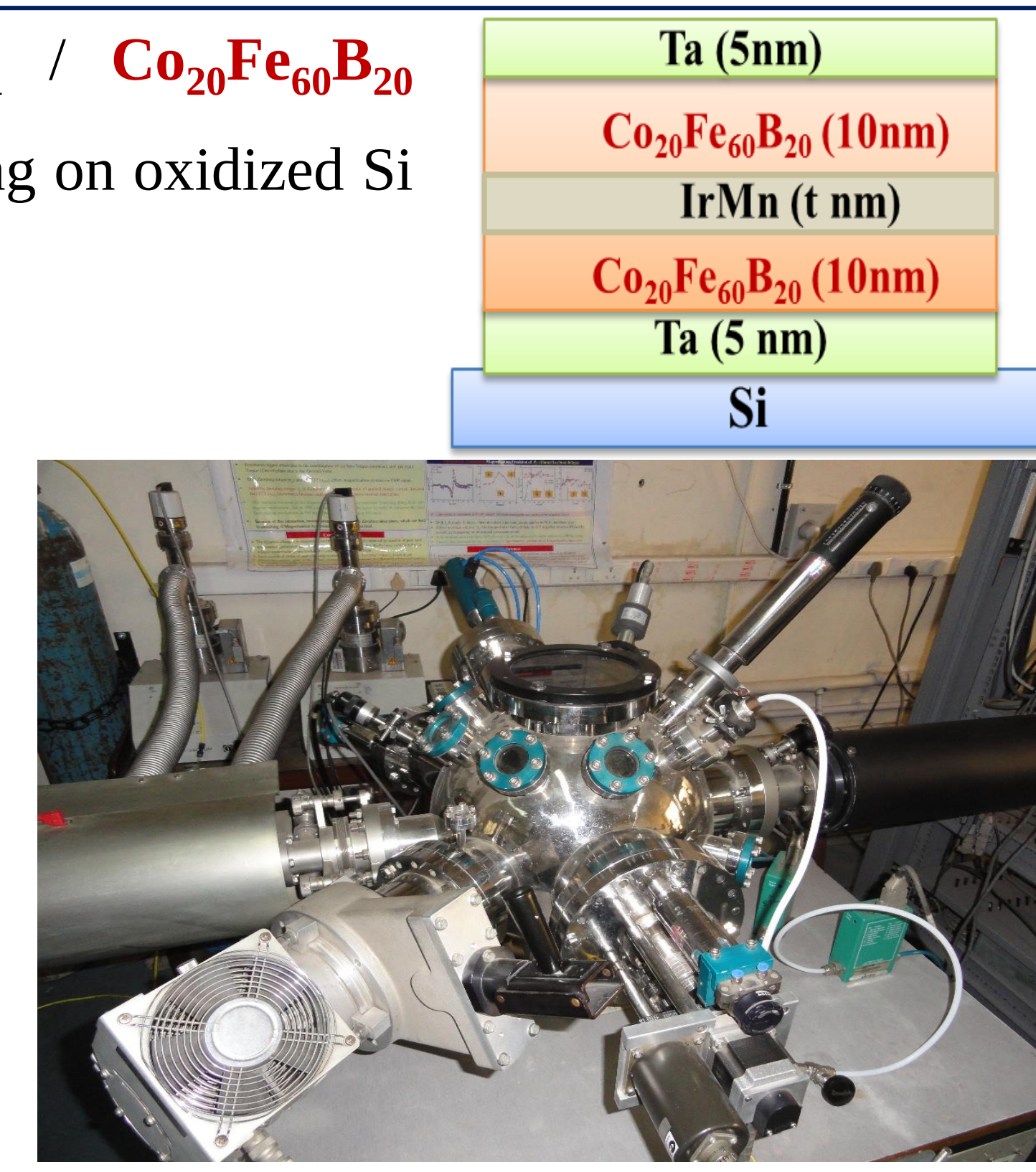
$$\frac{d\mathbf{M}}{dt} = \underbrace{-\gamma\mu_0\mathbf{M} \times \mathbf{H}_{eff}}_{\text{Precession term}} + \underbrace{\frac{G}{\gamma M_s^2} \left(\mathbf{M} \times \frac{d\mathbf{M}}{dt} \right)}_{\text{Damping term}}$$



Experimental

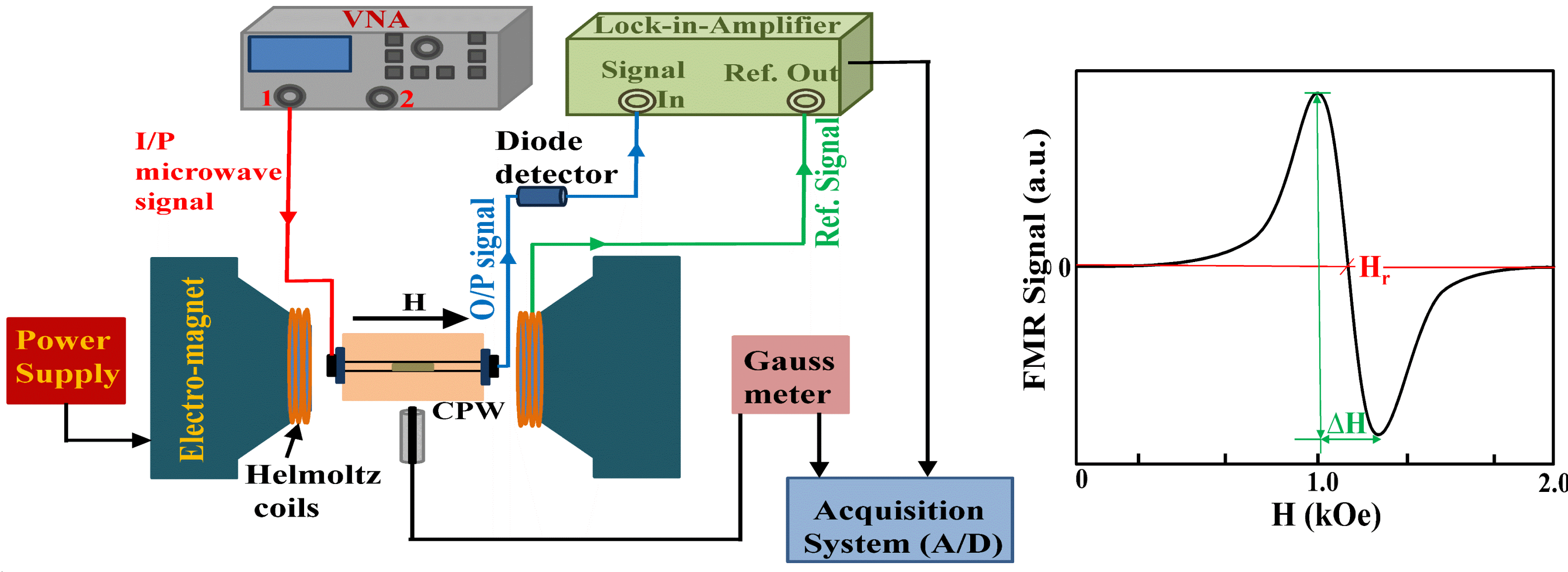
- Magnetic FM/AF/FM **Co₂₀Fe₆₀B₂₀** / **Ir₁₉Mn₈₁** / **Co₂₀Fe₆₀B₂₀** multilayers were prepared by magnetron sputtering on oxidized Si wafers with a Ta 5 nm seed and cap layer
- The **t_{IrMn}** is varied in 1 nm steps from **0 to 7 nm**

Power of CoFeB target (W)	120
Power of IrMn target (W)	40
Power of Ta target (W)	40
Base Pressure (Torr)	2×10 ⁻⁷
Working Pressure (Torr)	3.2×10 ⁻³
Deposition rate of CoFeB (nm/min)	8
Deposition rate of IrMn (nm/min)	4
Deposition rate of Ta (nm/min)	3



Experimental Details

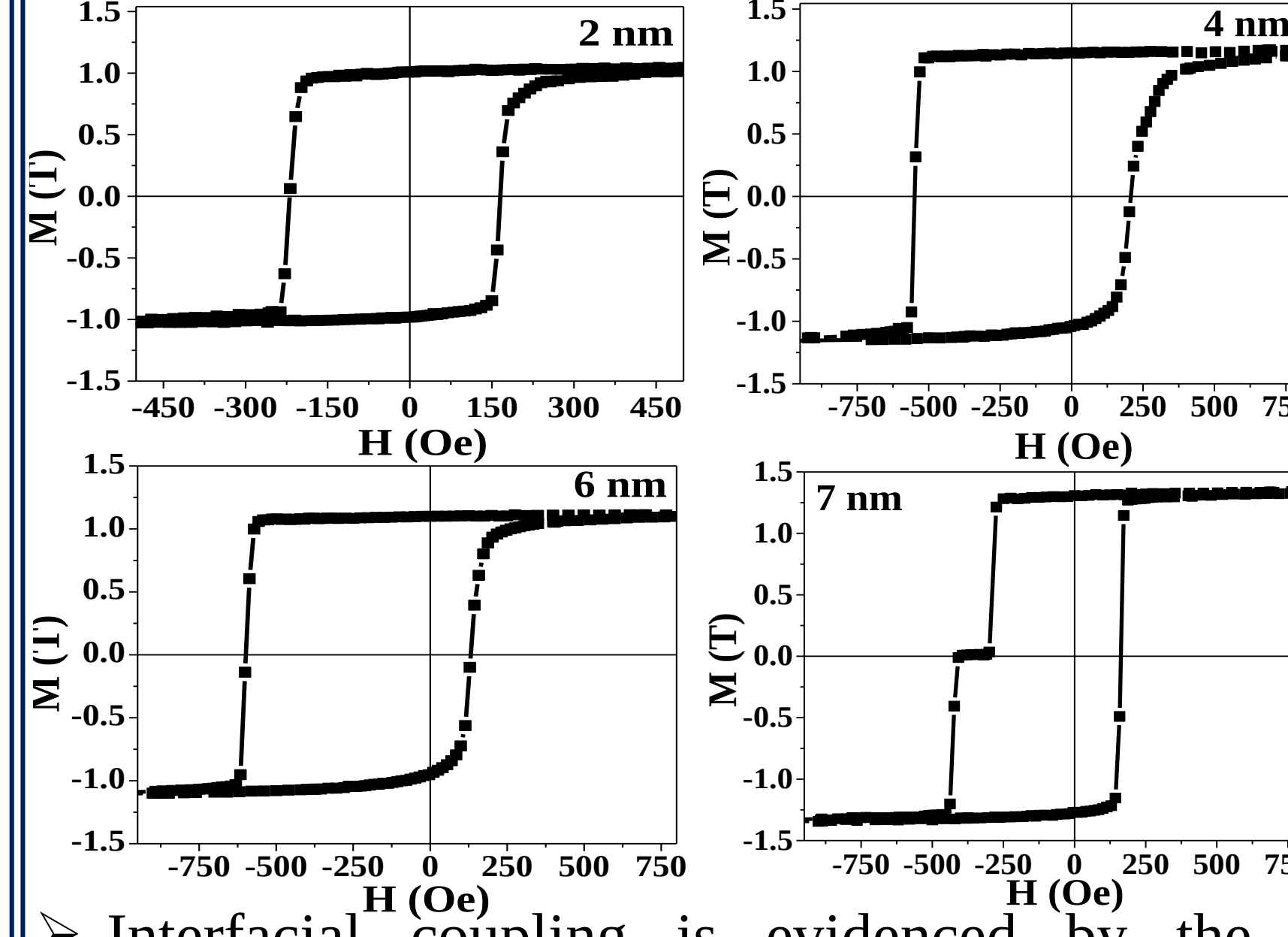
Lock In Amplifier Detection Technique



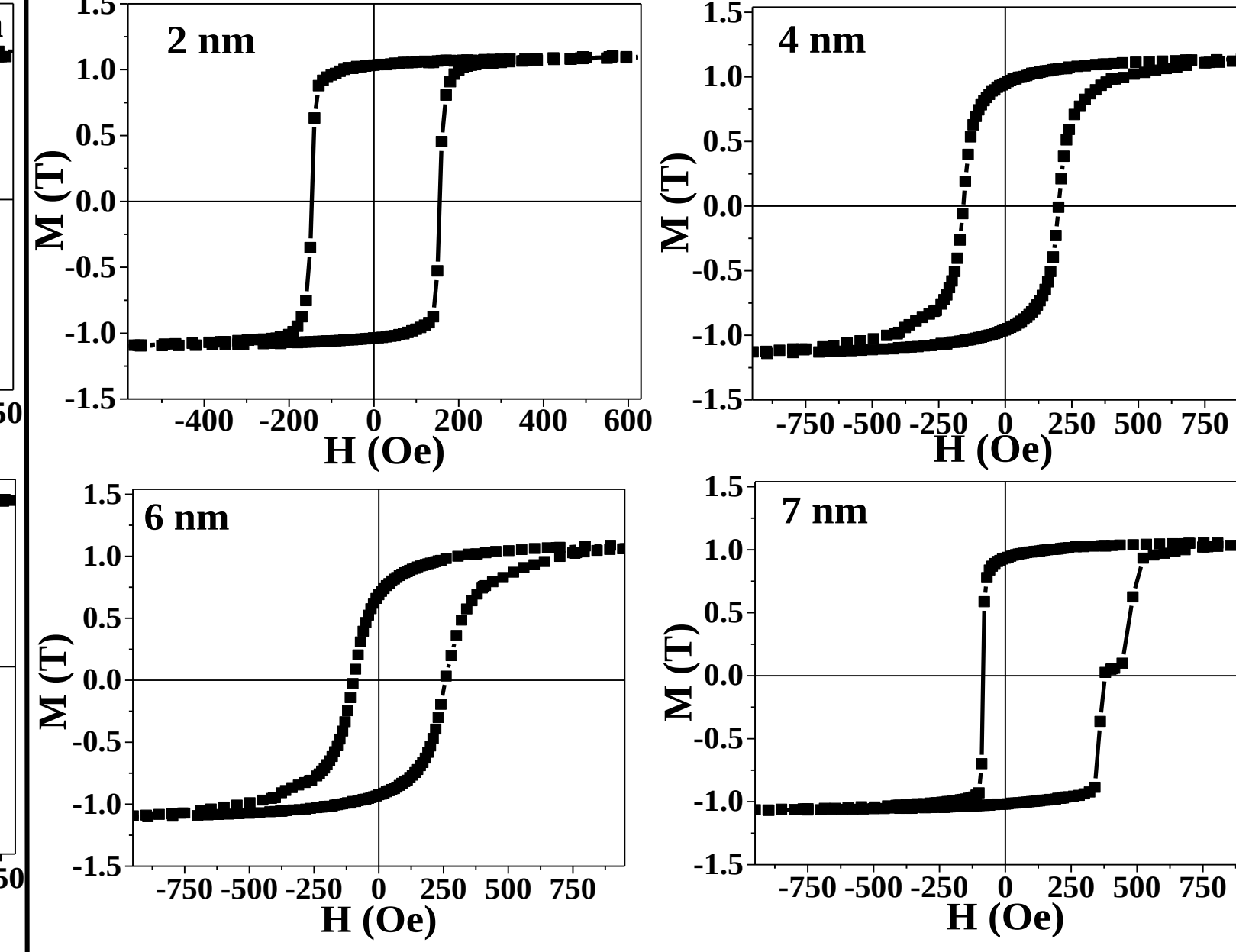
- Dynamic response of films recorded at room temperature by broadband (5-13 GHz) **lock-in amplifier ferromagnetic resonance (LIA-FMR)** technique in-plane configuration
- A pair of Helmholtz coils provided a small modulation field of 1.3 Oe (at 211.5 Hz)

Static Magnetization

M-H Loops at 10K after +FC

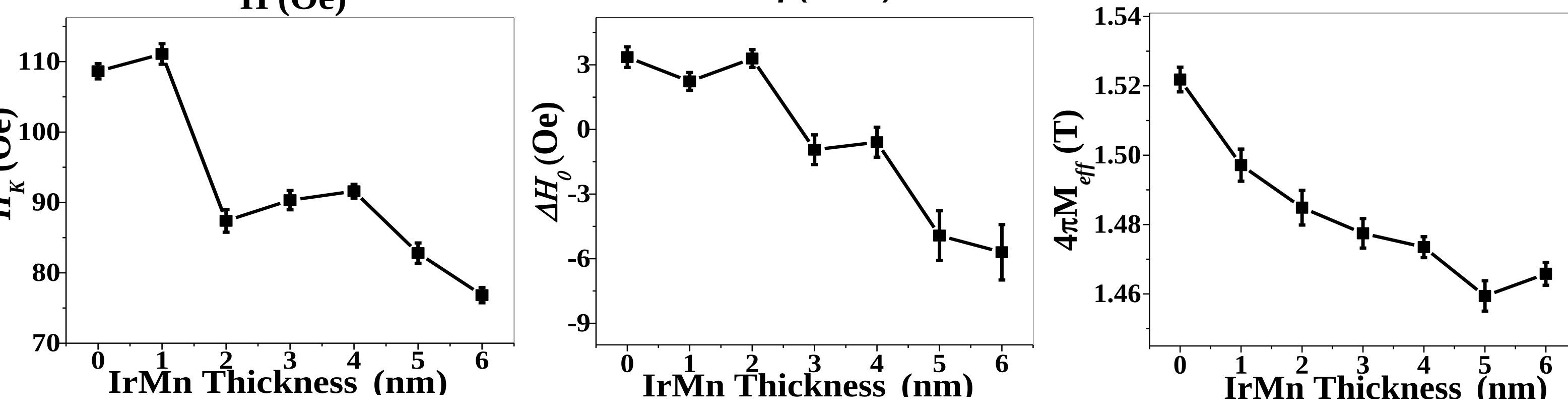
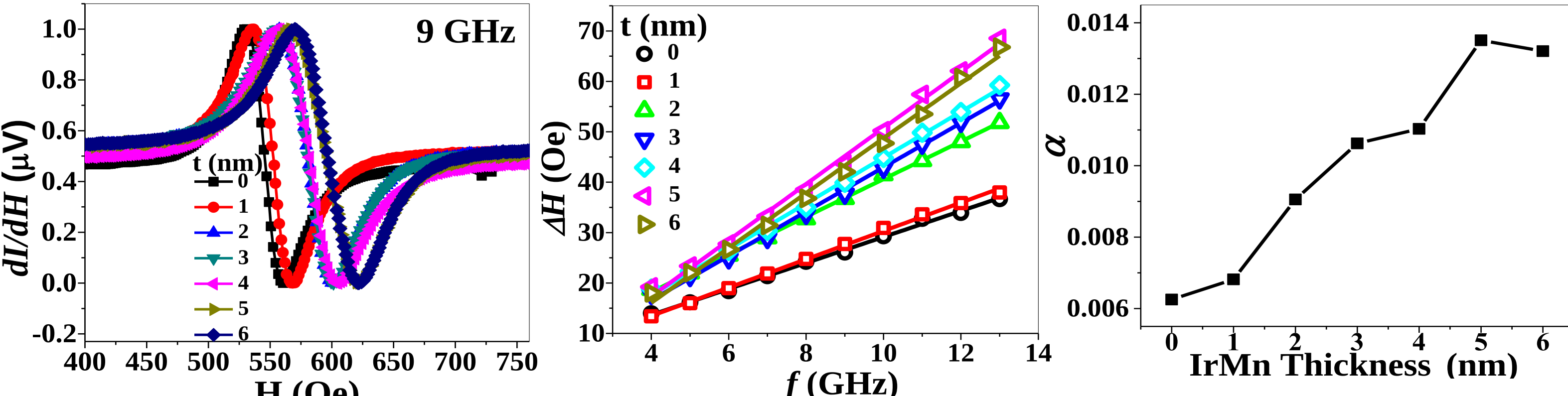


M-H Loops at 10K after -FC



- Interfacial coupling is evidenced by the presence of **-H_{eb}** after **positive FC** and strength of **-H_{eb}** increase with **increase in t_{IrMn}**
- On **negative FC**, **+H_{eb}** appears, though smaller in magnitude compared to **-H_{eb}**

Dynamic Magnetization



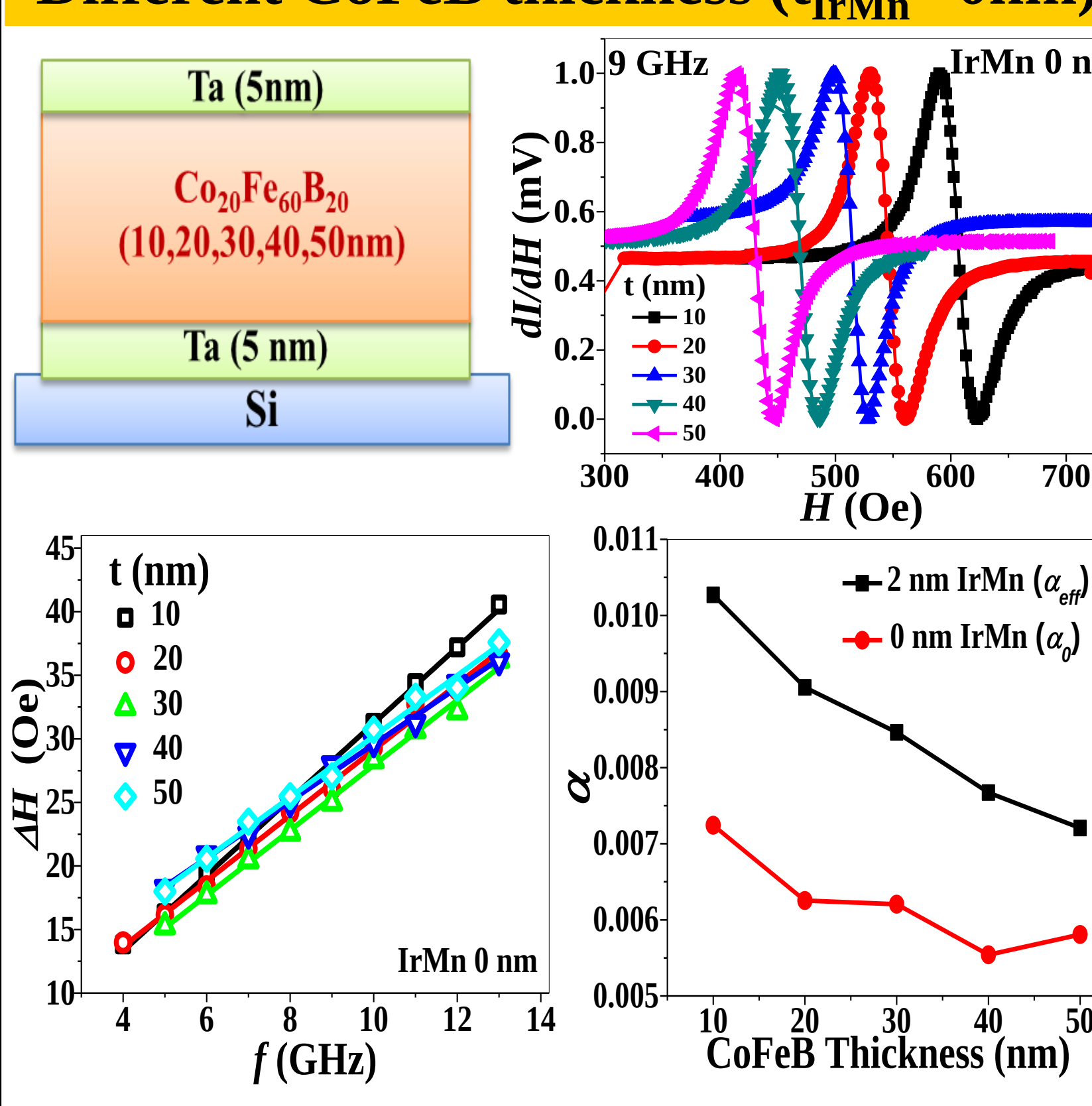
➤ FMR signal was recorded in 5 - 13 GHz range using FMR lock-in spectrometer

Kittle Equation $\omega^2 = \gamma^2 (H_r + H_k) (H_r + H_k + 4\pi M_{eff})$ where $4\pi M_{eff} = 4\pi M_s - (2K_s/M_s) t_{FM}^{-1}$

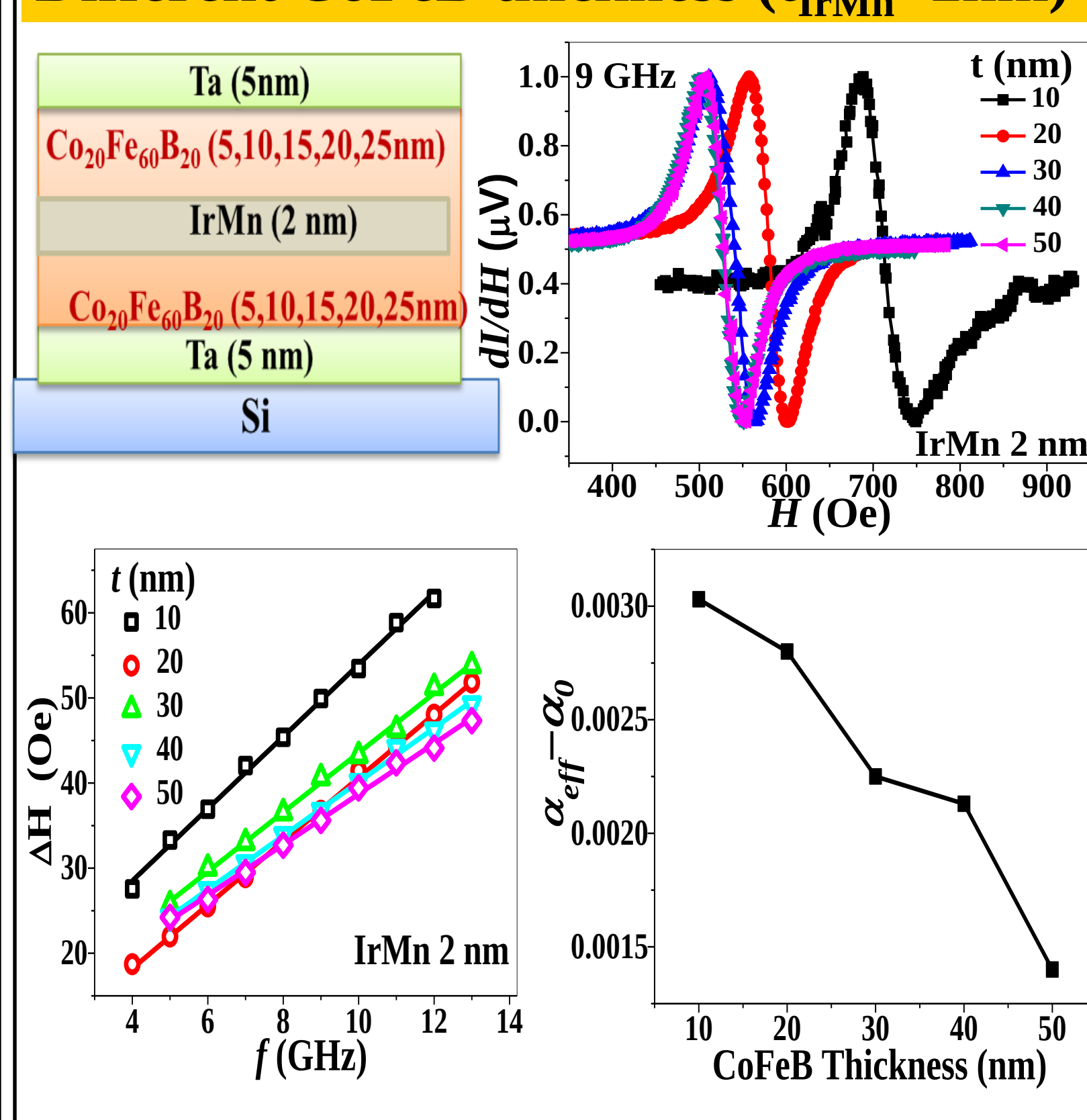
- For **damping constant α** $\Delta H_{pp} = \frac{2\alpha}{\gamma\sqrt{3}} \omega + \Delta H_0$
- α value increases while H_k value decreases on increasing **t_{IrMn}**
- Low values of ΔH_0 signify good sample quality although its value shows slight increase with increasing **t_{IrMn}**

Dynamic Magnetization

Different CoFeB thickness (t_{IrMn}=0nm)



Different CoFeB thickness (t_{IrMn}=2nm)



- Linear increase in values of $\alpha_{eff} - \alpha_0$ with decreasing CoFeB thickness indicates **interfacial origin**

Conclusions

- For thin **IrMn layers (<7 nm)** the antiferromagnetic spins are very rigid and only a small twist may form resulting in a strong **ferromagnetic coupling** between ferromagnetic layers
- **Interfacial coupling** is evidenced by presence of **exchange bias** at 10K after field cooling. On ZFC, the reversal of two layers occurs separately
- **Damping is increased** due to interfacial effect, which is **ascertained by large increase in damping** and resonance field for lower CoFeB thickness

References

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2. W. Kuch, L. I. Chelaru, F. Offi, J. Wang, M. Kotsugi And J. Kirschner, Nature Materials, **5** 128 (2006)
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