

Dynamic Properties of Exchange Spirals in Fe/CoO Bilayer with Strong Interfacial Exchange Coupling



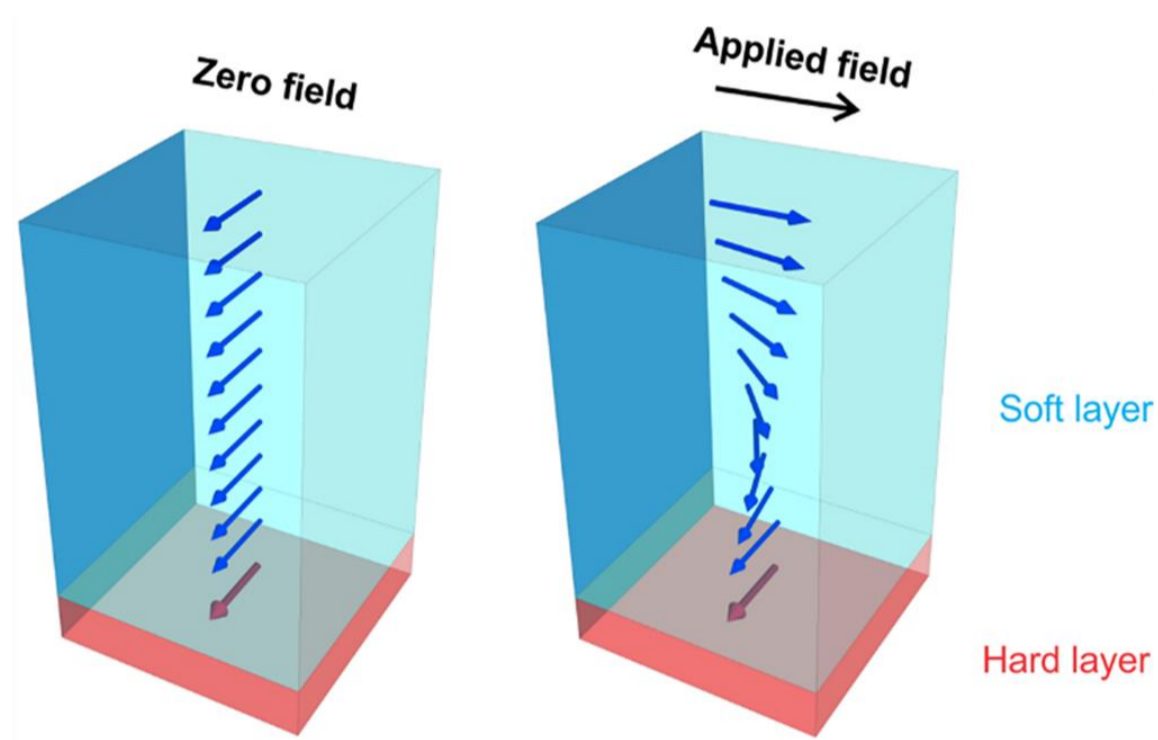
Yuanfei Fan, Hongyue Xu, Tong Wu, Yizheng Wu*

Department of Physics, Fudan University, Shanghai, China

Background & Motivation

Magnetic exchange spirals

- ✓ Hard/soft FM bilayers

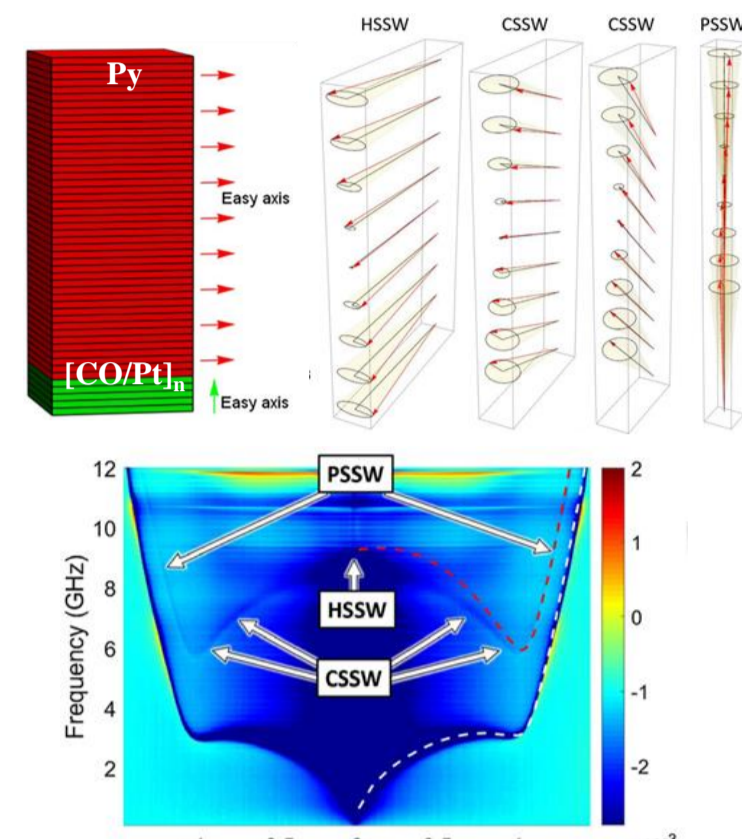


A. Frisk, et al. Phys. Rev. Applied (2023)

- Non-collinear spin structure

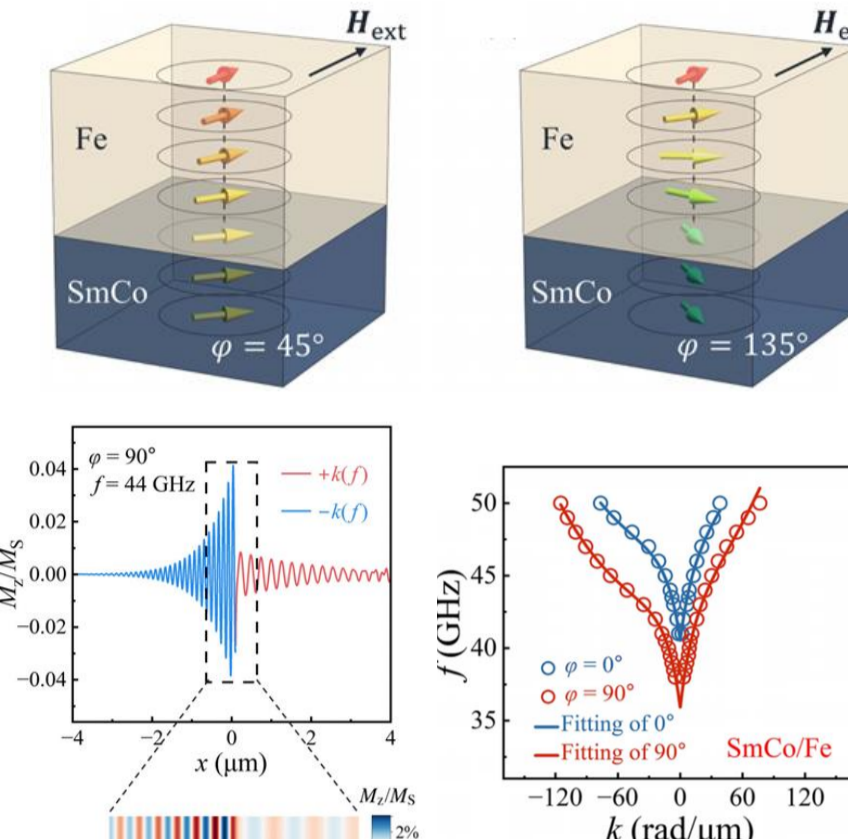
Spin dynamics of exchange spirals

- ✓ Canted standing spin-wave modes



M. Dabrowski, et al. New J. Phys. (2021)

- ✓ Nonreciprocal spin-wave propagation

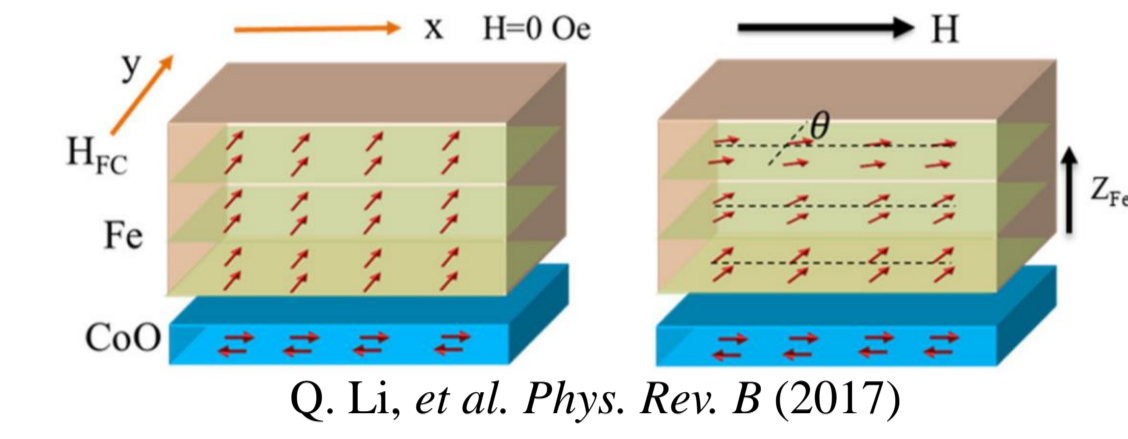


M. X. Jiang, et al. Phys. Rev. B (2025)

- Spiral dynamics in FM/FM systems

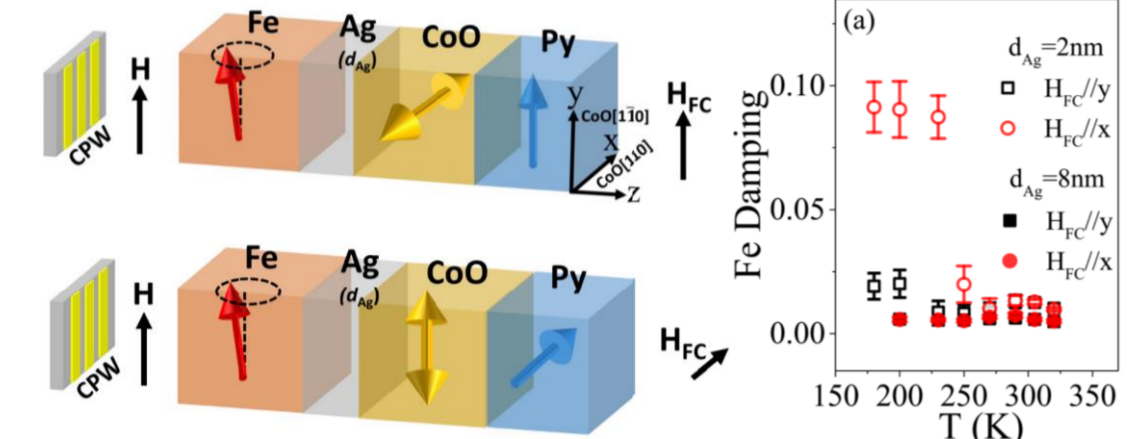
Exchange spiral in FM/AFM

- ✓ Fe/CoO bilayer



Q. Li, et al. Phys. Rev. B (2017)

- ✓ Anisotropic damping in Fe/CoO



M. Yang, et al. Phys. Rev. B (2020)

- Unexplored spiral dynamics in FM/AFM

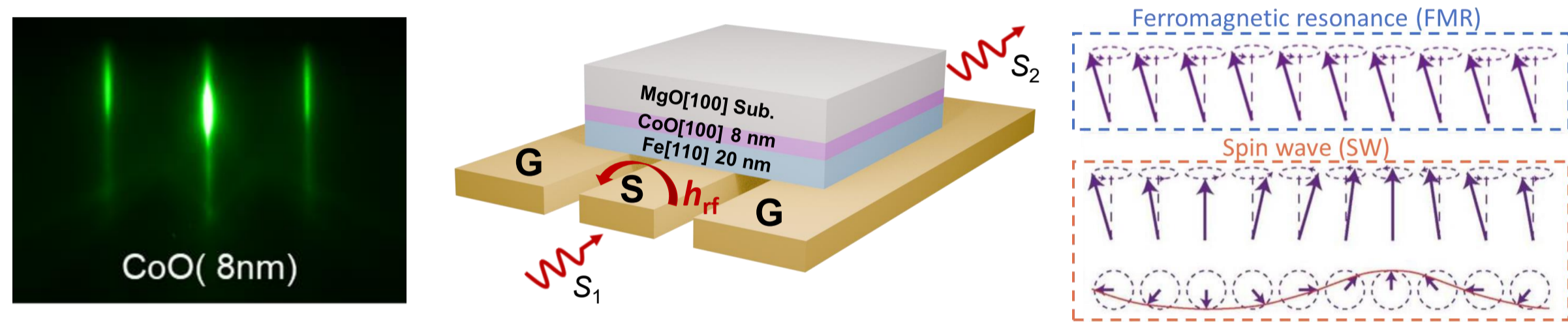
Strong interfacial exchange coupling

Exchange spirals in Fe/CoO bilayer

Spin dynamic properties in Fe/CoO?

Experimental methods and theory

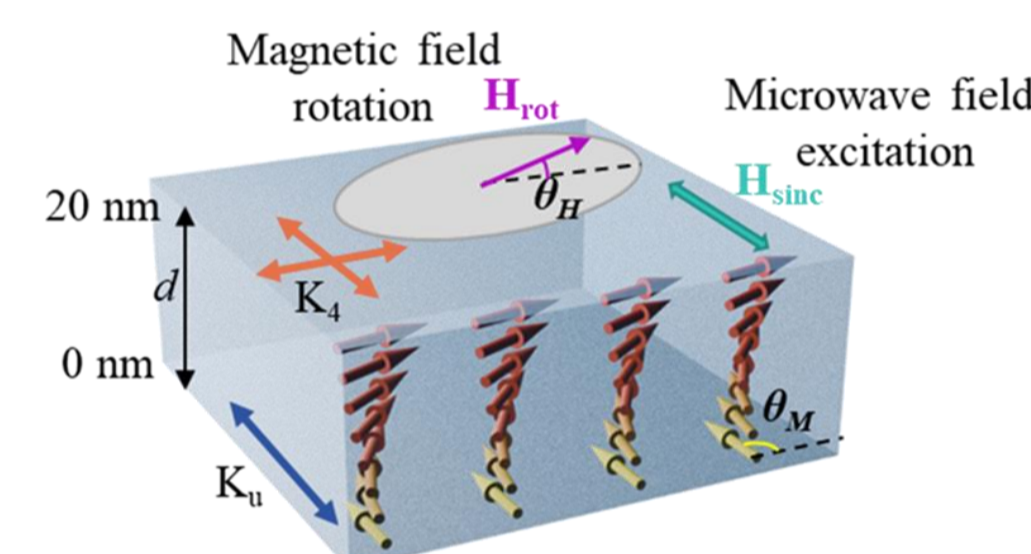
- RHEED pattern
- FMR measurement
- Basic theory



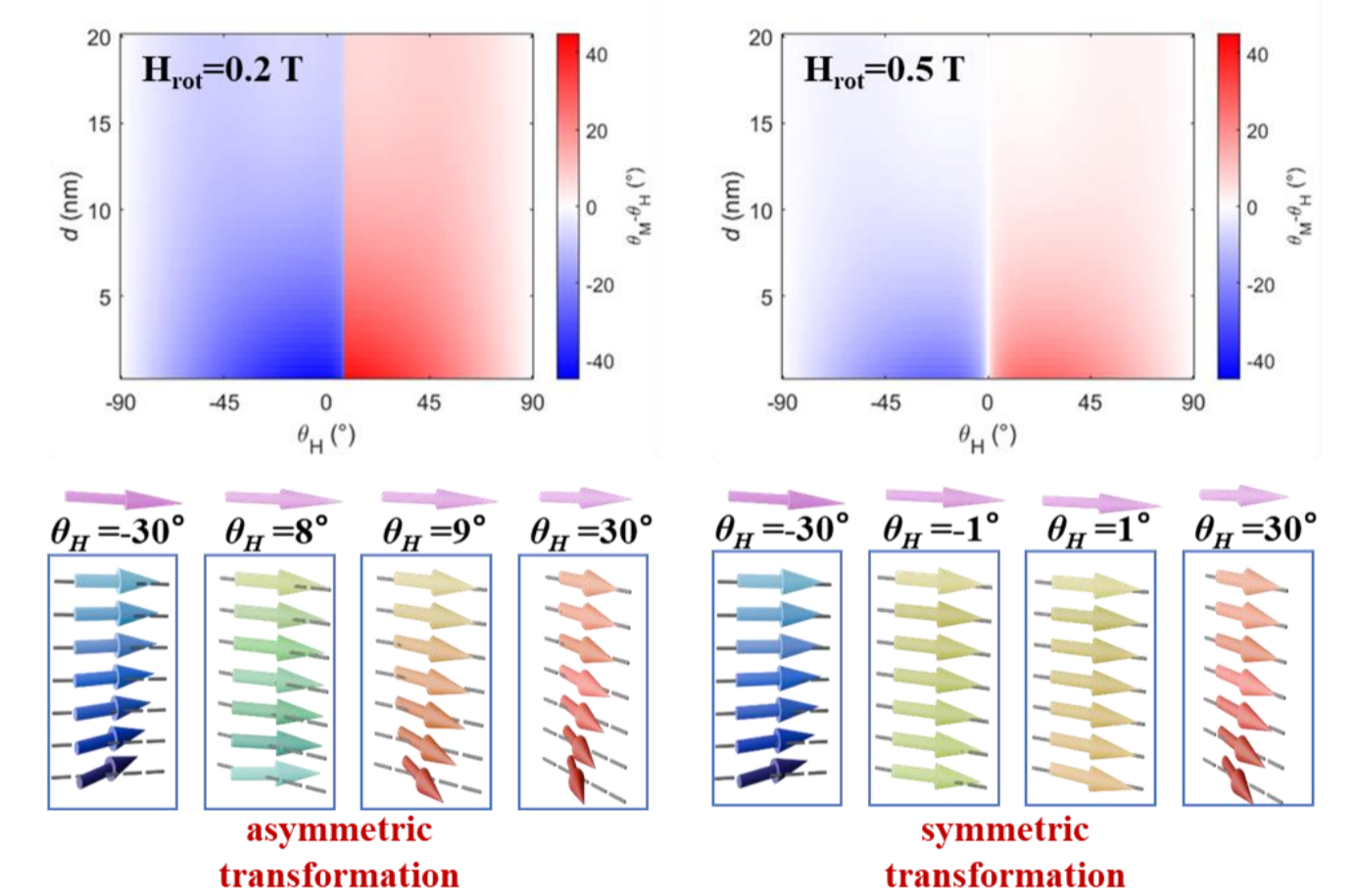
Micromagnetic simulation of exchange spirals

- Structure of exchange spirals under different H_{rot}

- ✓ Simulation configuration



- ✓ Layer-resolved magnetization profiles



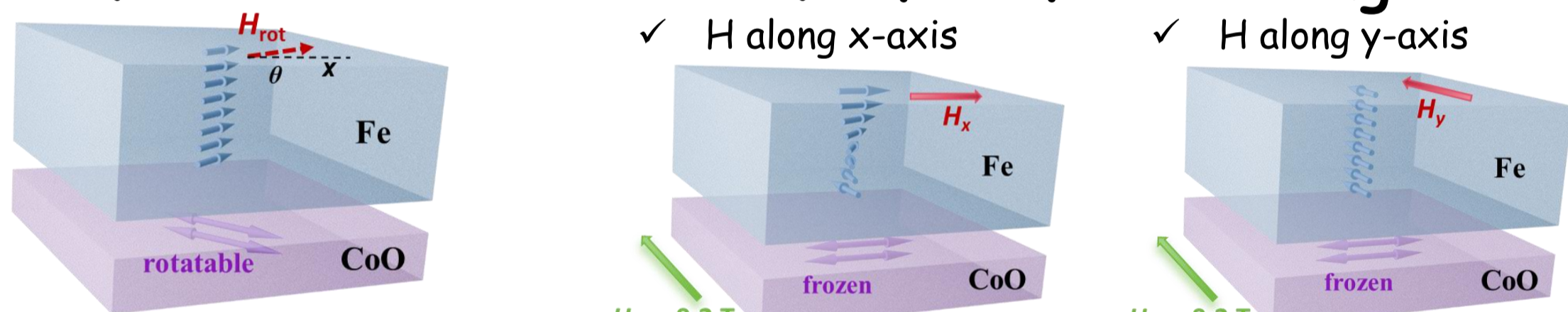
- K_u : exchange-coupling induced interface uniaxial anisotropy ($H_u = 7$ T)
- K_d : cubic anisotropy of Fe ($H_d = 0.0525$ T)

Interfacial exchange coupling (anisotropic field) → Exchange spiral

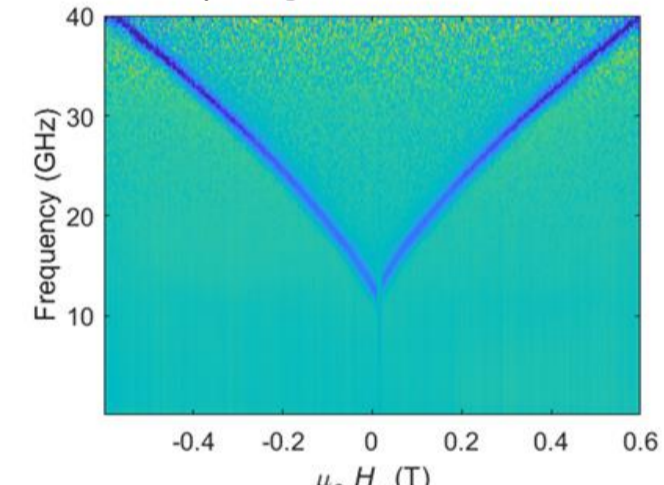
In-plane FMR measurements

- 300 K
- 50 K after field cooling

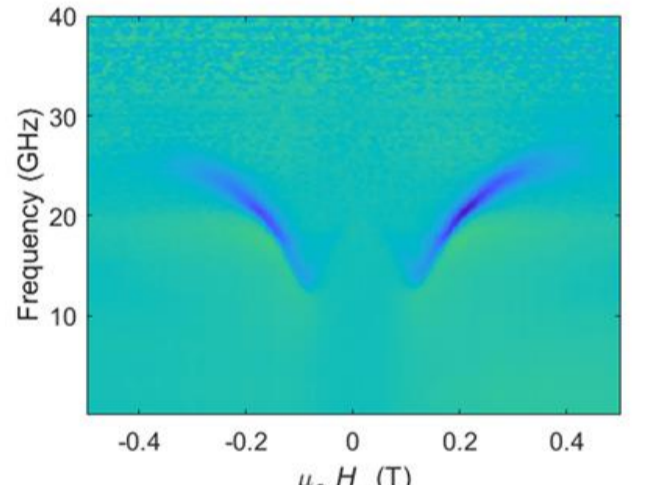
- ✓ H along x-axis
- ✓ H along y-axis



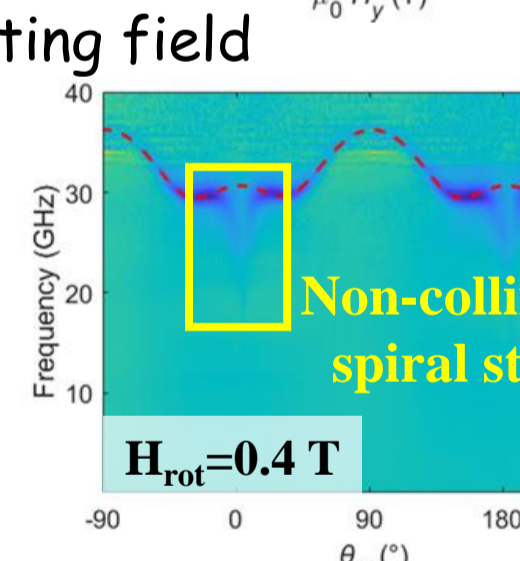
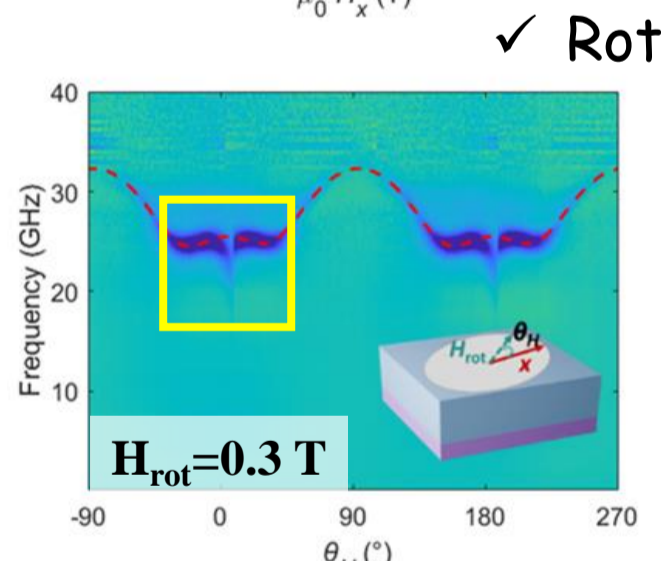
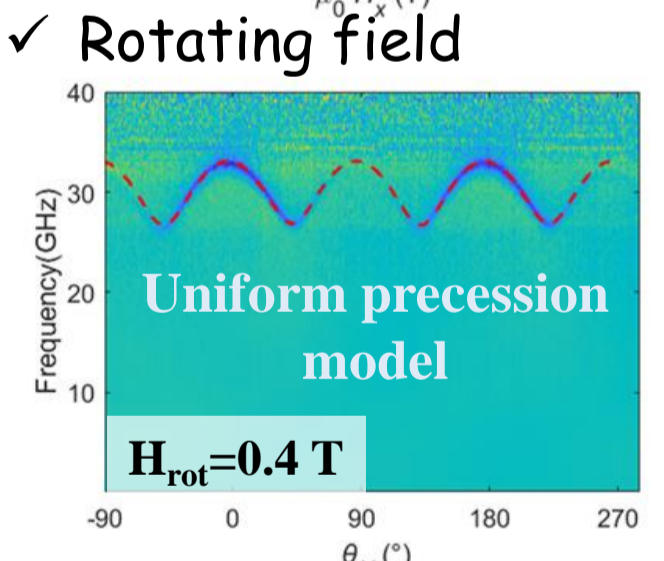
- ✓ Sweeping field



- ✓ Sweeping field



- ✓ Rotating field



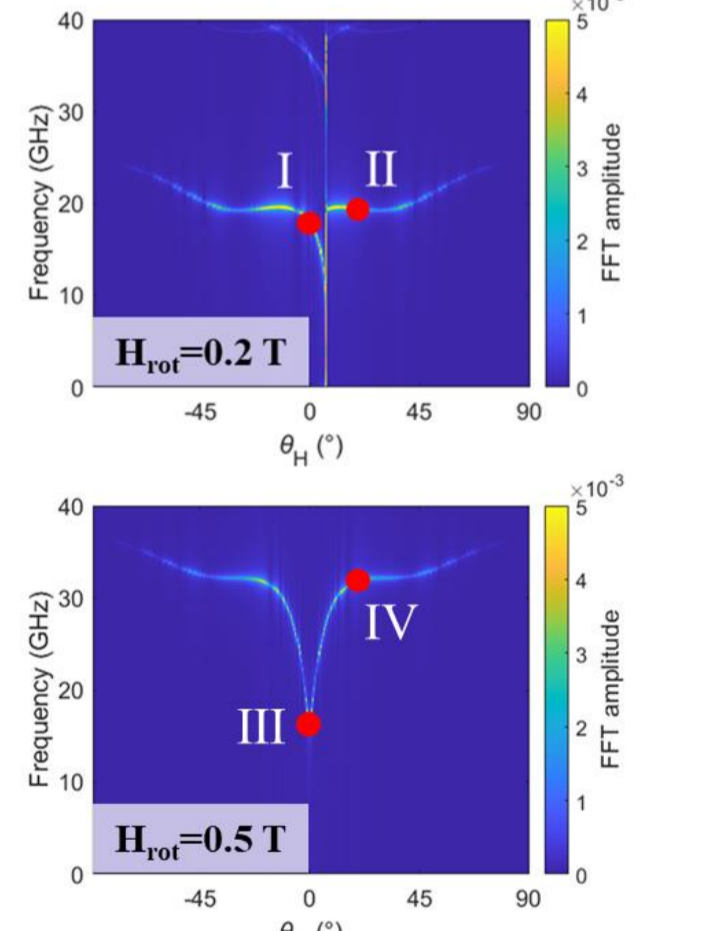
$$\left(\frac{\omega}{\gamma}\right)^2 = \left(H \cos(\varphi_M - \varphi_H) + 4\pi M + \frac{3}{4} H_{k_x} - \frac{1}{4} H_{k_x} \cos^4(\varphi_M - \varphi_{k_x}) + H_{k_u} \cos^2(\varphi_M - \varphi_{k_u}) \right) \left(H \cos(\varphi_M - \varphi_H) - H_{k_x} \cos^4(\varphi_M - \varphi_{k_x}) + H_{k_u} \cos^2(\varphi_M - \varphi_{k_u}) \right)$$

Spiral → frequency dip / linewidth anomaly / asymmetric switching

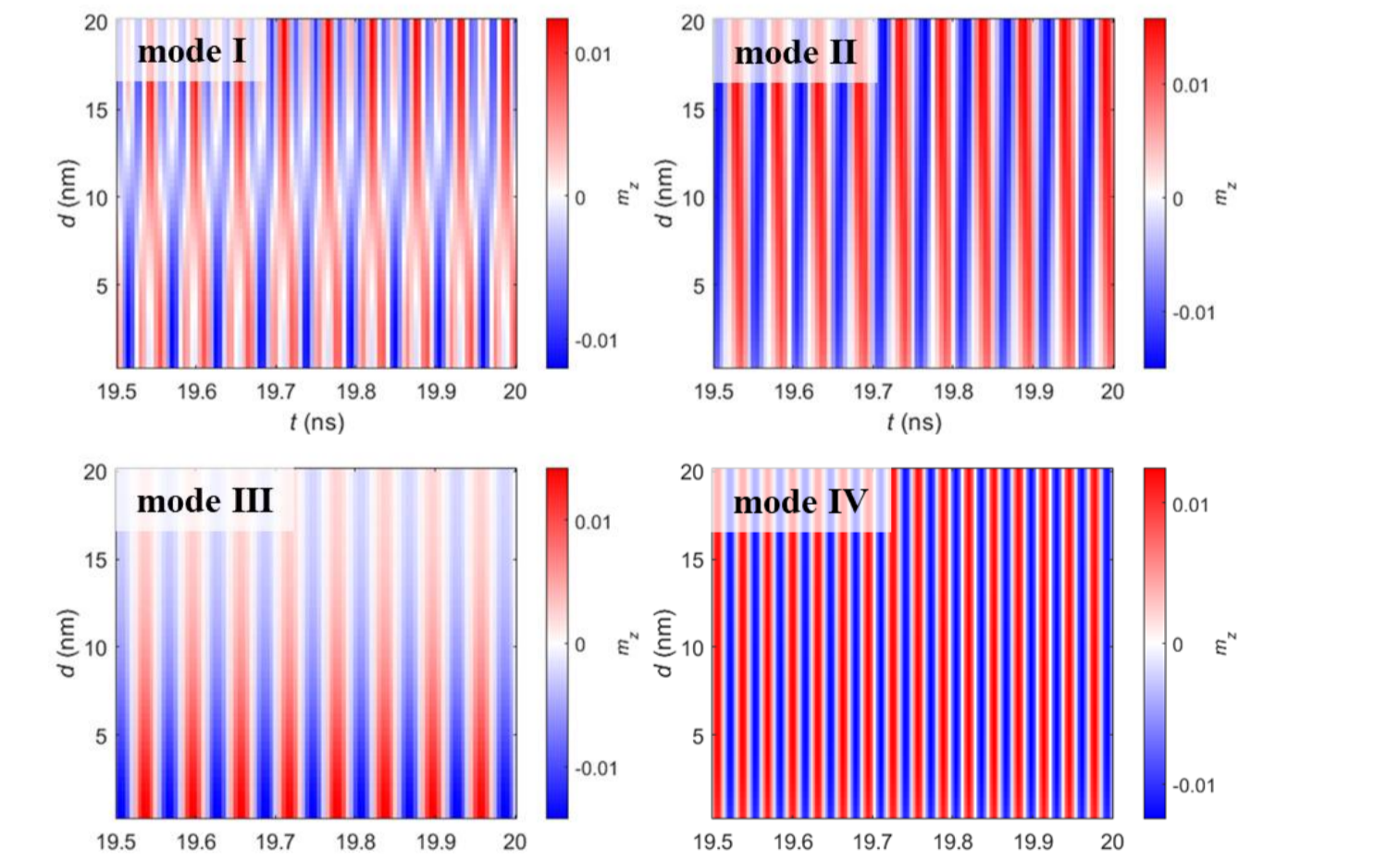
Simulation of spin dynamics

- Dynamic response of exchange spiral

- ✓ FMR spectrum



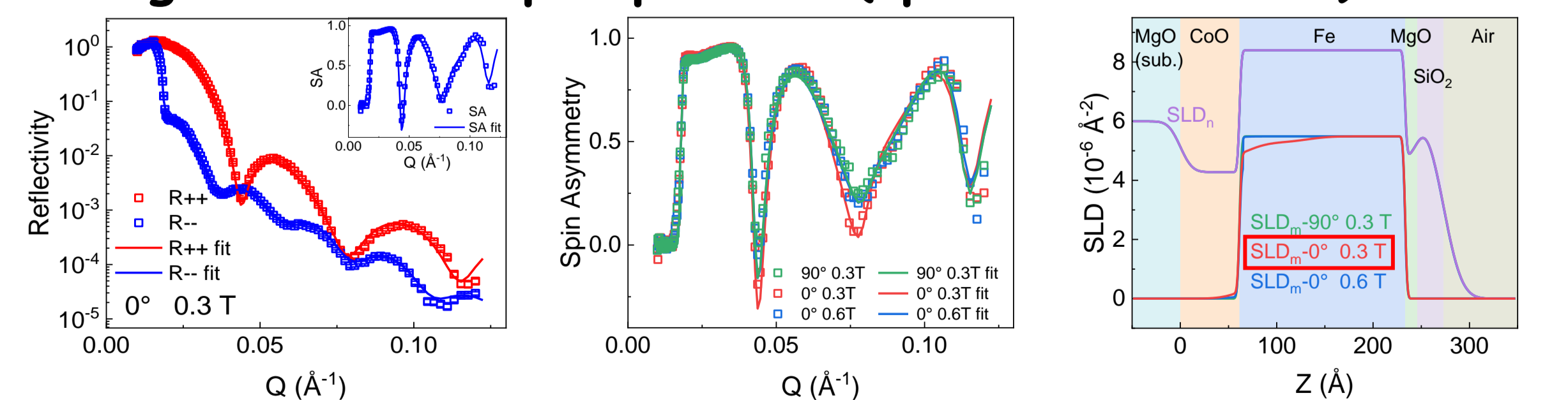
- ✓ Layer-resolved precession modes



Non-uniform effective field H_{eff} → Non-uniform precession dynamics

PNR characterization of exchange spirals

- Magnetization depth profiles (spiral vs. uniform)

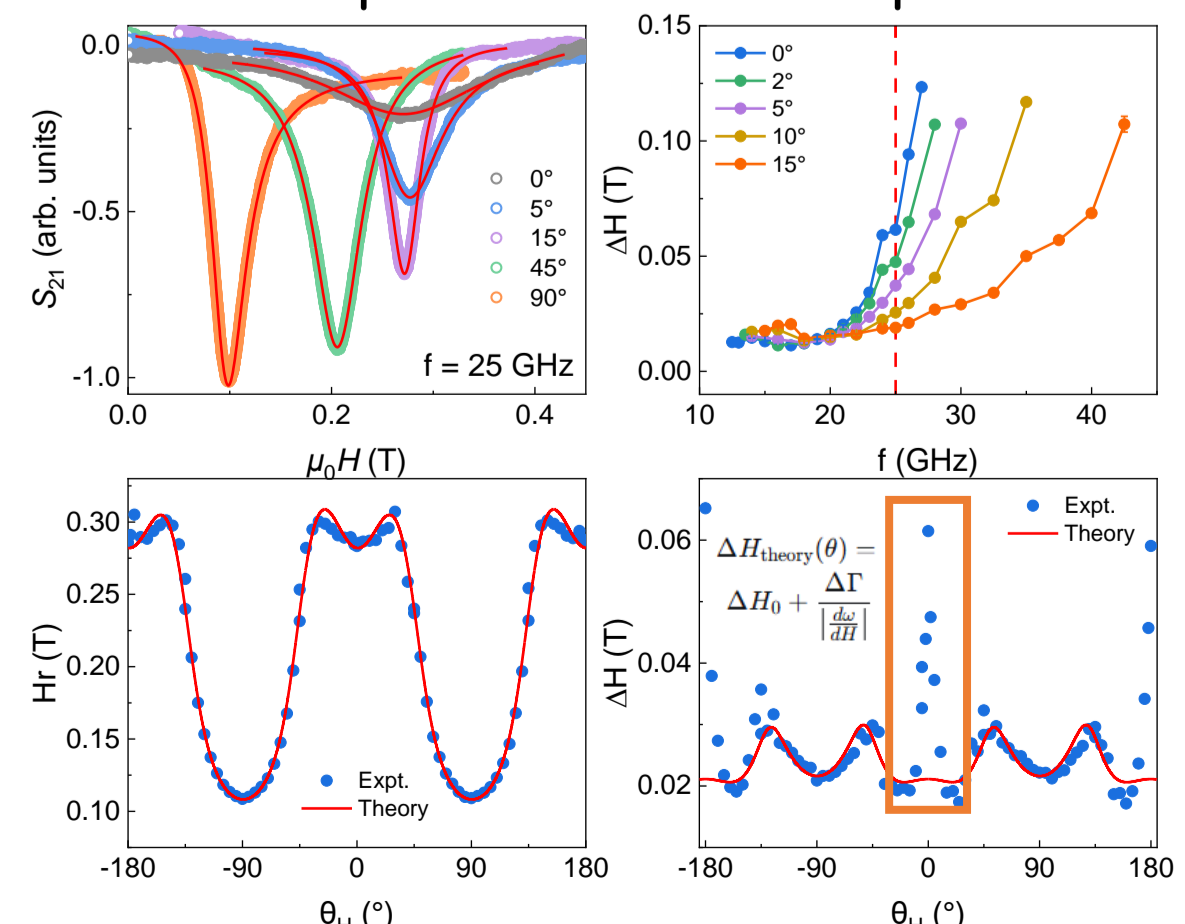


Direct evidence of the interfacial spiral

Angular-dependent dynamic properties

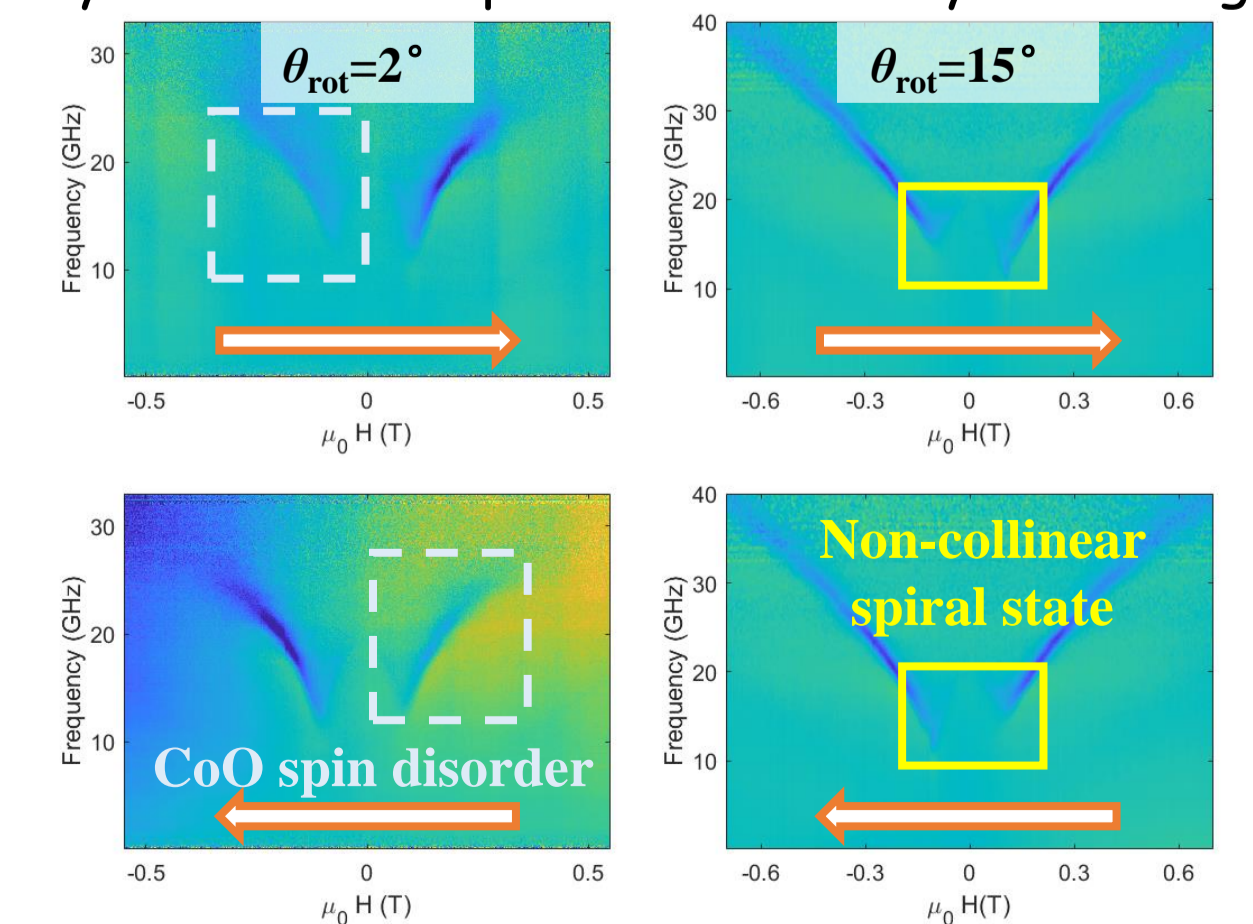
- Anisotropic damping

- ✓ Anisotropic interfacial dissipation



- Unidirectional asymmetry

- Asymmetric dissipation
- Chirality switching



$$\Delta H_{Fe/CoO} \gg \Delta H_{Fe,CoO}$$

Interfacial exchange coupling → unique dynamic properties

Nonreciprocal

Conclusion

- Exchange spirals were studied by ferromagnetic resonance (FMR).
- The structure of exchange spirals was confirmed by micromagnetic simulation and PNR.
- Spin-wave excitation modes of spirals with different structures were simulated.