Nonreciprocity and Unidirectional Invisibility in Cavity Magnonics

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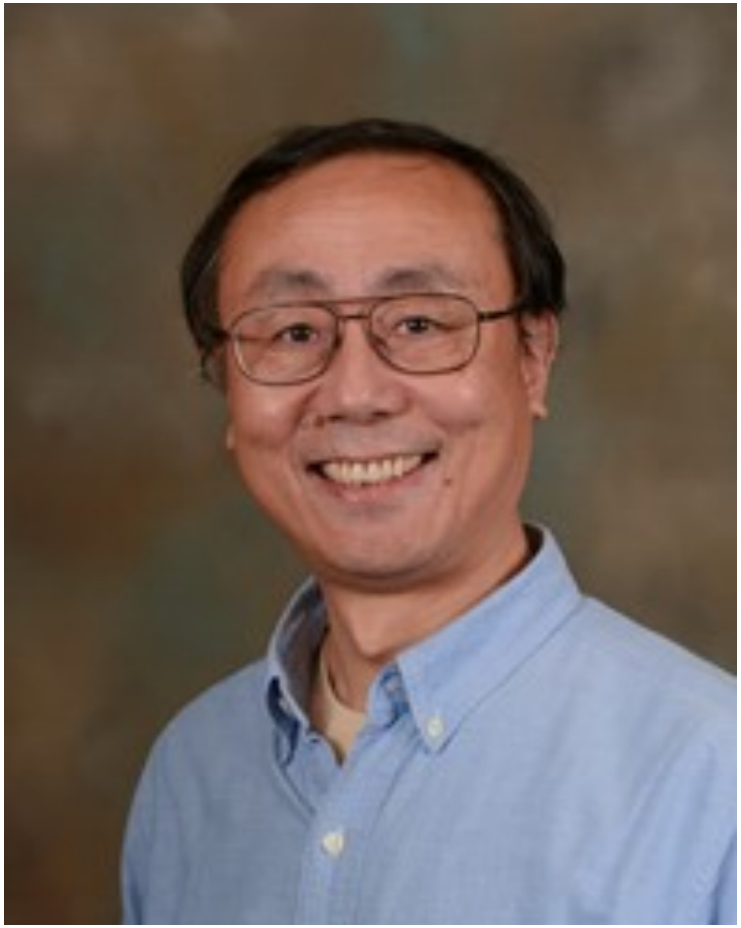
Can-Ming Hu



Biography

1995: PhD, Wuerzburg University in Germany.

1998-1999: NTT Basic Laboratories in Japan.

1999-2005: Subgroup leader(Habilitation), University Hamburg, Germany.

2012 - present: Full Professor, University of Manitoba, Canada.

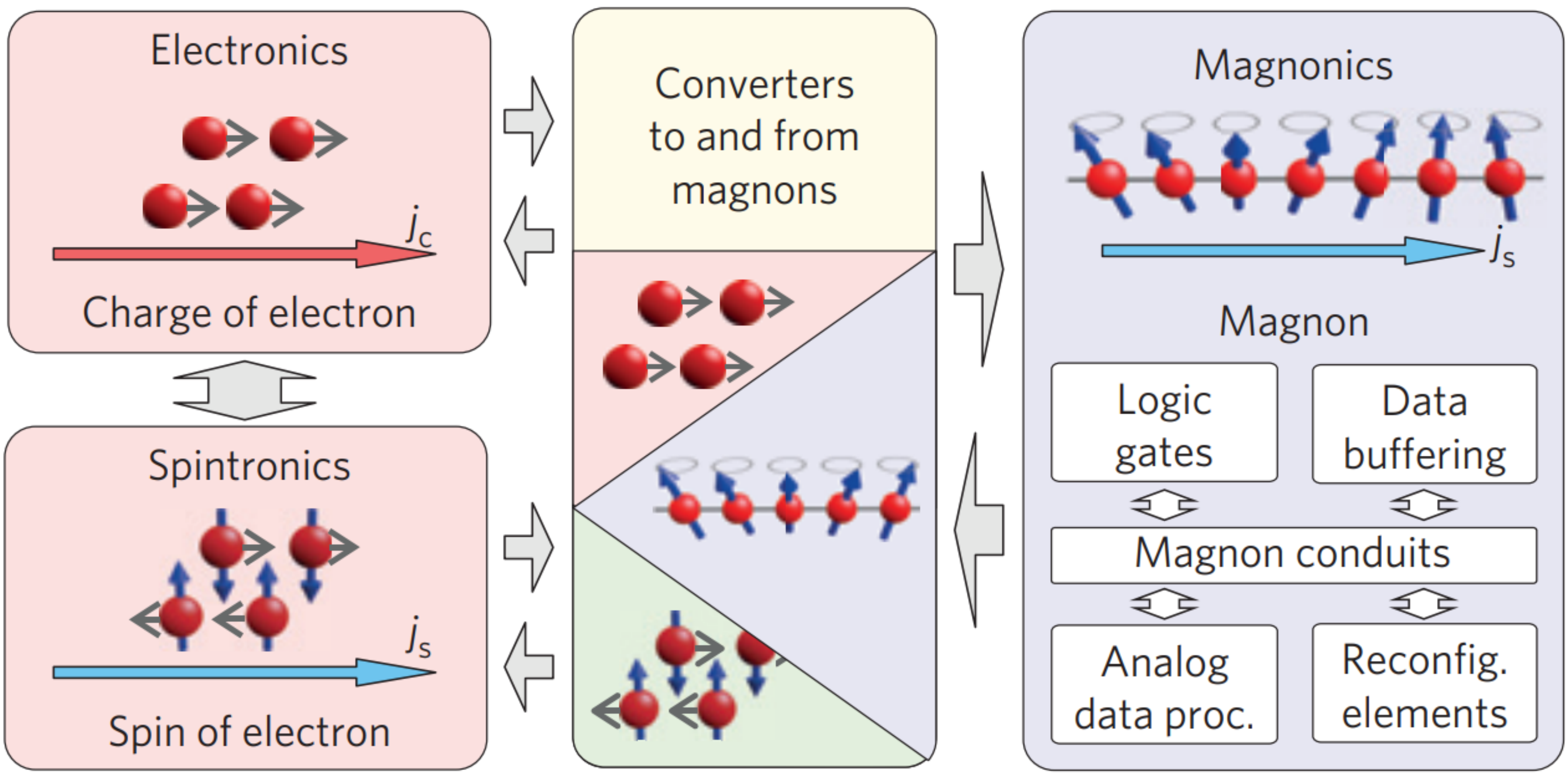
RESEARCH INTERESTS

Cavity Spintronics

Contemporary Magnetism

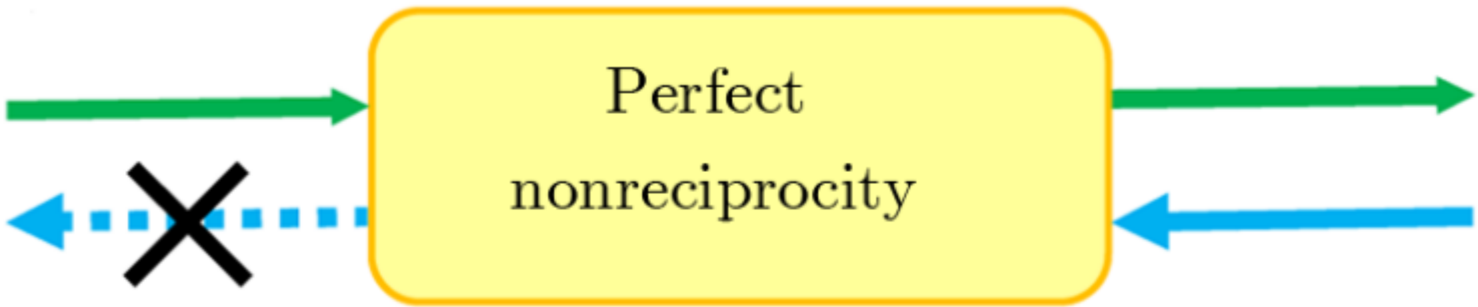
Ferromagnetic Semiconductors

Magnonics



Electronics
j_c
Charge of electron
Spintronics
j_s
Spin of electron
Converters
to and from
magnons
Magnonics
j_s
Magnon
Logic
gates
Data
buffering
Magnon conduits
Analog
data proc.
Reconfig.
elements

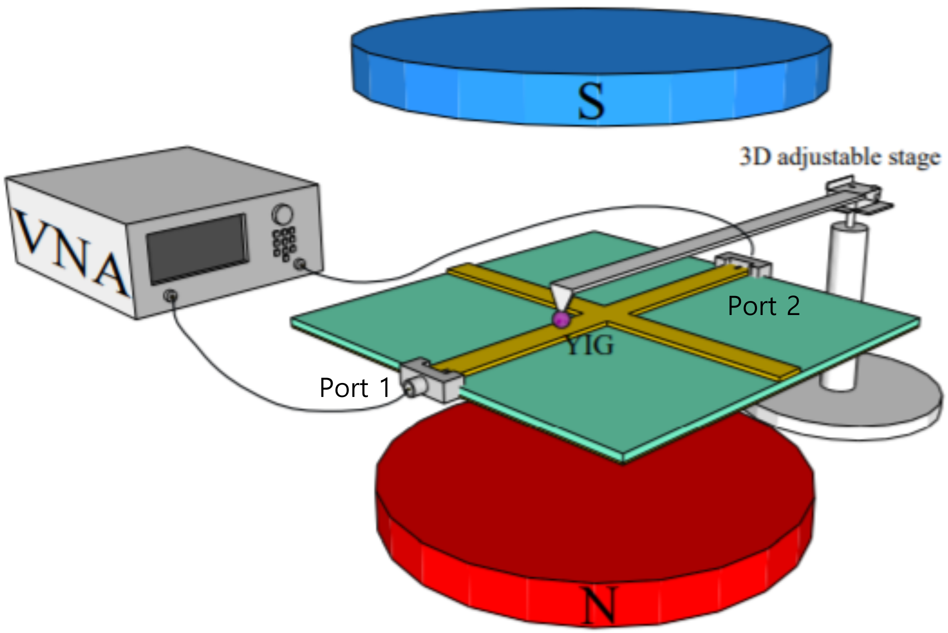
Nonreciprocity



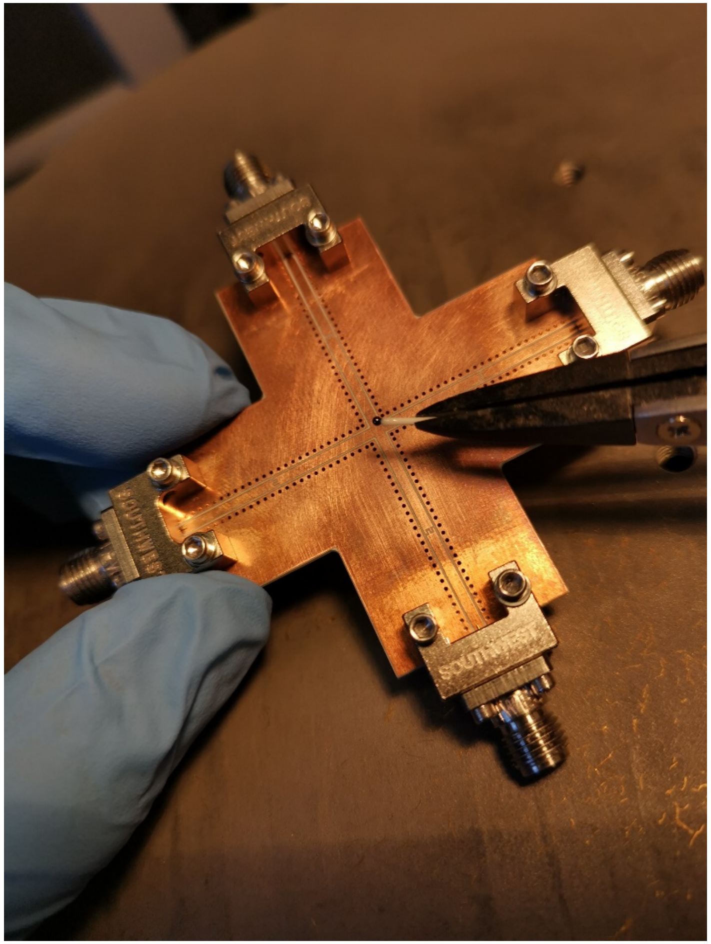
For application

1. Large reverse isolation
2. High efficiency (low insertion loss)
3. Low output noise

Experimental setup



J : Coherent magnon-photon coupling rate
Γ : Dissipative magnon-photon coupling rate



Nonreciprocity and Unidirectional Invisibility

$$\hat{H}/\hbar = \tilde{\omega}_c \hat{a}^\dagger \hat{a} + \tilde{\omega}_m \hat{b}^\dagger \hat{b} + (J - i\Gamma e^{i\Theta})(\hat{a}^\dagger \hat{b} + \hat{b}^\dagger \hat{a})$$

$$\widetilde{\omega}_{\mathrm{c}} = \omega_{\mathrm{c}} - i\beta$$

$$\widetilde{\omega}_{\mathrm{m}} = \omega_{\mathrm{m}} - i\alpha$$

$$\widetilde{\omega}_{\pm} = \frac{1}{2}\left[\omega_{\mathrm{c}} + \omega_{\mathrm{m}} - i(\beta + \alpha) \pm \sqrt{[(\omega_{\mathrm{c}} - \omega_{\mathrm{m}}) - i(\beta - \alpha)]^2 + 4(J - ie^{i\Theta}\Gamma)^2}\right]$$

Intrinsic damping rate $\mathrm{Im}(\tilde{\omega}_{\pm}) \rightarrow 0$

at zero-damping condition (ZDC)

Nonreciprocity and Unidirectional Invisibility

$$S_{21(12)} = 1 + \frac{\kappa}{i(\omega - \omega_c) - (\kappa + \beta) + \frac{-[iJ + \Gamma e^{i\Theta_{1(2)}}]^2}{i(\omega - \omega_m) - (\alpha + \gamma)}}$$

$$\Theta_1 = 0, \ \ \Theta_2 = \pi$$

κ, γ : External damping rates of the cavity and magnon modes.

For ZDCs at $\omega_m = \omega_c \pm 2J\Gamma/\alpha$

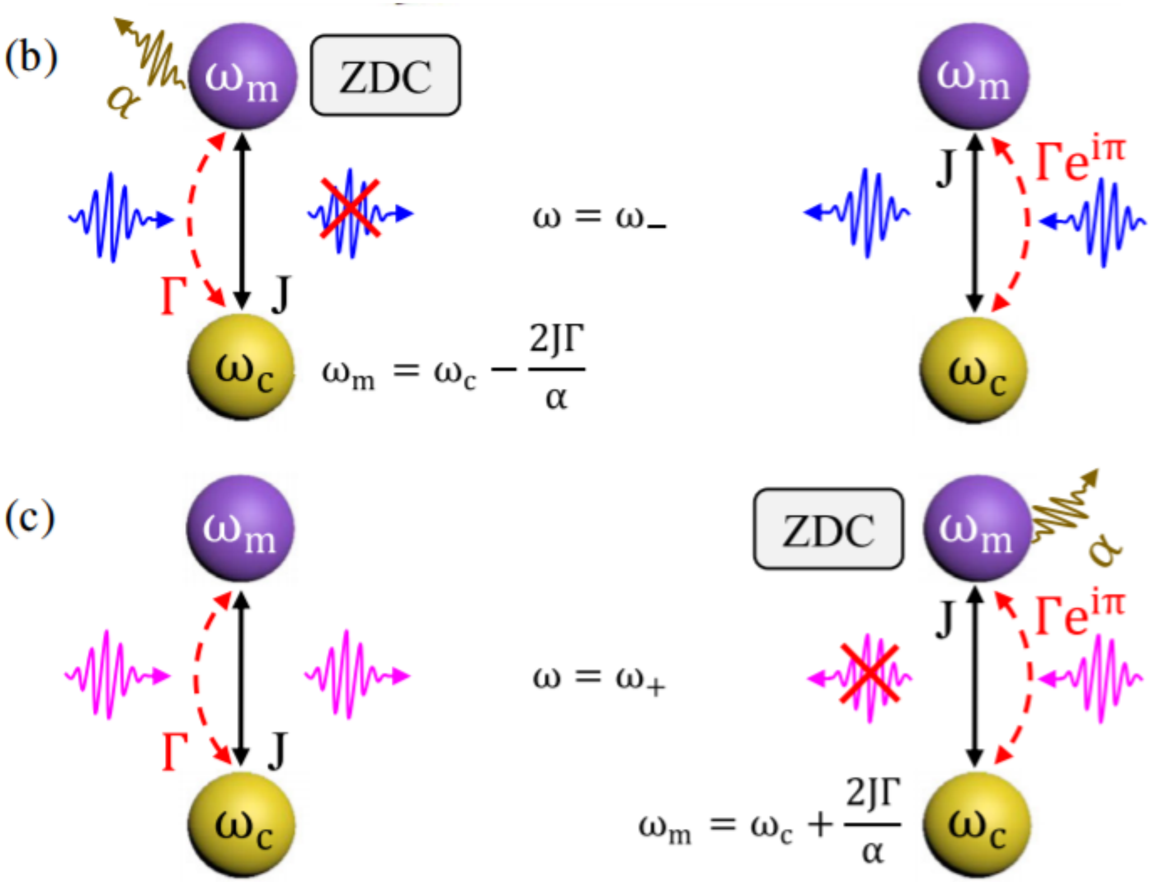
$$|S_{21}(\omega_-)| = |S_{12}(\omega_+)| = 0,$$

$$|S_{12}(\omega_-)| = |S_{21}(\omega_+)| > 0,$$

Nonreciprocity and Unidirectional Invisibility

$$|S_{21}(\omega_-)| = |S_{12}(\omega_+)| = 0, \tag{3a}$$

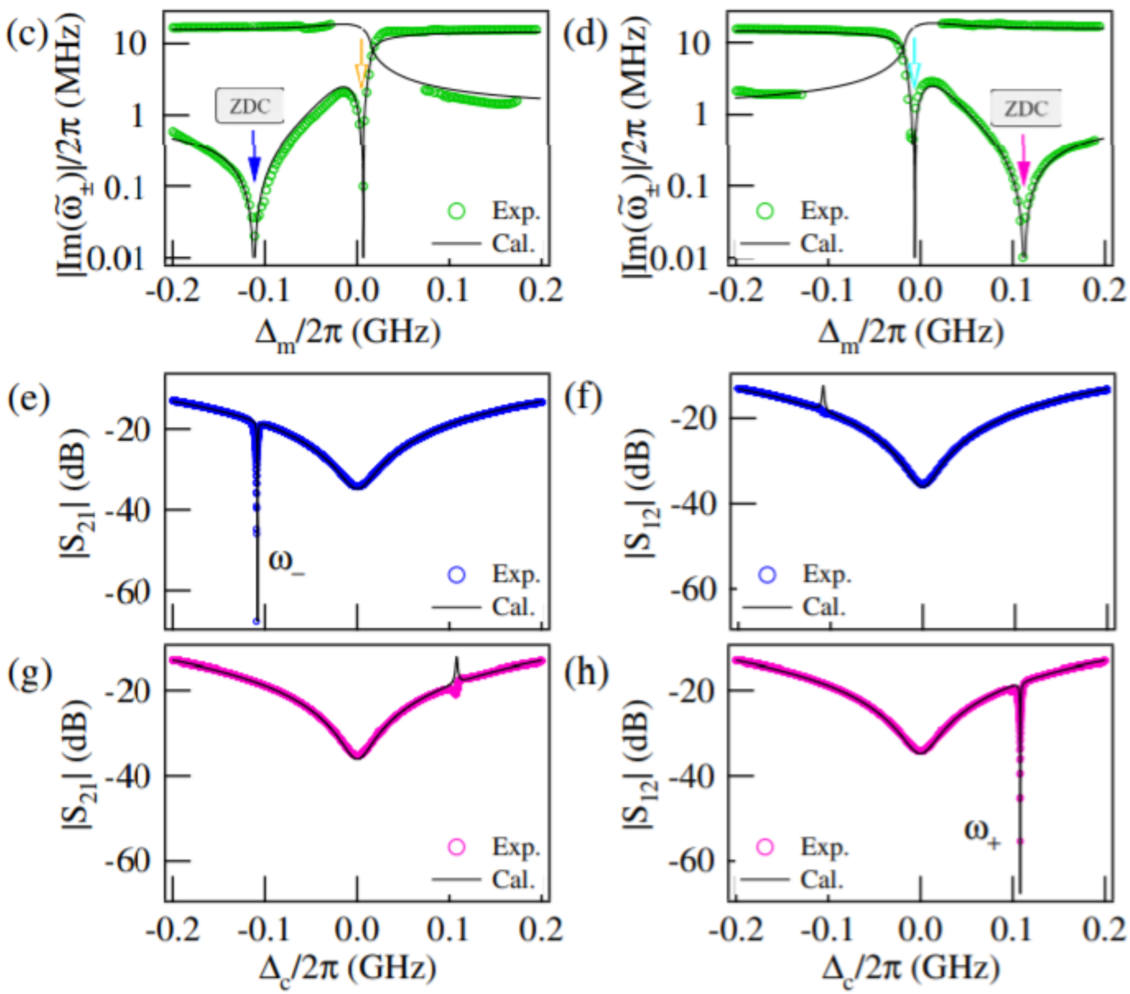
$$|S_{12}(\omega_-)| = |S_{21}(\omega_+)| > 0, \tag{3b}$$



Experimental Results

$J = \Gamma$, $\omega_c/2\pi = 4.724$ GHz, $\Delta_m = \omega_m - \omega_c$

$|S_{21}(\omega)|$ $|S_{12}(\omega)|$



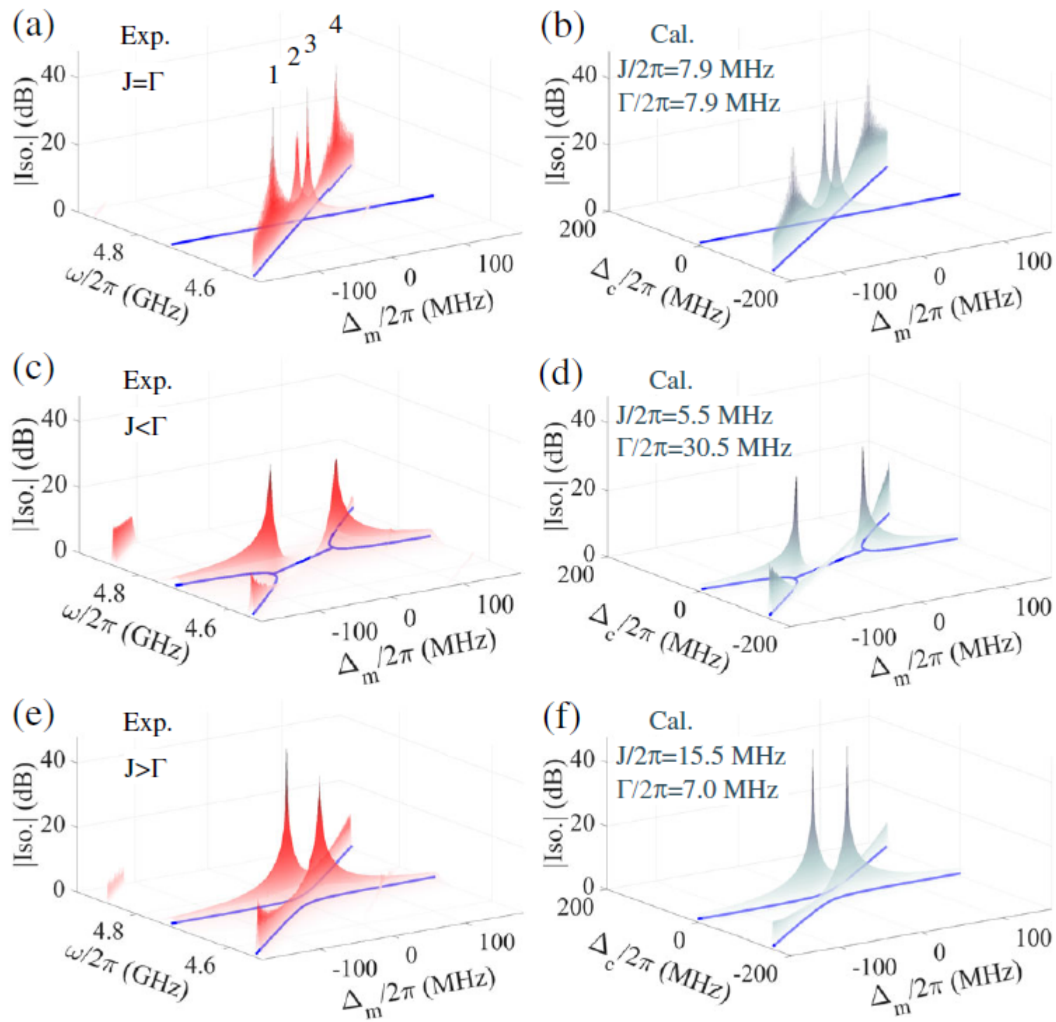
Flexible Controllability

Isolation ratio : $20 \times |\log_{10}(|S_{21}/S_{12}|)|$

$J = \Gamma$

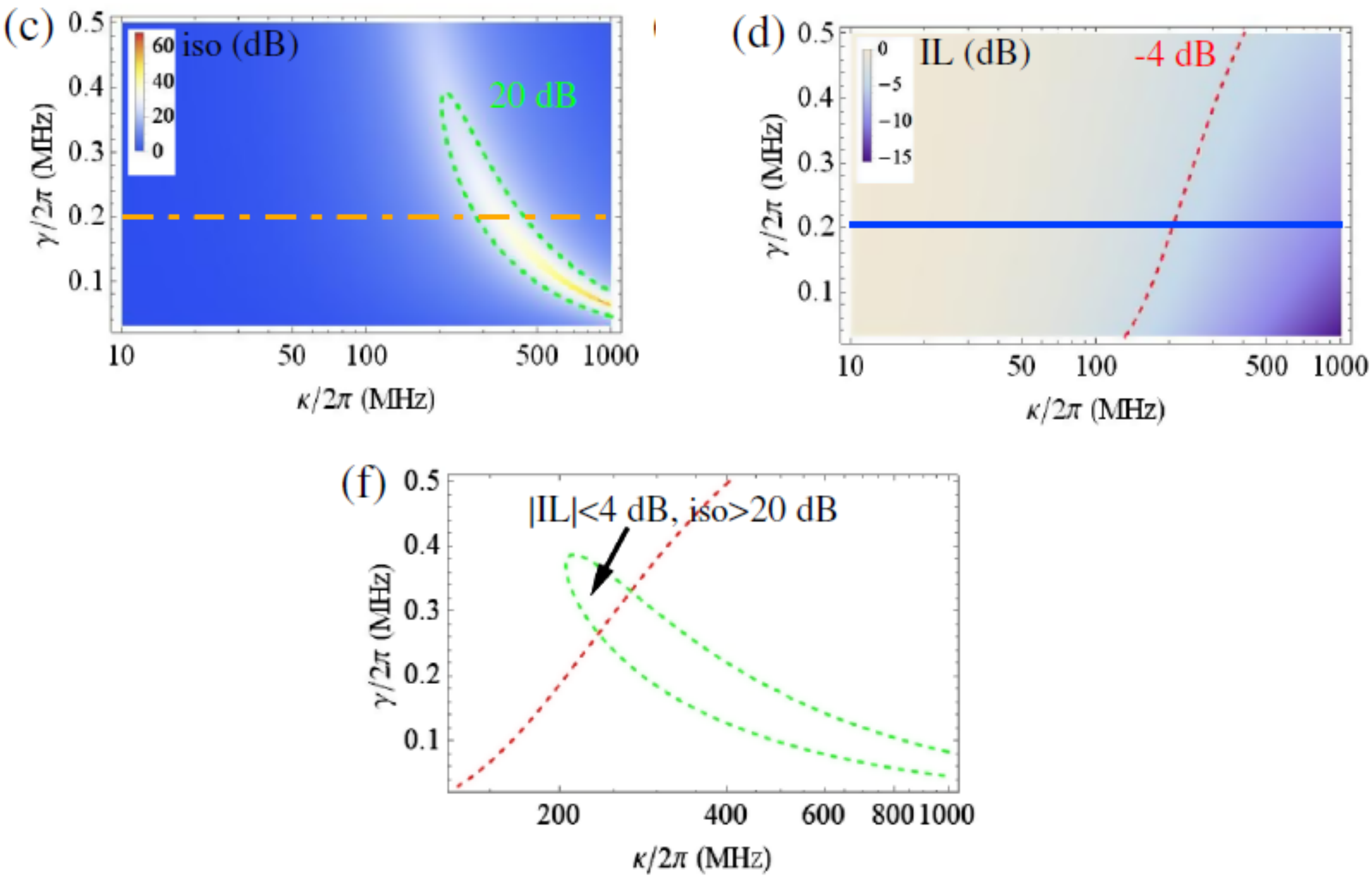
$J < \Gamma$

$J > \Gamma$



Conditions for Ideal Performance

κ, γ : External damping rates of the cavity and magnon modes.



Conclusion

◆New scheme for realizing nonreciprocal microwave transmission.

- Unidirectional invisibility of microwave propagation by cooperative effect of coherent and dissipative magnon-photon couplings.

- Flexible controllability

- Optimized performance with large nonreciprocity and low insertion loss.