

Shaping non-reciprocal spin wave beams using gold nanowire grating

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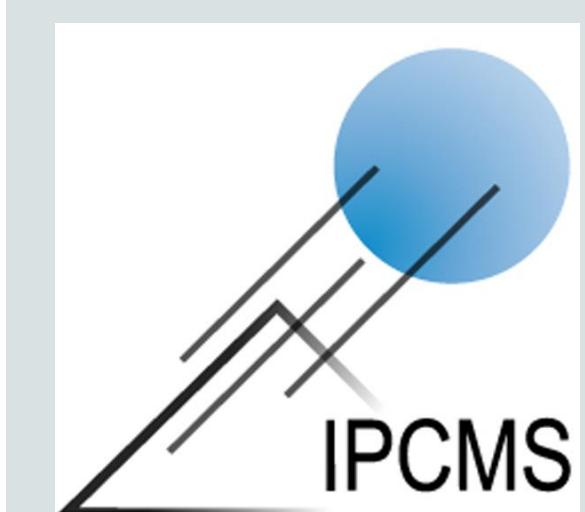
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Fundings



ANR "MagFunc"



Project "SOSMAG"

References

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- [3] L. Temdie, V. Castel, et al., 10.20944/preprints202306.1441.v1. (2023).
- [4] V. Vlaminck, L. Temdie, et al., Journ. of Appl. Phys. 10.1063/5.0128666 (2023).
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Motivations

► Miniaturization of non-reciprocal components

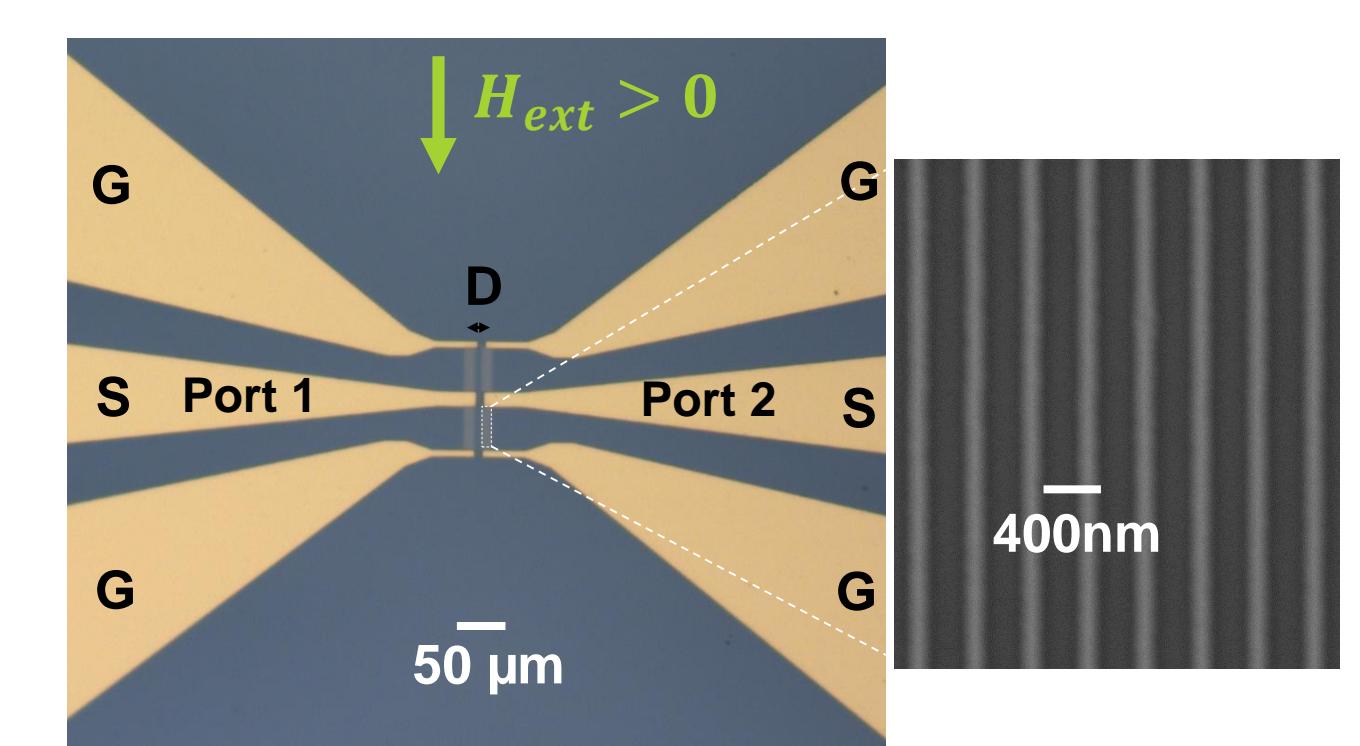
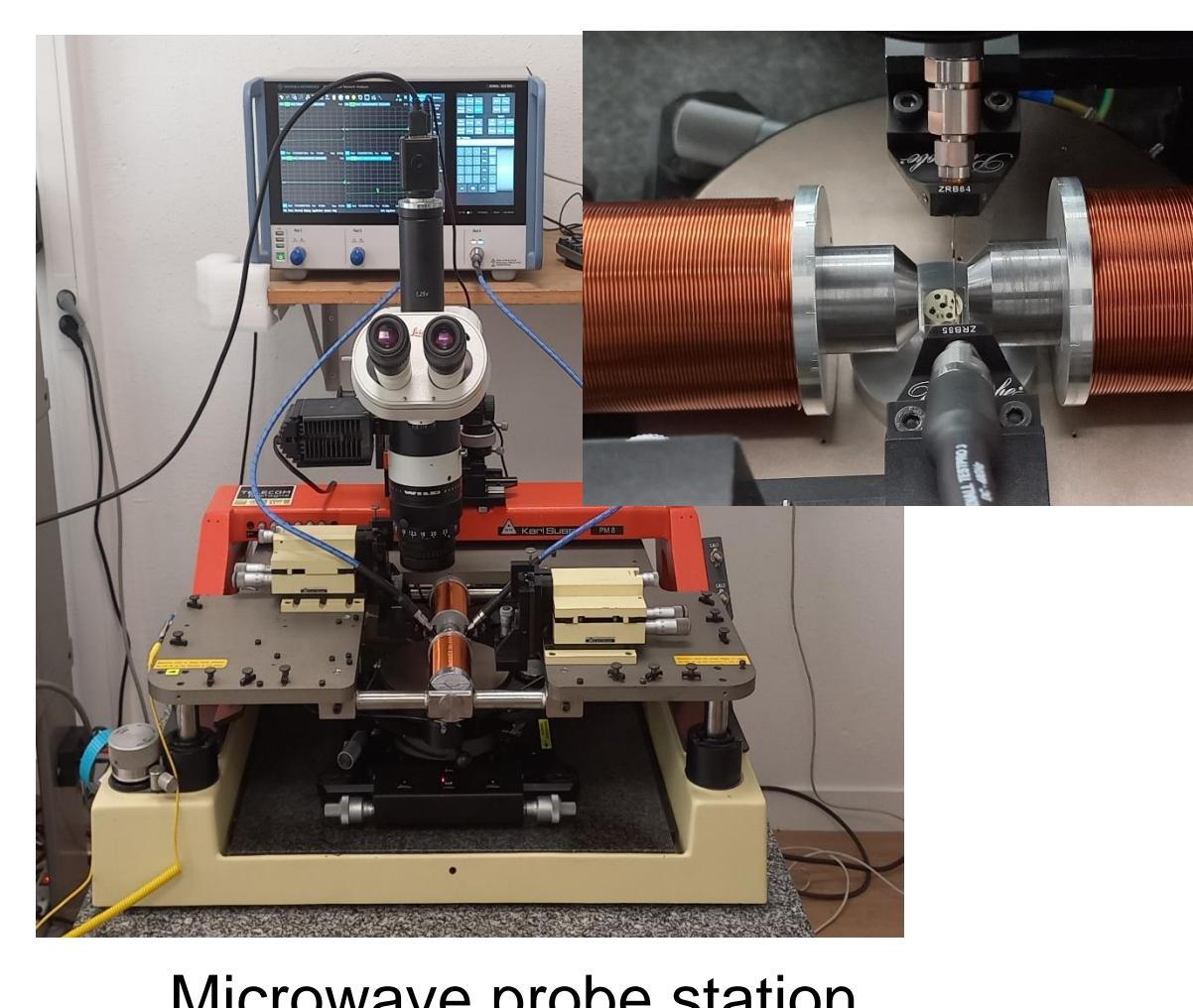
Unidirectional excitation of spin wave for isolators and circulator [1,2,3]

► Spin wave beamforming

Exploration of interferometric magnonics sensors [4]

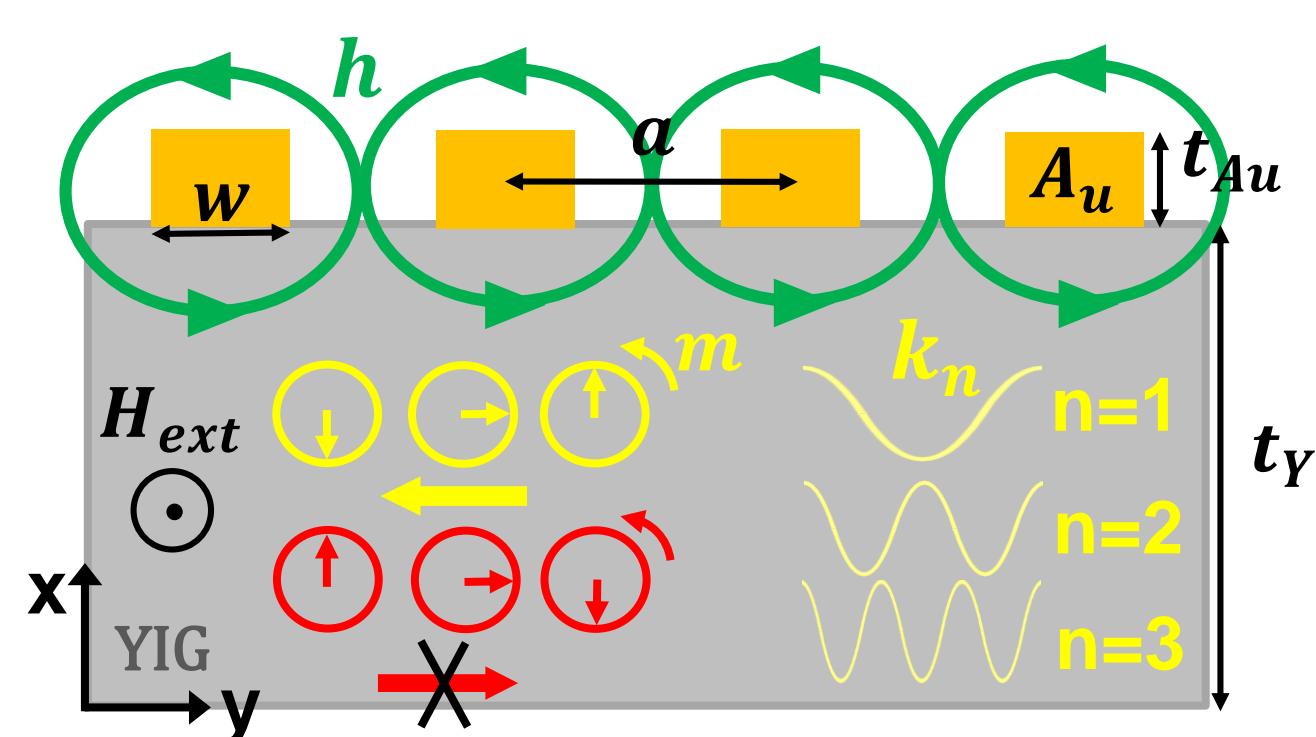
► High k-vector propagation properties

Broadband k-dependence of the spin-wave relaxation time



Two Gold (Au) nanowires (NW) of $D=20\mu\text{m}$ distant : 40nm-thick, 100nm-wide, 35μm-long 400nm lattice constant / 80nm Au-antennas

Principle of chiral excitation and grating conception

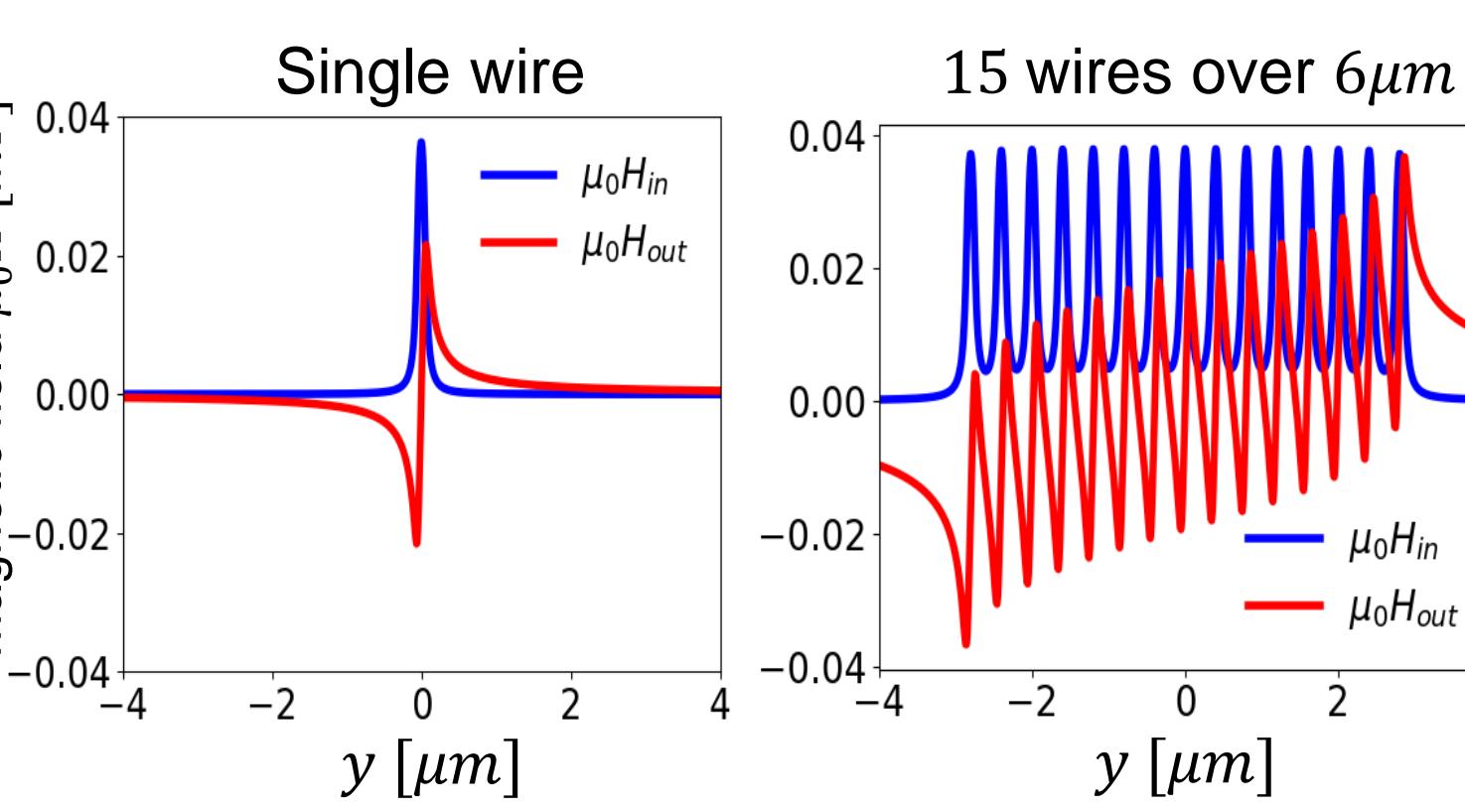


- Excited wave mode $k_n = n2\pi/a$ (i.e. $\lambda_n = a/n$)
- Chiral coupling between NW field \mathbf{h} and \mathbf{m} in YIG
- Degree of chirality related to aspect ratio : t_{Au}/w

In- and out-of-plane field of Au NW

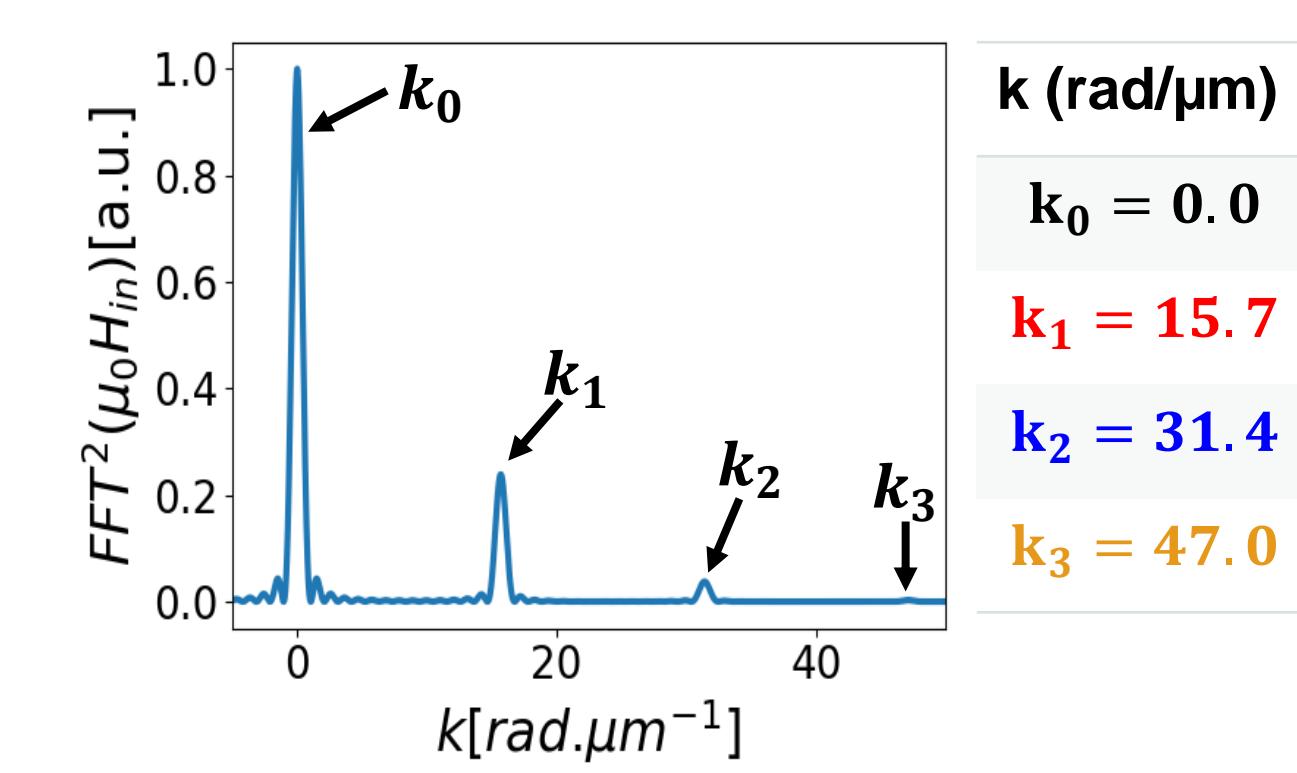
NW length $\ll \lambda_{EM} \Rightarrow$ DC current [5]

$I=0.01\text{ mA}$, $w=100\text{ nm}$, $t=40\text{ nm}$, $a=400\text{ nm}$



Fourier transform of NW field \mathbf{h}

Coupling efficiency in reciprocal space



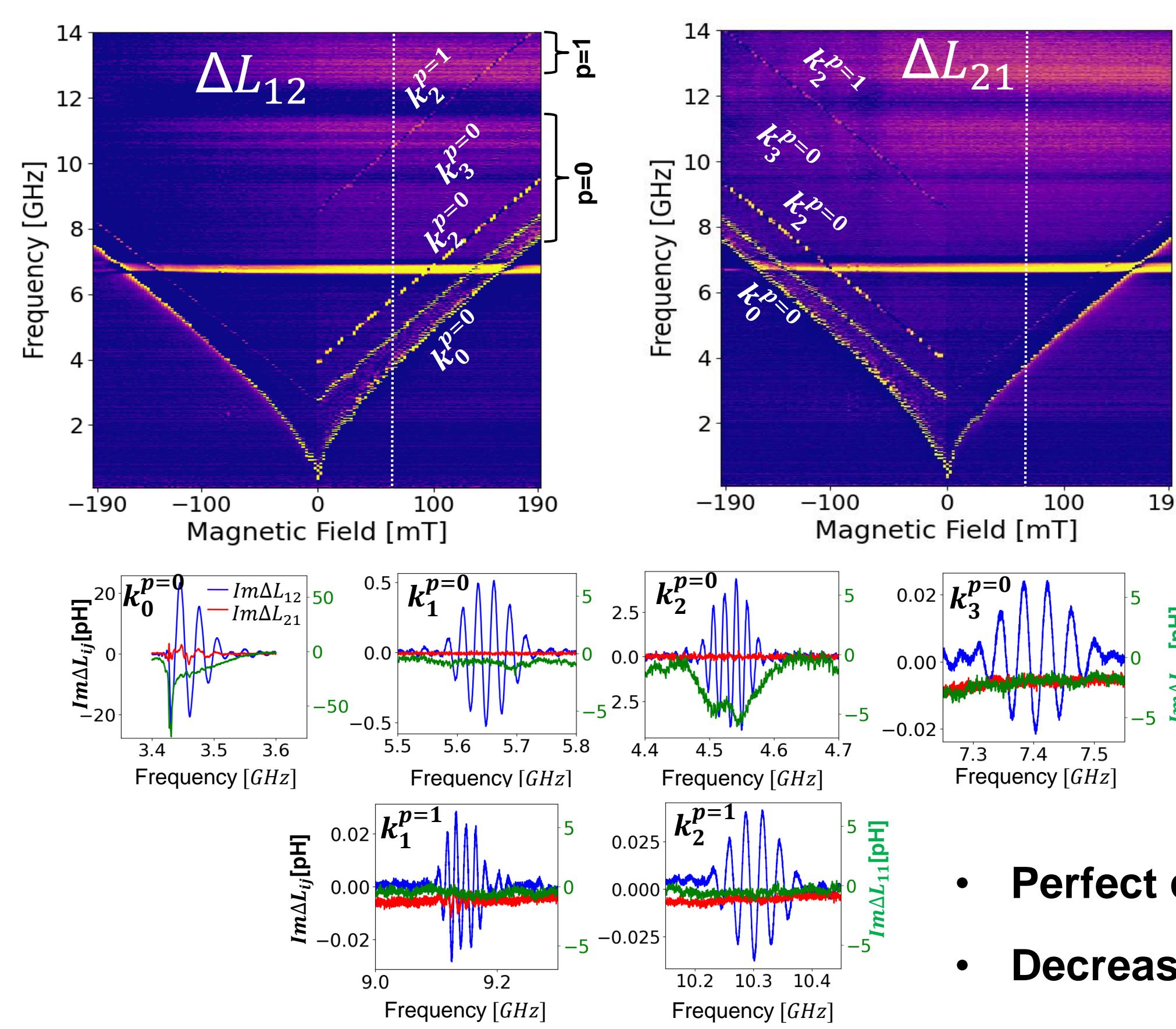
Well-defined comb of wavevector

VNA transmission parameter converted into mutual inductance

$$S_{ij} \rightarrow Z_{ij} \rightarrow \Delta L_{ij} : \Delta L_{ij}(f, H) = \frac{1}{i2\pi f} (Z_{ij}(f, H) - Z_{ij}(f, H_{ref}))$$

Propagative spin wave spectroscopy

❖ $t_{YIG} = 55\text{ nm}$, $t_{Au} = 40\text{ nm}$



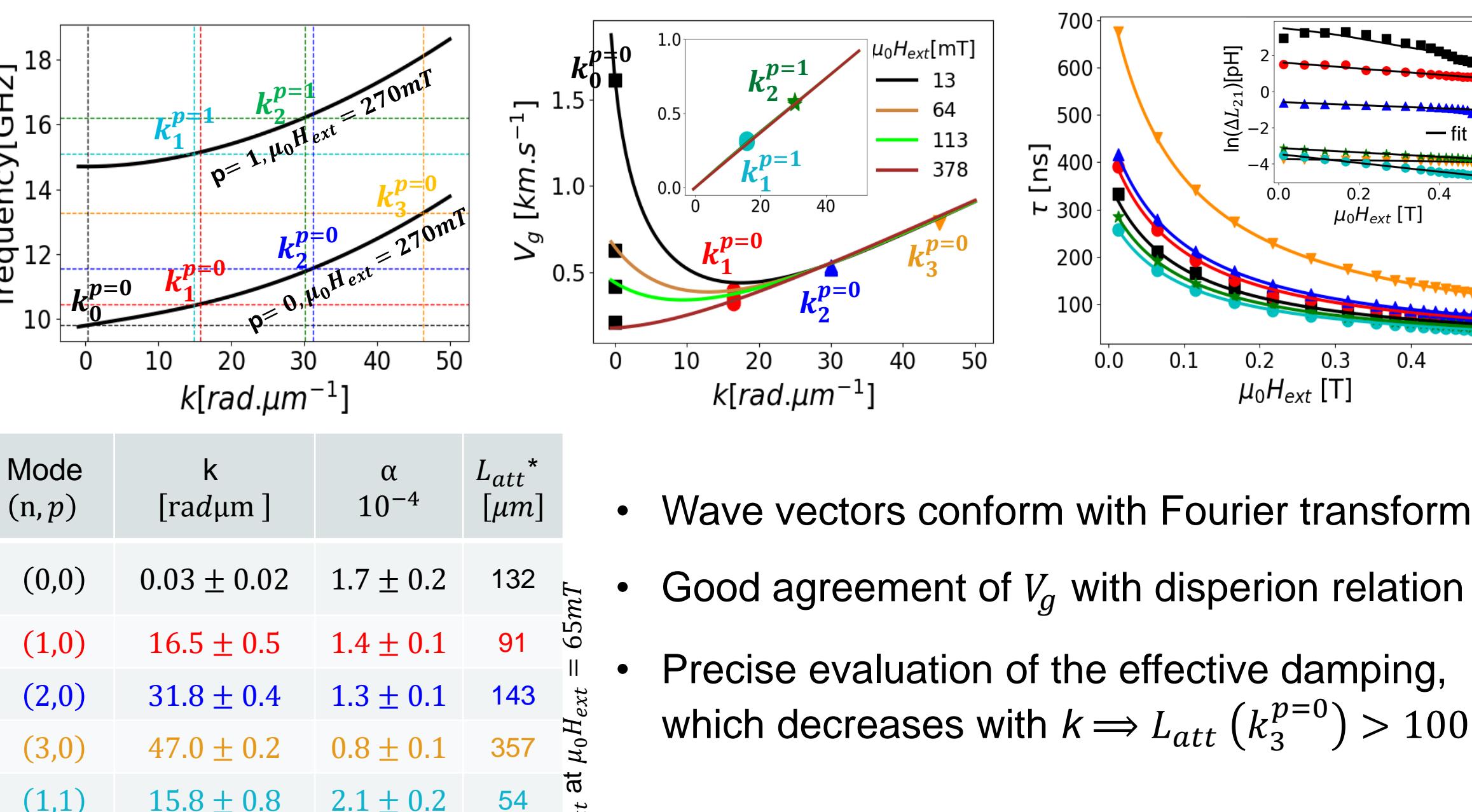
- Perfect chirality for higher wave vector ($k_2^{p=0}$, $k_3^{p=0}$, $k_2^{p=1}$) reversed when field switches
- Decrease of the coupling efficiency as t_{Au} increase

❖ Mode identification, Group velocity, and relaxation time

H-dependence of attenuation for a single device

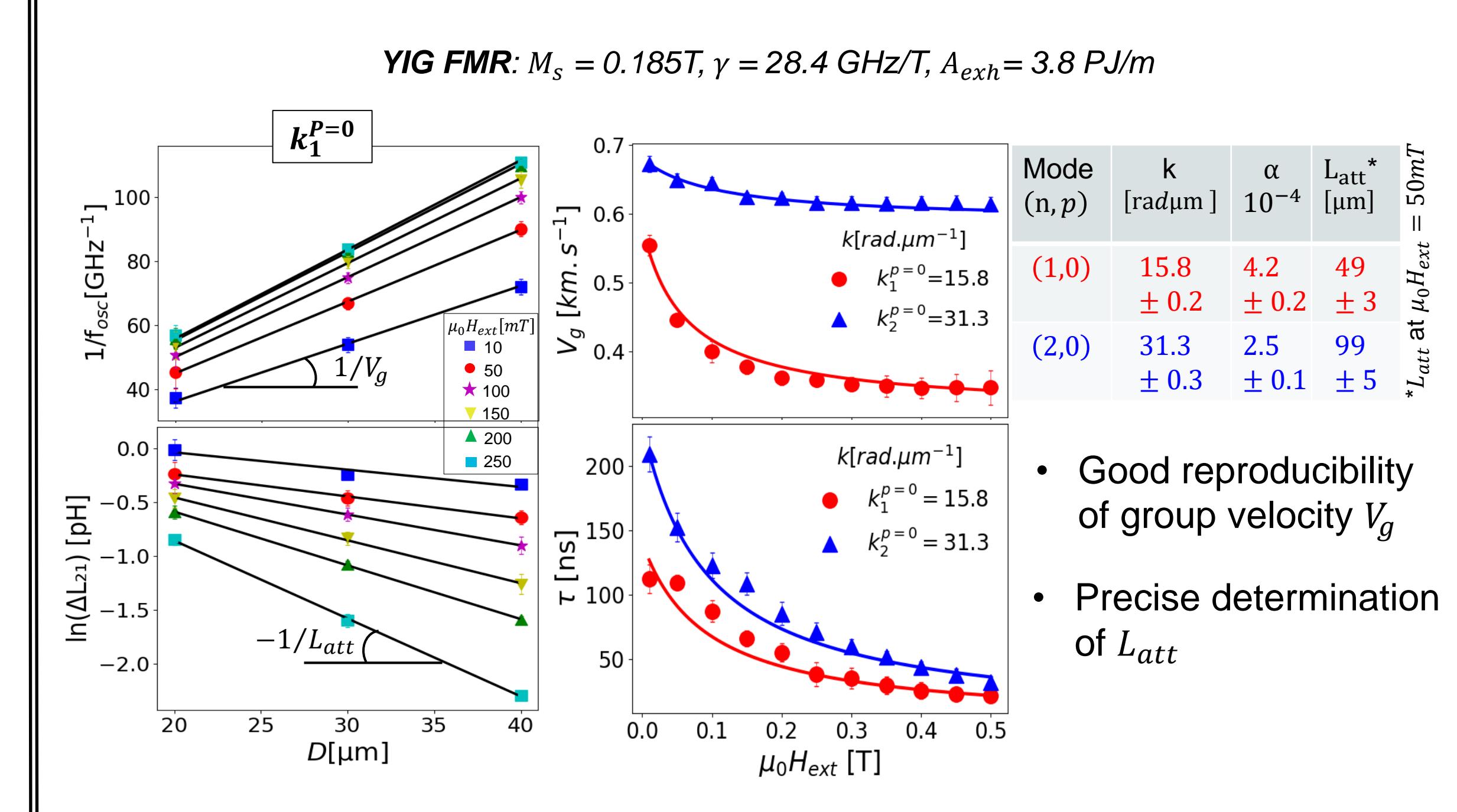
$$\Delta L_{21} \propto Ae^{-\frac{D}{L_{att}}}, \quad L_{att}(H) = v_g(H)\tau_k(H), \quad \tau_k = \frac{2}{\alpha[2(\omega_H + \eta k^2) + \omega_M]}$$

YIG FMR: $M_s = 0.183T$, $\gamma = 28.2\text{ GHz/T}$, $A_{exh} = 3.8\text{ PJ/m}$



D-dependence of attenuation $D = [20, 30, 40]\text{ μm}$

YIG FMR: $M_s = 0.183T$, $\gamma = 28.4\text{ GHz/T}$, $A_{exh} = 3.8\text{ PJ/m}$



- Good reproducibility of group velocity V_g
- Precise determination of L_{att}

Conclusions

► Unidirectional propagation of spin wave beam up to $50\text{ rad.}\mu\text{m}^{-1}$ over a 20 GHz frequency band

► Well-resolved mode (k_n^p) for high k spin-wave spectroscopy studies (higher k with reduced grating periodicity)

► Increase of relaxation time (τ_k) with k contrary to expectations, further study in-progress