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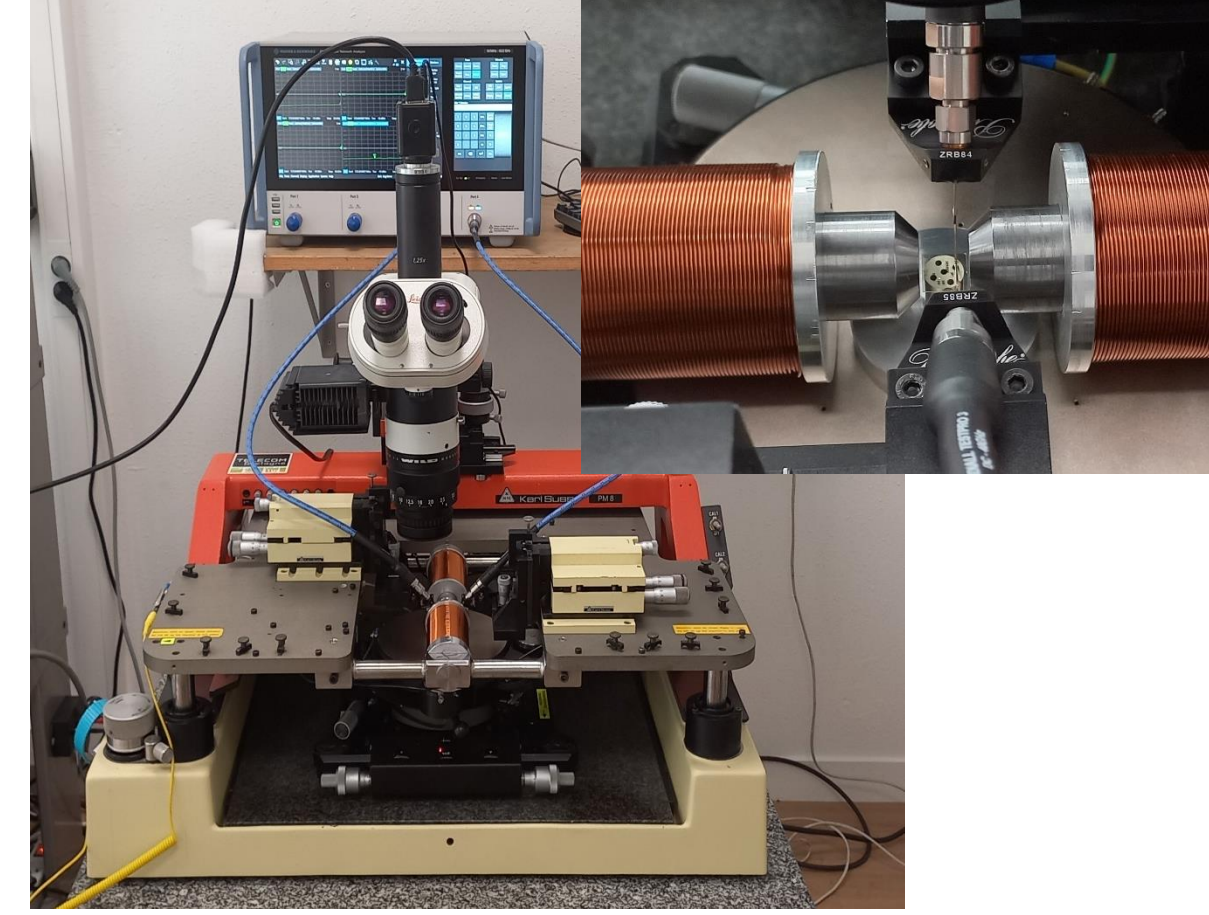


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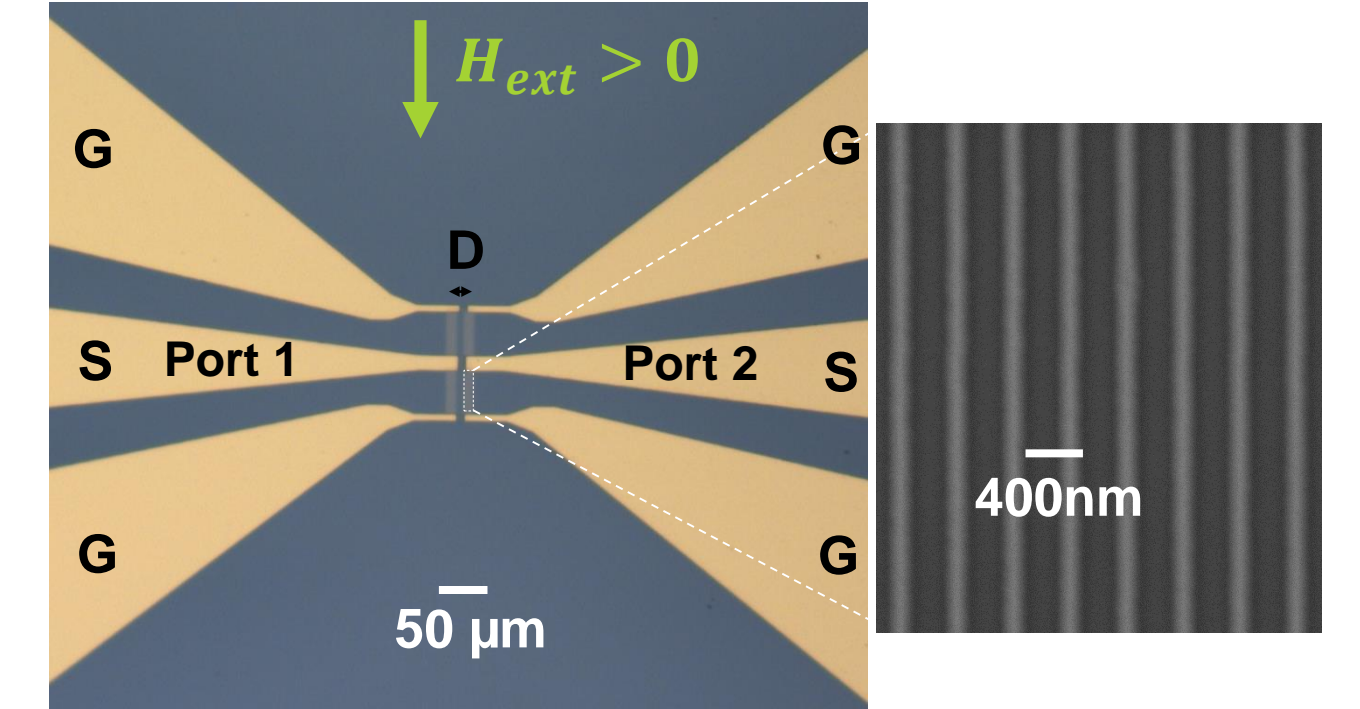
# Shaping non-reciprocal spin wave beams using gold nanowire grating

## 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



Microwave probe station



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

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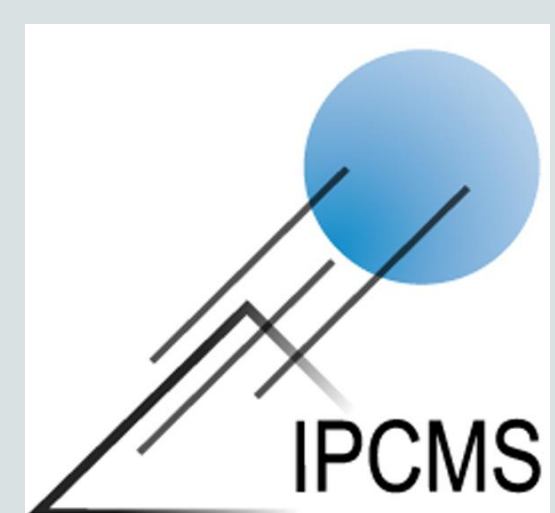
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## Fundings



ANR "MagFunc"

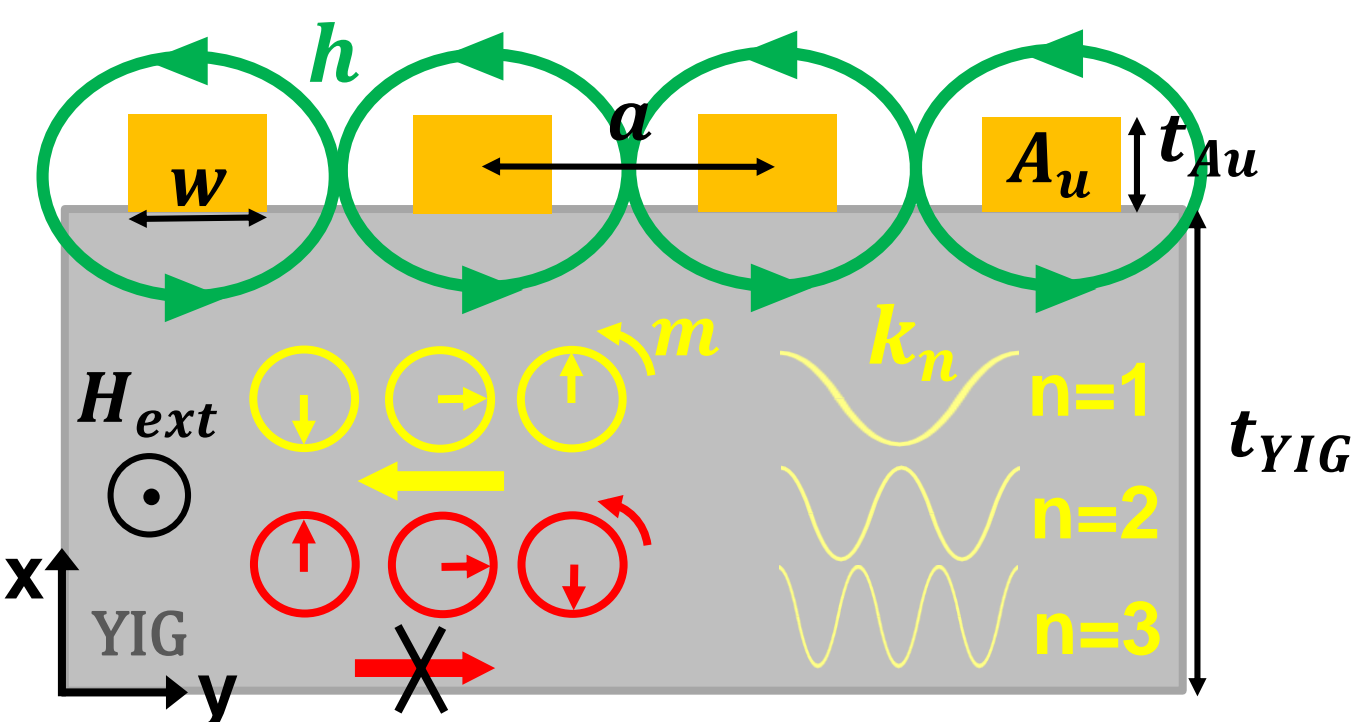


Project "SOSMAG"

## References

- [1] L. Peng, L. Tzu-Hisang et al., Appl. Phys. Letter, 10.1063/5.0156369. (2023).
- [2] L. Temdie, V. Castel, et al., AIP Advances, 10.1063/9.0000535. (2023).
- [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).
- [5] T. Brächer, O. Bouille, et al., Phys. Rev. B, 10.1103/PhysRevB.95.064429 (2017).

## Principle of chiral excitation and grating conception

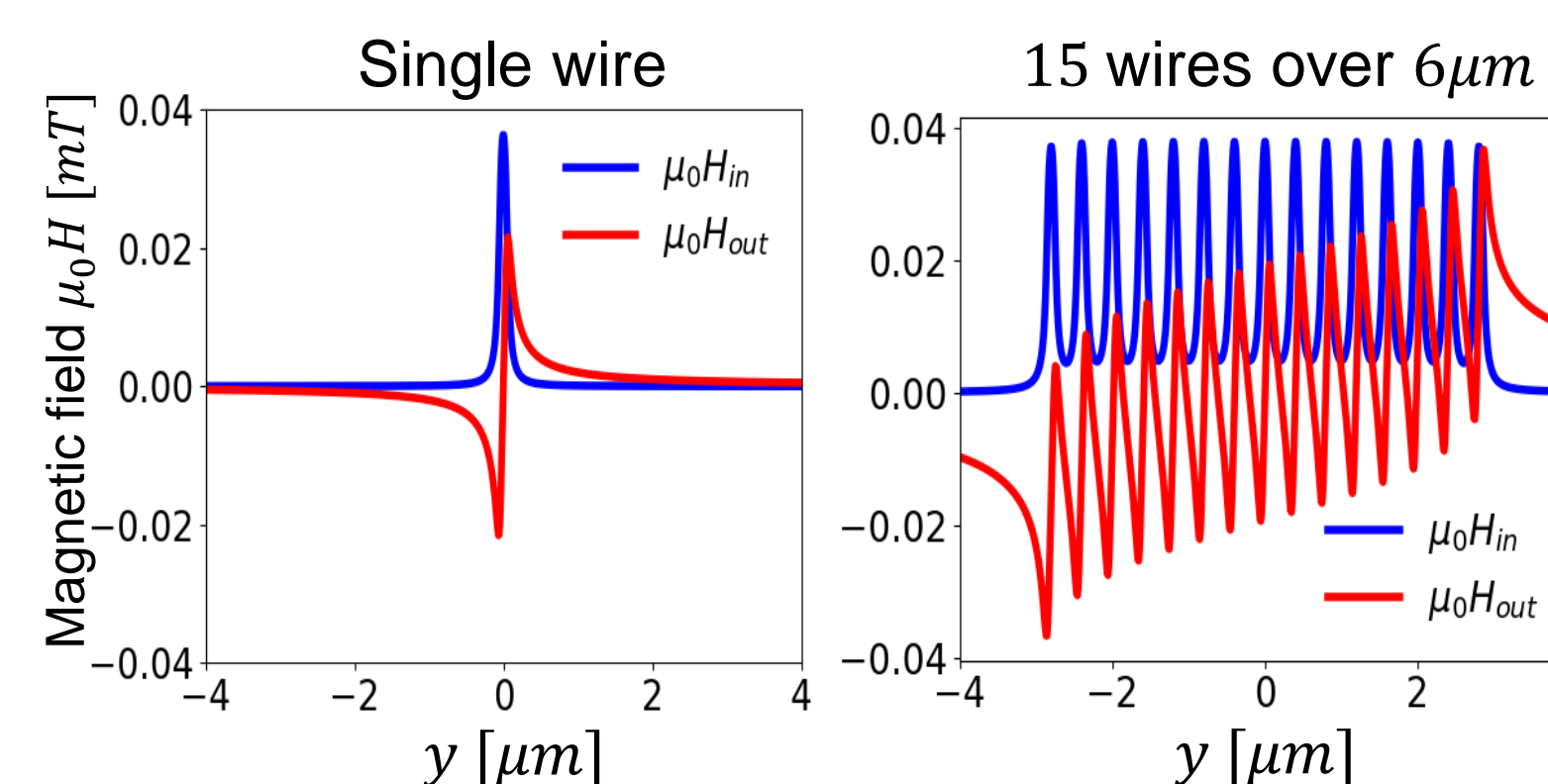


- Excited wave mode  $k_n = n2\pi/a$  (i.e.  $\lambda_n = a/n$ )
- Chiral coupling between NW field  $h$  and  $m$  in YIG
- Degree of chirality related to aspect ratio :  $t_{Au}/w$

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

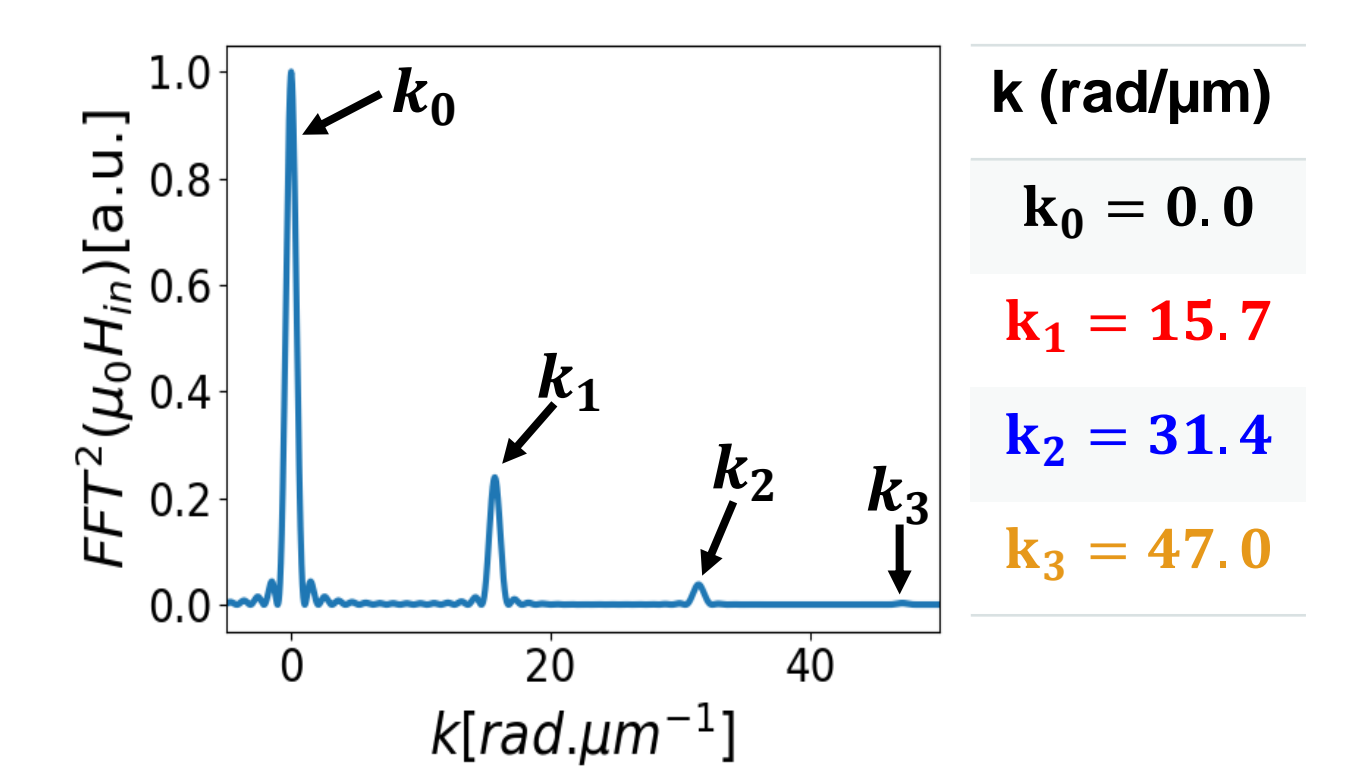
NW length  $\ll \lambda_{EM} \Rightarrow$  DC current [5]

$I=0.01$  mA,  $w=100$  nm,  $t=40$  nm,  $a=400$  nm



## Fourier transform of NW field $h$

Coupling efficiency in reciprocal space



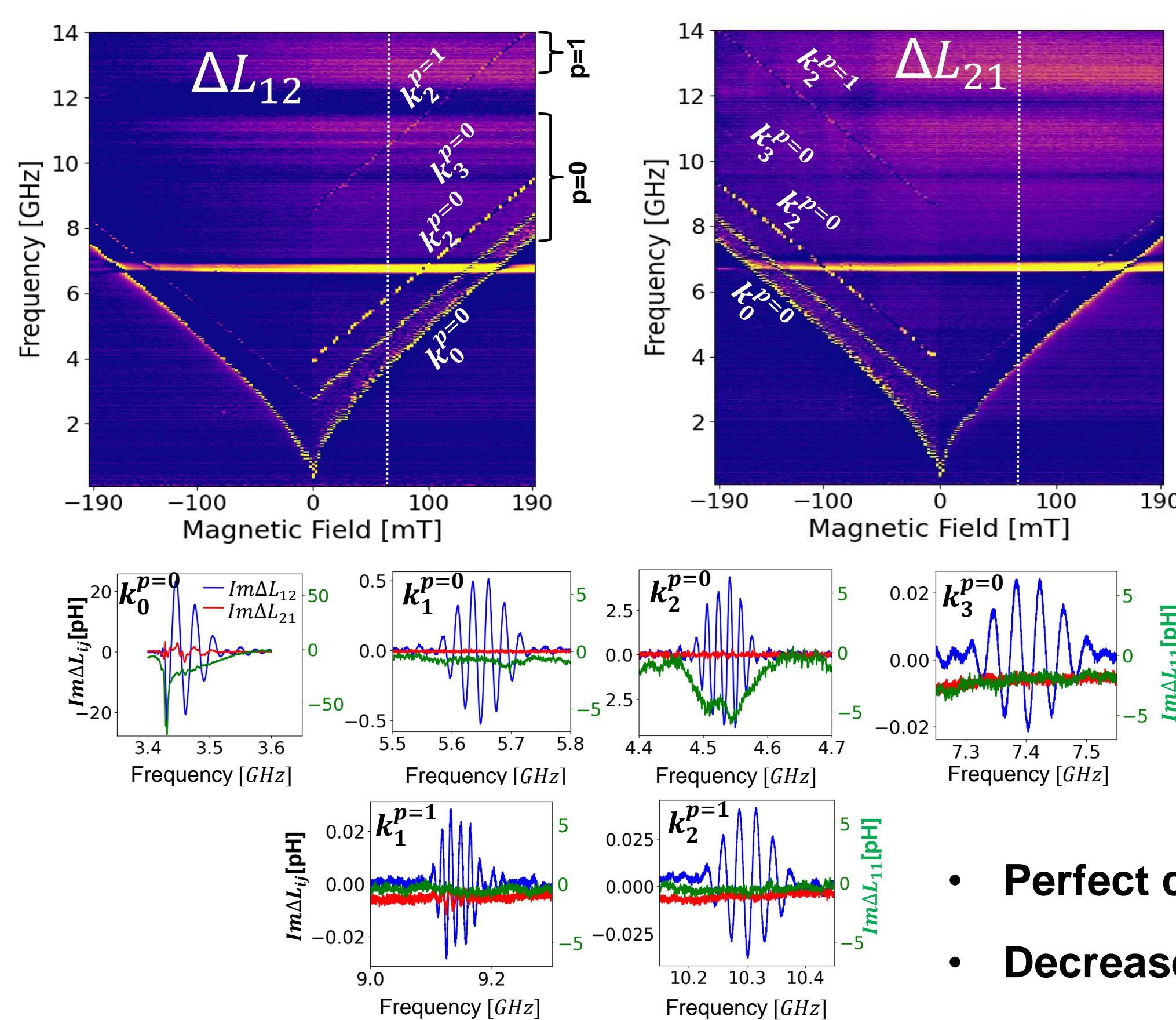
Well-defined comb of wavevector

## Propagative spin wave spectroscopy

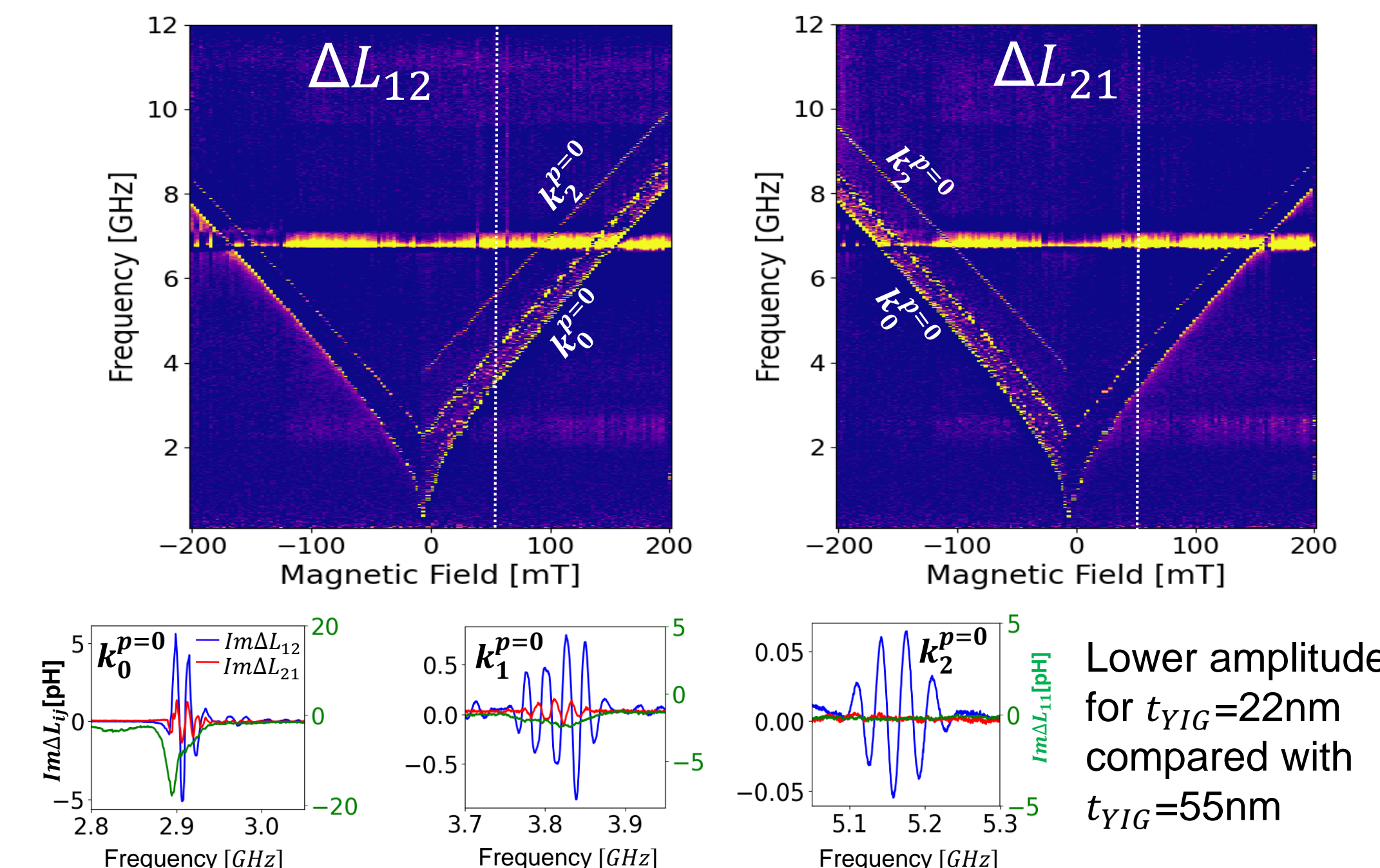
VNA transmission parameter converted into mutual inductance

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

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



❖  $t_{YIG} = 22$  nm,  $t_{Au} = 60$  nm



Lower amplitude for  $t_{YIG}=22$  nm compared with  $t_{YIG}=55$  nm

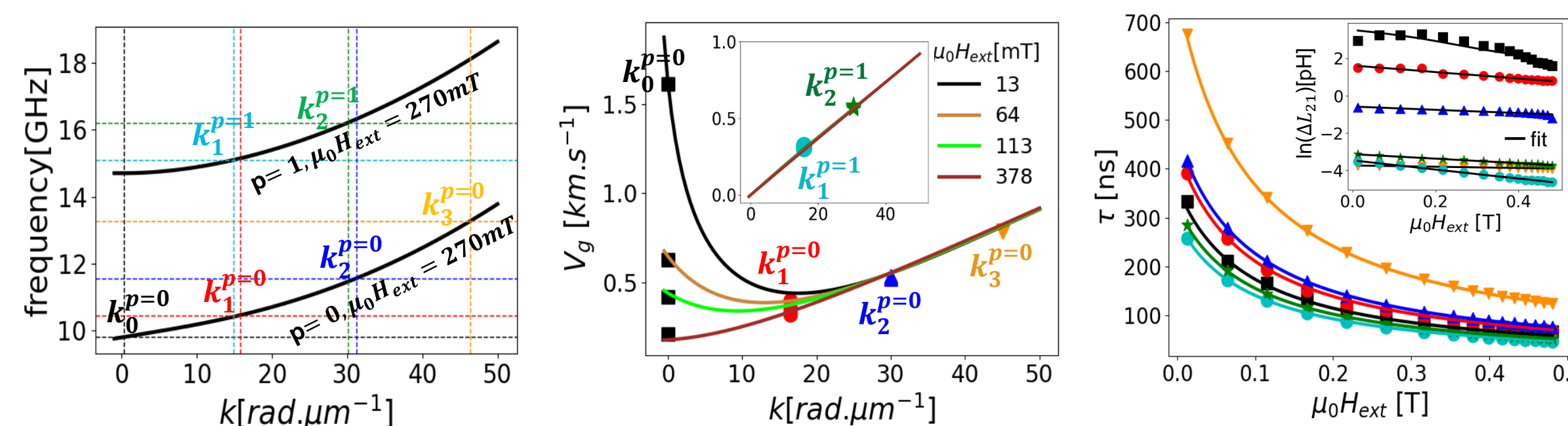
- Perfect chirality for higher wave vector ( $k_2^{p=0}$ ,  $k_3^{p=0}$ ,  $k_2^{p=1}$ ) reversed when field switches
- Decrease of the coupling efficiency as  $t_{Au}$  increase

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

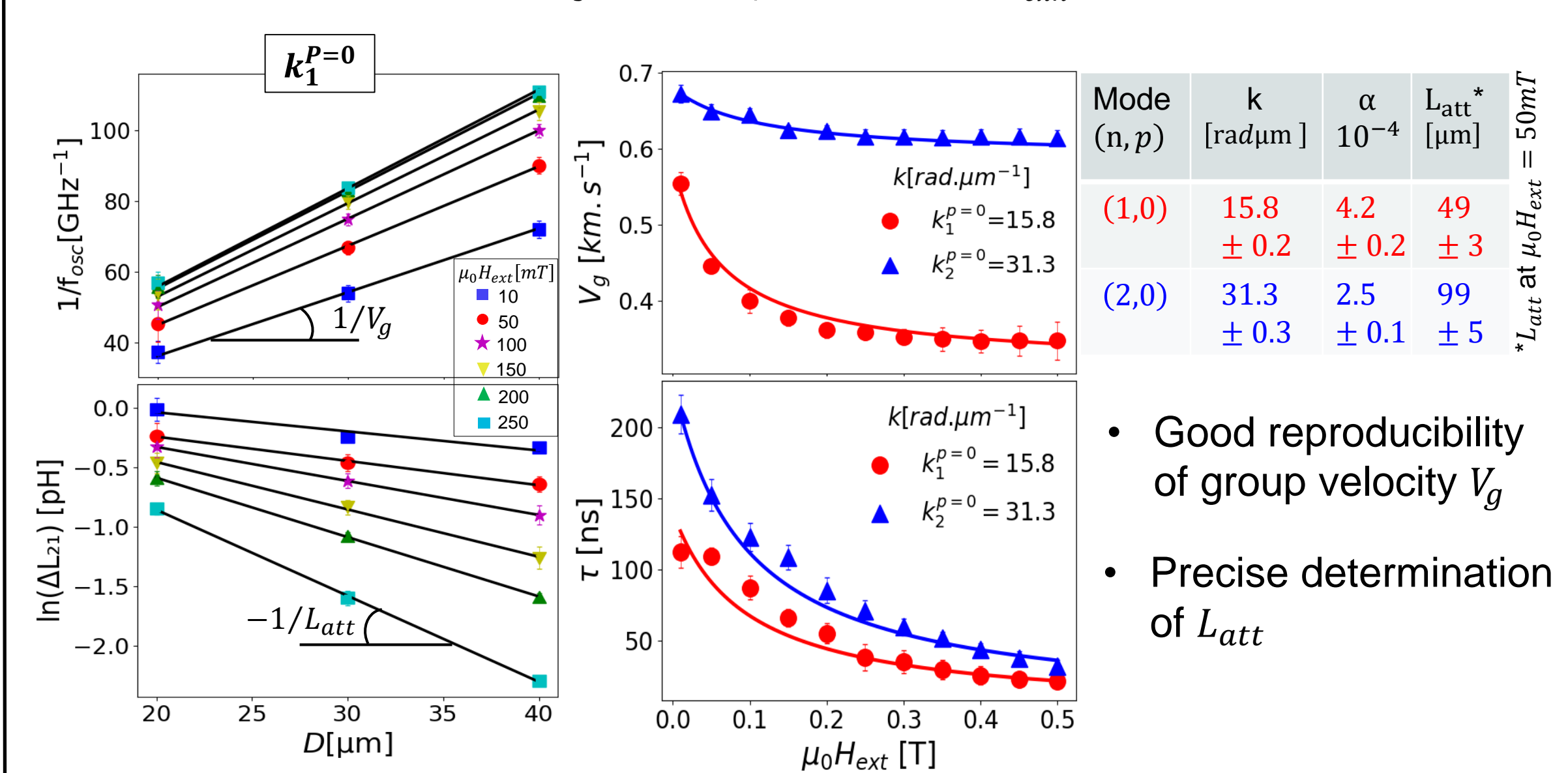


Mode (n,p)	k [rad/μm]	$\alpha \cdot 10^{-4}$	$L_{att}^*$ [μm]
(0,0)	$0.03 \pm 0.02$	$1.7 \pm 0.2$	132
(1,0)	$16.5 \pm 0.5$	$1.4 \pm 0.1$	91
(2,0)	$31.8 \pm 0.4$	$1.3 \pm 0.1$	143
(3,0)	$47.0 \pm 0.2$	$0.8 \pm 0.1$	357
(1,1)	$15.8 \pm 0.8$	$2.1 \pm 0.2$	54
(2,1)	$30.4 \pm 0.7$	$1.9 \pm 0.1$	110

- Wave vectors conform with Fourier transform
- Good agreement of  $v_g$  with dispersion relation
- Precise evaluation of the effective damping, which decreases with  $k \Rightarrow L_{att}(k_3^{p=0}) > 100\mu\text{m}$

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

YIG FMR:  $M_s = 0.185$  T,  $\gamma = 28.4$  GHz/T,  $A_{exh} = 3.8$  PJ/m



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

## Conclusions

- ▶ Unidirectional propagation of spin wave beam up to  $50 \text{ rad} \cdot \mu\text{m}^{-1}$  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 ( $\tau_k$ ) with k contrary to expectations, further study in-progress