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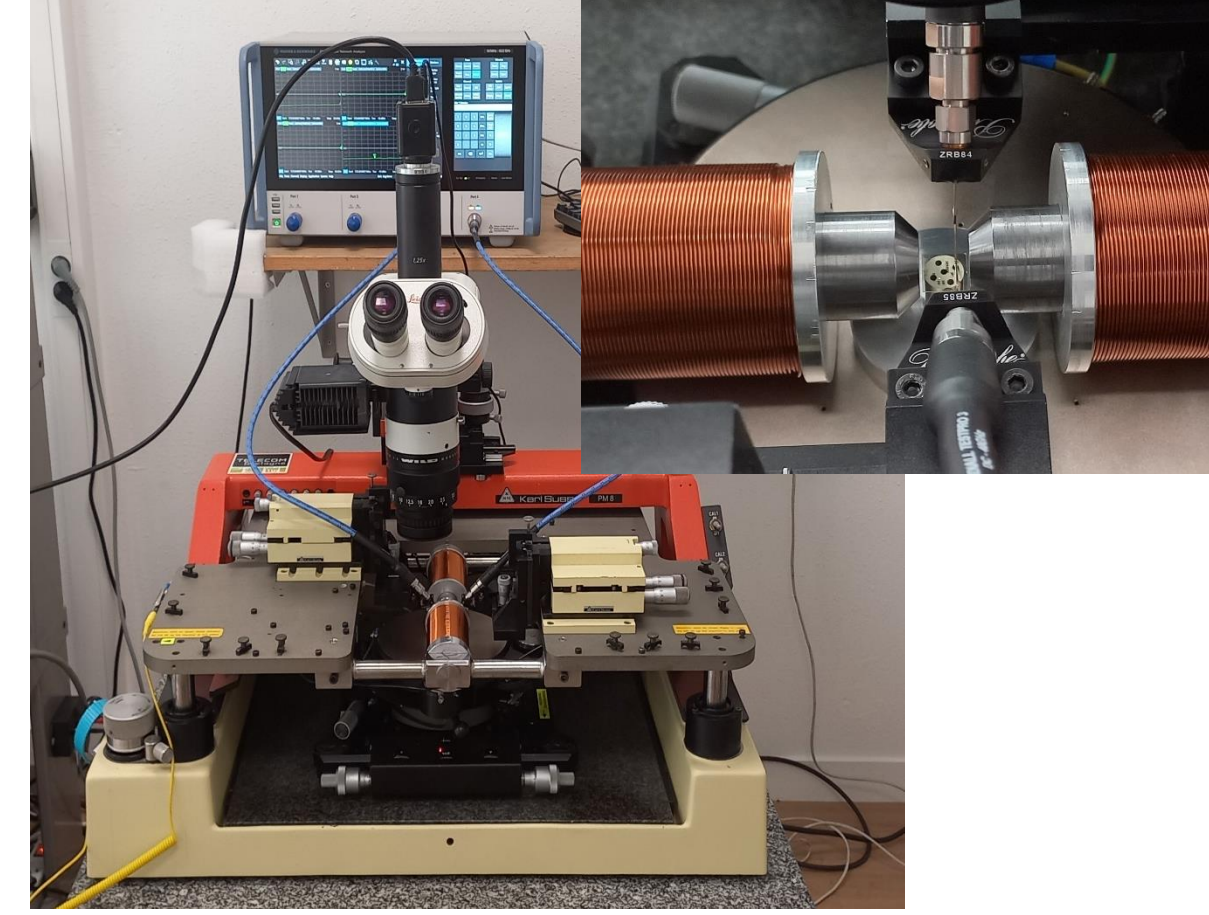


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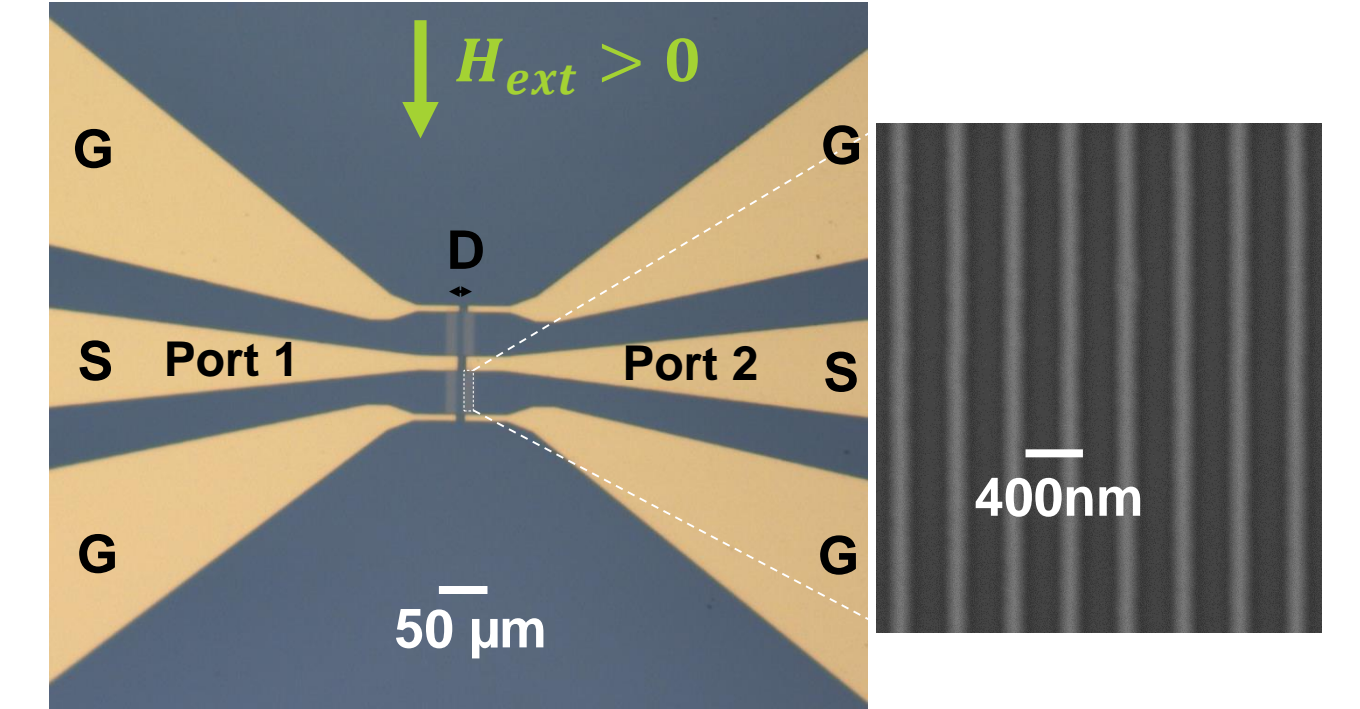
Shaping non-reciprocal spin wave beams using gold nanowire grating

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 μm -long 400nm lattice constant / 80nm Au-antennas

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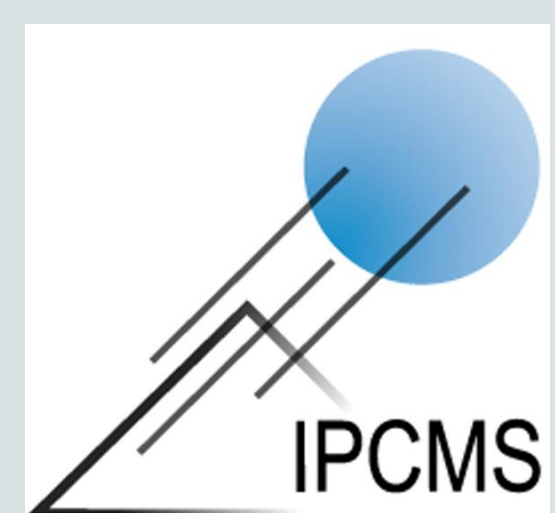
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Fundings



ANR "MagFunc"

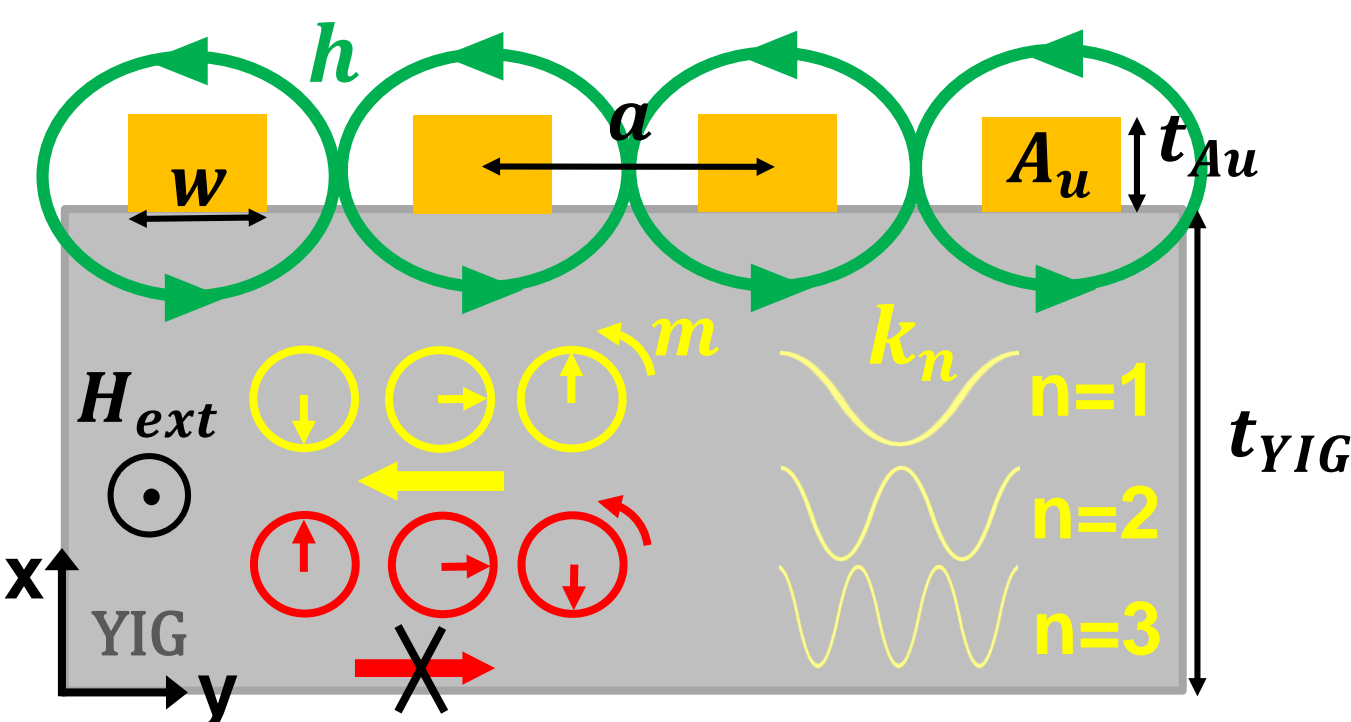


Project "SOSMAG"

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- [3] L. Temdie, V. Castel, et al., 10.20944/preprints202306.1441.v1. (2023).
- [4] V. Vlaminc, L. Temdie, et al., Journ. of Appl. Phys, 10.1063/5.0128666 (2023).
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Principle of chiral excitation and grating conception

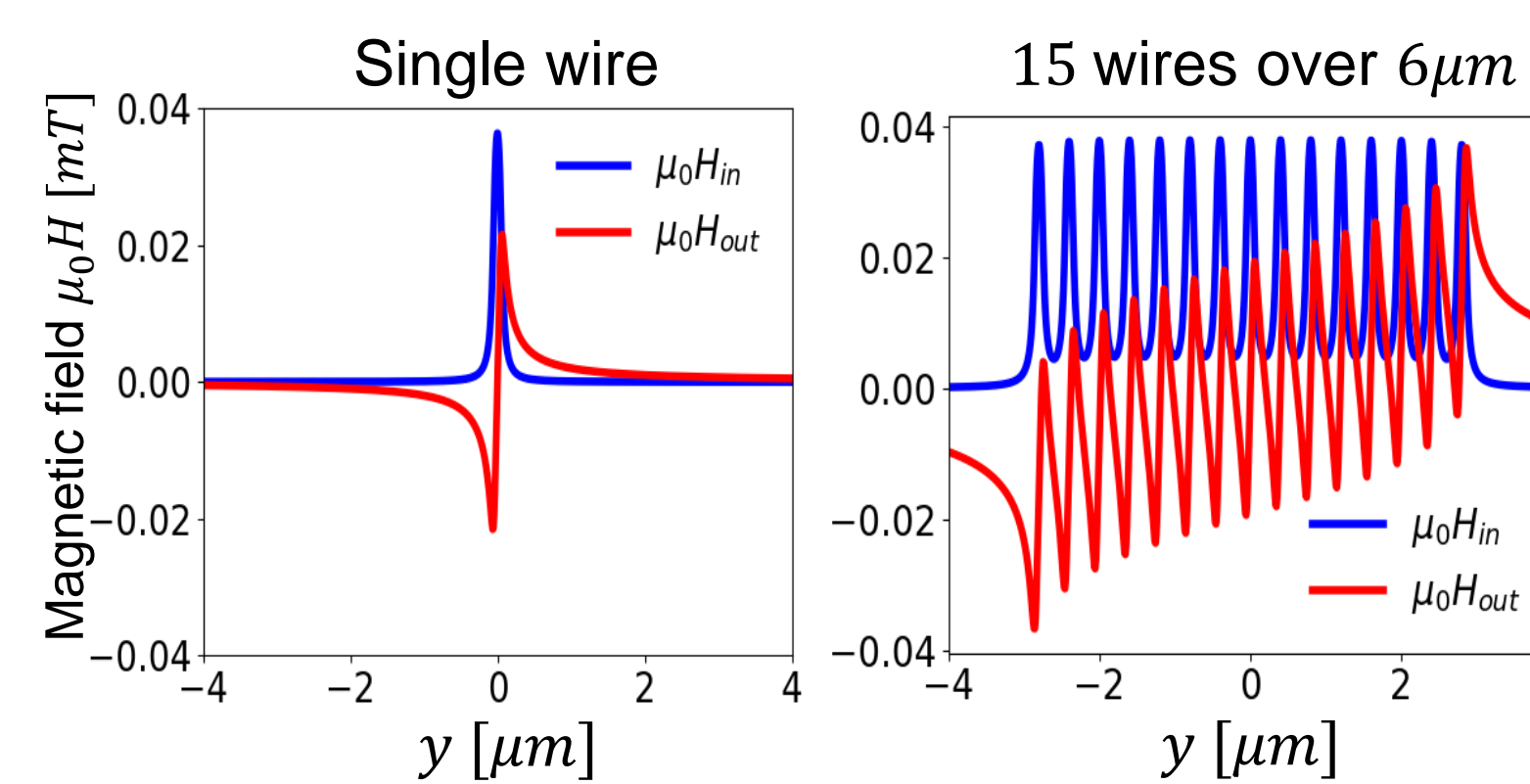


- Excited wave mode $k_n = n2\pi/a$ (i.e. $\lambda_n = a/n$)
- Chiral coupling between NW field h and m in YIG
- Degree of chirality related to aspect ratio : t_{Au}/w

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

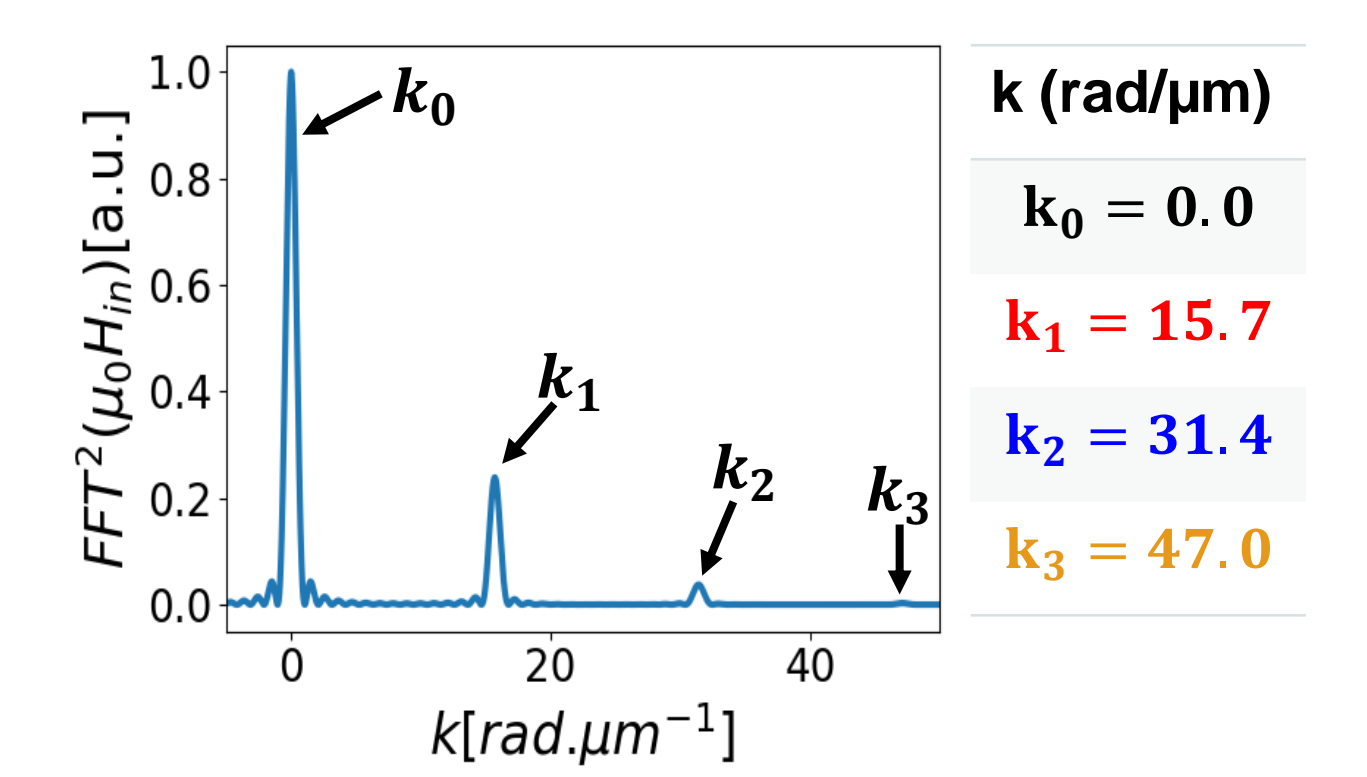
NW length $\ll \lambda_{EM} \Rightarrow$ DC current [5]

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



Fourier transform of NW field h

Coupling efficiency in reciprocal space



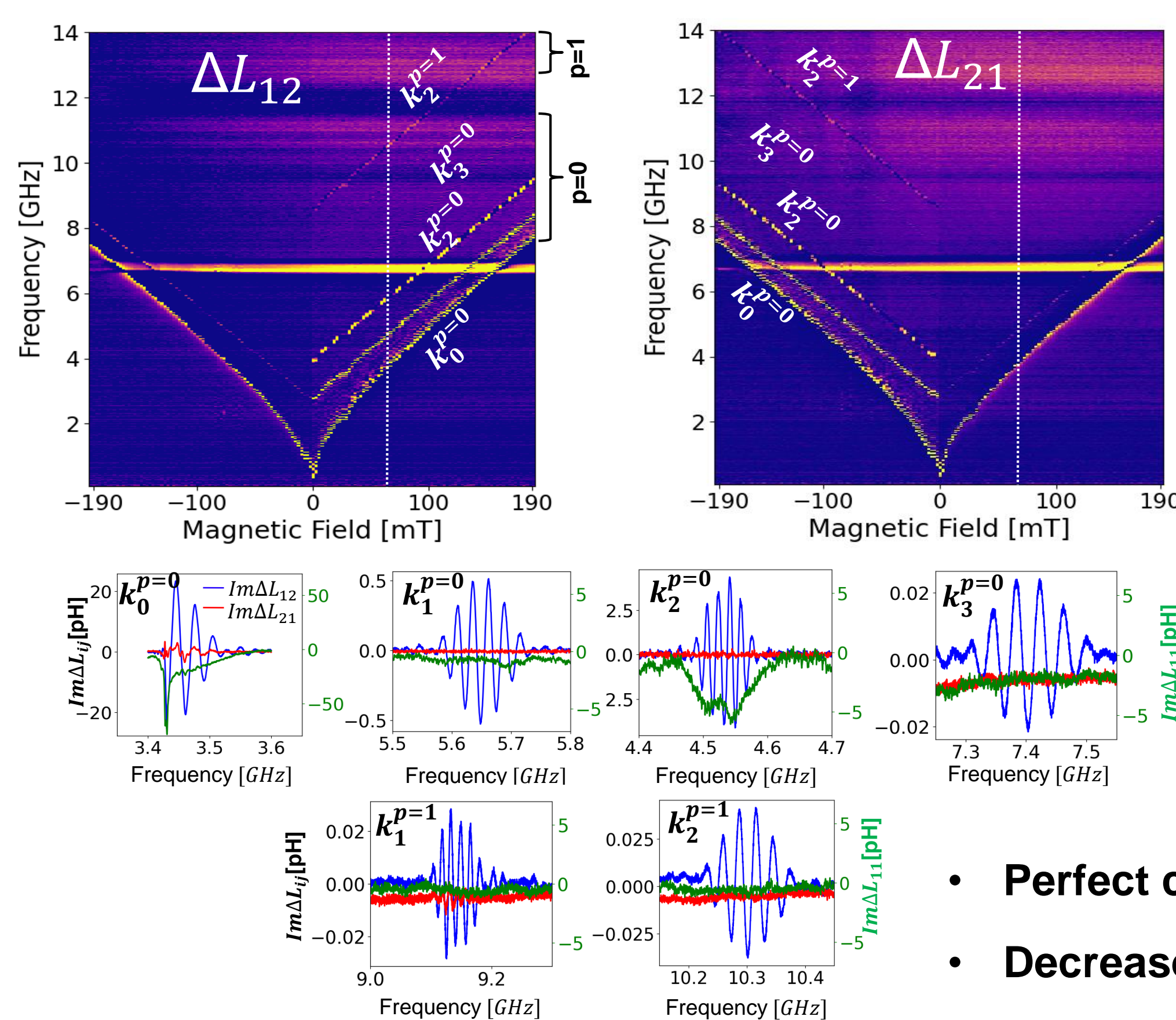
Well-defined comb of wavevector

Propagative spin wave spectroscopy

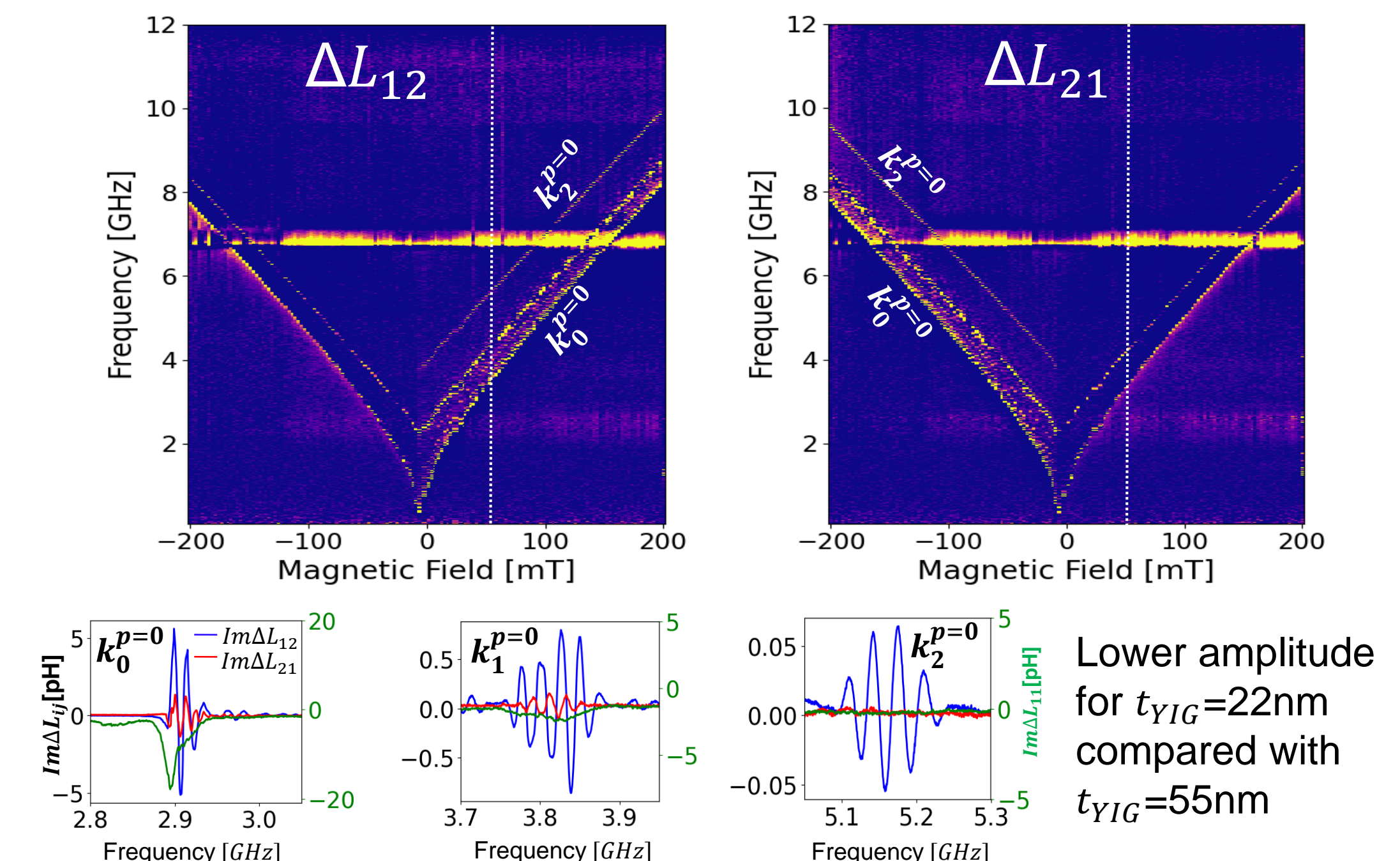
VNA transmission parameter converted into mutual inductance

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

❖ $t_{YIG} = 55$ 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

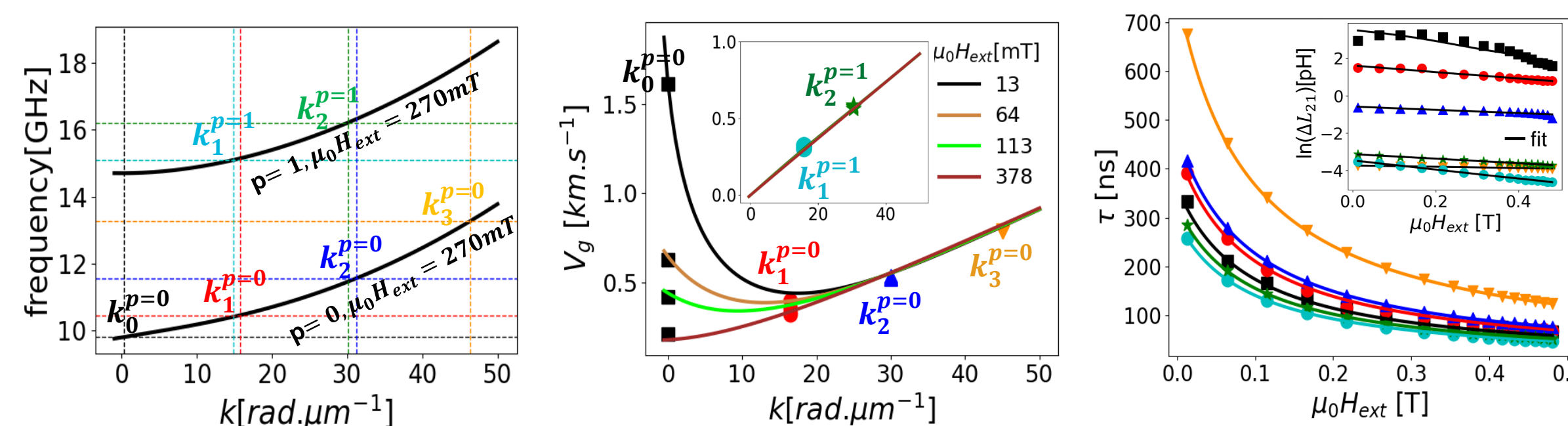
- Perfect chirality for higher wave vector ($k_2^{p=0}$, $k_3^{p=0}$, $k_2^{p=1}$) reversed when field switches
- Decrease of the coupling efficiency as t_{Au} increase

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

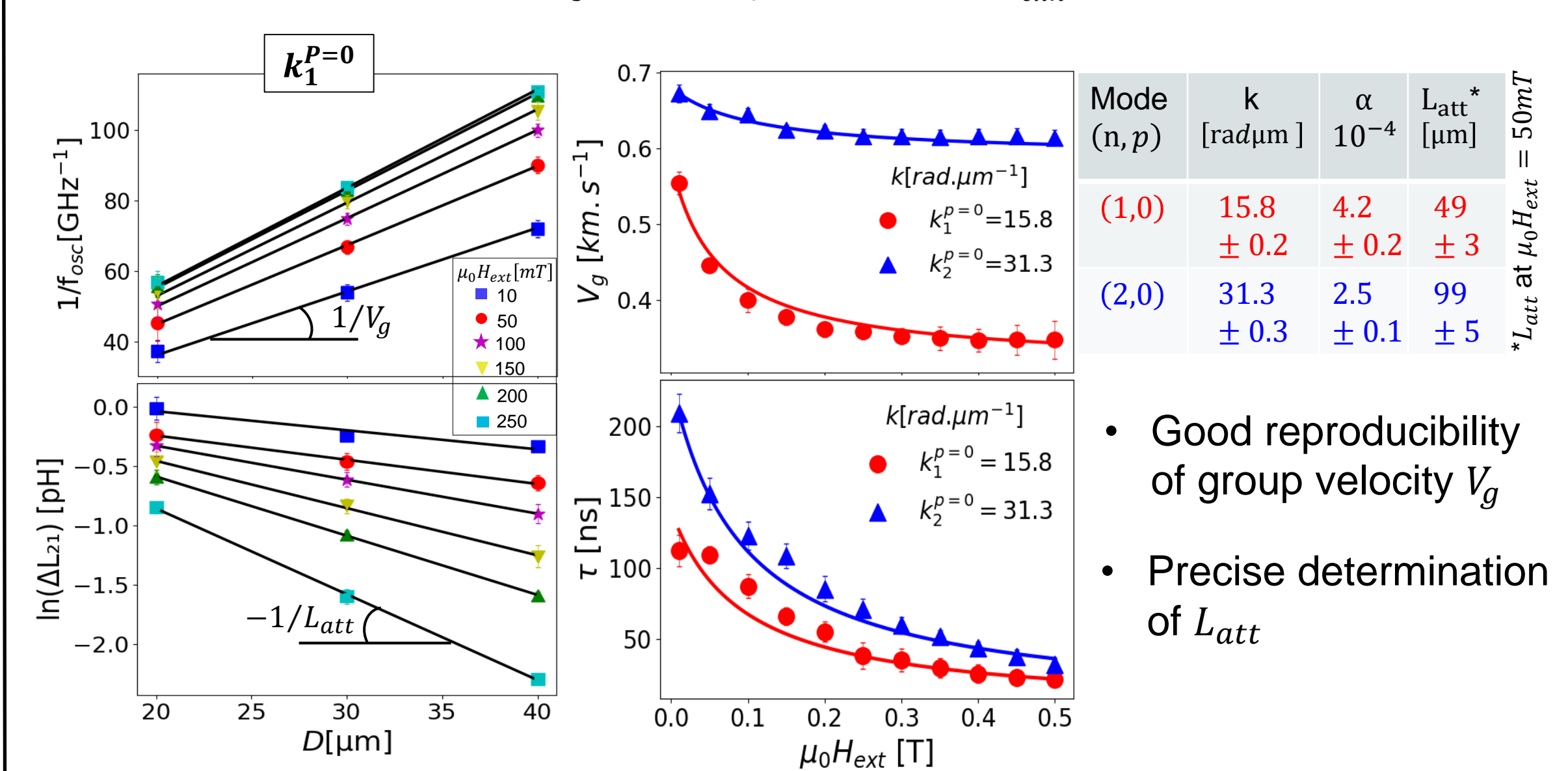


Mode (n,p)	k [rad/μm]	α 10 ⁻⁴	L _{att} * [μm]
(0,0)	0.03 ± 0.02	1.7 ± 0.2	132
(1,0)	16.5 ± 0.5	1.4 ± 0.1	91
(2,0)	31.8 ± 0.4	1.3 ± 0.1	143
(3,0)	47.0 ± 0.2	0.8 ± 0.1	357
(1,1)	15.8 ± 0.8	2.1 ± 0.2	54
(2,1)	30.4 ± 0.7	1.9 ± 0.1	110

- 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 rad.μm⁻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