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High wave vector non-reciprocal spin wave beams

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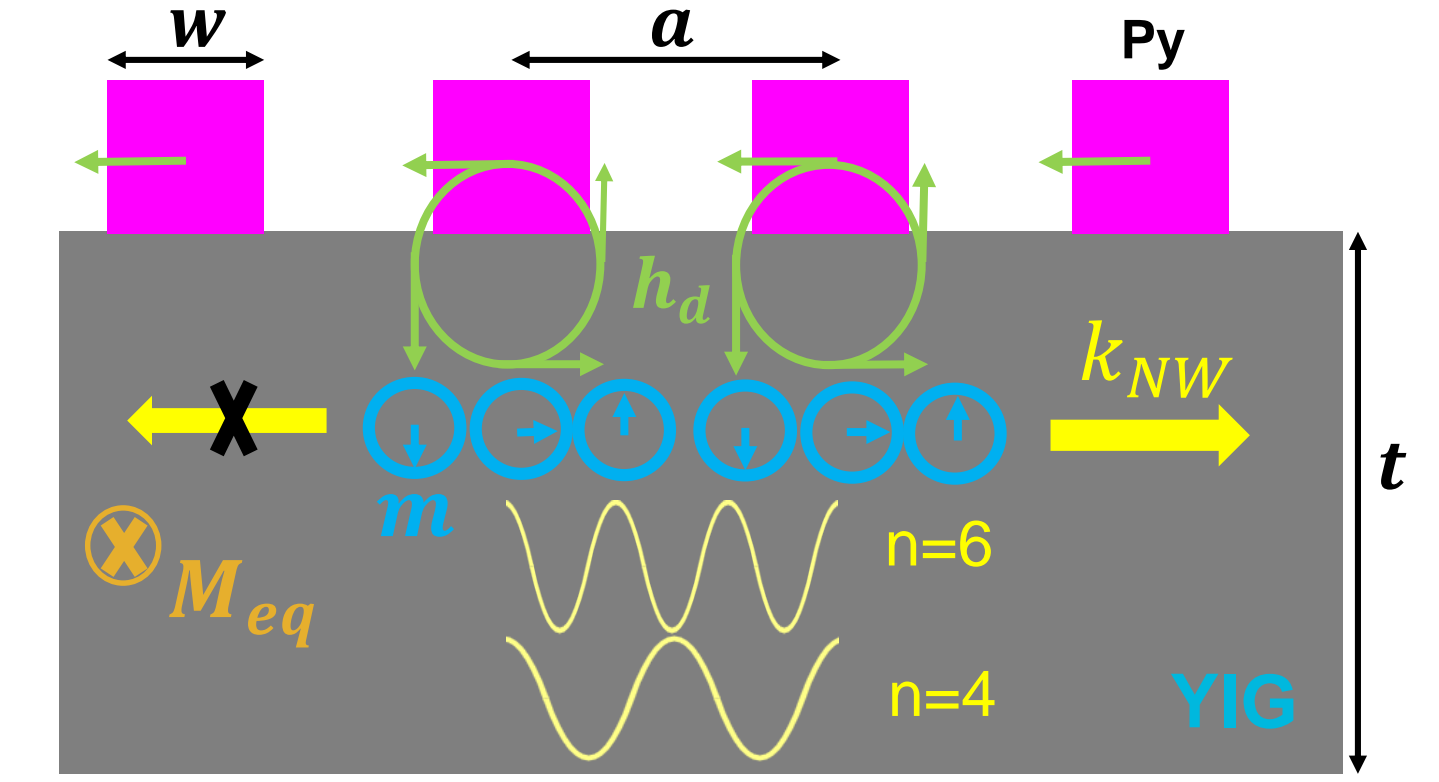
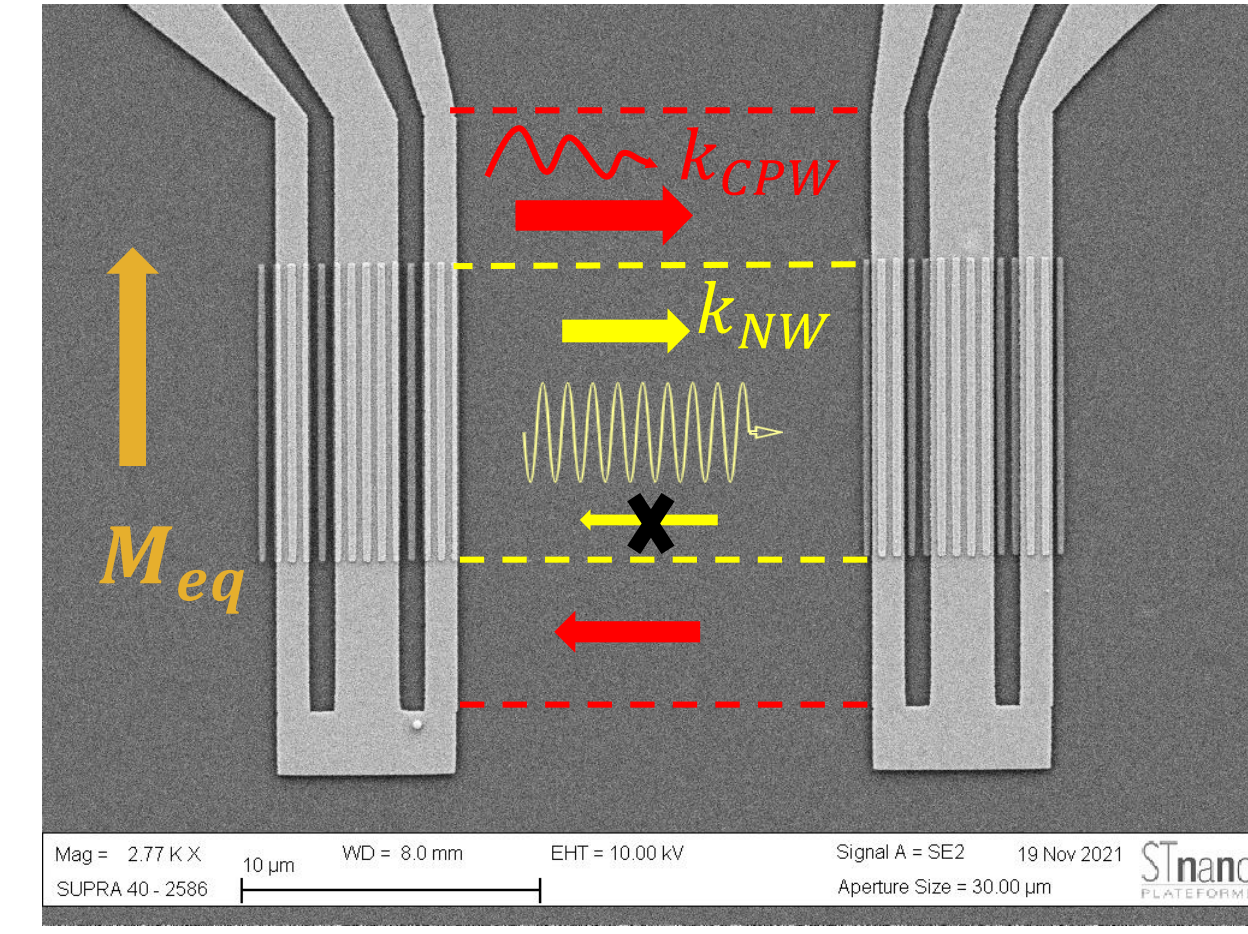


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High wave vector non-reciprocal spin wave beams

Motivations

- ▶ **Miniaturization of non-reciprocal devices**
Integrate circulators, isolators, and phase shifters in today's communication systems [1,2]
- ▶ **Shaping non-reciprocal spin wave beams**
in a continuous thin YIG film using chiral coupling from nanowire arrays [3]
- ▶ **High k-vector magnon spectroscopy**



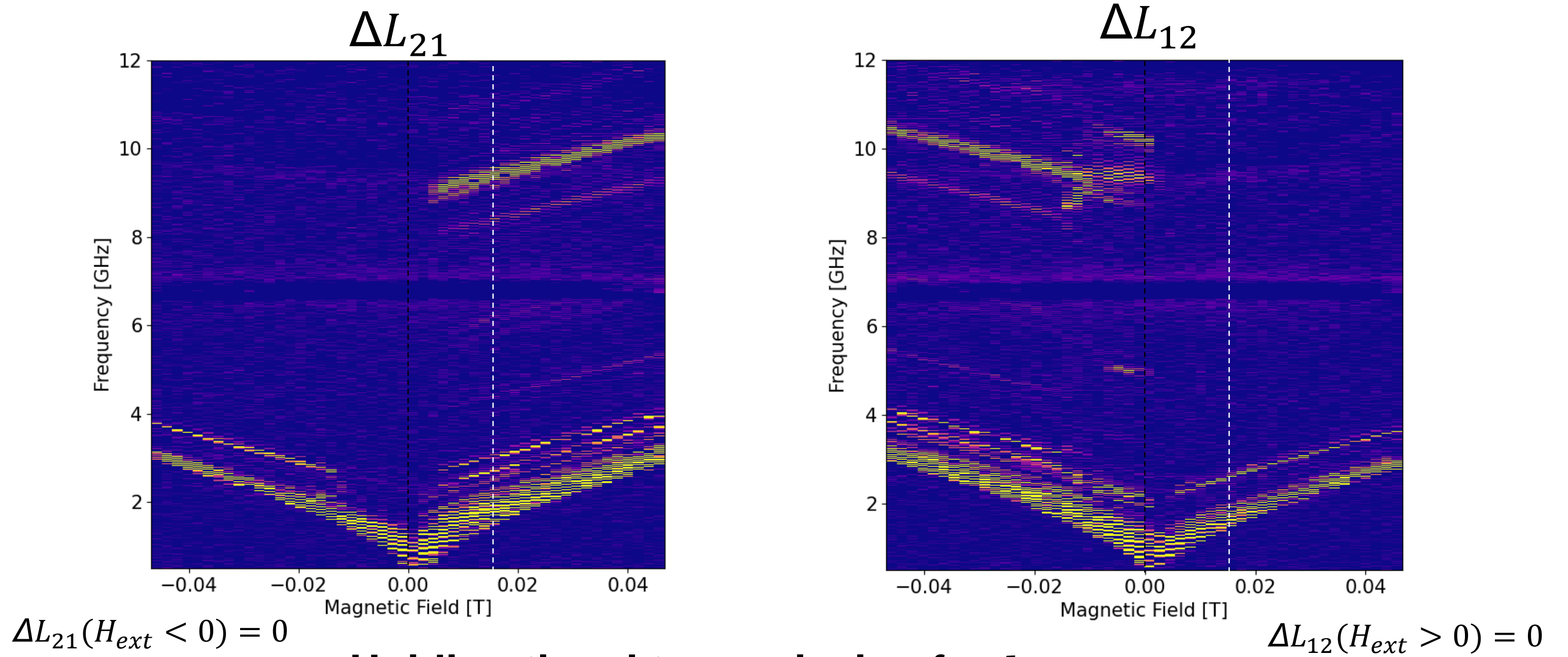
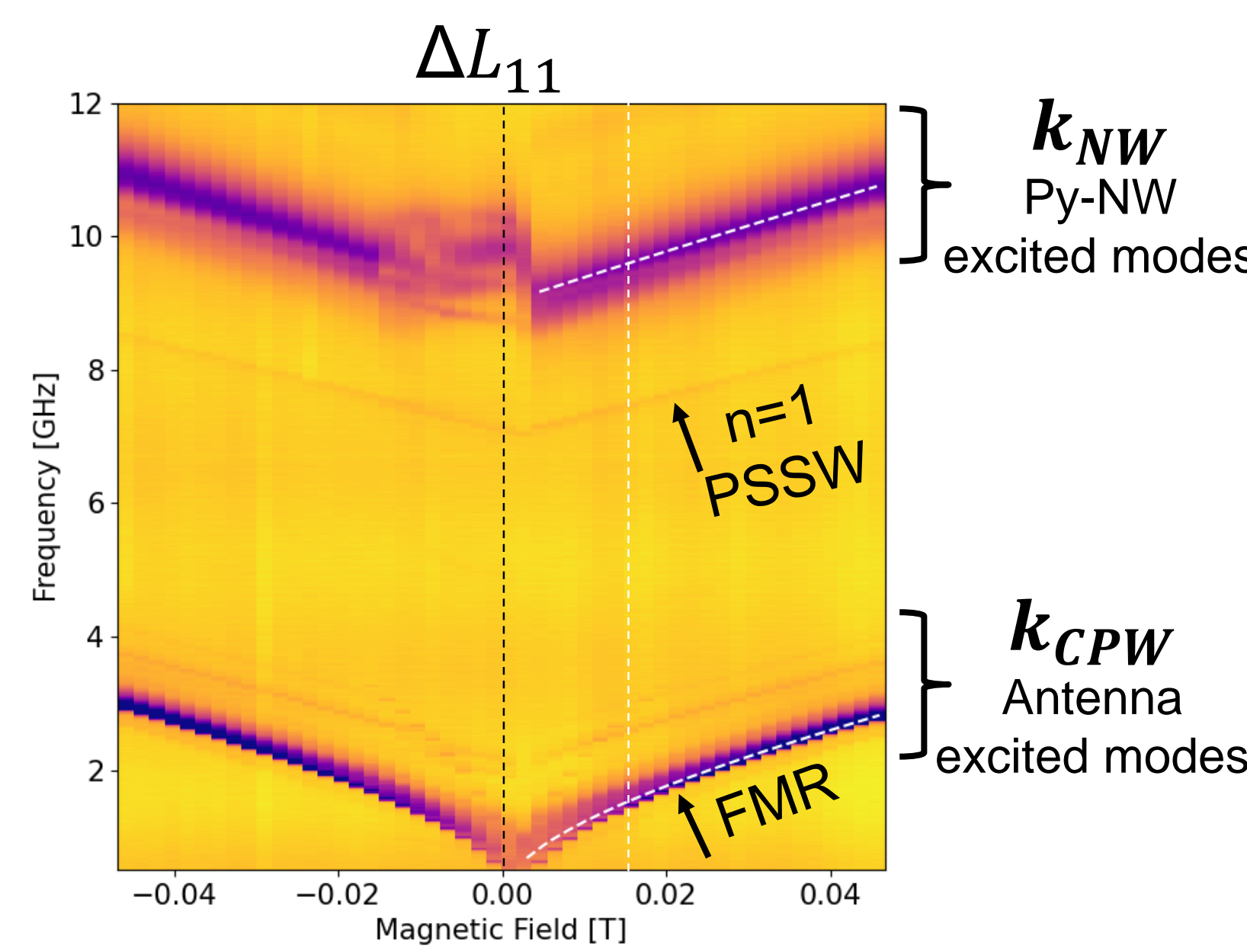
Chiral coupling between FMR-dynamic dipolar field of Py-NW (h_d) and high k-vector magnon modes ($k_n = \frac{2n\pi}{a}$) in YIG:
Chirality due to circular polarization of h_d

Perfect non-reciprocal transmission of spin wave beams

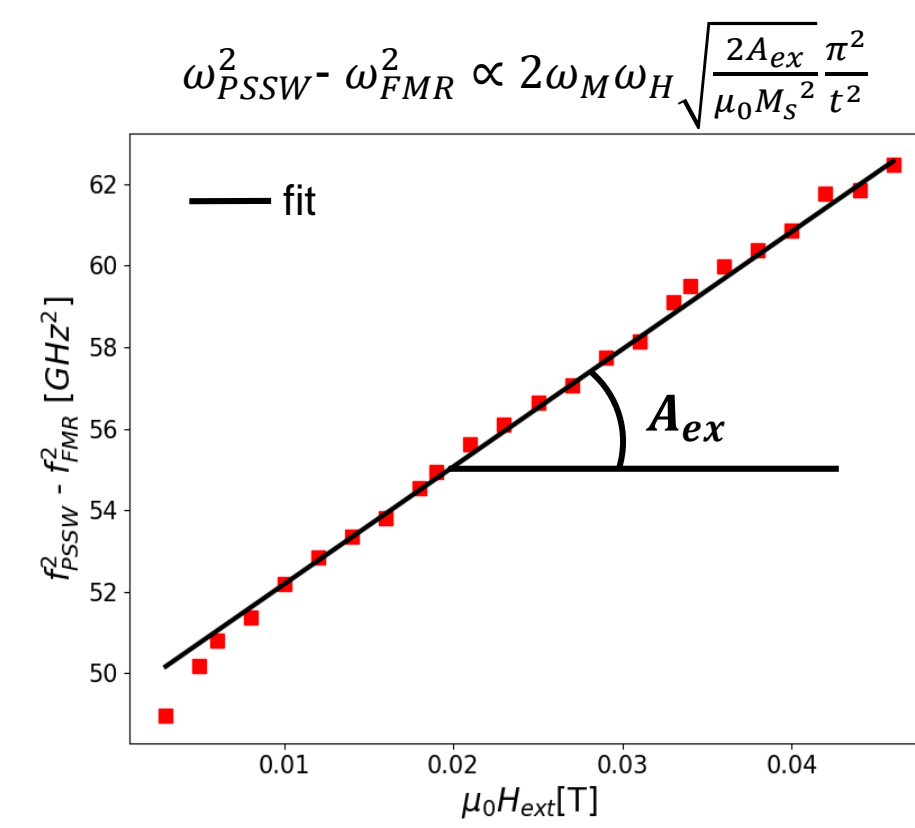
- ▶ **VNA SW Spectroscopy [4,5]**

Mapping (f, H) of self- and mutual inductance spectra

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



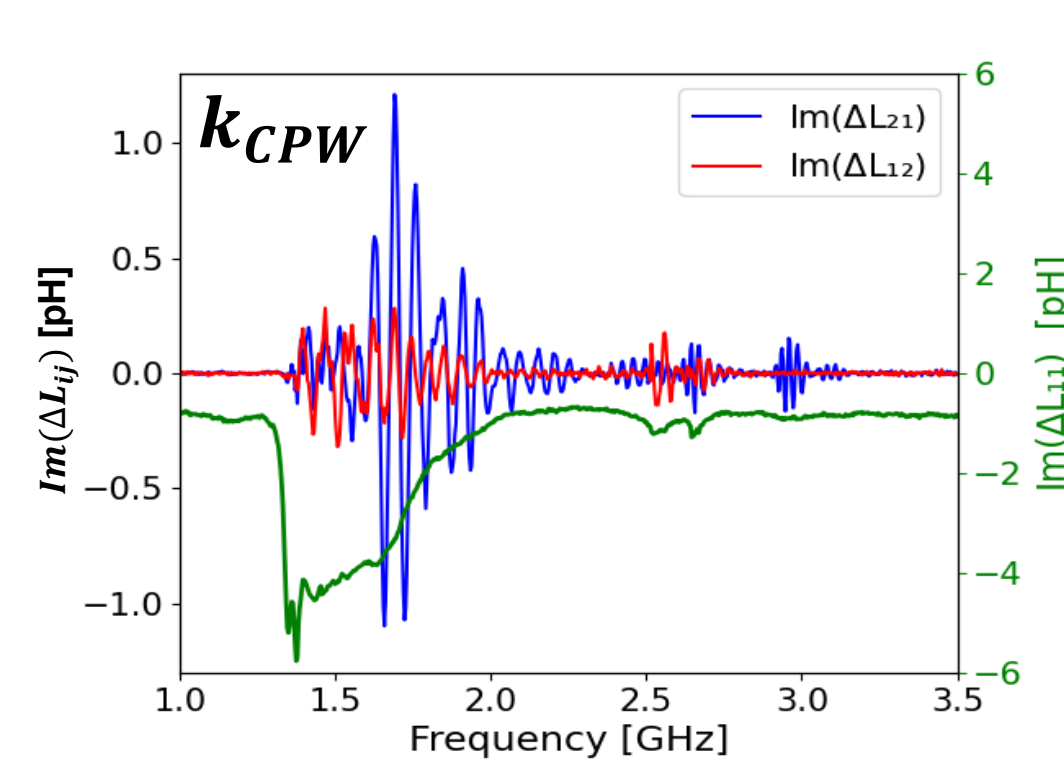
- **YIG FMR: no in-plane anisotropy [6]**



$$\frac{\gamma}{2\pi} = 27.7 \pm 0.2 \text{ GHz} ; \mu_0 M_s = 185 \pm 1 \text{ mT}$$

$$A_{ex} = 3.85 \pm 0.1 \text{ pJ.m}^{-1}$$

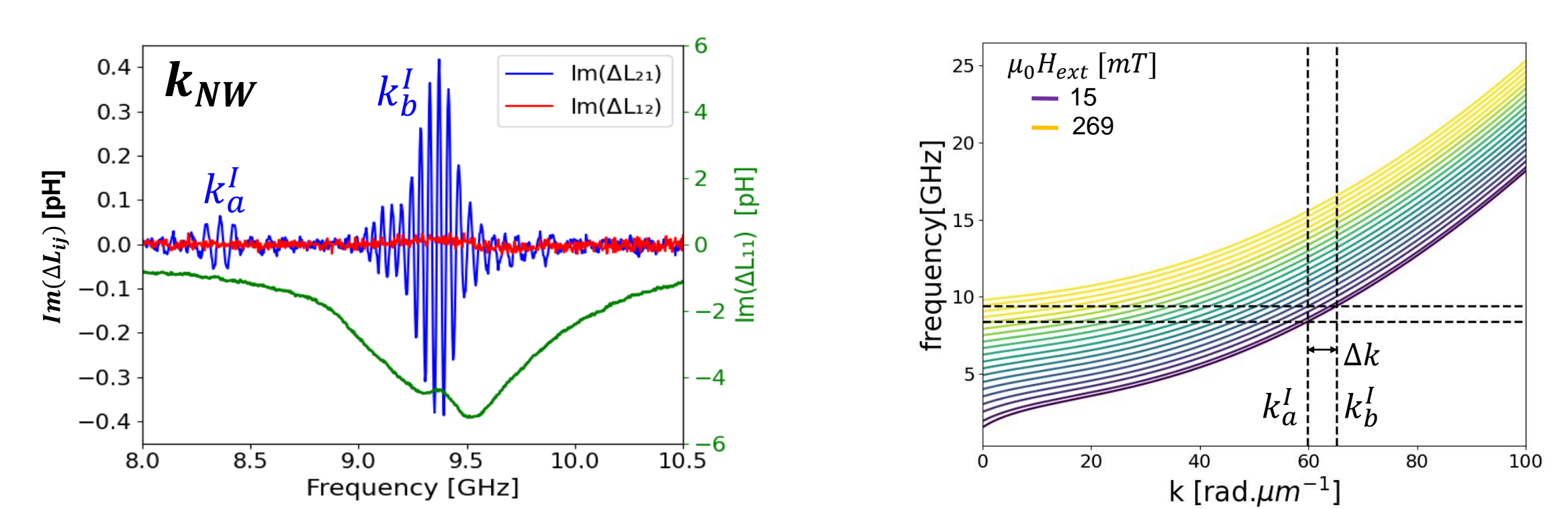
- **Spectra at $\mu_0 H_{ext} = 15 \text{ mT}$**



Ellipticity of CPW Oersted field
→ Partial non-reciprocity

Unidirectional transmission for k_{NW} reversed when field switches

- **Dispersions $f(k, H)$**

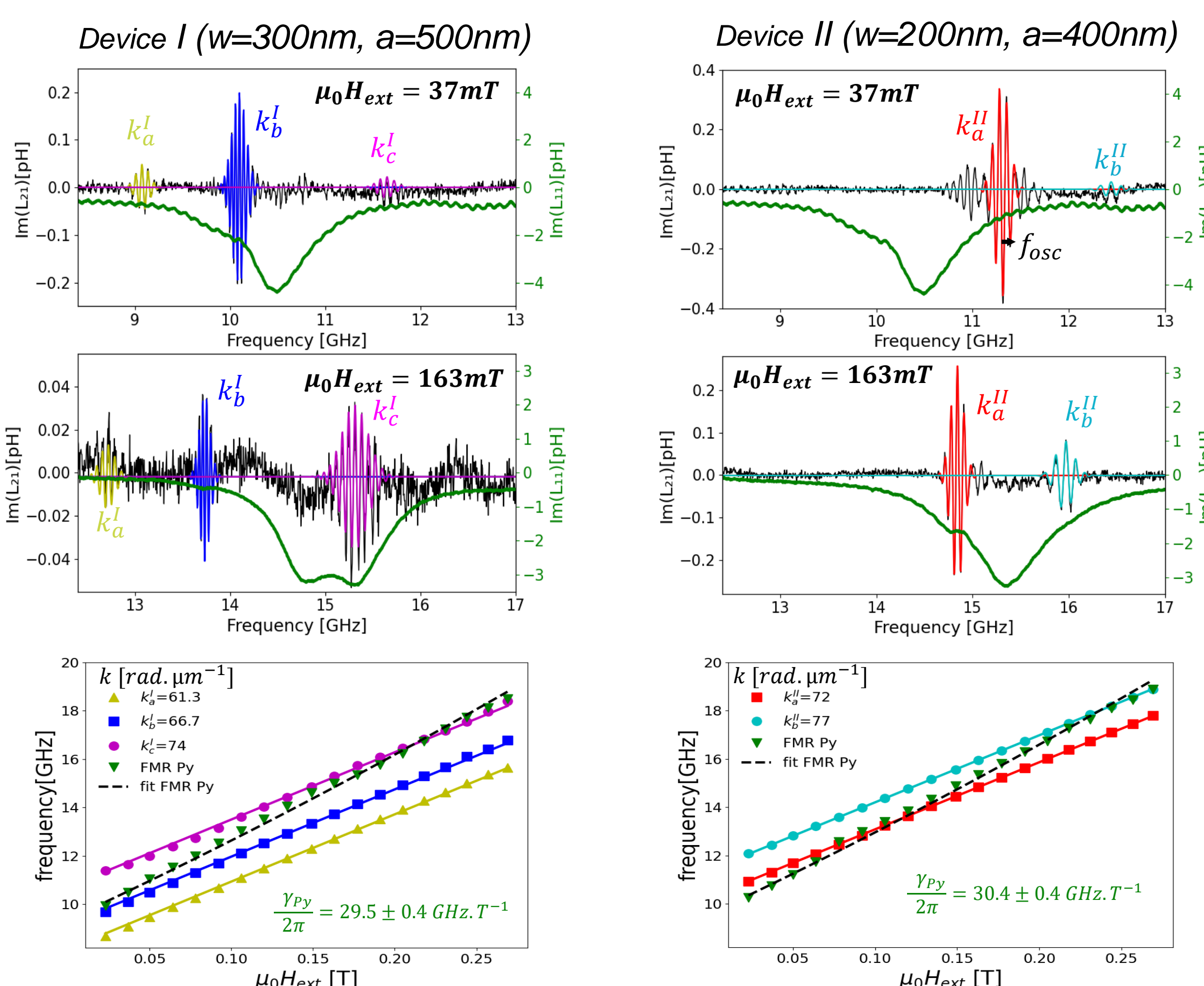


Separation between two adjacent modes k_a^l and $k_b^l < \frac{2\pi}{a}$
($\Delta k = k_b^l - k_a^l = 5.3 \text{ rad}/\mu\text{m} < \frac{2\pi}{a} = 12.5 \text{ rad}/\mu\text{m}$)

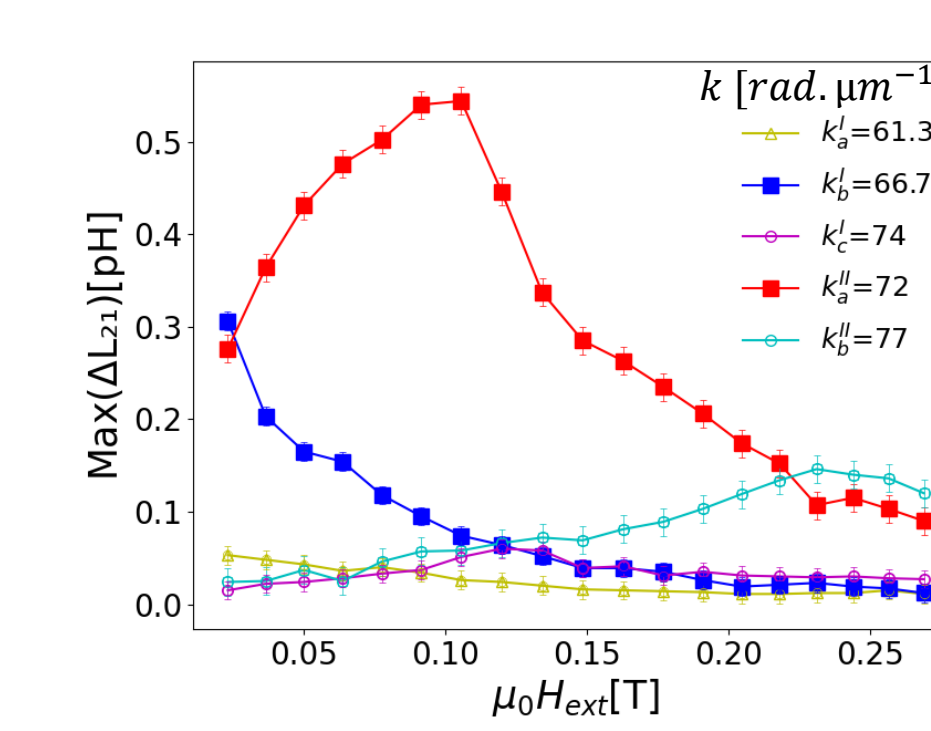
High wave vector spin wave spectroscopy

- ▶ **Field dependence of modes features (A, f_{res}, f_{osc})**

Fitting ΔL_{ij} with: $A \exp\left(\frac{(f-f_{res})^2}{\sigma^2}\right) \cos\left(\frac{2\pi}{f_{osc}}(f-f_{res}) + \varphi\right)$



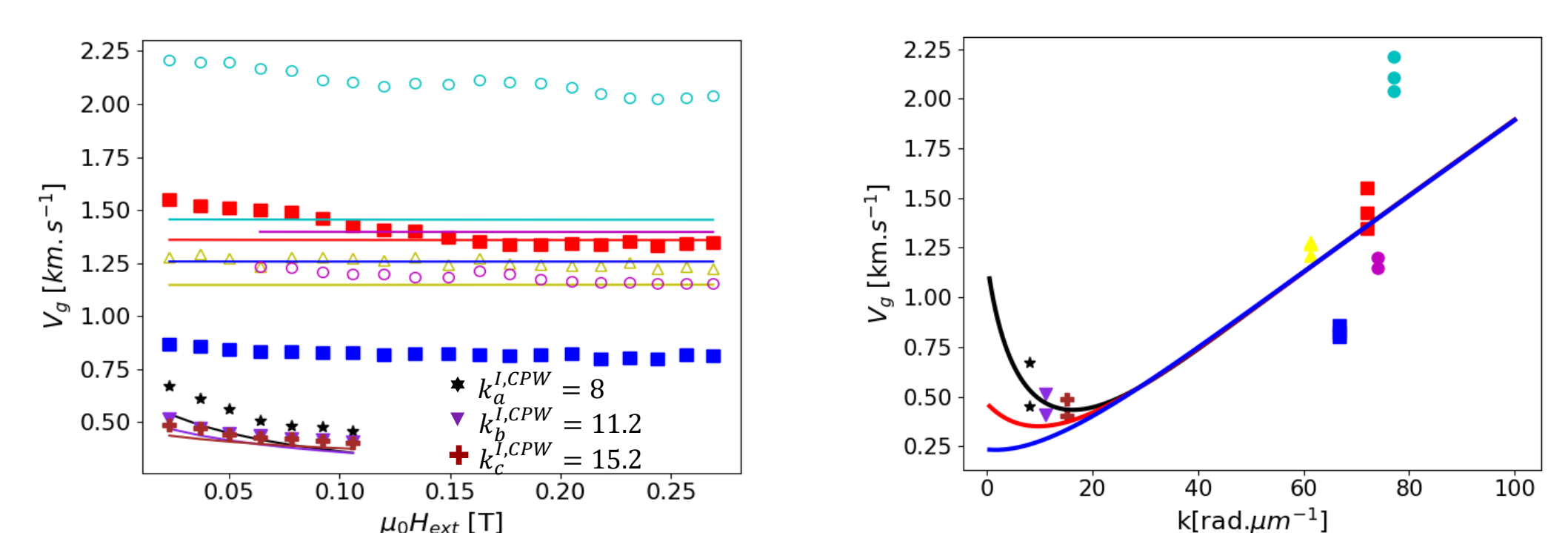
- **Field dependence of the amplitude for k_{NW} -modes**



- Non-monotonous coupling efficiency
→ no estimation of L_{att}
- $\gamma_{Py} > \gamma_{YIG} \rightarrow$ field dependence of the coupling efficiency all the stronger that $f(k_{NW}) \sim f(k_{Py})$

- **Group velocity**

Marker : from spectra $V_g = D * f_{osc}$; Solid line : from $V_g = d\omega/dk$



Agreement at lower wavevector, but discrepancies for $V_g(k_{NW})$ due to possible inhomogeneous static field

Conclusions

- ▶ **Unidirectional transmission of 10µm wide spin wave beams up to 77 $\text{rad.}\mu\text{m}^{-1}$ in [9,20] GHz frequency range**
- ▶ **Miniaturization of NWA complicates the SW spectroscopy analysis : modes selection, non-monotonous coupling efficiency, inhomogeneous static field**

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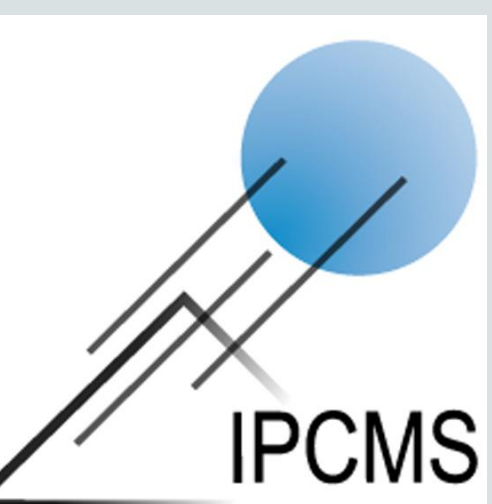
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