



HAL
open science

Antenna Design for Spin Wave Caustic Beams

Loic Temdie, Vincent Castel, Benjamin Jungfleisch, Dinesh Wagle, Mojtaba T Kaffash, Yves Henry, Daniel Stoeffler, Matthieu Bailleul, Vincent Vlaminck

► **To cite this version:**

Loic Temdie, Vincent Castel, Benjamin Jungfleisch, Dinesh Wagle, Mojtaba T Kaffash, et al.. Antenna Design for Spin Wave Caustic Beams. Magnonics 2023, Jul 2023, Le Touquet-Paris-Plage, France. . hal-04191773

HAL Id: hal-04191773

<https://hal.science/hal-04191773v1>

Submitted on 30 Aug 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Antenna Design for Spin Wave Caustic Beams

Authors

Loic TEMDIE^{1,2}
Vincent CASTEL^{1,2}
Benjamin JUNGFLAISCH³
Dinesh Wagle³,
Mojtaba T. Kaffash³,
Yves HENRY⁴
Daniel STOEFLER⁴
Matthieu BAILLEUL⁴
Vincent VLAMINCK^{1,2}

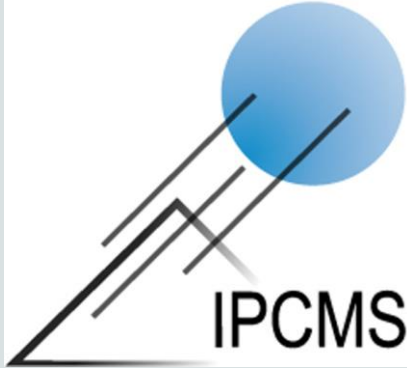
Affiliations



¹ IMT- Atlantique
Département Micro Ondes,
² Lab-STICC - UMR 6285 CNRS,
Technopole Brest-Iroise
CS83818, 29238 Brest Cedex 03



³ University of Delaware
Dept. of Physics and Astronomy
Newark, Delaware, USA



⁴ IPCMS - UMR 7504 CNRS
Institut de Physique et Chimie des
Matériaux de Strasbourg

Fundings



Thomas Jefferson
Magnon
Interferometry



References

- [1] N. LOAYZA et al., Phys. Rev. B **98**, 144430 (2018)
- [2] T. SCHNEIDER et al., Phys. Rev. Lett. **104**, 197203 (2010)
- [3] F. HEUSSNE et al., Phys. Status Solidi RRL **14**, 1900695 (2020)
- [4] V. VLAMINCK, et al., JAP **133**, 053903 (2023)
- [5] B. A. KALINIKOS, Soviet Physics Journal **24**, 718 (1981)
- [6] K. GUSLIENKO, A. SLAVIN, JMM **323**, 2418 (2011)

Motivations

- ▶ **Non-reciprocal magnonic devices**
Miniaturizing isolator, circulator, delay lines
- ▶ **Shaping spin-wave beams in extended layer**
Development of magnon interferometric devices [1-3]
- ▶ **Diffraction model for in-plane spin-wave modes**
Efficient tool to map the Near-Field Diffraction (NFD) patterns of any shape of spin-wave antennas [4]

Near-Field diffraction model for in-plane magnetized films

❖ Kalinikos's approach to express $\vec{m}(u, v, t)$ [5]

- **(ξ, η, ζ) SW Propagation frame** \Rightarrow dynamic dipolar field $\vec{h}_d(\xi)$ from Green functions [6]

$$\vec{h}_d(\xi) = \int_{-\frac{l}{2}}^{\frac{l}{2}} \vec{G}_{xy}(\xi - \xi') \vec{m}(\xi') d\xi' = -\vec{N}_{dip} \vec{m}$$

$$\vec{G}_{\xi\eta\zeta}(\xi - \xi') = \begin{pmatrix} G_p - \delta(\xi - \xi') & 0 & iG_Q \\ 0 & 0 & 0 \\ iG_Q & 0 & -G_p \end{pmatrix} \Rightarrow \vec{N}_{dip}^{00} = \begin{pmatrix} 1-P & 0 \\ 0 & P \sin^2 \phi \end{pmatrix}$$

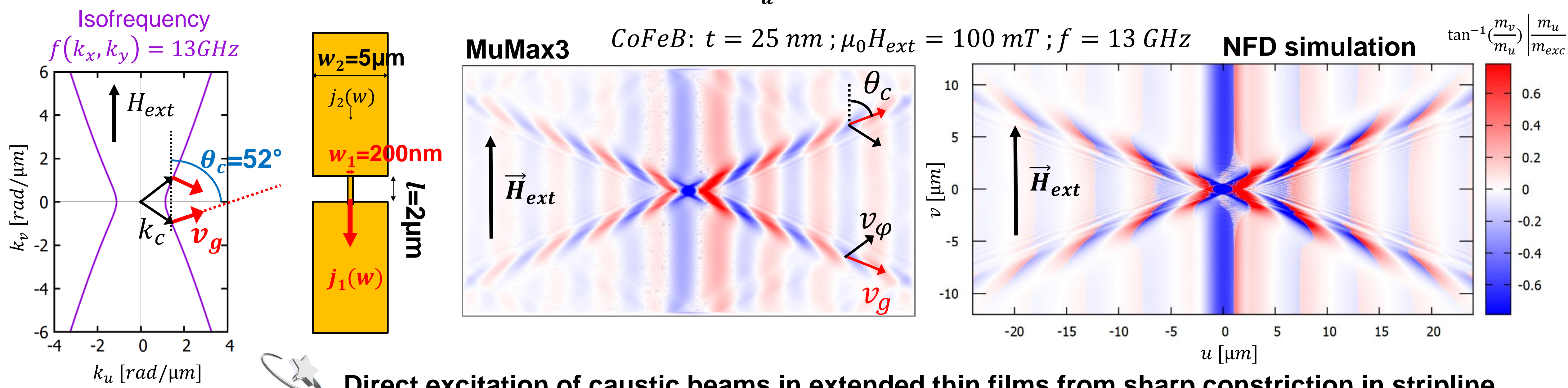
change of frame $(\xi, \eta, \zeta) \Rightarrow (x, y, z)$ $(P = 1 - \frac{1-e^{-kt}}{kt})$

- **(x, y, z) $\vec{M}(\vec{r}, t)$ frame** \Rightarrow Linearizing LLG

$$i\omega \vec{m} = -\gamma \mu_0 H_{equ} \vec{m} \times \vec{u}_z + \gamma \mu_0 M_{equ} \vec{h} \times \vec{u}_z - \alpha i\omega \vec{m} \times \vec{u}_z \Rightarrow \vec{\chi}^{-1} \vec{m} = \vec{h}_{exc} \Rightarrow \frac{1}{\omega_M} \begin{pmatrix} \Omega_k + i\alpha\omega + \omega_M \vec{N}_{d,xx}^{00} & -i\omega + \omega_M \vec{N}_{d,xy}^{00} \\ i\omega + \omega_M \vec{N}_{d,yx}^{00} & \Omega_k + i\alpha\omega + \omega_M \vec{N}_{d,yy}^{00} \end{pmatrix} \begin{pmatrix} m_x \\ m_y \end{pmatrix} = \begin{pmatrix} h_x \\ h_y \end{pmatrix}$$

- **(u, v, ξ) Lab frame** - antenna orientation $\Rightarrow FFT^{-1}\{\vec{m}(\vec{k})\} \Rightarrow \vec{m}(u, v, t) = e^{i\omega t} \iint_{-\infty}^{+\infty} dk_u dk_v \vec{\chi}(k_u, k_v) \cdot \vec{h}_{exc}(k_u, k_v) e^{-i(k_u u + k_v v)}$

❖ Anisotropic dispersion \Rightarrow Caustic beam when $\frac{d^2 k_v}{dk_u^2} = 0$



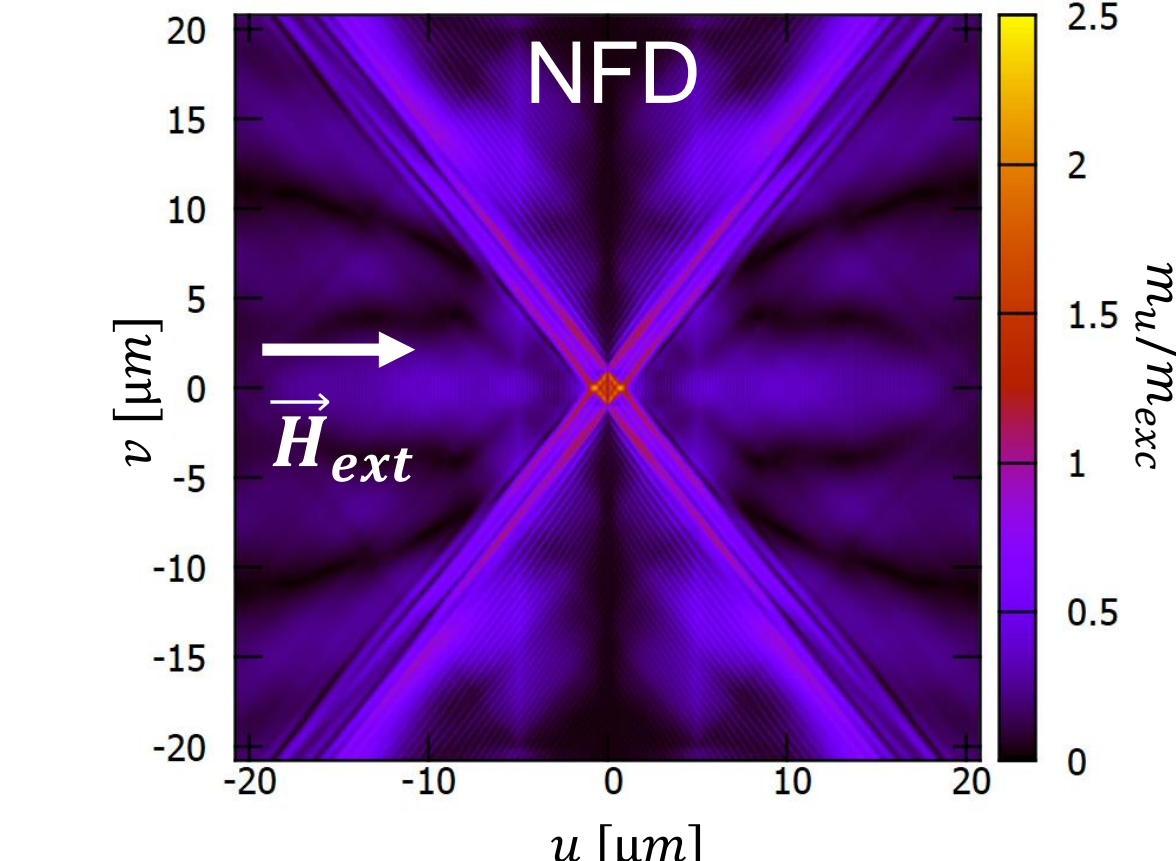
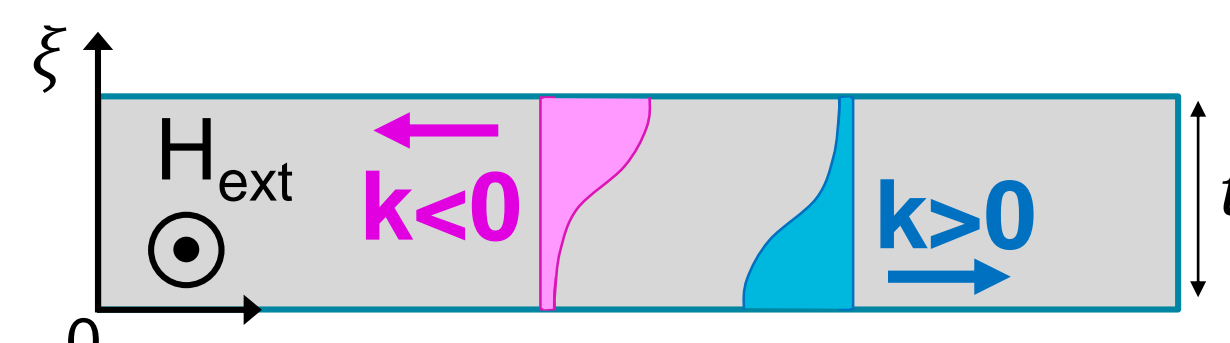
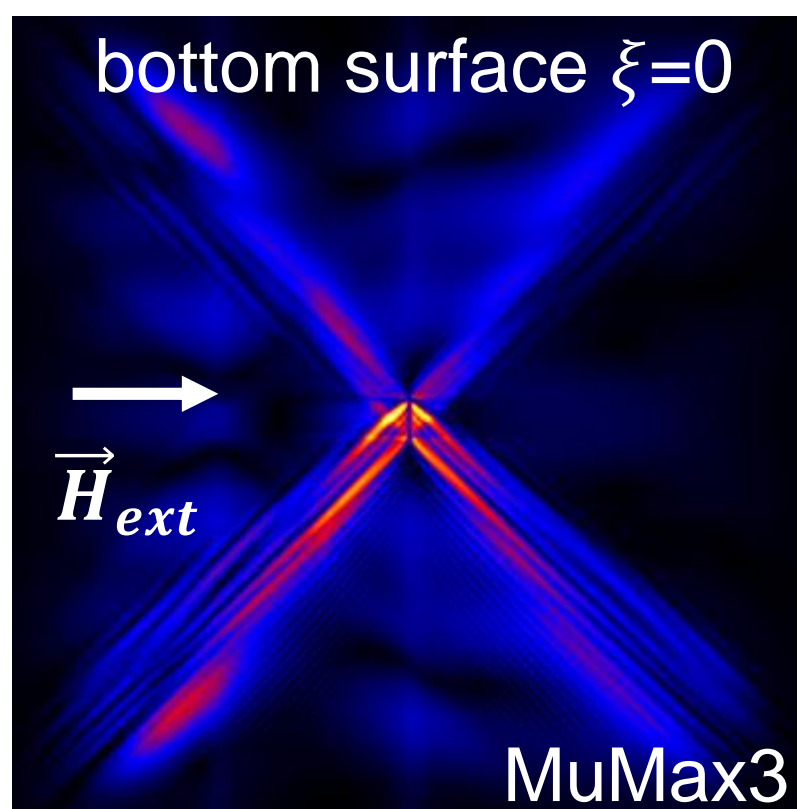
Caustic beam definition

❖ Thickness dependence $t_{YIG} = 200 \text{ nm}$

$$w_1 = 200 \text{ nm}$$

$$w_2 = 10 \mu\text{m}; l = 2 \mu\text{m}$$

$$\mu_0 H_{ext} = 50 \text{ mT}; f = 3.2 \text{ GHz}$$



non-uniform thickness profile
 \Rightarrow need to account for higher order mode ($n > 0$), and their coupling:

$$\begin{pmatrix} \vec{\chi}_{00} & \vec{\chi}_{01} & \vec{\chi}_{02} & \dots \\ \vec{\chi}_{10} & \vec{\chi}_{11} & \vec{\chi}_{12} & \dots \\ \vec{\chi}_{20} & \vec{\chi}_{21} & \vec{\chi}_{22} & \dots \\ \dots & \dots & \dots & \dots \end{pmatrix} \begin{pmatrix} \vec{h}_0 \\ \vec{h}_1 \\ \vec{h}_2 \\ \dots \end{pmatrix} = \begin{pmatrix} \vec{m}_0 \\ \vec{m}_1 \\ \vec{m}_2 \\ \dots \end{pmatrix}$$

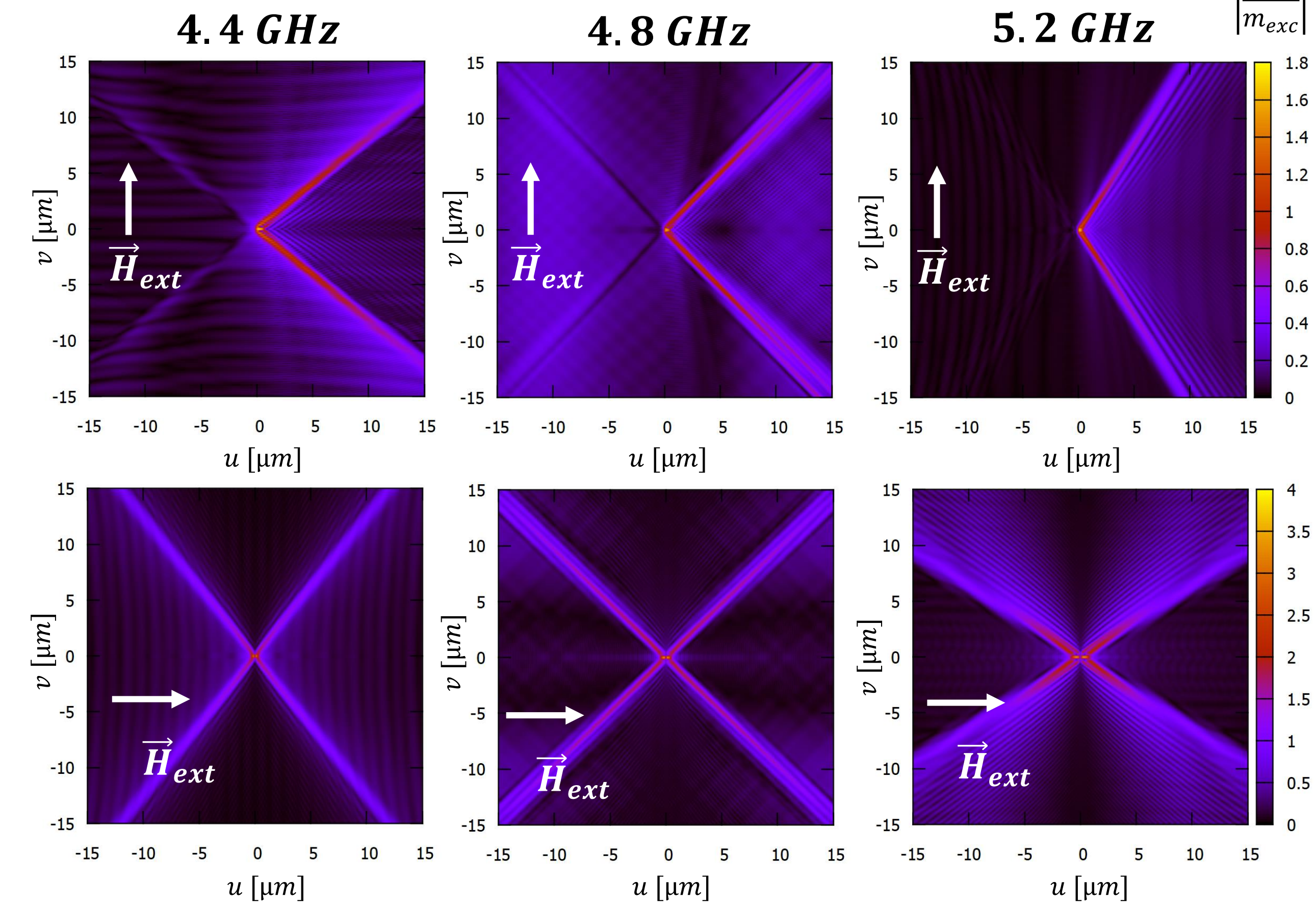
Conclusions

- ▶ Validation of NFD model for in-plane mode for thin film \Rightarrow Caustic beam excitation from point-like excitation
- ▶ Powerful tool to explore constriction shapes for spin-wave beamforming
- ▶ Upgraded needed for NFD model to obtain non-reciprocal thickness profile of the diffraction patterns

❖ Frequency and constriction size dependence

$$w_1 = 200 \text{ nm}; w_2 = 40 \mu\text{m}; l = 500 \text{ nm}$$

$$\mu_0 H_{ext} = 100 \text{ mT}; t_{YIG} = 200 \text{ nm}$$



Caustic beam angle adjustable with frequency