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

► **To cite this version:**

Loic Temdie, Vincent Vlaminc, Vincent Castel, Benjamin Jungfleisch, Dinesh Wagle, et al.. Antenna Design for Spin Wave Caustic Beams. JEMS 2023: 13th Joint European Magnetic Symposia, Aug 2023, Madrid, Spain. . hal-04203267

**HAL Id: hal-04203267**

**<https://hal.science/hal-04203267>**

Submitted on 11 Sep 2023

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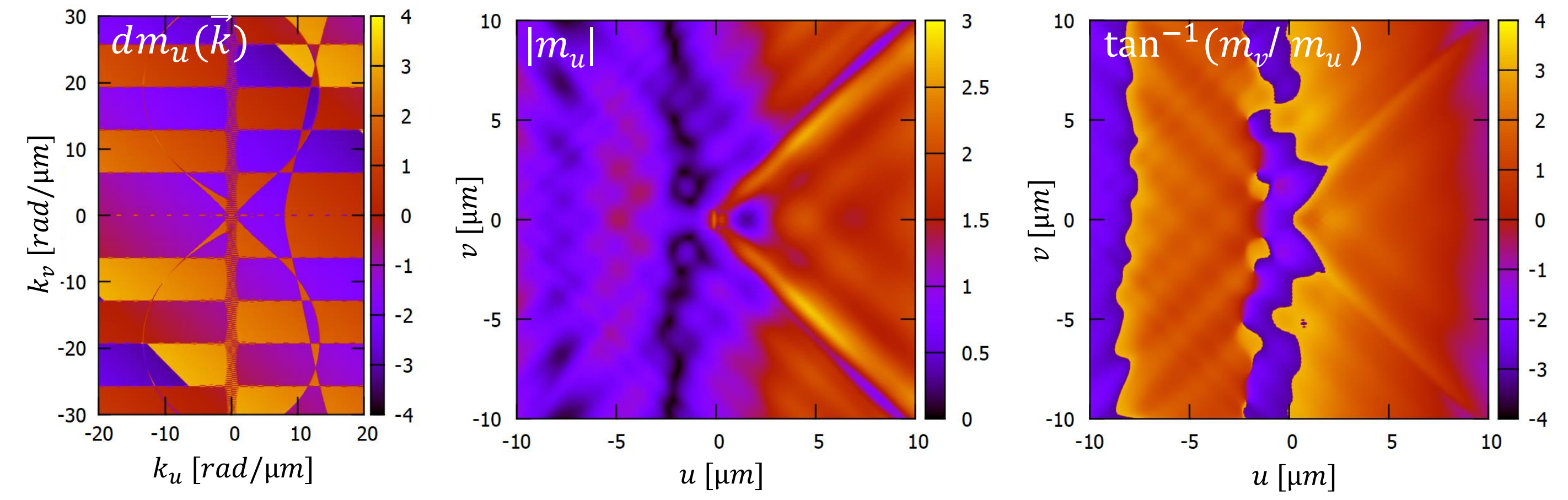


# Antenna Design for Spin Wave Caustic Beams

## 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]

Constricted stripline: YIG 200nm -  $\mu_0 H_{ext} = 100 \text{ mT}$  -  $f = 4.7 \text{ GHz}$



## Near-Field diffraction model for in-plane magnetized films

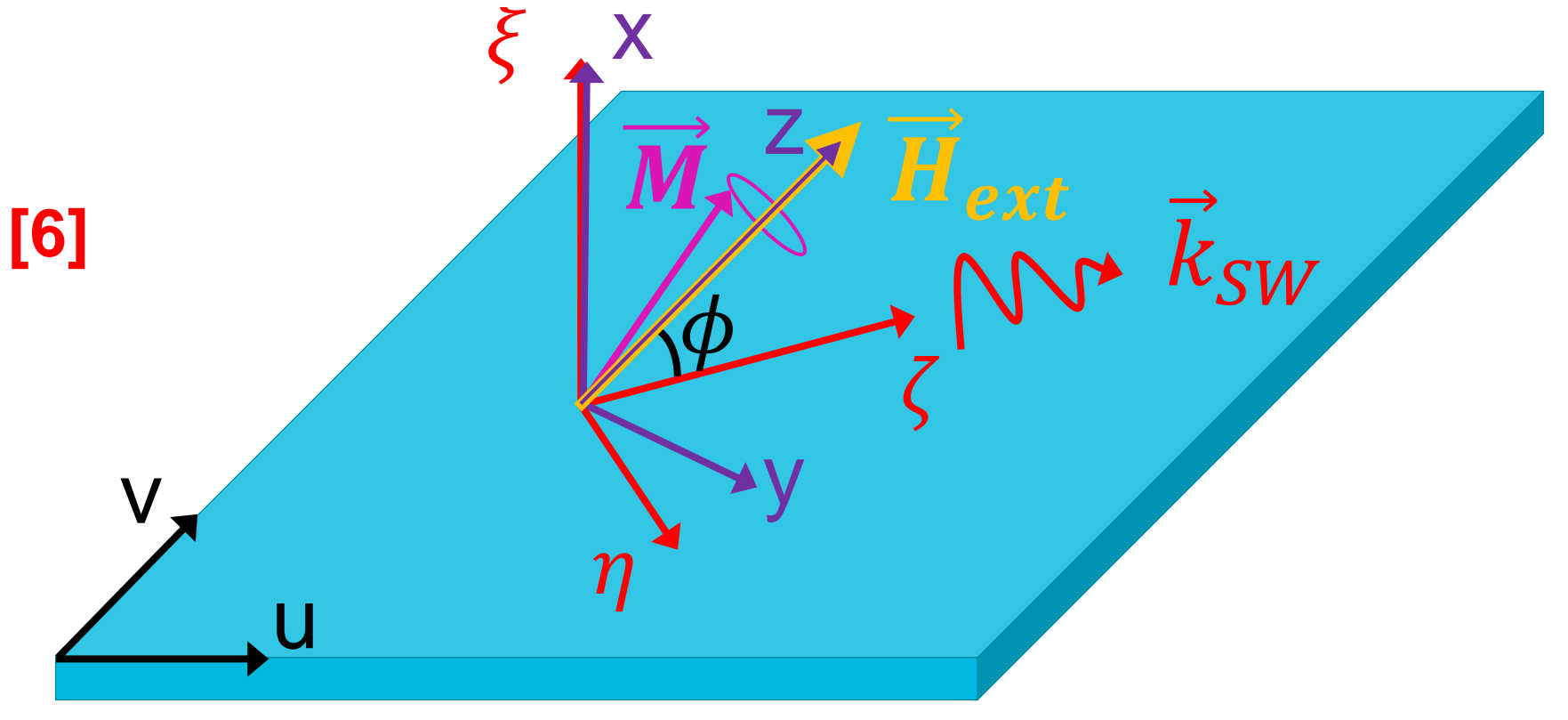
### ❖ Kalinikos's approach to express $\vec{m}(u, v, t)$ [5]

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

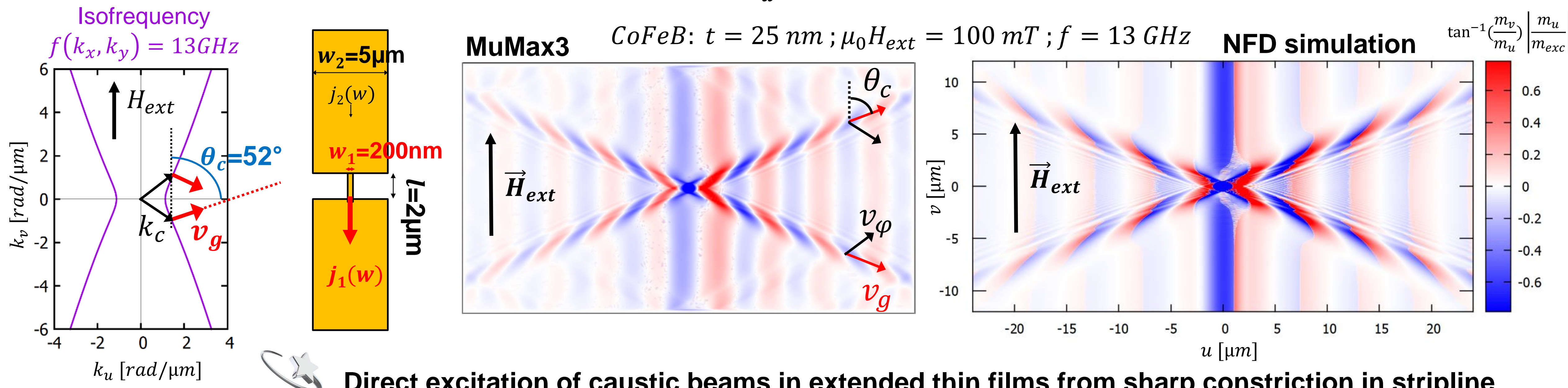


- **$(x, y, z)$   $\vec{M}(\vec{r}, t)$  frame**  $\Rightarrow$  Linearizing LLG

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

- **$(u, v, \xi)$  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 $\frac{d^2 k_v}{dk_u^2} = 0$



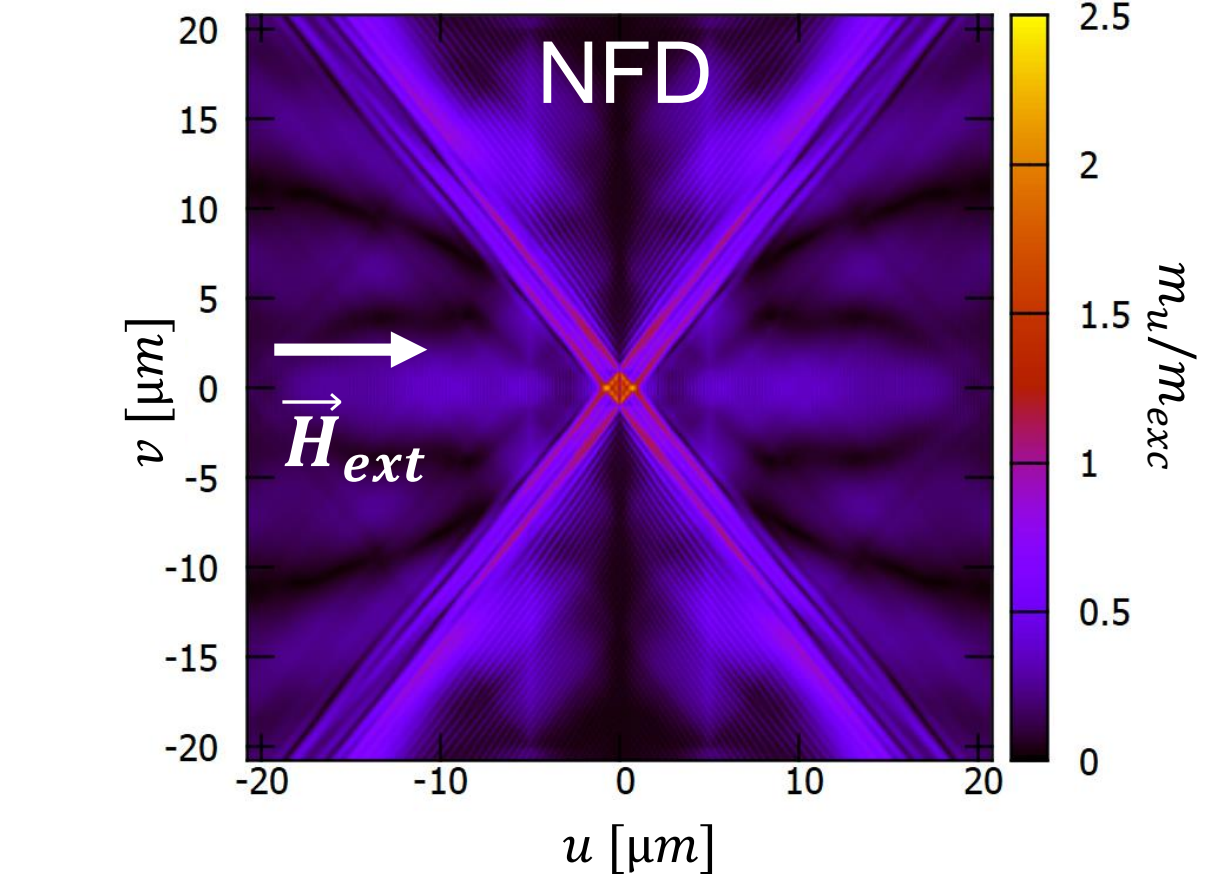
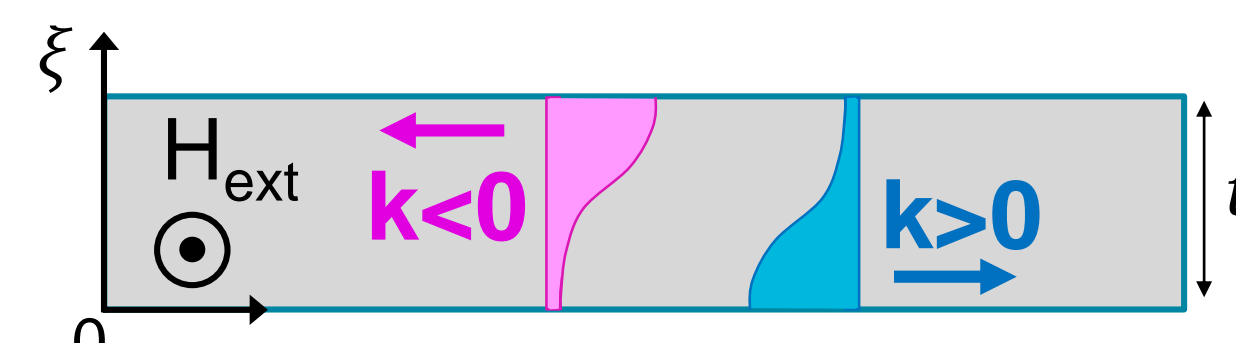
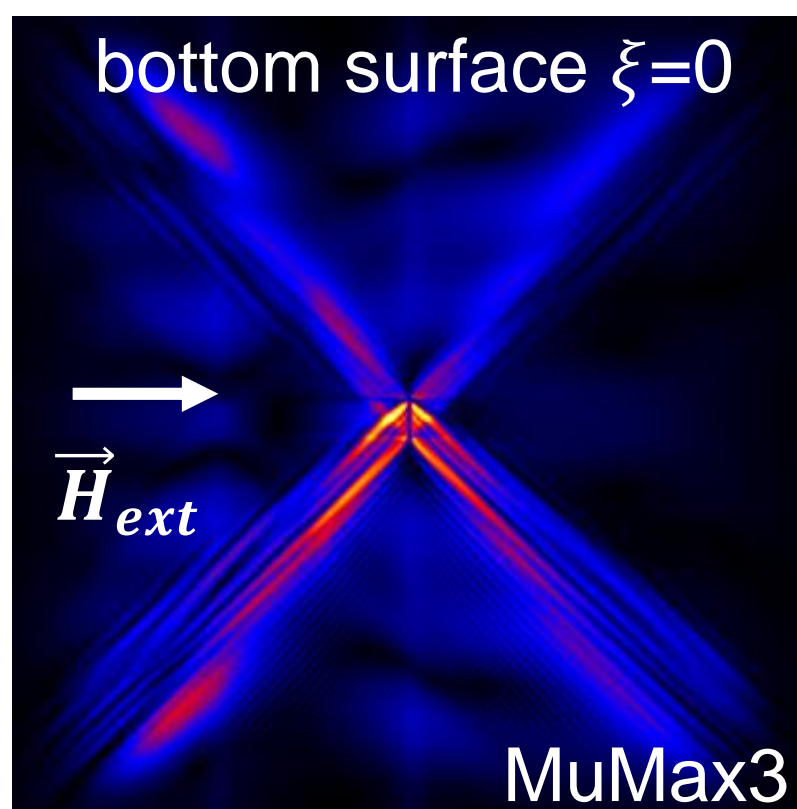
Direct excitation of caustic beams in extended thin films from sharp constriction in stripline

## Caustic beam definition

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

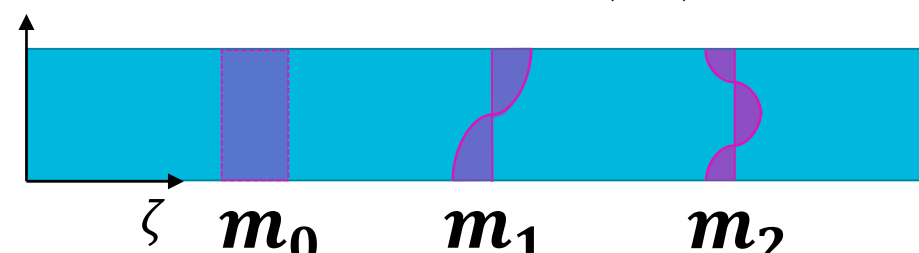
$$w_1 = 200 \text{ nm} \\ w_2 = 10 \mu\text{m}; l = 2 \mu\text{m}$$

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



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

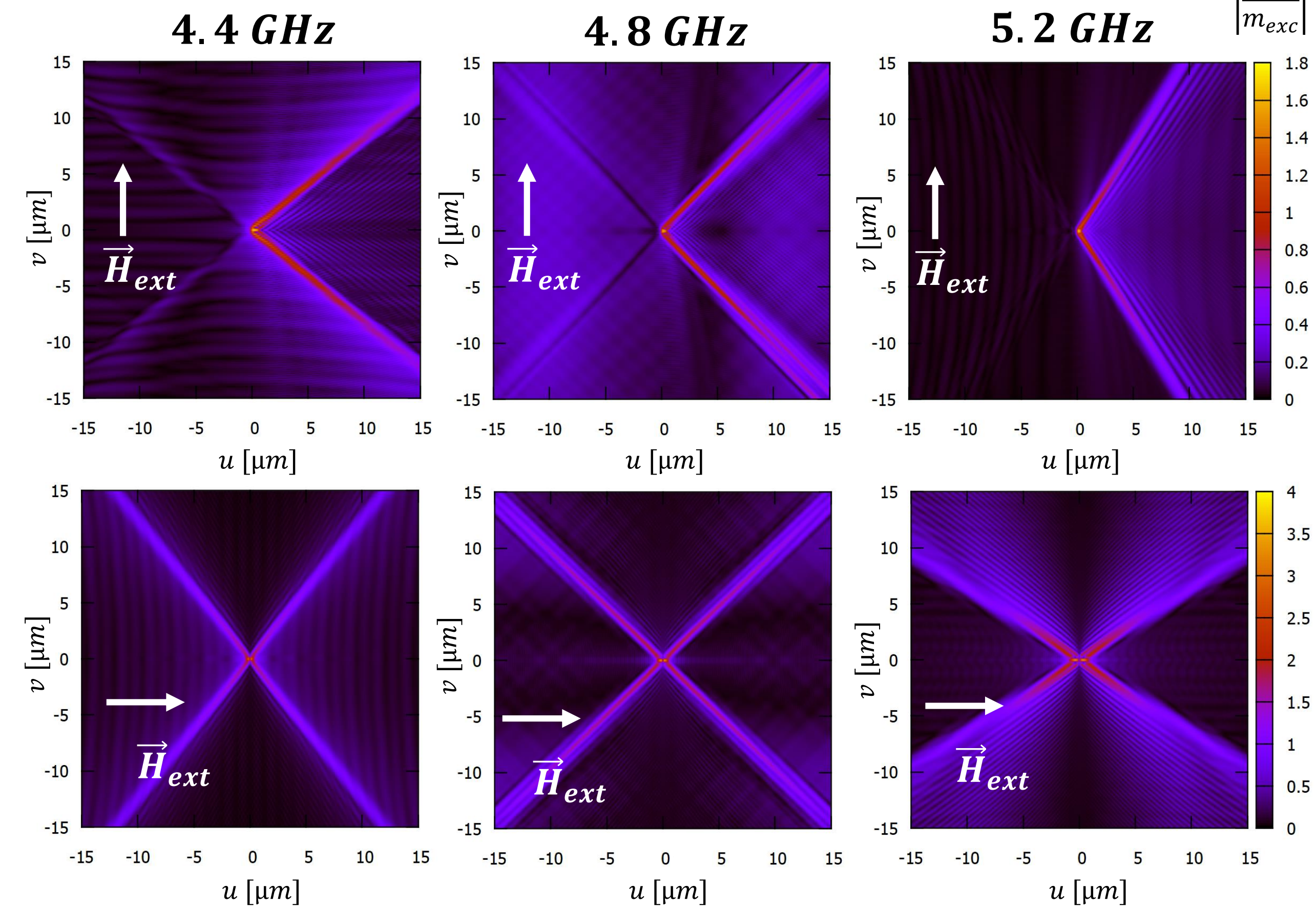
$$\begin{pmatrix} \vec{\chi}_{00} & \vec{\chi}_{01} & \vec{\chi}_{02} & \dots \\ \vec{\chi}_{10} & \vec{\chi}_{11} & \vec{\chi}_{12} & \dots \\ \vec{\chi}_{20} & \vec{\chi}_{21} & \vec{\chi}_{22} & \dots \\ \dots & \dots & \dots & \dots \end{pmatrix} \begin{pmatrix} \vec{h}_0 \\ \vec{h}_1 \\ \vec{h}_2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



### ❖ 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

## 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

## Authors

Loic TEMDIE<sup>1,2</sup>  
Vincent VLAMINCK<sup>1,2</sup>  
Vincent CASTEL<sup>1,2</sup>  
Benjamin JUNGFLAISCH<sup>3</sup>  
Dinesh Wagle<sup>3</sup>  
Mojtaba T. Kaffash<sup>3</sup>  
Yves HENRY<sup>4</sup>  
Daniel STOEFFLER<sup>4</sup>  
Matthieu BAILLEUL<sup>4</sup>

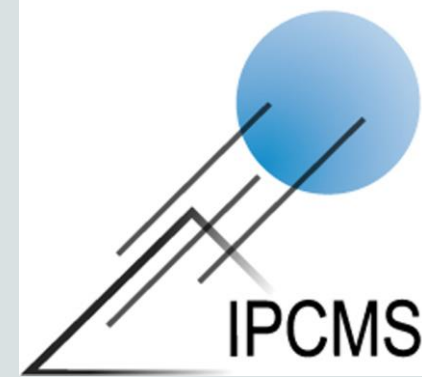
## Affiliations



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



<sup>3</sup> University of Delaware  
Dept. of Physics and Astronomy  
Newark, Delaware, USA



<sup>4</sup> IPCMS - UMR 7504 CNRS  
Institut de Physique et Chimie des  
Matériaux de Strasbourg

## Fundings



Thomas Jefferson  
Magnon  
Interferometry



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