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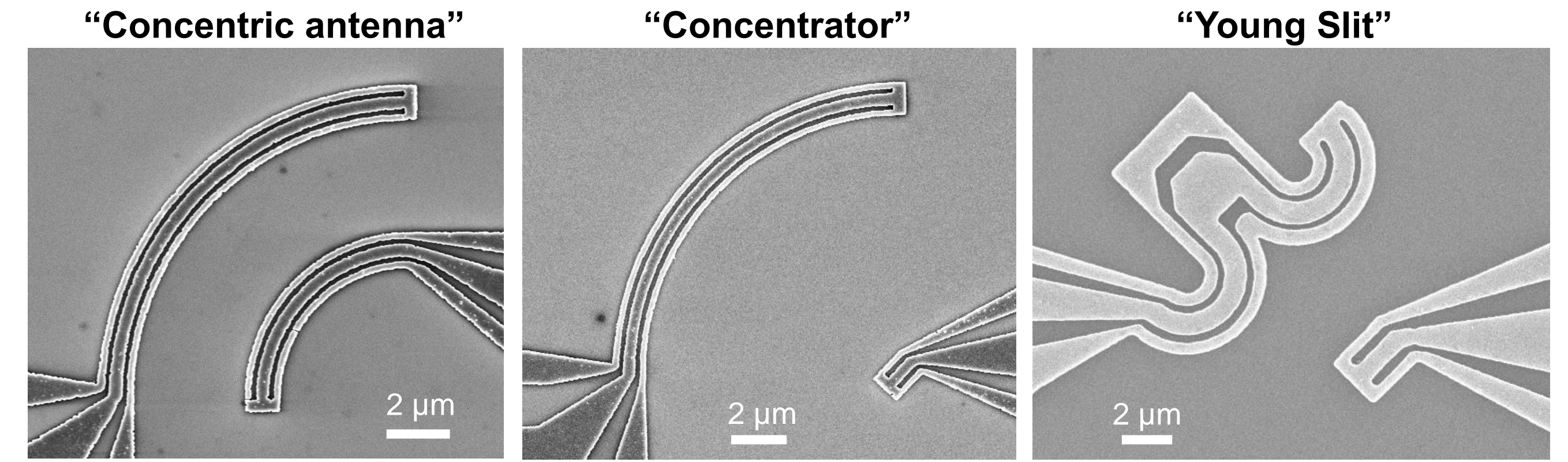


IMT Atlantique
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Spin Waves Diffraction from Curvilinear Antennas

Motivations

- ▶ **Shaping spin wave beams in continuous layers**
Design 3 demonstrators of curvilinear microwave antennae
- ▶ **Diffraction model for all spin wave modes**
Efficient tool to map the Near-Field Diffraction (NFD) patterns of any shape of spin wave antennas [1]
- ▶ **2D discrete mapping with SW spectroscopy [2,3]**



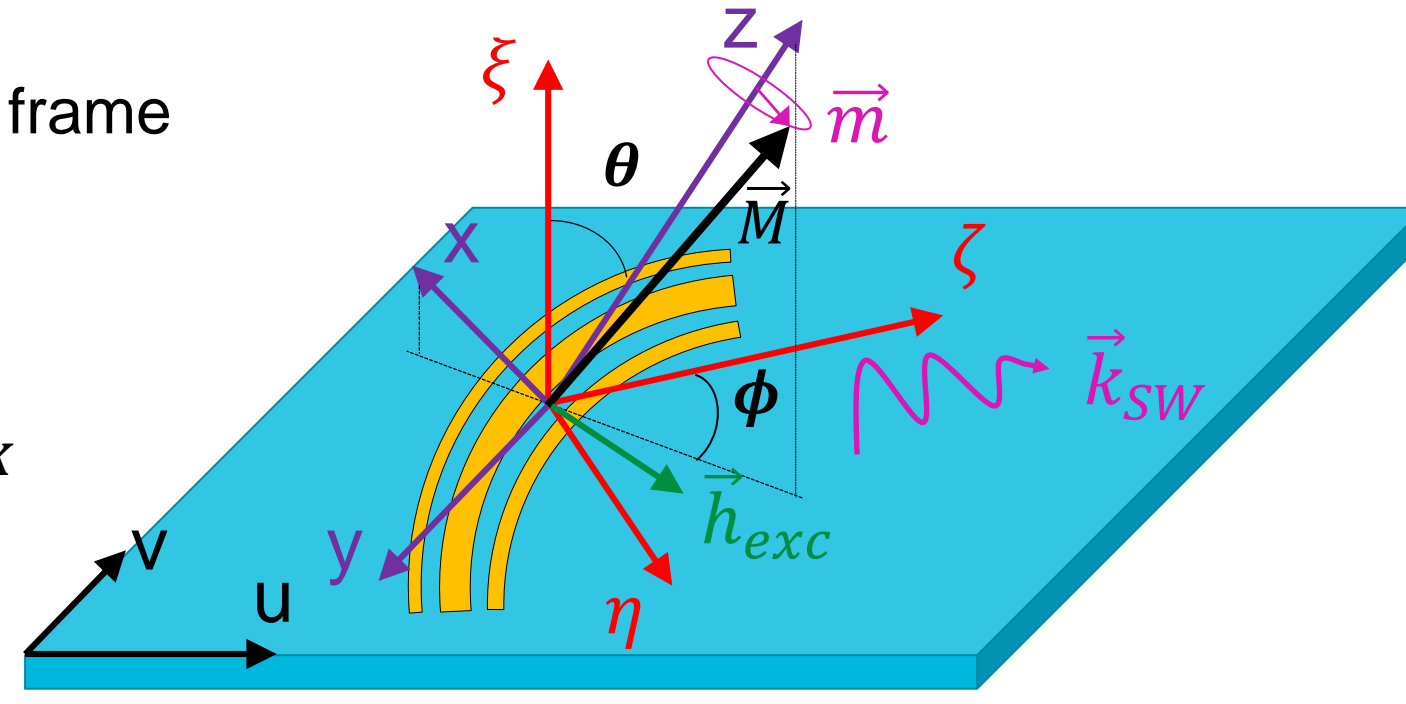
Near-Field diffraction model for arbitrary shaped antenna

- ▶ **Kalinikos approach to express $\vec{m}(u, v, t)$ [4]**

Curvilinear antenna $\vec{h}_{exc}(k_u, k_v)$ – All spin wave modes (\vec{k}, \vec{H}_{ext})

$$\vec{m}(u, v, t) = e^{i\omega t} \iint_{-\infty}^{+\infty} dk_u dk_v \{ \vec{\chi}(k_u, k_v) \cdot \vec{h}_{exc}(k_u, k_v) \} e^{-i(k_u u + k_v v)}$$

- (ξ, η, ζ) SW Propagation frame
- (x, y, z) $\vec{M}(\vec{r}, t)$ frame
- (u, v, ξ) Lab frame



Linearized LLG in the (x, y, z) frame

$$i\omega \vec{m} = -\gamma \mu_0 H_{equ} \vec{m} \times \vec{u}_z + \gamma \mu_0 M_s \vec{h} \times \vec{u}_z - \alpha i\omega \vec{m} \times \vec{u}_z$$

- **Dipolar:** $\vec{h}_d(\xi, \zeta, t) = \vec{h}_d(\xi) e^{i(\omega t - k\zeta)}$ Green function in (ξ, η, ζ) [5]

$$\vec{N}_{dip, xy} = \begin{pmatrix} P \cos^2 \phi & P \sin 2\phi \\ P \sin 2\phi & P \sin^2 \phi \end{pmatrix}$$

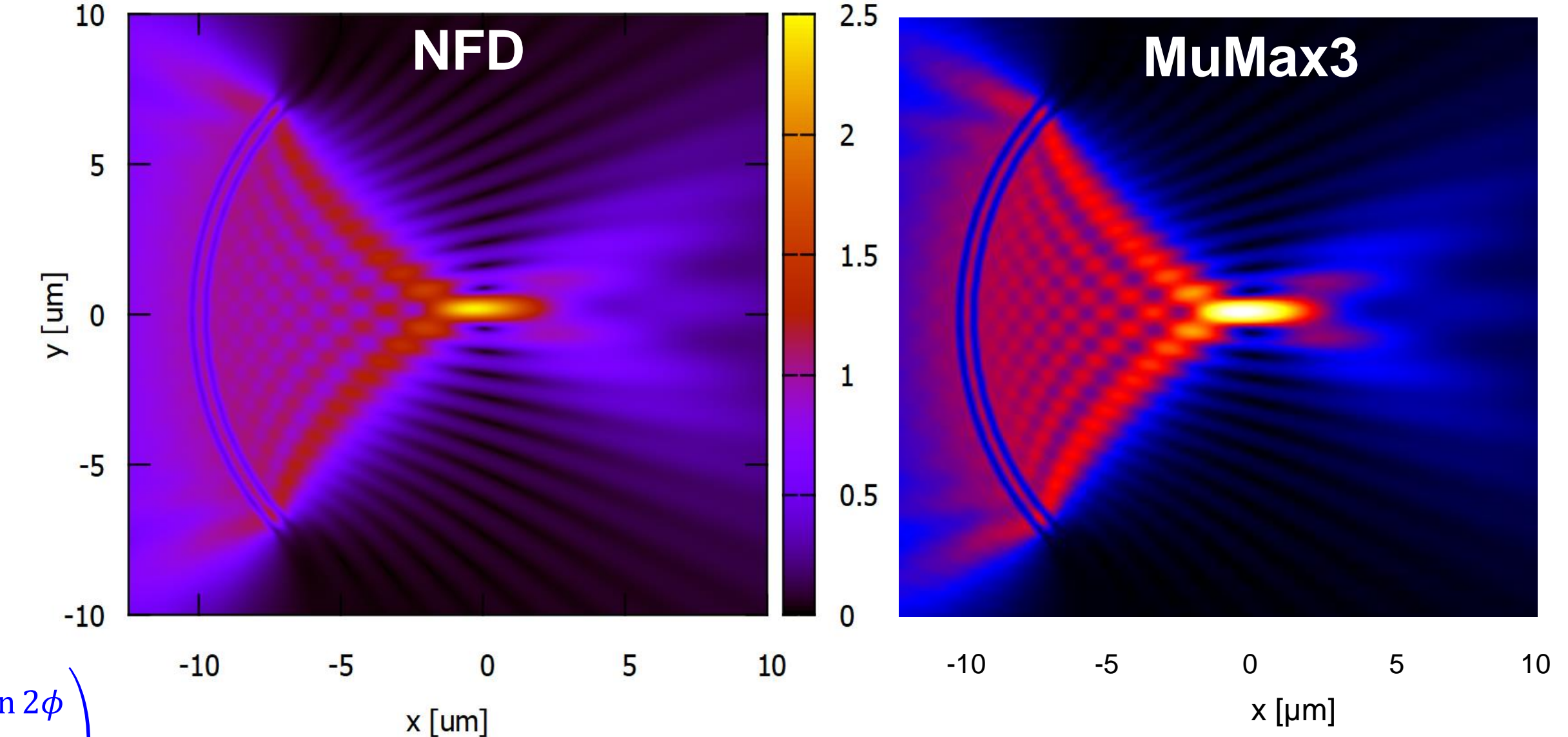
- **Exchange:** $\vec{h}_x(k) = \Lambda^2 \left(\frac{\partial^2}{\partial \xi^2} - k^2 \right) \vec{m}$ ($\Lambda = \sqrt{\frac{2A}{\mu_0 M_s^2}}$; $\Omega_k = \omega_H + \omega_M \Lambda^2 k^2$)

- ▶ **Comparison Model and MuMax3 ($\theta = 0$, out-of-plane)**

Circular antenna ($\frac{\pi}{2}$ arc; $R=10\mu m$) - No anisotropy - Only $n=0$ mode

Thin YIG film 30nm: $\mu_0 M_s = 198 mT$ - $A_{exc} = 4 pJ \cdot m^{-1}$ - $\alpha = 7.5 \cdot 10^{-4}$ - $K_u = 4.88 kJ \cdot m^{-3}$

$f = 5.15 GHz$ - $\mu_0 H_{ext} = 308 mT$

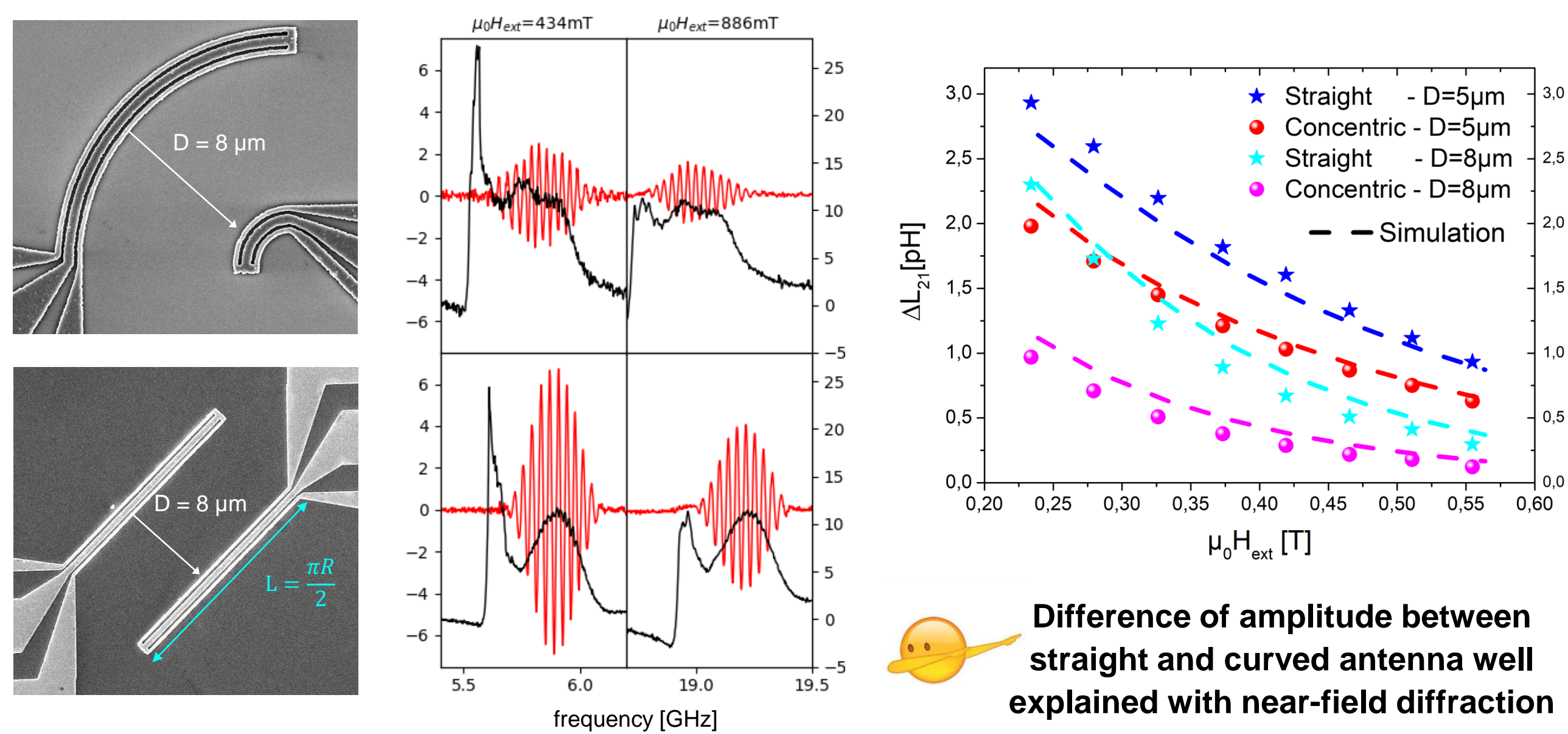


$$\vec{N} \vec{m} = \vec{h}_{exc} \Rightarrow \frac{1}{\omega_M} \begin{pmatrix} \Omega_k + i\alpha\omega + \omega_M \vec{N}_{d,xx}^{00} & -i\omega + \omega_M \vec{N}_{d,xy}^{00} \\ i\omega + \omega_M \vec{N}_{d,yx}^{00} & \Omega_k + i\alpha\omega + \omega_M \vec{N}_{d,yy}^{00} \end{pmatrix} \begin{pmatrix}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

Measuring interference patterns of curvilinear antennas

- ▶ **Concentric vs straight antennas**

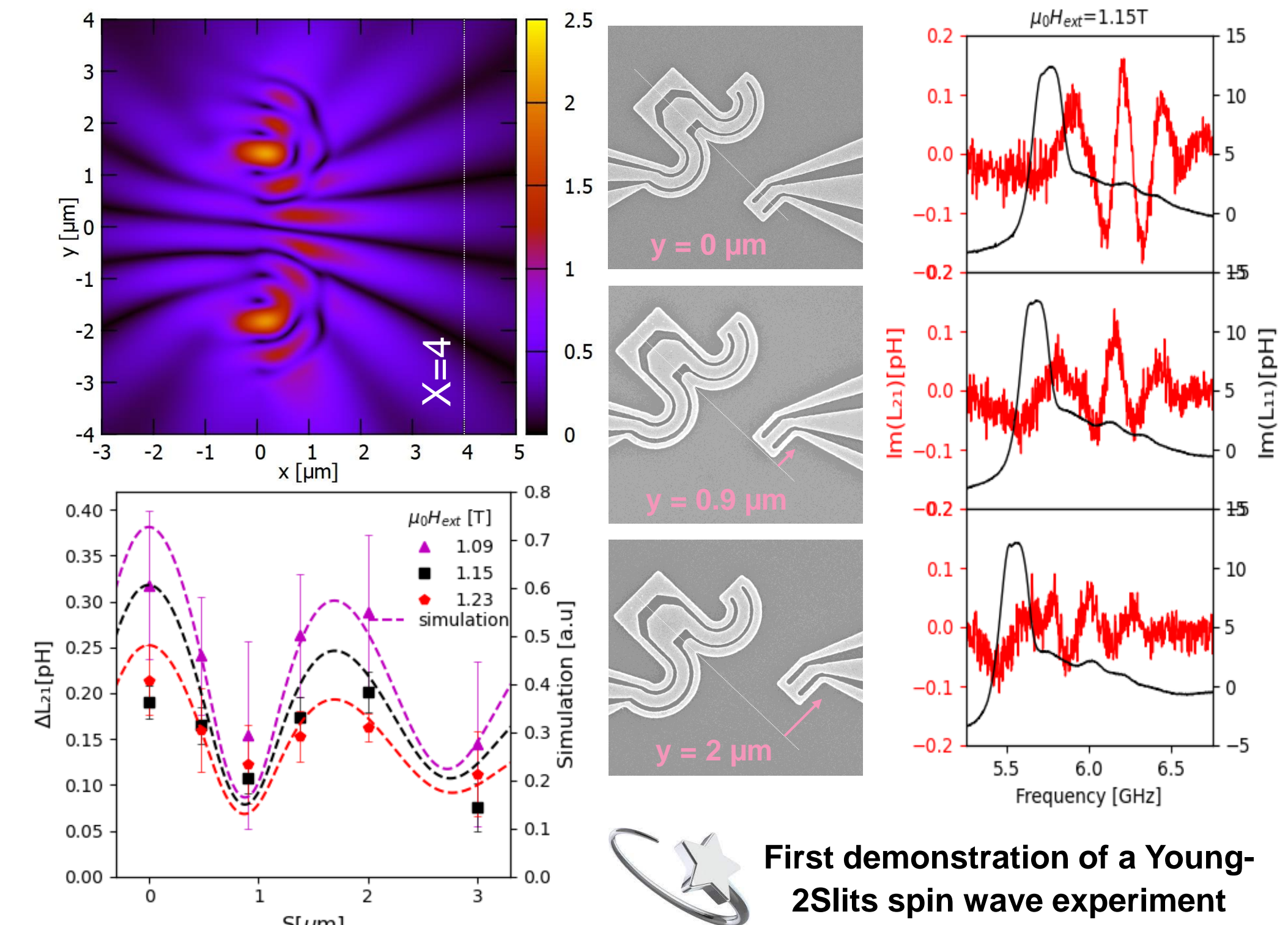
Comparing straight and curved antenna of same length $L = \frac{\pi R}{2}$



Difference of amplitude between straight and curved antenna well explained with near-field diffraction

- ▶ **Young-2Slits Emulate two apertures of circular waves**

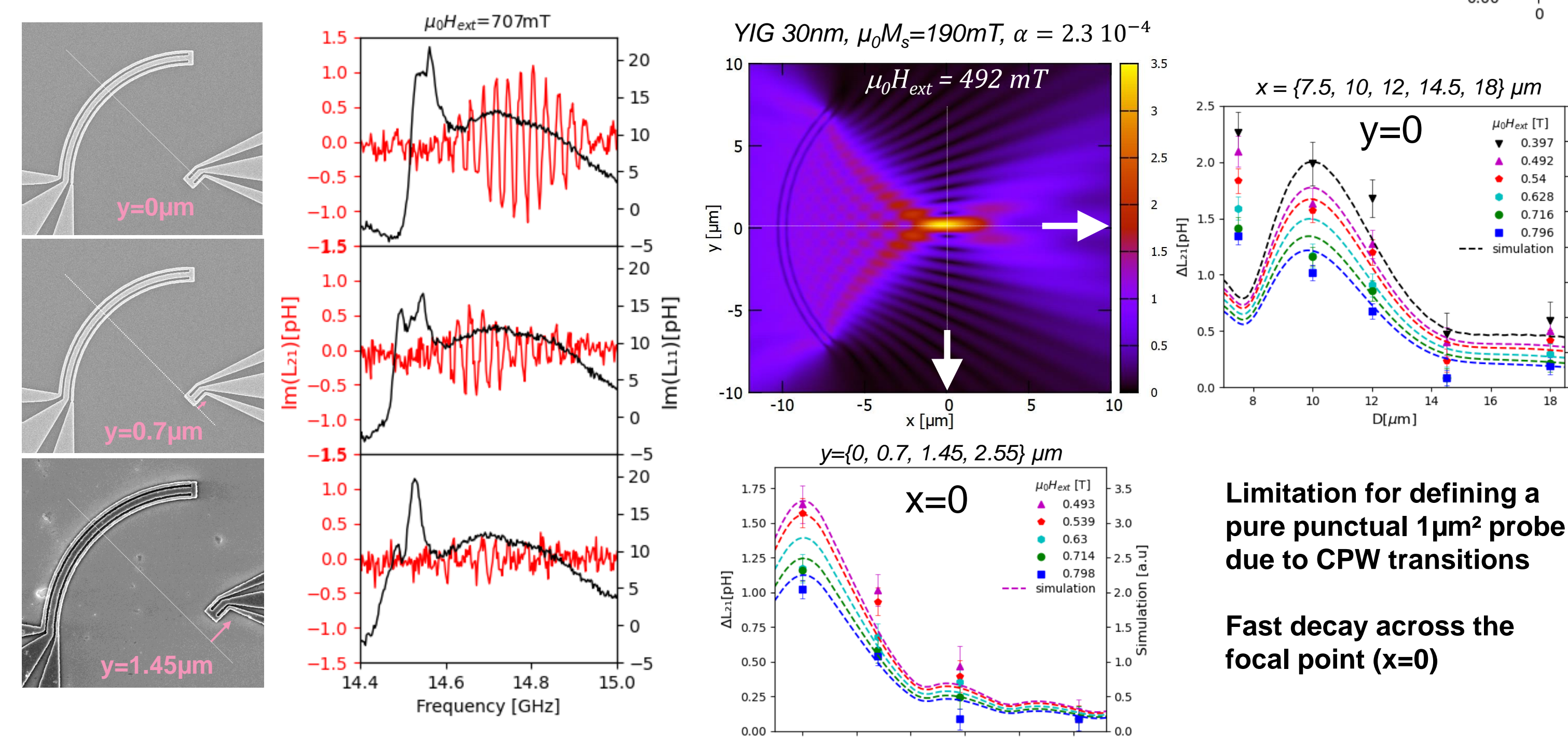
$Py 20nm$ - $\mu_0 M_s = 1 T$ - $A_{ex} = 7.5 pJ \cdot m^{-1}$ - $\alpha = 0.006$



First demonstration of a Young-2Slits spin wave experiment

- ▶ **Concentrator**

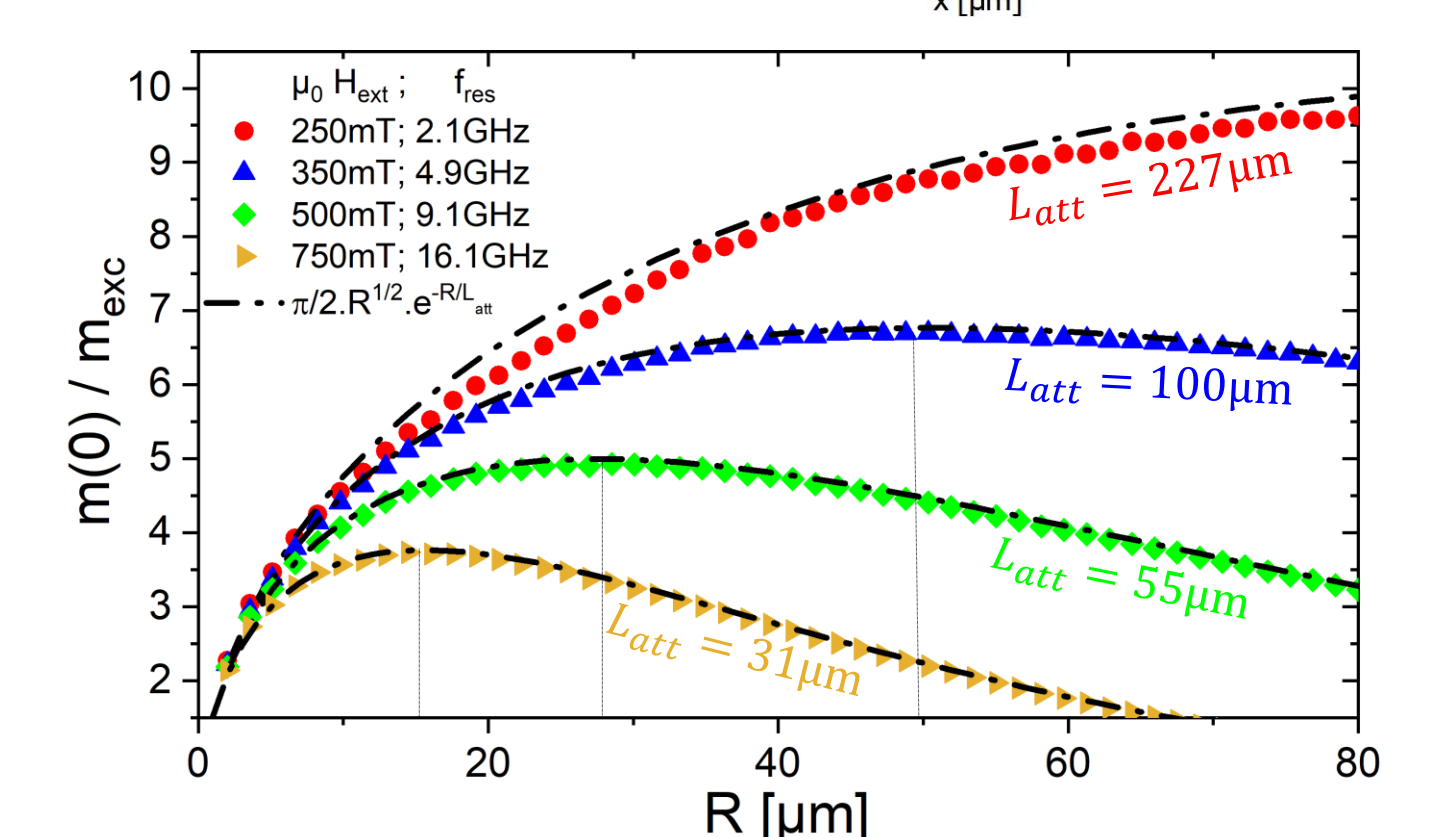
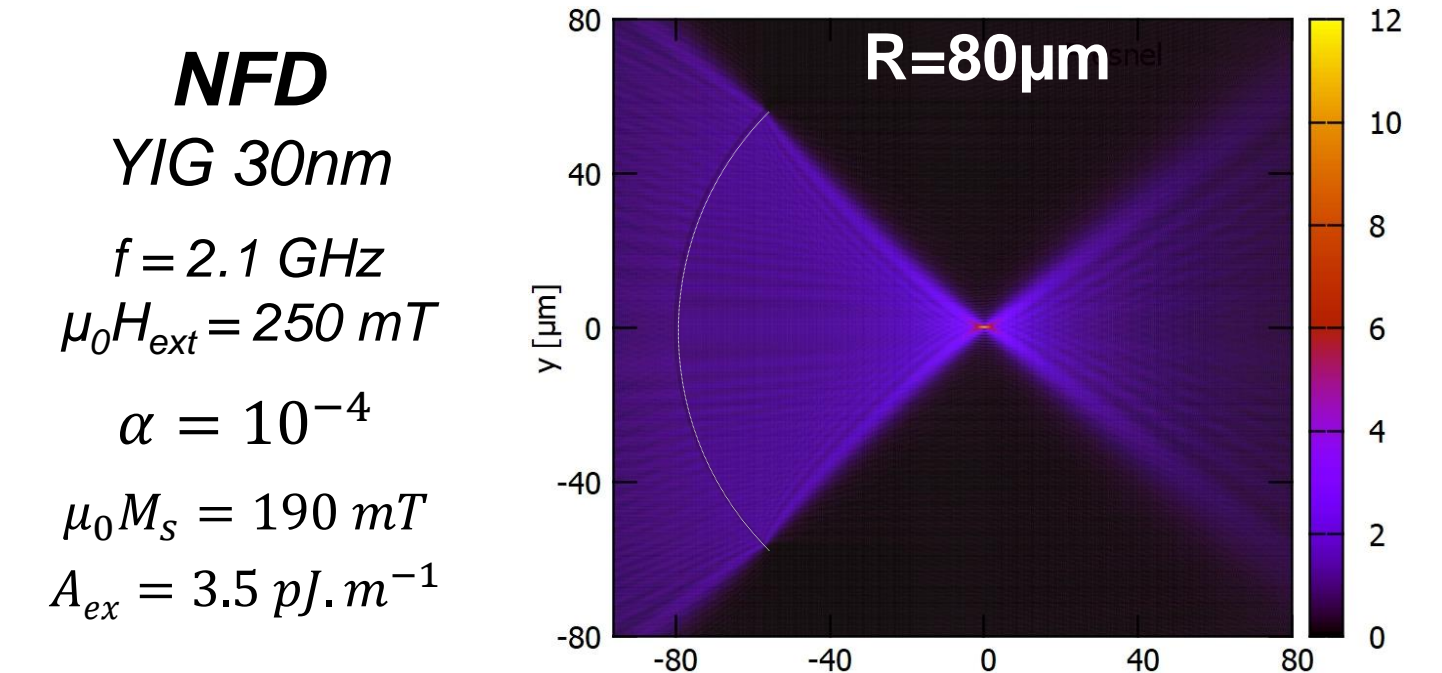
Probes across the focal point ($x=0$) & along the x-axis ($y=0$)



Limitation for defining a pure punctual $1\mu m^2$ probe due to CPW transitions

Fast decay across the focal point ($x=0$)

- ❖ **R-dependence of the amplification**



Amplification follows $\vec{m}(R) = \sqrt{R} \frac{\pi}{2} e^{-\frac{R}{L_{att}}}$
max at $R=L_{att}/2$: $\vec{m}(L_{att}/2) \propto \sqrt{L_{att}/2}$
up to a factor 10 ($R=80\mu m$, $f=2GHz$)

Conclusions

- ▶ Excellent agreement between a NFD model and MuMax3 simulations
- ▶ Discrete mapping of SW amplitude with a $\sim 1\mu m^2$ resolution
- ▶ Experimental demonstration of SW diffraction from curvilinear antennae
- ▶ Exploration of multiport spin wave interferometric devices [6,7]

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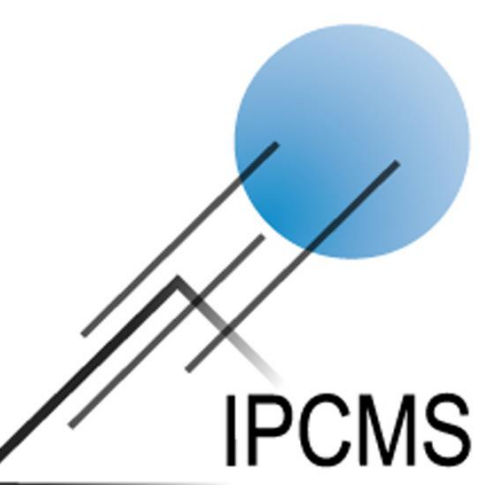


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Fundings



ANR "MagFunc"



Project "SOSMAG"

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