Structure and dynamic magnetic properties of thin and thick synthetic antiferromagnets (SAFs)

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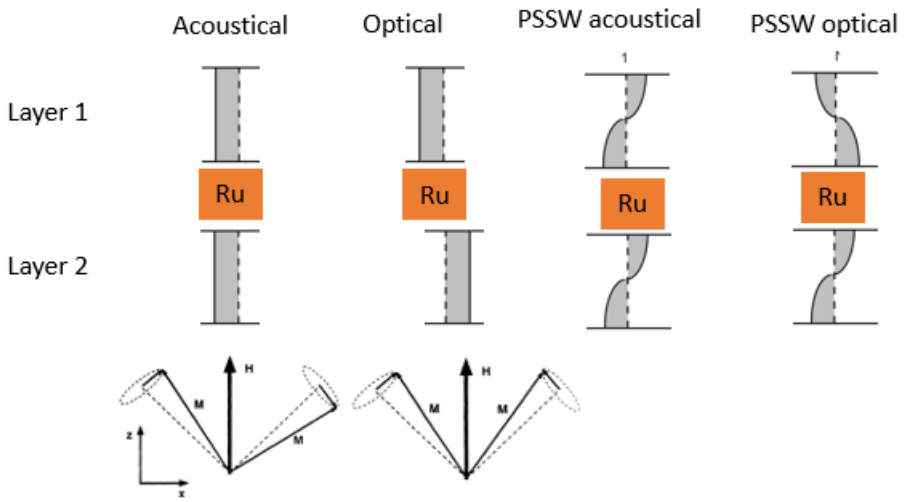
From natural antiferromagnet to synthetic antiferromagnet

Spin wave

The spin wave is an elementary fluctuations of the long-range magnetic order.

SYNTHETIC antiferromagnet

M1+M2=0



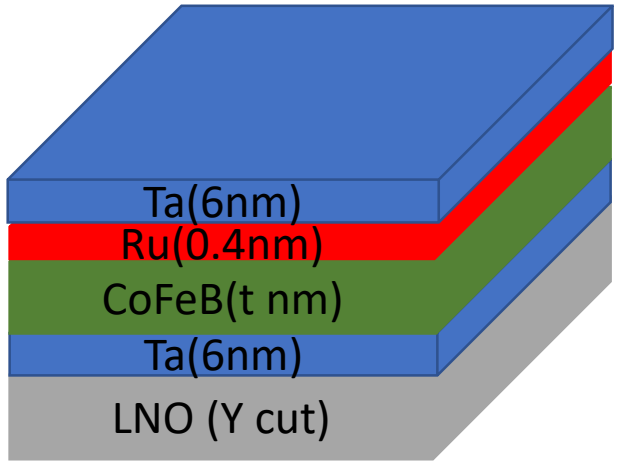
Why we are interested on the spin wave in SAF?

- Higher frequencies (tens of GHz)
- Short wavelength (10 nm)
- Anisotropic propagation
- Non-reciprocty
- Strong non linearity
- Can be coupled with surface acoustical wave (SAW) for RF applications

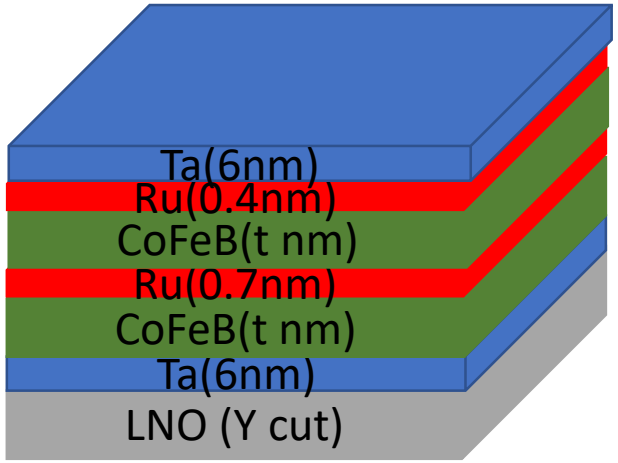
Kamimaki et al, P.R Applied 13,044036 (2020)

Synthetic antiferromagnets (SAF)

Sputtering deposition

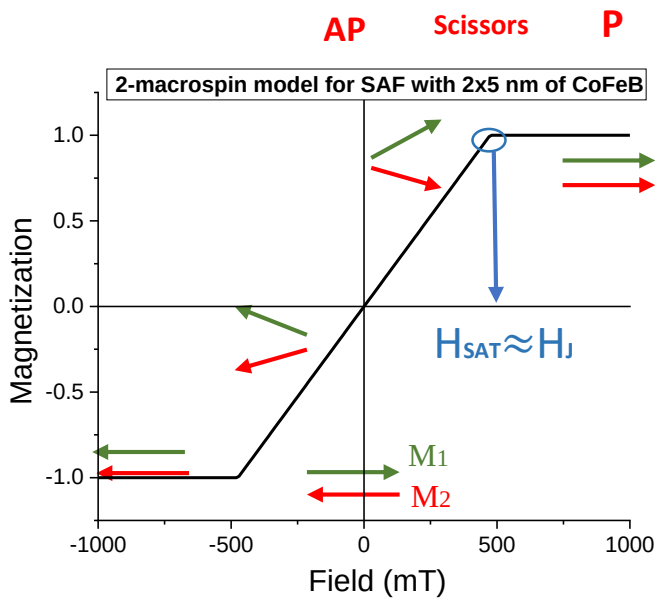


Single Layer of CoFeB



Synthetic antiferromagnet

Differents state and criticals fields of the SAF



Optimization of sputtering parameters on a 17 nm thick single layer

The Magnetic parameters were measured by VNA and PMOKE

- In plane magnetization $\mu_0 M_s = 1.7$ T
- $\alpha = 4.48 \times 10^{-3}$
- Weak residual in plane anisotropy $\mu_0 H_k = 3$ mT (will be neglected in the following)

The thicknesses of the deposited SAF

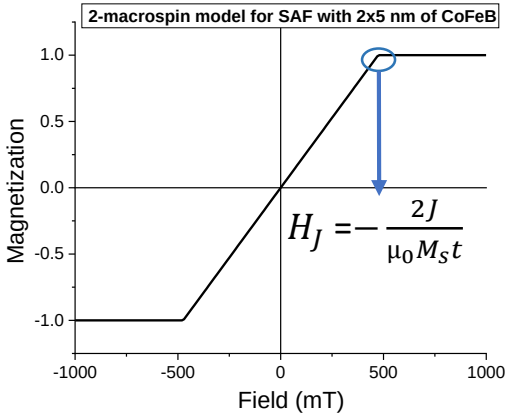
- t = 5, 10, 15, 16.9, 20, 28, 40 nm

$$E_J = J\,\overrightarrow{M_1}\,.\,\overrightarrow{M_2}$$

Effectif interaction field : $H_J = -\dfrac{2J}{\mu_0 M_s t}$

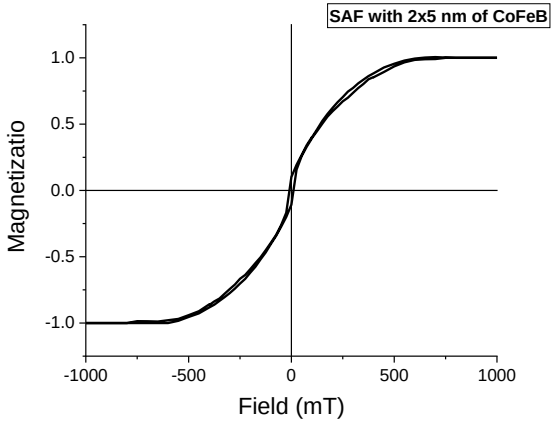
Hysteresis loop and AFM results of the SAF

2-macrospin model

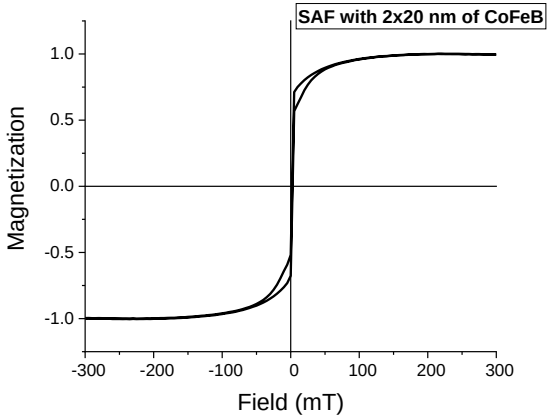


2x5 nm

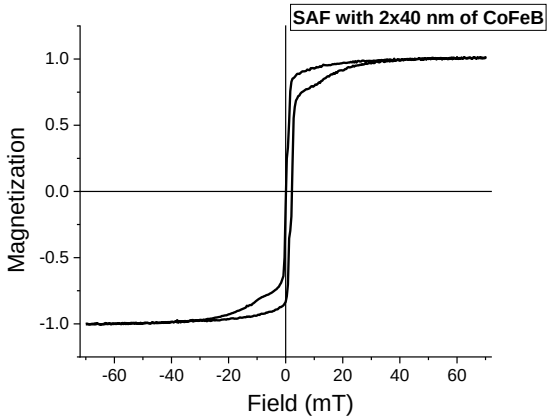
VSM measurements



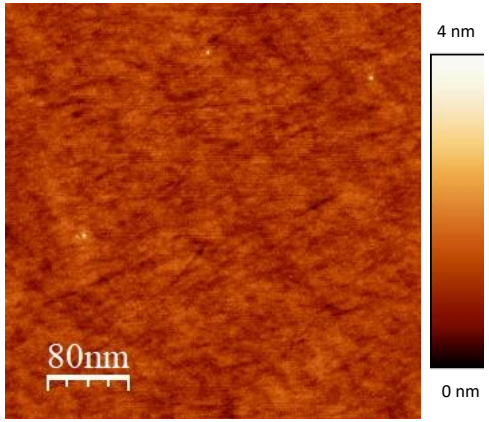
2x5 nm

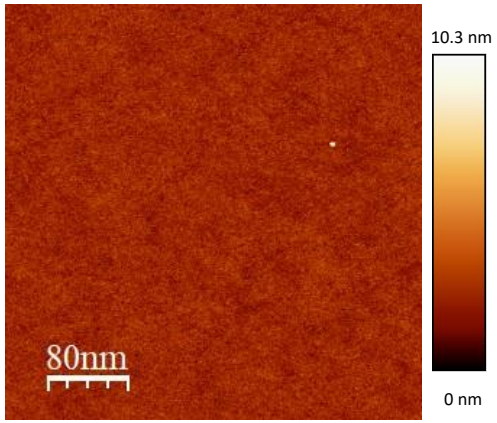


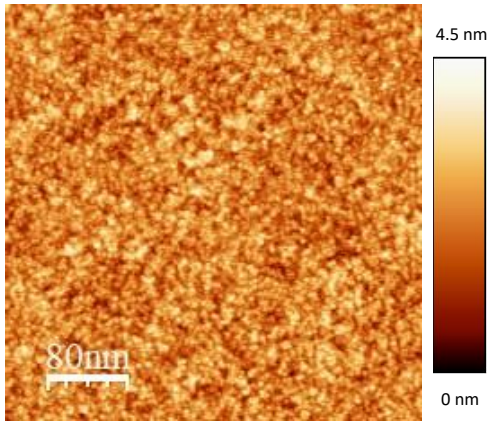
2x20 nm



2x40 nm

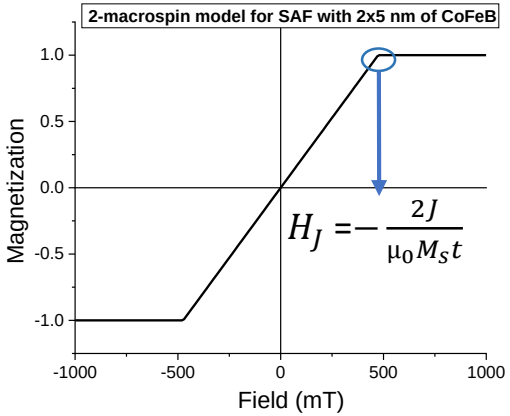




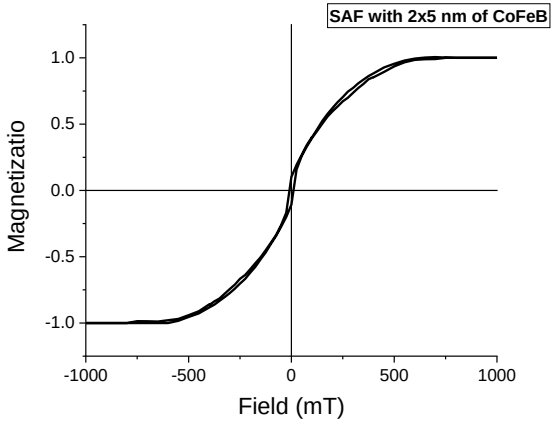


Hysteresis loop and AFM results of the SAF

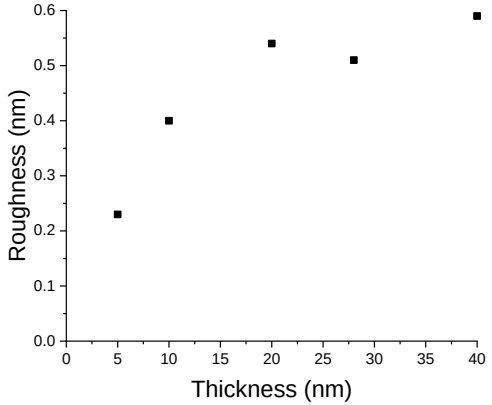
2-macrospin model



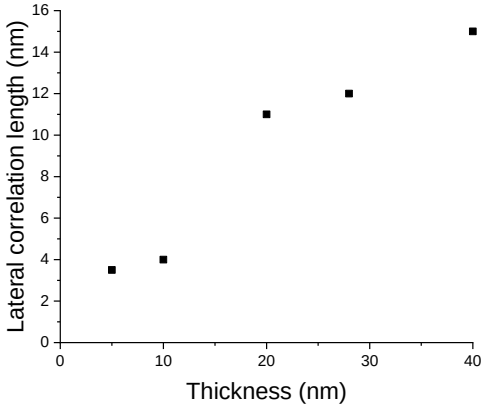
2x5 nm



2x5 nm

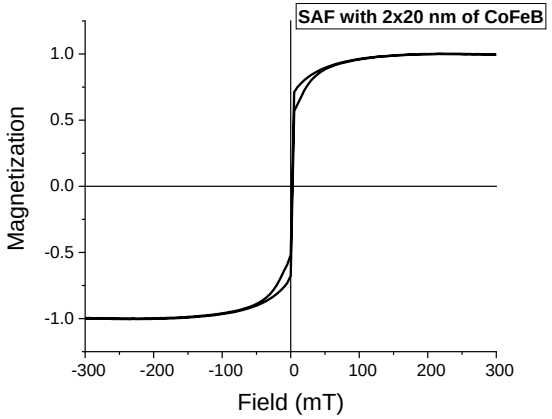


Roughness

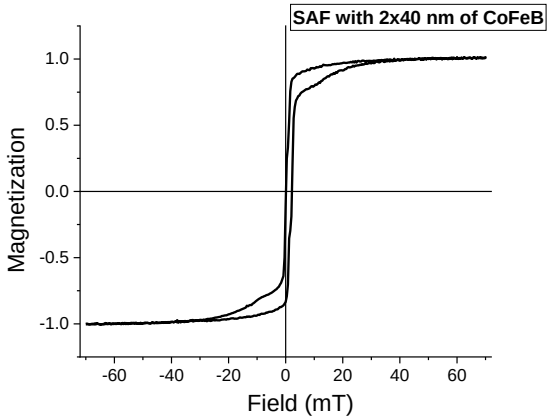


Lateral correlation length

VSM measurements

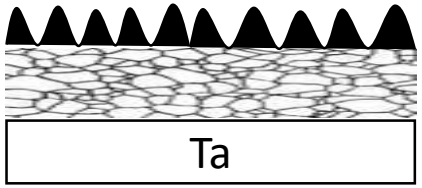


2x20 nm

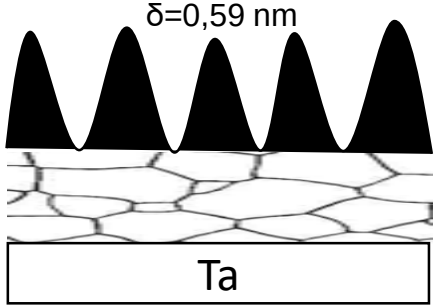


2x40 nm

2x5 nm de CoFeB
δ=0,20 nm

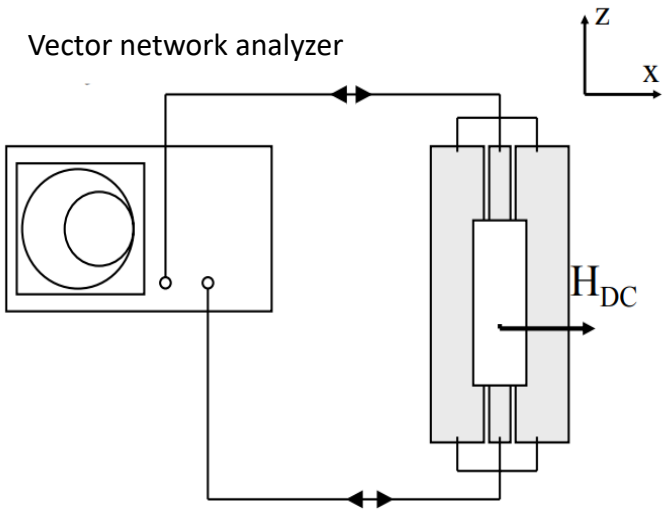


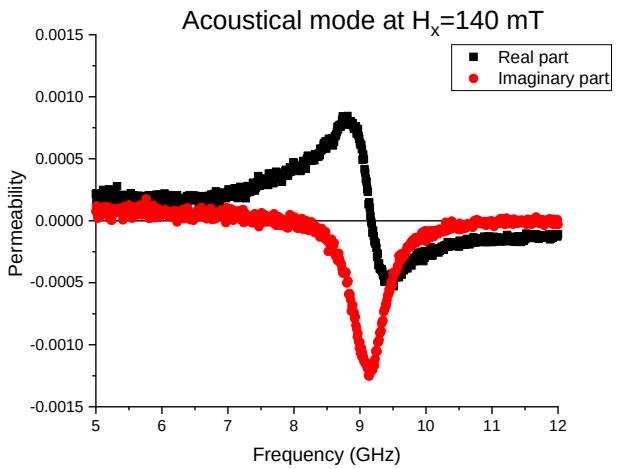
2x40 nm de CoFeB
δ=0,59 nm

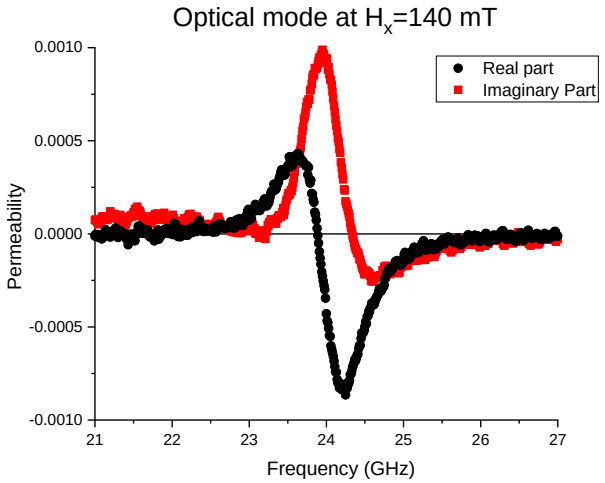


Thickness of CoFeB layers increase → Lateral correlation length and roughness increase

Ferromagnetic resonance of thin SAF with 2x5 nm of CoFeB

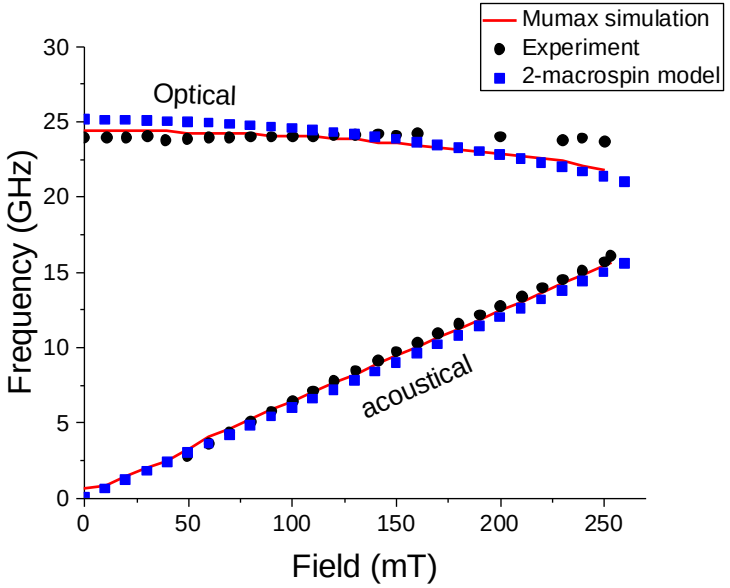


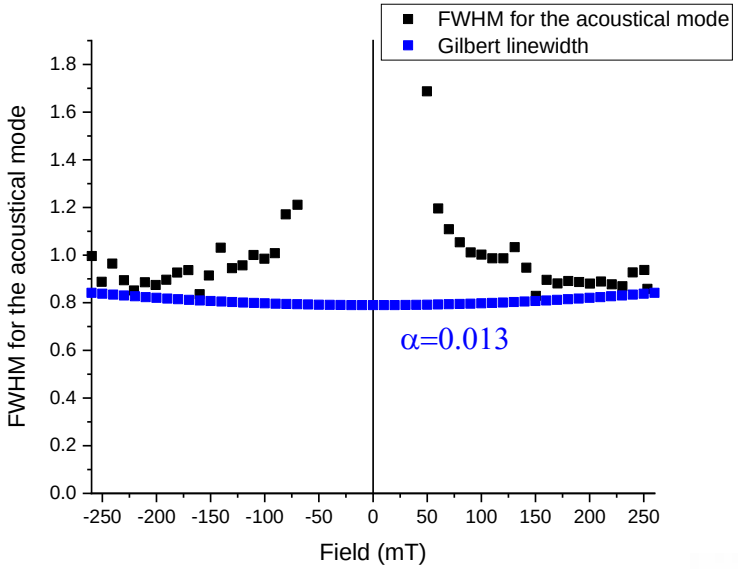




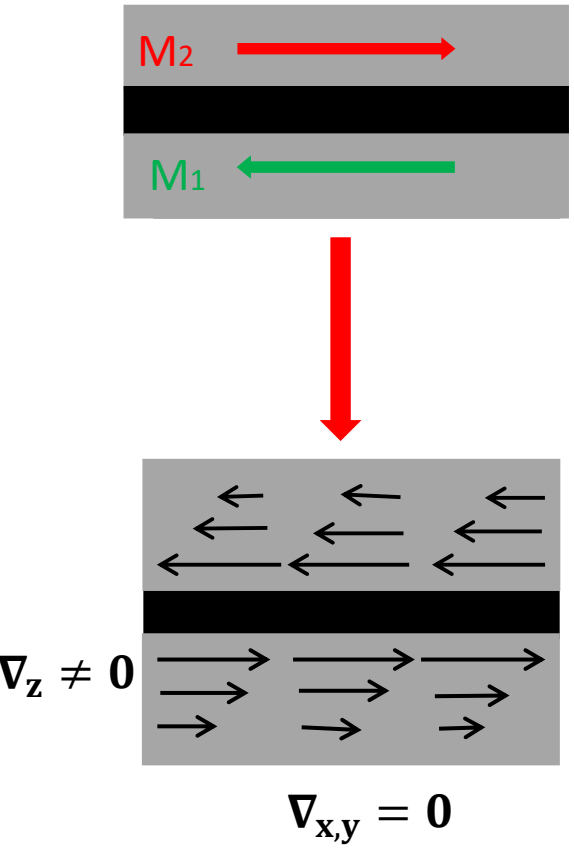
Macrospin model

- $\omega_{ac} = \gamma_0 H_x \sqrt{\frac{M_S+H_J}{H_J}}$
- $\omega_{op} = \sqrt{\frac{M_S}{H_J}} \sqrt{{H_J}^2 - {H_x}^2}$
- $\Delta_{\omega_{ac}} = \alpha\gamma_0 \left(M_S + \frac{{H_J}^2+{H_x}^2}{{H_J}^2} \right)$





The gradient of orientation of magnetization in thick SAFs



$$t_{exch} \ll \frac{A}{J} \approx 7\ nm$$

Uniform magnetization

YES

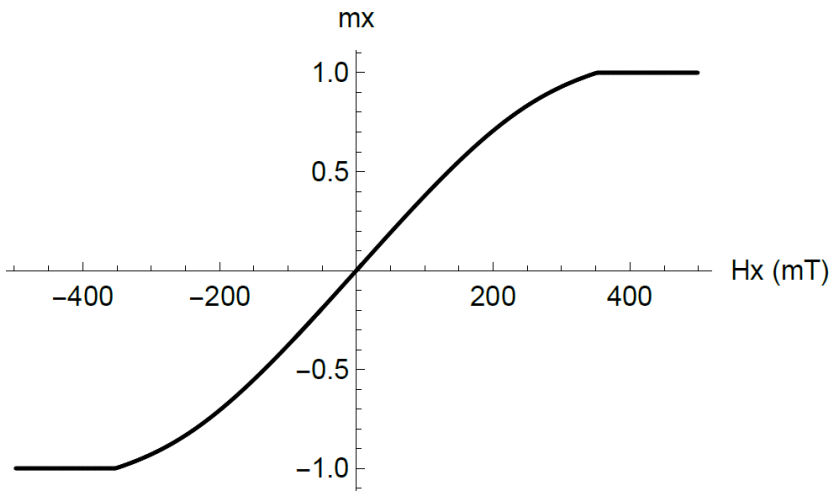
Macrospin approximation

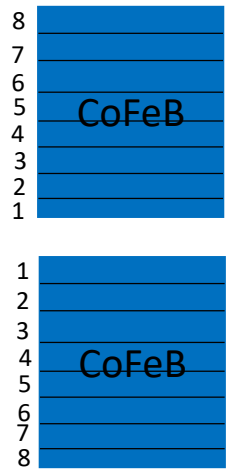
NO

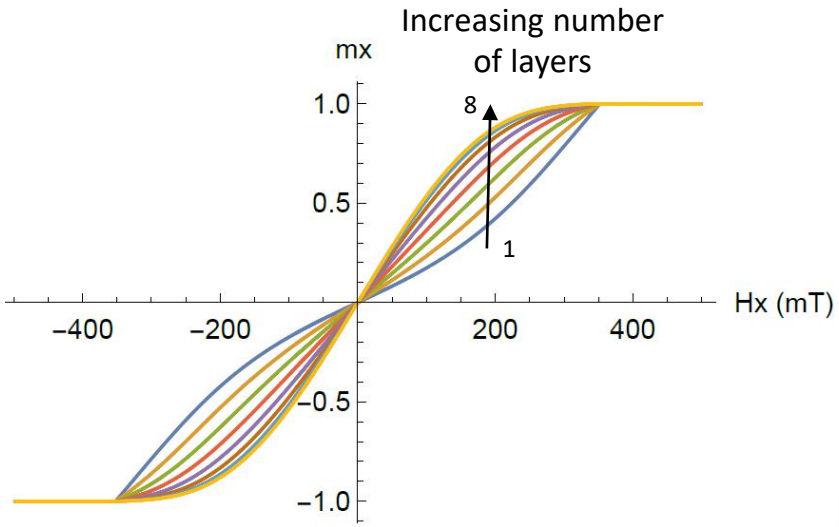
t >> t_{exch}

Gradient of magnetization orientation

Micromagnetic simulation on 2x40 nm of CoFeB

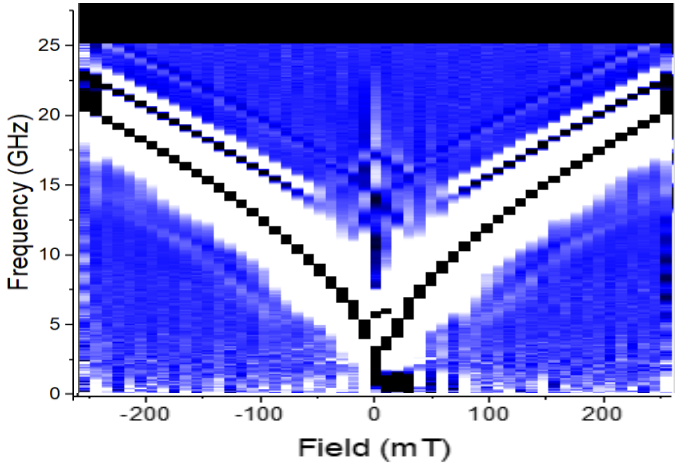




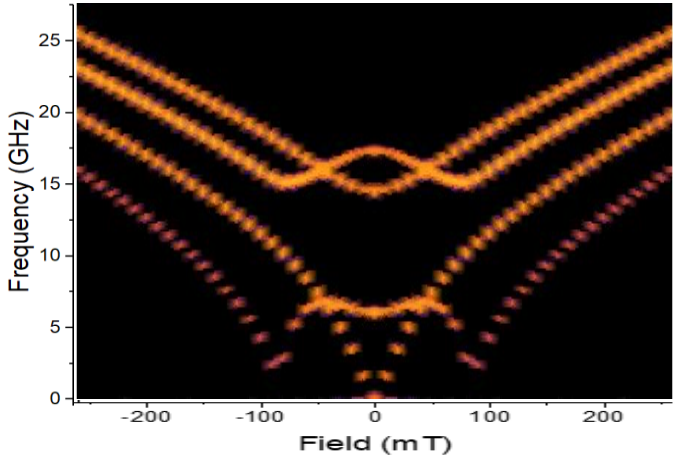


Ferromagnetic resonance of thick SAF with 2x40 nm of CoFeB

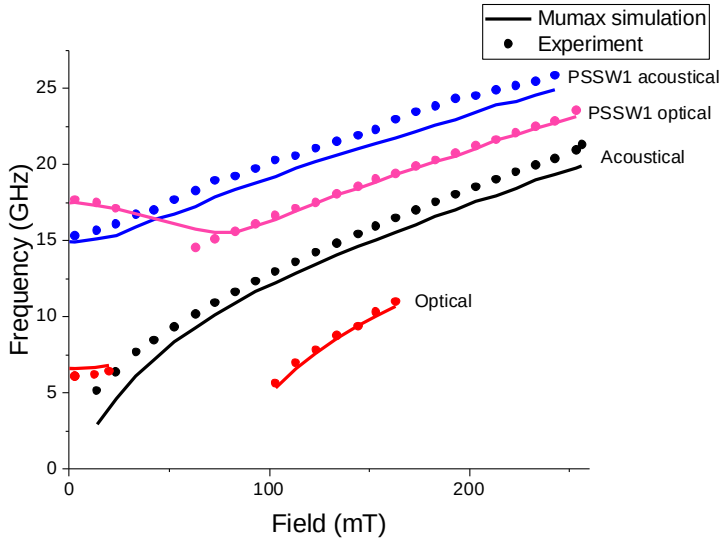
VNA measurement



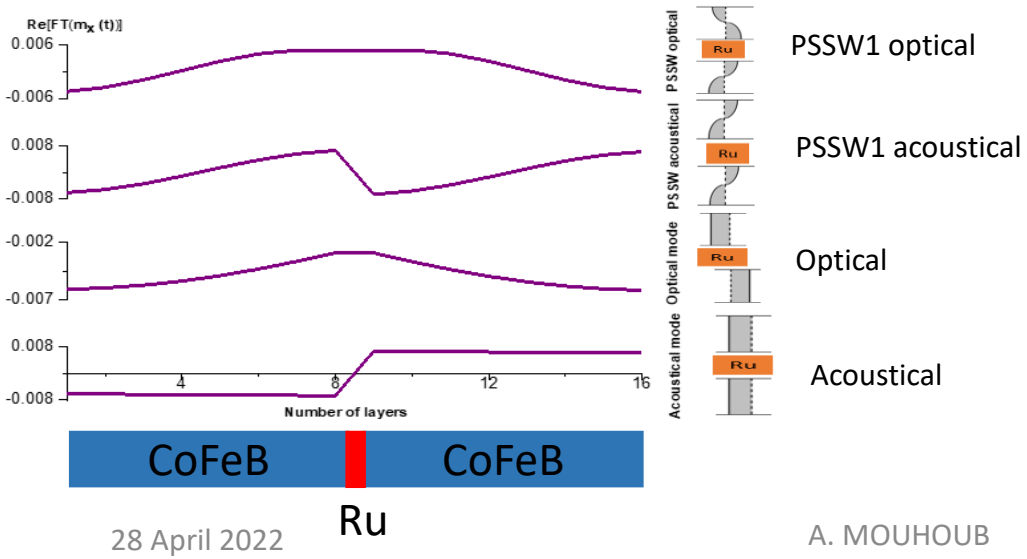
Simulation



Exp & Simulation

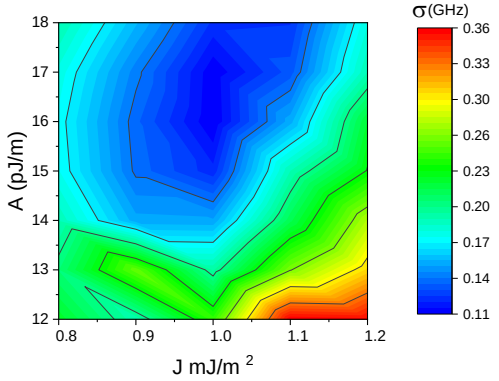


Mode profil at H_x = 110 mT

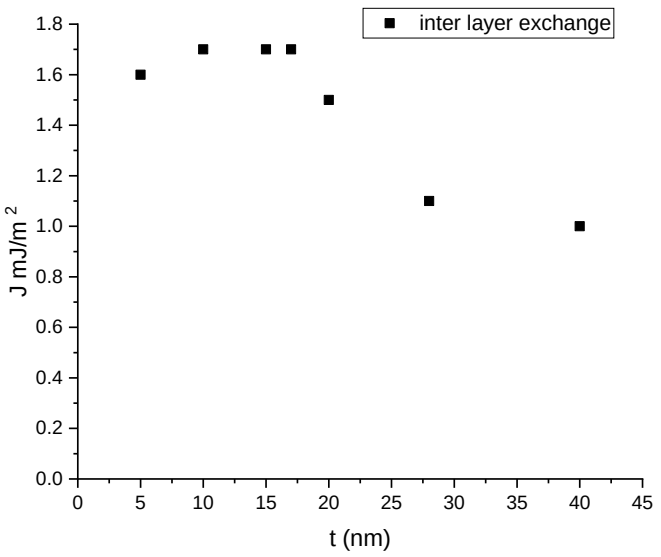


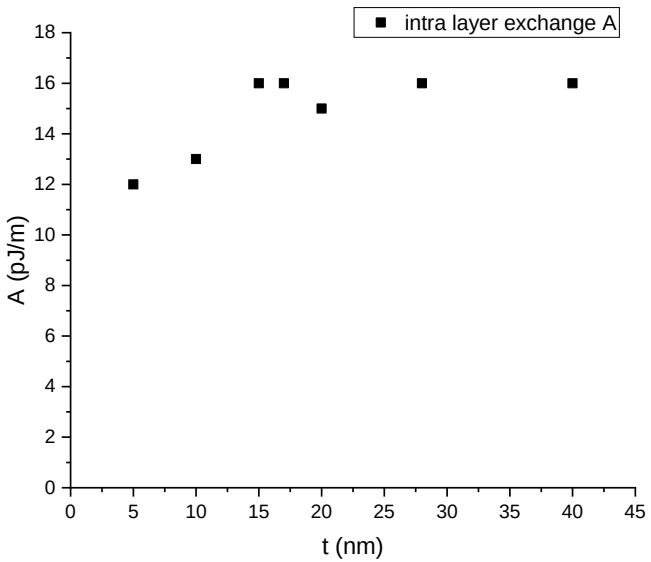
Inter and intra layer exchange (A and J)

Mapping of standard deviation vs A and J



The inter and intra layer exchange of SAF





- J increases with decreasing CoFeB thickness until some saturation below 17 nm

- A increases with increasing CoFeB thickness until some saturation above 17 nm

Conclusion

- We could grow a SAF with a good properties.
- The macrospin model is valid for low thicknesses of CoFeB
- We develop a micromagnetic model to study the dynamical properties of thick SAF
- **To do next :** study the non linearty of spin waves