Excitation of short wavelength spin waves in ferromagnetic conduit with microwave pumped perpendicularly magnetized nanodot

<u>Mathieu Moalic</u>[1], Mateusz Zelent[1], Maciej Krawczyk[1]

[1]Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

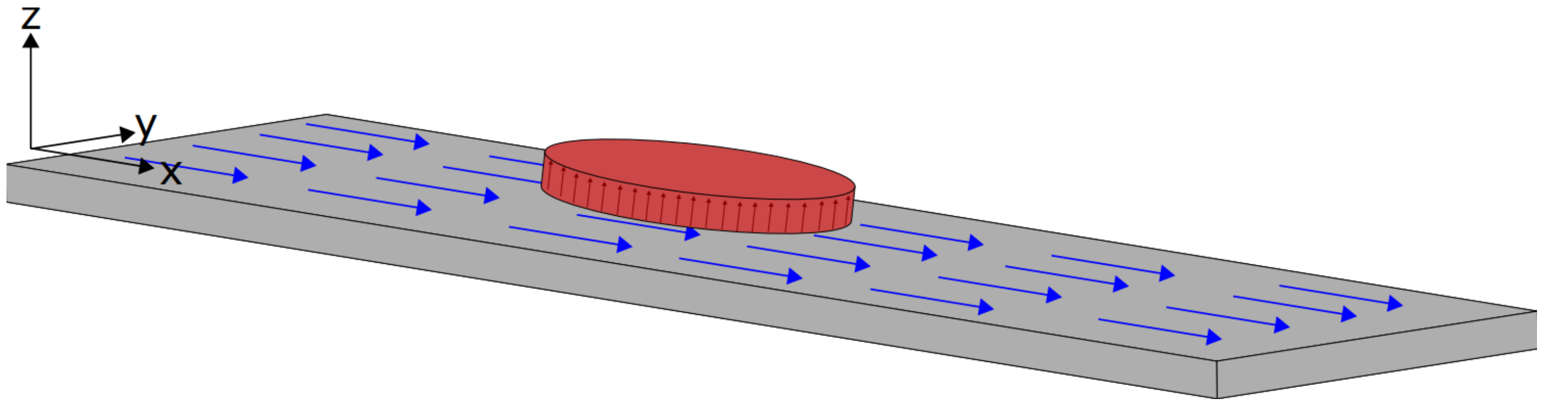


Figure 1: The waveguide (WG) and the nanodot (ND), separated by a vacuum layer, the system used in micromagnetic simulations.

- The Nanodot (red) possesses perpendicular magnetic anisotropy and magnetic parameters favorable to the formation of skyrmions.
- The waveguide (grey) is a saturated Permalloy stripe.

Static Analysis

- Simulated using Mumax3 [1]
- When the value of the DMI is high enough, the Skyrmion is deformed. This is due to the influence of the dipolar interaction with the waveguide below.
- The skyrmion is also casting an imprint in the magnetization of the waveguide (Rows 2 and 3)

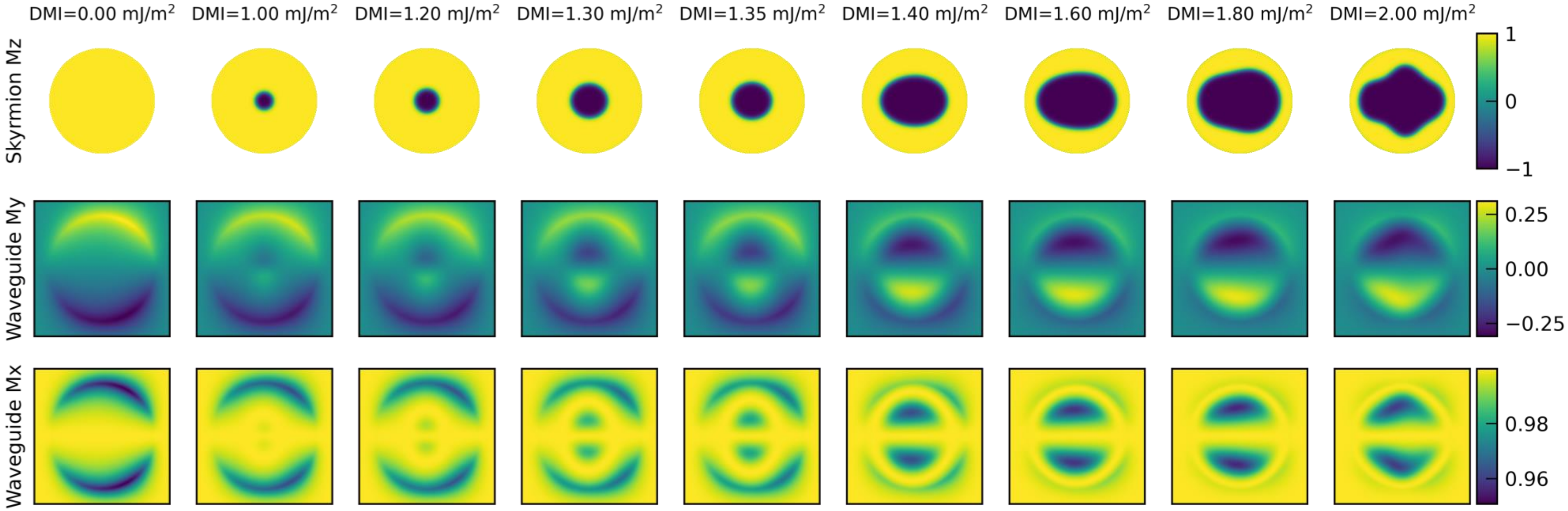


Figure 1: Skyrmion dependance on the value of the Interfacial Dzyaloshinskii-Moriya interaction in the Nanodot.

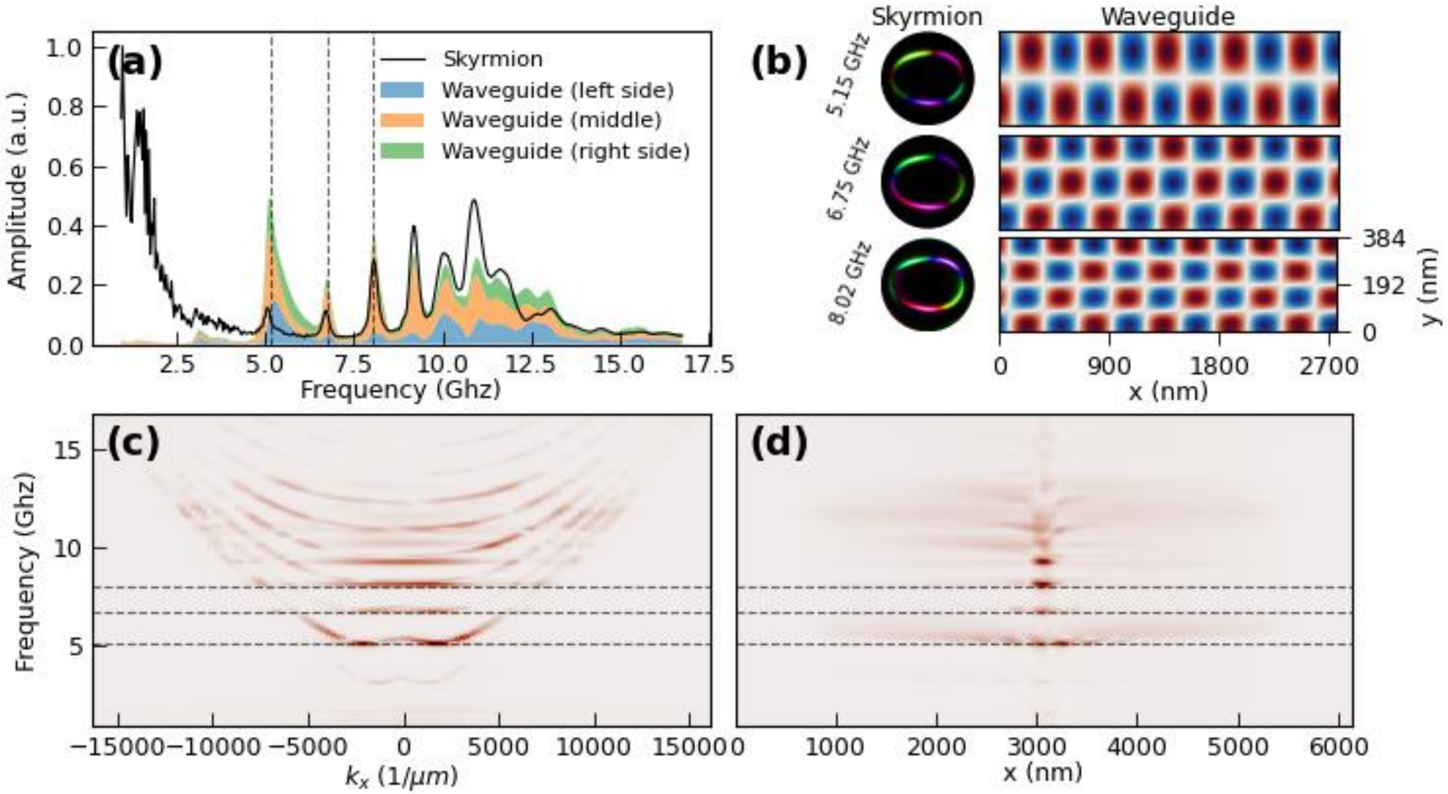
<u>Waveguide (Py)</u>
- M_S = 800 kA/m
- A_{EX} = 13 pJ/m
- α = 0.01

<u>Nanodot (Pt/Co/Ir)</u>
- M_S = 956 kA/m
- A_{EX} = 10 pJ/m
- K_{U1} = 717 kJ/m3
- α = 0.03

- Cell size = 1.5 x 1.5 x 1.5 nm
- Nanodot diameter = 300 nm
- Waveguide width = 384 nm
- Periodic Boundary Conditions (x axis)

[1] Vansteenkiste, Arne, et al. "The design and verification of MuMax3." *AIP advances* 4.10 (2014): 107133.

Dynamic Analysis



Spin wave generation analysis for a SK with a DMI = 1.6 mJ/m²

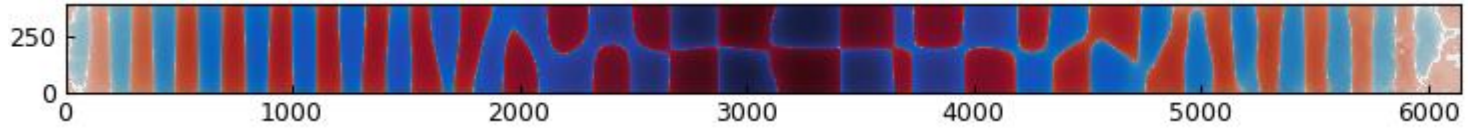
(a) Ferromagnetic resonance spectra for the SK and combined parts of the WG, below the ND, and on each side (areas are highlighted in (d)).

(b) Visualization of the resonant modes found in the FMR spectrum.

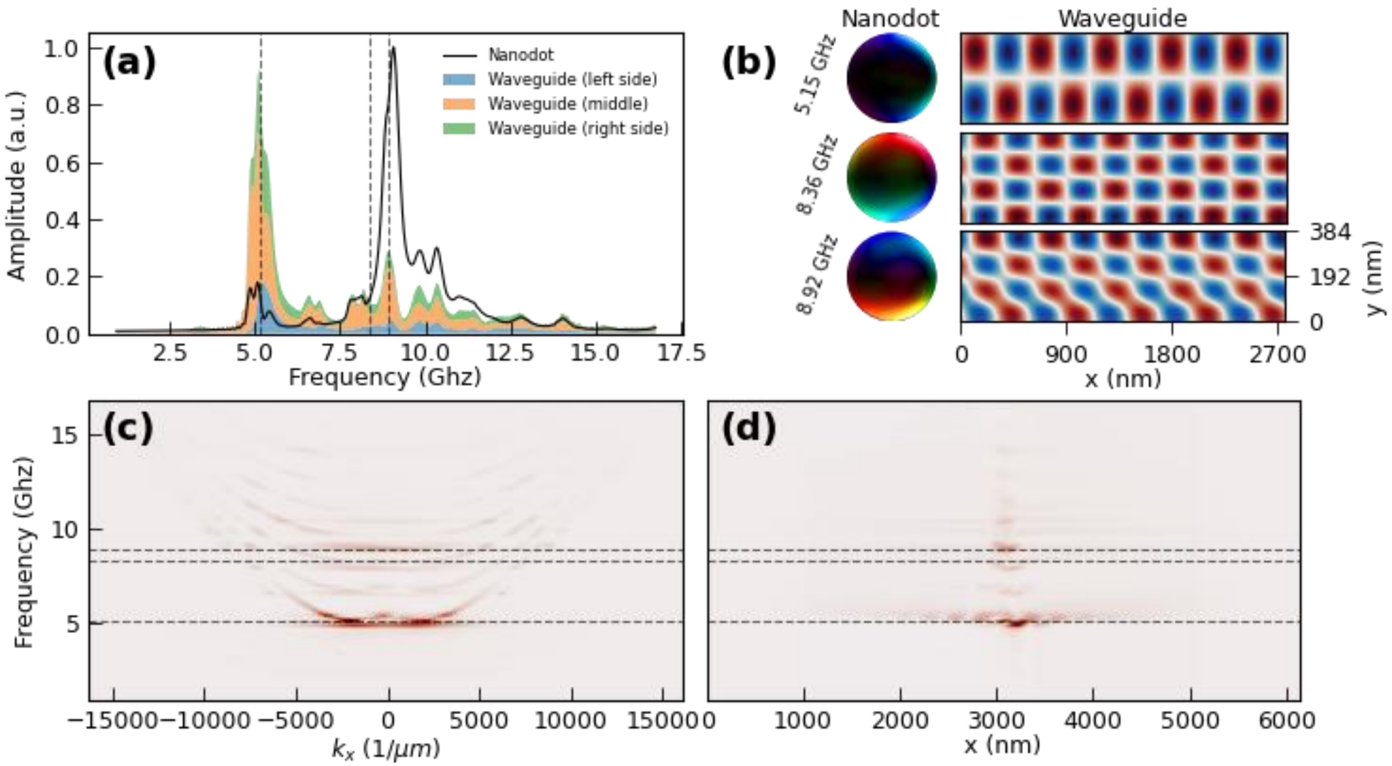
(c) Spin wave dispersion in the waveguide. Almost every branch is excited in this case.

(d) Spin wave propagation along the x axis.

- The external excitation is a small (1mT) varying magnetic field applied on the whole system.
- The higher frequency (5 GHz +) skyrmionics modes generate high amplitude spin waves in the waveguide below.
- The peaks correspond to multiples of the fundamental asymmetric mode.
- For specific frequencies, the spin waves propagate further. There is also a slight asymmetry between the left and right propagation that’s coming from the shape of the imprint.



Dynamic Analysis without Skyrmion



Spin wave generation analysis for a saturated nanodot

- The DMI is set to null and the stable state is an out-of-plane magnetically saturated nanodot. The same excitation is applied as in the case of the skyrmion.
- The FMR spectrum shows a lot less intense coupling in the higher frequencies. This is also visible on the dispersion where only the main peak at 5 GHz is efficiently transmitted to the waveguide.

- The propagating SW modes are antisymmetric across the waveguide width and their wavelength can be shorter than 100 nm

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