Electromagnetic wave induced resonance in ferromagnetic nanowires and metamaterial

(**Poster**: preliminary report)

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Ferromagnetic nano-structures form important constituents in electromagnetic metamaterials and composites. They offer higher moments and permeabilities for high frequency applications in communications and electromagnetic wave absorption [1]. Understanding the magnetisation dynamics and resonance mechanism of individual magnetic nano-structures and their effective behaviour in patterned arrays enable tailoring for targeted bandwidths and scattering properties for various applications.

Practical confined 2-D and 3-D magnetic nano-structures in metamaterials and composites can have different ground states and surface conditions, multi-layered with dielectrics, and experience non-uniform internal electromagnetic fields that yield precession and resonance modes that are complex to model and study. In this work, we solve the coupled system of Maxwell's and Landau-Lifshitz-Gilbert equations using a stable algorithm based on the finite-difference time-domain (FDTD) method [2,3], to study the transient electromagnetic wave propagation and resonance in high aspect-ratio cobalt nanowires (solid, hollow and core-shell). The nanowires are fractions of the electromagnetic skin depth and excited by a millimetre pulsed plane wave. The simulations are used here to calculate the local magnetisation distribution and local and integrated power absorption spectra (see Fig. 1 for a core-shell structure) to reveal the magnetic skin depth and size dependence of resonance modes and frequencies. The effective permeabilities for periodic arrays of nanowires (metamaterial) at different packing fractions are also computed from scattering parameters.

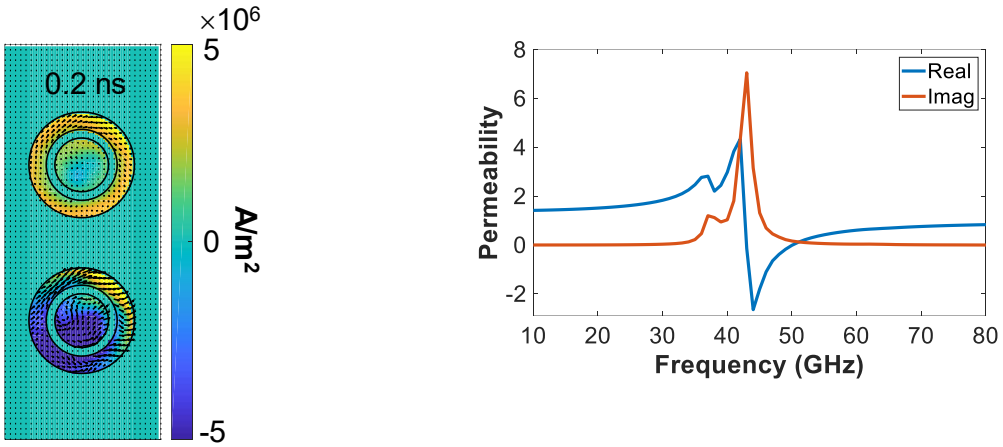

Fig. 1 Left: Calculated local transient magnetisation (arrows) and current density (intensity) for a periodic array of 300 nm diameter core-shell nanowires at a packing fraction of 0.35, excited by a 70 GHz plane wave. Right: Calculated effective permeability of the array from S_{11} and S_{21} parameters. The shell is 50 nm thick with non-magnetic separation of 25 nm from the 150 nm diameter core.

[1] L. Kraus, G. Infante, Z. Frait, and M. V´azquez, Phys. Rev. B 83, 174438 (2011).

[2] M. M. Aziz and C. McKeever, Phys. Rev. Applied 13, 034073 (2020).

[3] M. M. Aziz, and C. McKeever, J. Phys. D: Appl. Phys. 54, 345003 (2021).