Magnonic Neurons

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We explore all-magnonic artificial neural networks using chiral magnonic resonators [1,] as their building blocks – magnonic neurons [3]. In Ref. 3, we showed, using micromagnetic simulations and analytical modelling, that one-dimensional chiral magnonic resonators can concentrate energy of incident linear spin waves, leading to a strongly nonlinear response of the resonators' confined modes to the excitation. Here, we extend these conclusions to two-dimensional arrays of nanoscale chiral magnonic resonators, i.e. realizing artificial neural networks proposed in Ref. 1. For modest excitation levels, the effect is described in terms of a nonlinear shift of the resonant frequency ('detuning'), which results in amplitude-dependent scattering of monochromatic spin waves. We show how this behaviour can be harnessed to realize a sigmoid-like activation and so to implement artificial neurons in a deep neural network linked by spin waves propagating in a linear medium. Figure 1 exemplifies a numerically simulated spin wave pattern that varies as a function of the excitation strength of a magnonic neuron formed by a Permalloy nanodisk placed above a YIG film (inset). Our numerical results are in good agreement with a phenomenological model in which the nonlinear detuning of the confined mode is quadratic in its amplitude, while the propagation in the medium is linear.

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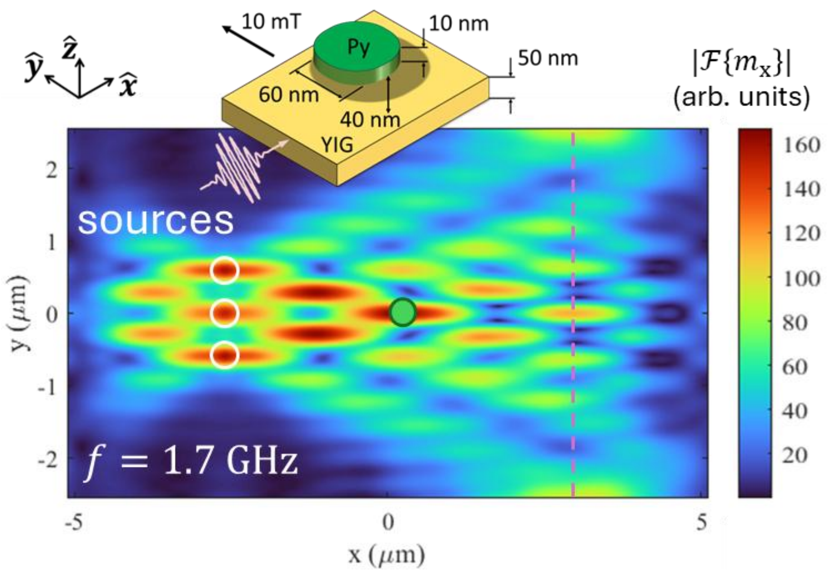

Fig. 1. Pattern created in a YIG medium by spin waves emitted by three Gaussian magnonic sources in the input neural layer and incident on a nanoscale magnonic neuron (inset). The dashed line shows the position of the next neural layer.

[1] V. V. Kruglyak, *Chiral magnonic resonators: Rediscovering the basic magnetic chirality in magnonics*, Appl. Phys. Lett. **119**, 200502 (2021).
[2] K. G. Fripp, A. V. Shytov, and V. V. Kruglyak, *Spin-wave control using dark modes in chiral magnonic resonators*, Phys. Rev. B **104**, 054437 (2021).
[3] K. G. Fripp, Y. Au, A. V. Shytov, and V. V. Kruglyak, *Nonlinear chiral magnonic resonators: Toward magnonic neurons*, Appl. Phys. Lett. **122**, 172403 (2023).