Non-uniformly magnetized resonators for neuromorphic computations

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Effective artificial neural networks based on physical systems require three essential characteristics: nonlinearity, fading memory, and tunable parameters that enable reprogrammability. Magnonic nanoresonators positioned above ferromagnetic layers or waveguides represent a compelling approach for realizing hardware-based artificial neural networks utilizing spin waves (SWs) [1]. In this work, we depart from the uniformly magnetized chiral magnonic resonators described in [1] and instead investigate various shapes of resonators with non-uniform magnetization profiles (Fig. 1). Our design uses the beneficial properties of noncolinear magnetic configurations that remain stable under low bias magnetic fields. Two rows of resonators are placed above a Yttrium Iron Garnet (YIG) thin film (Fig. 1). Through micromagnetic simulations performed using the mumax3 framework [2], we demonstrate how SWs emitted from three Gaussian sources propagating in the underlying YIG layer get resonantly scattered. Using the Greedy Iterative Thresholded Least Squares method and linear regression, we demonstrate the functionality of full adder logic based on SWs.

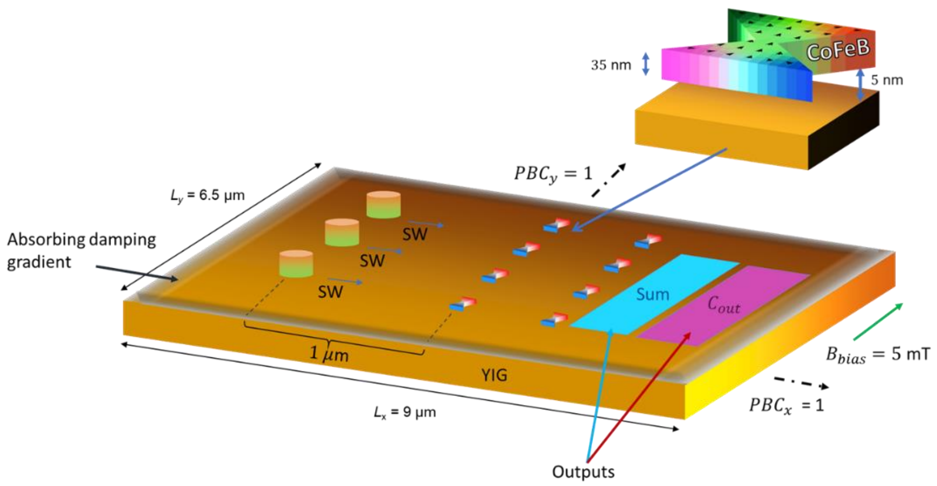

Fig. 1. Schematic picture of the studied system . A YIG waveguide with thickness $d_{YIG} = 50$ nm. The bias field is applied in the y direction, and three SW Gaussian sources. The bowtie-shaped resonators are placed in two rows ,$d_{gap} = 5$ nm above the waveguide. The resonator is non-collinearly magnetized with magnetization in the left trapezoid pointing in the $+y$ direction, and $-y$ in the right. Absorbing boundary conditions are applied on all the edges of the system. Two output regions are defined, labelled Sum and Cout.

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[1] K. G. Fripp, Y. Au, A. V. Shytov, V. V. Kruglyak; Nonlinear chiral magnonic resonators: Toward magnonic neurons. *Appl. Phys. Lett.* 24 April 2023; 122 (17): 172403.
[2] Vansteenkiste, A., Leliaert, J., Dvornik, M., Helsen, M., Garcia-Sanchez, F., & Van Waeyenberge, B. (2014). The design and verification of MuMax3. AIP Advances, 4(10), 107133.