Bowtie-shaped resonators for neural network applications

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When designing an artificial neural network based on a physical system, it is crucial to create a system characterized by nonlinearity, fading memory, and parameters for reprogrammability. The use of magnonic nanoresonators placed over a ferromagnetic layer or waveguide for this purpose is a promising direction in the creation of such hardware artificial neural networks based on spin waves (SWs) [1]. Here, instead of using uniformly magnetized chiral magnonic resonators [1], we use non-uniformly magnetized bowtie-shaped resonators (see Fig. 1) and exploit the additional advantage of a noncolinear magnetic configuration that is stable at low bias magnetic fields. The bowtie-shaped resonator is composed of two trapezoidal shapes joined at their short edges and is placed above Yttrium Iron Garnet (YIG) film (see Fig. 1). The trapezoidal shapes are designed to stabilize domain states with parallel or antiparallel relative magnetization orientation. In the former case, the domain wall is formed between the trapezoidal elements. This choice of resonator shape is intended to ensure their reprogrammability through the various possible magnetic textures that can be stabilized in them, and the presence of various low-frequency resonant modes that can easily couple to SWs with a wavelength of about 1 µm. Using micromagnetic simulations in the mumax3 environment [2], we show how the presence of bowtie-shaped resonator affects the propagation of spin waves in the YIG layer placed below it, both in the linear and nonlinear regime. In particular, we focus on the effects in the context of the resonator's applications as a nonlinear scatterer in magnonic-based artificial neural networks.

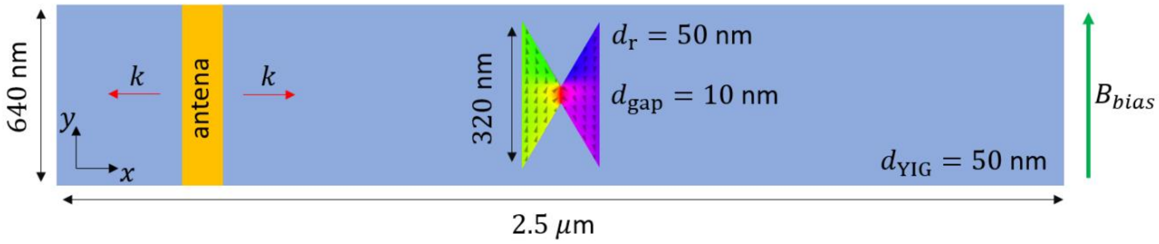

Fig. 1. Schematic picture of the studied system . A YIG waveguide with thickness $d_{YIG} = 50$ nm. The bias field is applied in the y direction, and SW exciting antenna is shifted from the center. The bowtie-shaped resonator is placed $d_{gap} = 10$ nm above the waveguide, it is 320 nm wide, and $d_r = 50$ nm thick. The resonator is non-collinearly magnetized with magnetization in the left trapezoid pointing in the $+y$ direction, and $-y$ in the right. Between the trapezoids a formation of a domain wall is visible.

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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.