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Nanomagnonics from in-plane to out-of-plane

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Magnonics addresses the physical properties of spin waves and utilizes them for data processing [1-2]. Nano-magnonics addresses the investigation of spin waves in magnetic nanostructures of minimal sizes of a few hundred nanometers or less. Such sizes allow for a qualitative change in the magnon dynamics and allow for: (*i*) single-mode dispersion curve, (*ii*) the phenomenon of exchange unpinning resulting in the uniform profiles of magnon modes in them, and (*iii*) the suppression of parasitic multi-magnon scattering.

In the first half of my talk, I will present briefly the experimental realization of a nanoscale magnonic directional coupler, which consists of two separated single-mode waveguides with a width of 350 nm. A U-shaped antenna is used to excite spin waves and microfocus Brillouin Light Scattering (μBLS) spectroscopy is exploited for detection. After that, I will present the method of inverse-design magnonics, in which any functionality can be specified first, and a feedback-based computational algorithm is used to obtain the device design [3]. To demonstrate the universality of this approach, we explore linear, nonlinear and nonreciprocal magnonic functionalities and use the same algorithm to create a magnonic (de-)multiplexer, a nonlinear switch and a circulator.

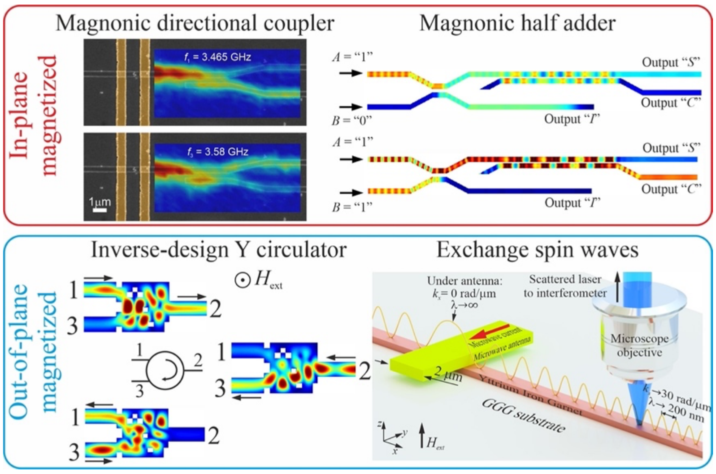

Figure 1: Nanomagnonics from in-plane to out-of-plane

In the second part, I will present a new approach to excite exchange spin waves with a wavelength down to around 200 nm in a 200 nm-wide yttrium iron garnet waveguide with a 2 μm-wide antenna. The physical concept of the proposed method is based on the nonlinear phenomena that can be observed in the normally-magnetized waveguides. By using μBLS spectroscopy, we observed an unprecedented 2.1 GHz up-shift of the FMR frequency. The analytic calculations and micromagnetic simulations show that such a huge nonlinear frequency shift provides a large wavenumber conversion of up to 30 rad/mm in *k*-space for spin waves propagating away from the antenna. The proposed method removes the wavelength limitations imposed by the size of antennas and allows for direct integration on-chip.

[1] A. V. Chumak, et al., *IEEE Trans. Magn.* **2** (2022). DOI: 10.1109/TMAG.2022.3149664
[2] Q. Wang, et al., *Nat. Electron.* **3**, 765 (2020) [3] Q. Wang, A. V. Chumak, P. Pirro, *Nat. Commun.* **12**, 2636 (2021)