Neuromorphic Magnonics

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Neural networks are powerful tools to learn patterns and make inferences in complex problems. However, they rely on a massive number of neurons and interconnecting weights which require extensive training using a large dataset. To compensate for this, reservoir computing is based on recurrent neural networks with randomly fixed weights. Thereby, only the output weights require training for a particular task, reducing the training to a simple linear regression. Recently, there has been a shift towards physical reservoir computing, offering potential advantages in speed, energy efficiency, and hardware simplicity. Physical reservoir computing utilizes the inherent nonlinearity of physical systems to map the input into a higher-dimensional space in which different input patterns become linearly separable. New advancements and experimental implementations use diverse physical substrates, including mechanical structures, optical systems, and spintronic devices.

In our work, we take advantage of the rich nonlinear dynamics inside magnetic vortices. Their eigenmode system comprises the gyrotropic motion of the vortex core as well as magnon modes with well-defined radial and azimuthal quantization in the vortex skirt. A few mode profiles are depicted in Figure 1. By harnessing the nonlinear interactions between these different vortex eigenmodes in reciprocal space, it is possible to perform temporal information processing and pattern recognition without relying on information transport in real space [1]. This presentation will give a comprehensive overview of experimental results and numerical simulations demonstrating the capabilities and advantages of magnon reservoir computing inside a magnetic vortex.

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References

[1] L. Körber, C. Heins, T. Hula, J.-V. Kim, S. Thlang, H. Schultheiss, J. Fassbender, K. Schultheiss, Nature Communications, 14 (2023) 3954.

Figures

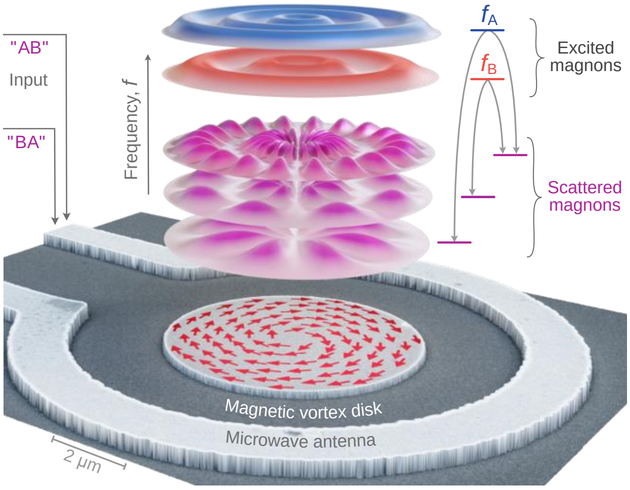

Figure 1. Working principle of a magnon-scattering reservoir. Radiofrequency pulses with different temporal order but the same average frequency content are used to trigger nonlinear scattering between the magnon eigenmodes in a magnetic vortex disk. The dynamic response is experimentally detected using Brillouin-light-scattering microscopy. In contrast to a linear system, the magnon-scattering reservoir produces different outputs depending on the temporal order of the input.