Low-loss current- and flux quanta-controlled magnonics (FluMag)
OPUS-LAP project

Besides the well-known digital information processing, used in modern computers, it is possible to use dedicated circuits operating on signals in the form of waves. The idea of wave-computing is used in photonics and phononics, where information is encoded as an amplitude and/or phase of light and elastic waves, respectively. It is also possible to use for wave-computing the magnetic systems where wave excitations in the form of propagating oscillations of magnetization are observed. They are called spin waves. Such waves are characterized by short wavelength (systems processing spin waves may be tens of nanometers in size) and relatively high frequency (information recorded in a spin wave may be processed with high, gigahertz frequency).

In order to manipulate the propagating waves, they must be controlled by external biases. In the case of spin waves, this is possible by using the magnetic field, including the electromagnetic microwave field. This solution, however, has limitations due to the relatively large (micrometer) size of the antennas and the low efficiency of such systems.

An alternative solution is to use antennas made of a superconductor. This not only eliminates the losses associated with the heat generated by the flowing current, but also provides the possibility of controlling the spin waves with the magnetic field generated by superconducting currents. In a superconductor, currents flow around its surface or around the magnetic field vortices called fluxons. In our research, we intend to control superconducting currents by the shape of the superconductor in which the spin waves propagate or by producing and moving vortices in the superconductor.

(Ferro)magnetism and superconductivity are competing phenomena, and the physics of effects occurring at the interface of these materials is very complex. In addition to the contact coupling between superconductor and ferromagnet, these two systems also interact magnetically at distance, through the field produced by (i) oscillating magnetization (i.e., by the spin waves) and (ii) the dynamic magnetic field generated by eddy currents in the superconductor. This classical (i.e. non-quantum) interaction is very complex and not fully explored. The goal of our research is a formal (mathematical) description of this interaction and the design of hybrid devices where a superconductor is magnetically coupled to a ferromagnet, such as directional couplers (acting as diodes or circulators for spin waves), or generators of very short spin waves (impossible to generate using conventional antennas).

The project is carried out by three teams: a theoretical group that will also simulate and design hybrid superconductor/ferromagnetic systems (led by Jarosław Kłos from the Adam Mickiewicz University in Poznań) and two experimental groups dealing with fabrication and measurements of the above-mentioned structures (led by Michal Urbanek from the Central European Institute of Technology in Brno and by Oleksander Dobrovolskiy from the University of Vienna).