Flux Quanta Matter

Superconductivity is a macroscopic quantum phenomenon which finds applications in quantum technologies and allows for engineering various hybrid systems. A hallmark of technologically relevant superconductors is the presence of magnetic flux lines, each carrying one magnetic flux quantum - Abrikosov vortices - and appearing in the presence of external magnetic fields or transport currents. The interaction of vortices with the currents and fields, structural imperfections in the superconductor, and with each other, make them to a useful playground for studying many-body systems with competing interactions and allows for the use of vortices as elemental building blocks in superconducting electronics.

In this talk, after a brief introduction to the basics of superconductivity and vortex matter, I will introduce some of our activities, particularly focusing on the combination of superconductors with other materials and technologies. Namely, I will talk about the microwave radiation detection using superconductor/normal metal and superconductor/semiconductor hybrid structures [1], and the interaction of vortex lattices with collective spin precessions (spin waves and their quanta - magnons) in superconductor/ferromagnet heterostructures [2]. In the regime of high (a few km/s) vortex velocities, these studies yield information on the microscopic scattering mechanisms of the charge carriers in the superconductors and are relevant for the design of single-photon detectors [3]. Finally, as an emerging research direction, I will outline our recent studies of 3D superconductor and ferromagnetic nanoarchitectures in which the non-trivial topology of the Meissner screening currents and the magnetization, respectively, determines the new states unseen in planar systems [4].

[1] Microwave emission from superconducting vortices in Mo/Si superlattices,
O. V. Dobrovolskiy, et al. Nat. Commun. 9 (2018) 4927.

[2] Magnon-Fluxon interaction in a ferromagnet/superconductor heterostructure
O. V. Dobrovolskiy, et al. Nat. Phys. 15 (2019) 477.

[3] Fast Dynamics of Vortices in Superconductors,
O. V. Dobrovolskiy, in “Encyclop. Cond. Matt. Phys.” Elsevier, 2024, chap. 9, pp. 735-754.

[4] Three-dimensional magnetic nanotextures with high-order vorticity in soft magnetic wireframes,
O. M. Volkov, et. al. Nat. Commun. 15 (2024) 2193.