Anomalous Josephson effect via magnets with strong spin-orbit coupling

A.M. Bobkov [1]*, G.A. Bobkov[1], I.A. Shvets[2], S.V. Eremeev[3], I.V. Bobkova[1], and E.V. Chulkov[4]
[1] Moscow Institute of Physics and Technology, Dolgoprudny, Russia
[2] Tomsk State University, Tomsk, Russia
[3] Institute of Strength Physics and Materials Science RAS, Tomsk, Russia
[4] Donostia International Physics Center, 20018 Donostia-San Sebastian, Basque Country, Spain
*email: ambobkov@mail.ru

Key words: anomalous Josephson effect, SFS, magnetization control

In this talk the anomalous Josephson effect in superconductor/ferromagnet/superconductor junctions with strong spin-orbit coupling is discussed. In such systems, a direct magnetoelectric coupling arises between the magnetic moment of the ferromagnetic weak link and the phase of the superconducting condensate. This allows one to control the magnetization of the weak link and switch it using supercurrent pulses [1]. In addition, in a coupled chain of Josephson S/F/S junctions with an anomalous phase shift of the ground state, a long-range interaction between the magnetic moments of the weak links is predicted [2], which makes this system suitable for studying collective magnetic states controlled by the superconducting phase [3,4]. Also in the talk, based on the results of first-principles calculations of the electronic structure of ferromagnetic films of RET_2Si_2 intermetallic magnets, where RE - rare earth, T - transition metal [5], and subsequent calculations of the Josephson current through weak links made of them, it is demonstrated that Josephson junctions through such materials are a natural platform for the experimental implementation of magnetoelectric coupling between the magnetic moment and the phase of a superconducting condensate. The results of calculations of current-phase relationships (CPRs) are presented. The combination of ferromagnetism and strong spin-orbit interaction results in two key properties of the CPRs. First of all, the CPRs manifest the anomalous phase shift depending on the magnetization direction, which allows for the control of the magnetization by the Josephson phase. Second, in such systems, the superconducting diode effect occurs, i.e. the critical Josephson current is different when passing electric current in opposite directions. The efficiency of the superconducting diode effect is quite high and reaches several tens of percent.

The financial support from the Russian Science Foundation via the RSF project No. 24-12-00152 is acknowledged.

Bibliography

[1] I. V. Bobkova, A. M. Bobkov, and M. A. Silaev, J. Phys.: Condens. Matter **34** 353001 (2022).
[2] G. A. Bobkov, I. V. Bobkova, and A. M. Bobkov, Phys. Rev. B **105**, 024513 (2022).
[3] G. A. Bobkov, I. V. Bobkova, and A. M. Bobkov, Phys. Rev. B **109**, 054523 (2024).
[4] G. A. Bobkov, I. V. Bobkova, and A. M. Bobkov, JETP Lett. **119**, 251 (2024).
[5] S. Schulz, et. al Phys. Rev. B **103**, 035123 (2021).