Stanislav Dolgopolov
e-mail address: dolgopolov-s@list.ru

Experimental Verification of the BCS Theory of Superconductivity by Using Persistent Supercurrents

Abstract: According to the BCS theory of superconductivity, the superfluid density must smoothly decrease with increasing temperature; hence a persistent supercurrent in a superconducting ring must decrease at warming and dissipate in temperature cycles below T_c. Here we propose a direct experiment of temperature dependence of persistent supercurrents to examine this BCS prediction.

A simple experiment may confirm (or deny) an important prediction of the BCS theory of superconductivity.

Imagine, in a mercury ring (superconductivity below T_c=4.15 K [1]) we establish at 2.5 K a persistent supercurrent density j

$$j = N_s \cdot 2e \cdot V \qquad (1)$$

Where N_s is the electron pair density, $2e$ is the charge of electron pair, V is the average velocity of pairs into supercurrent direction.

After that we organize temperature cycles (T-cycles) in the cryostat, from 2.5 K to 3 K and back. The actual j is lower than critical j_c at 3 K. According to the BCS theory of superconductivity [2], the pair density N_s smoothly decreases at warming, i.e. a not negligible fraction of pairs annihilates. Electrons of annihilated pairs become normal (i.e. unpaired, dissipative), hence their ordered supercurrent momentum (p_x) dissipates on the atom lattice; the lattice takes p_x and the momentum conservation law requires that the total supercurrent loses p_x; thus, according to BCS, j in Eq (1) smoothly decreases at warming. The same fraction of pairs emerges back at cooling; newly created pairs do not experience any electromotive-force (EMF), since the EMF is no longer available in the ring, so the new pairs cannot restore the lost p_x. Hence, according to the BCS theory, j must decrease at every T-cycle and dissipate after a number of T-cycles. If j remains stable, then the BCS prediction is wrong and below T_c the pair density is independent of temperature, as predicted in [3].

Notably, exceptional experiments for temperature dependence of persistent supercurrents are unknown. However, every cryostat device produces not negligible temperature fluctuations, so every observation of long-lived stable supercurrents [4], [5], [6], [7] may be considered as the experiment with T-cycles. Thus, one can expect that a direct experiment will confirm: below critical values of temperature and current the pair density and related supercurrent are independent of temperature.

Do the electron pairs really annihilate when they flow in an eternal supercurrent? By resolving this paradox, we find a deeper understanding of superconductivity. We hope the community will be interested to perform the experiment proposed for resolving the paradox.

References

[1] H. Kamerlingh Onnes, Konikl. Ned. Akad. Wetenschap. , Proc. 23, 12, 278 (1914).
[2] Bardeen, John; Cooper, Leon; Schrieffer, J. R. *Theory of Superconductivity*. Physical Review 8(5):1178 (1957).
[3] Stanislav Dolgopolov, *Formation of Cooper Pairs as a Consequence of Exchange Interaction*, arXiv:1501.14978 (2015).
[4] Yen, F. et al, "*Induced Currents in Closed-Ended Type-II Superconducting Coils*". IEEE Trans. Appl. Supercond. 23 (6): 8202005 (2013).
[5] T. Mukai et al, *Persistent Supercurrent Atom Chip*, Phys. Rev. Lett. 98, 260407 (2007).
[6] R. Gross et al, *Persistent supercurrents in composite rings of high-Tc and conventional superconductors*, Physica C. Volume 166, Issues 3–4 (1990).
[7] J C Gallop, *Use of persistent supercurrents in SQUID current stabilisers and their application to a resistivity measurement on niobium*, J. Phys. D: Appl. Phys. 9 2111 (1976).