Quantum decoherence of Cooper pairs

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We argue that electron-electron interactions yield dephasing of Cooper pairs penetrating from a superconductor (S) into a diffusive normal metal (N). At low temperatures this phenomenon imposes fundamental limitations on the proximity effect in NS hybrids restricting the penetration length of superconducting correlations into the N-metal to a temperature independent value and thereby defining the new length scale – decoherence length for Cooper pairs.

We evaluate the subgap conductance of NS hybrids in the presence of electron-electron interactions [1] and demonstrate that this new fundamental decoherence length can be directly extracted from conductance measurements in such structures. Our results agree qualitatively with earlier experimental observations [2] showing that the low temperature magnetoconductance of NS structures is determined by phase coherent electron paths with a typical size restricted by the temperature independent dephasing length rather than by the thermal length diverging in the low temperature limit. We also analyze the effect of electron-electron interactions on the critical Josephson current in diffusive hybrid SNS structures and demonstrate [3] that this current gets exponentially suppressed even at zero temperature provided the thickness of the N-layer exceeds the dephasing length for Cooper pairs. This our prediction appears to be consistent with recent experimental observations [4].

It is remarkable that the Coper pair dephasing length established both for NS- and SNS-systems up to a numerical prefactor coincides with zero temperature decoherence length obtained within a totally different theoretical framework [5] for a different physical quantity – weak localization correction to the normal metal conductance. This agreement emphasizes fundamental nature of low temperature dephasing by electron-electron interactions which universally occurs in different types of disordered conductors.

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