Influence of magnetic field on weak localization . ALTSHULER B.L., ARONOV A.G., SPIVAK B.Z. (1981); ALTSHULER B.L., ARONOV A.G.(1981)

The papers [1] and [2] appeared in the time of emergence of mesoscopic physics, when the basis of the theory of quantum transport in disordered metals was created.The initial impulse was given by the work of Gor'kov, Larkin and Khmelnytsky (1979)[3], where weak-localization correction to the conductivity of the metal was found. The correction occurs due to the electron interference on different paths. In this work by examining the "fan" diagrams, it was shown that in the first approximation quantum correction to the conductivity is determined by the probability of electron coming back to the starting point during quantum diffusion in a random potential.Further research on this topic in the early 1980-ies can be called a confirmation and development of results [3].

The influence of magnetic field on weak localization was investigated in the paper [4]. Fairly weak magnetic fields were considered, in which the curvature of the trajectories under the action of the Lorentz force can be neglected, and the main effect is the additional phase shift, different for different trajectories. Additional phase destroys the interference of long trajectories, reducing localization correction. As a result electron system demonstrates a positive magnetoresistance in low magnetic field: resistance growth at magnetic field increase. Such behaviour Is unexpected in the classical theory of metals. The characteristic value of the magnetic field is given by the condition $L_H \sim L_\phi$, where $L_H = \sqrt{\hbar c/2eB}$ is magnetic length, and L_ϕ is phase coherence length restricted by the inelastic scattering.

In the paper [1] ALTSHULER, ARONOV, and SPIVAK continued study of the influence of magnetic field on weak-localization correction to the conductivity. In this paper authors consider the case of thin-walled metal cylinder in a magnetic field parallel to cylinder axis. In the limit of small thickness of the wall the magnetic field has no effect on the classical motion of an electron on the surface of the cylinder, however, through the vector potential it is included in the quantum equation of motion.In this geometry, the vector potential cannot be eliminated by gauge transformation (mathematically this is due to the non-triviality of the fundamental group of the circle $\pi_1(S^1) = \mathbb{Z}$).

As a result, all single-electron properties are periodic functions of the magnetic flux through the cylinder with period hc/e (Aharonov-Bohm effect).However, according to [3], the quantum correction to the conductivity is determined by cooperon describing the diffusive motion of the two electrons. In this case, the equation for cooperon formally coincides with the Schrodinger equation for a particle of mass $\hbar^2/2D$ (D is the diffusion coefficient) and a doubled charge $2e$.

Therefore, as it was predicted in the work [1], the quantum correction to the conductivity of the thin-walled cylinder must experience oscillations of resistance as a function of magnetic flux with twice shorter period $hc/2e$. Later, this prediction was experimentally confirmed by Sharvin and Sharvin [5].

In the paper [2] Altshuler and Aronov studied quantum correction to the conductivity of thin films and wires in a magnetic field parallel to the film plane or axis of the wire. In this case, the magnetic field also suppresses weak-localization correction to the conductivity, leading to a positive magnetoresistance. However, the effect is less pronounced than in the perpendicular field; the characteristic value of the magnetic field is determined by the thickness of film or wire a: $L_H \sim \sqrt{aL_\phi}$.

Quantum correction to the conductivity is small compared with semiclassical Drude conductivity, so it is problematic to distinguish contribution of quantum correction by conventional conductivity measurements. Significantly different dependence of this correction and Drude conductivity on the magnetic field comes to the aid. Currently the study of the magnetoresistance is the standard method for the experimental observation of weak localization. It is based on the theory developed in the papers [1, 2, 4].

Seminal works of the early 1980s led to the realization that quantum effects in electronic transport in disordered metals should be described in terms of interacting diffusion modes but not in the language of single-particle excitations [6]. Subsequently, this knowledge has led to the formulation of the nonlinear sigma model [7] — one of the most powerful methods of modern theoretical condensed matter physics.

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