# Magnetotresistance of the Q1D electron system formed on a superfluid $^4$He surface

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**Abstract**

The longitudinal magnetoresistance, $\rho_{xx}$, of the Q1D electron system on the superfluid helium surface has been investigated under the magnetic field B up to 2.6T within the temperature range 0.48-2.05K. It was established that $\rho_{xx}$ is mainly an increasing function of B. The influence of the magnetic field on $\rho_{xx}$ is the stronger the lower temperature and the larger the width of the strip. The data were compared with theories of the magnetotransport of electrons on liquid helium for both Q1D and 2D electron systems. The negative magnetoresistance has been observed for both vapor atom and ripplon scattering regimes. This effect is assumed to be caused by weak localization of Q1D carriers interacting with scatterers.

*Key words:* surface electrons; quasi - onedimentional; magnetotresistance; ripplon.

## 1. Introduction

Electrons localized over the liquid helium surface form a clean two - dimensional (2D) conducting system with high carrier mobility. The well - known character of electron interaction with scatterers (helium atoms in vapour and thermal excitations of the liquid surface - ripplons) permits the exact theoretical description of the behaviour of kinetic properties of surface electrons. Despite a two - dimensional electron system on helium has been studied both experimentally and theoretically rather long [1,2], a structure close by its properties to the one - dimensional (1D) was realized only recently [3,4]. The experimental investigation of this system [3,4] revealed significant differences in transport characteristics of carriers in two - dimensional and one- dimensional electron systems. Measurements were made in zero magnetic field and this has been unlikely to detect all the peculiarities of this 1D system. The present work continues the study of transport properties of electrons in the 1D electron system over liquid helium in a magnetic field. Magnetoresistance $\rho_{xx}$ of Q1D channels on liquid helium has been measured in the temperature region 0.5 - 2.0 K, in the interval of linear electron densities $8{\cdot}10^3$ - $8{\cdot}10^4\mathrm{cm}^{-1}$ in magnetic field up to 2.5 T.

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## 2. Results and discussion

The Sommer - Tanner method was used to study transport properties of surface electrons. One - dimensional conducting channels were created, using a system of parallel grooves on the surface of the dielectric substrate with low dielectric permeability covered by a thin layer of liquid helium [4]. The grooves were formed by a nylon thread of the 0.1 mm diameter, wound turn by turn on a glass plate of 24.5 - 19.1 mm sizes and of 1.2 mm thickness. The effective width of the conducting channels on the liquid helium surface can be changed by varying the confined electric field E and the curvature radius of the liquid channels. These values were E = 450 V/cm and r = 35 micron, respec-

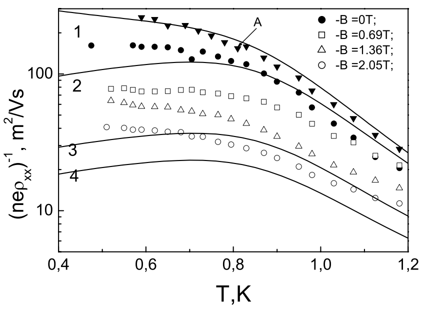


Fig. 1. The value of $(ne\rho_{xx})^{-1}$ as a function of temperature T for different magnetic fields. A - "clean" substrate. Other curves - the substrate with unhomogeneity on the surface. 1 - theory by Sokolov et al. 2 - B = 0.8 T; 3 - B = 1.5 T; 3 -B = 1.9 T - Yu.Monarkha theory [5] for a 2D system.

tively. The effective width of the conducting channels was $10^{-5}$ cm, and the distance between energy levels in 1D electron system was 0.13K [4]. It means electrons in conducting channels occupied a few energy levels at the temperature of experiment.

The results obtained are presented in Fig.1, where the value of (ne$\rho_{xx}$)$^{-1}$ is plotted as a function of temperature. It is seen that at temperature T > 0.9 K the value of (ne$\rho_{xx}$)$^{-1}$ depends on T exponentially, at T < 0.9 K such a dependence becomes more weak. Such a behaviour of (ne$\rho_{xx}$)$^{-1}$ is explained by predominant scattering of electrons by helium atoms at T> 0.9 K and ripplons at T < 0.9 K. The maximum electron mobility at T = 0.6 K is 160 $m^2$/V·s. The theoretical calculation by Monarkha et al [6] for 2D electron system is shown by solid (B = 0.8 T), dashed (B = 1.5 T), and dotted (B = 1.9 T) lines. The theoretical value of (ne$\rho_{xx}$)$^{-1}$ for B = 0.8 T is more than the experimental one, but for magnetic fields 1.5 and 1.8 T the theory gives less value of (ne$\rho_{xx}$)$^{-1}$ than the experiment. Such a discrepancy can be connected with the fact that electrons in Q1D channels are localized by the potential well across channels. In the classical limit transport processes in a magnetic field are described in the framework of the Drude model.

The Drude model describes the electron transport under the condition h$\omega_c$ << kT where $\omega_c$ = eB/m is the cyclotron frequency, k is Boltzman constant. When a magnetic field increases or temperature decreases, the transition to the quantum transport regime takes place. The properties of the electron transport in the quantum limit is determined by scattering within Landau levels. This scattering leads to the levels broadening. The level broadening and magnetoconductivity in the two-dimensional electron system were calculated by Ando and co-workers [7] in the self-consistent Born approximation and in a wide range of magnetic fields by Peters et al [8].

In Fig.2 the value of $\rho_{xx}/\rho_0$ ($\rho_0$ is the resistance of

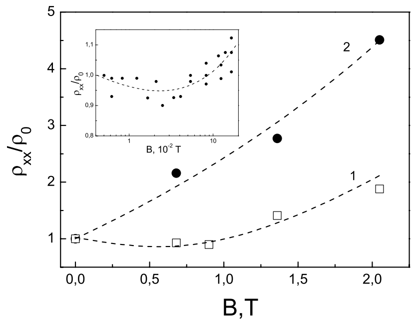


Fig. 2. The value of $\rho_{xx}/\rho_0$ ($\rho_0$ is resistance at $B = 0$) as a function of a magnetic field. 1 - 1.2 K; 2 - 0.6 K. Insert: $\rho_{xx}/\rho_0$ as a function of B for small magnetic fields. T = 0.6 K; E = 2000 $V/cm$.

conducting channels at B = 0) is plotted as a function of a magnetic field. The negative magnetoresistance has been observed for gas and ripplon scattering regions. These effects are connected with weak localization processes. Weak localization in 2D electron system on liquid helium in gas scattering region was studied in [9] and for Q1D electron system on liquid helium was observed in [10]. In this work we have been observed weak localization at temperature 0.6 K where ripplons play predominant role in electron scattering. Unfortunately in these experiments there was a small random potential along conducting channels due to inhomogenates of the substrate, so it is impossible to say, what is the reason of weak localization: ripplon scattering of electrons or interaction of carriers with random potential. This work is partly supported by INTAS Network 97 - 1643.

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