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Asymmetry of the Hall conductance fluctuations in a random magnetic field

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Transport in a two-dimensional electron gas (2 DEG) experiencing a random magnetic field has lately attracted intensive attention, due in large part to its relevance to the properties of the half-filled Landau level. One of the interesting features of the system is the absence of any time-reversal symmetry, which would, for example, preclude weak localization. The delocalization problem in a random magnetic field system has been studied in [1–4].

In this paper we report on measured fluctuations of the asymmetric part of the Hall conductance in small samples (2×2 μm$\times\mu$m) with a dimpled 2 DEG. This type of structures provides an experimental alternative for studying a spatially varying magnetic field, since only the magnetic field perpendicular to the surface will affect the electrons confined in the topologically dimpled heterojunction [6]. Previously, we have reported on universal conductance fluctuations in such structures [5]. It is found, that all interference effects can be considered as interference between random walk trajectories through a random, sign alternating magnetic field. The correlation properties of UCF in a random field are governed by the second order corrections to the flux through the closed loops. Here we find, by interchanging of current and voltage leads, that fluctuations Hall resistance violates the Onsager relation, $R_{xy}(B) \neq R_{yx}(-B)$, and thus the fluctuations of the antisymmetric part of the extracted Hall conductance are not equal to the fluctuations of the Hall conductance found when inversing the magnetic field. We also find that the amplitude of the antisymmetric part of the extracted Hall conductance is of the order of e^2/h, as predicted for a random magnetic field.

Samples were fabricated employing overgrowth of GaAs and $Al_{0.3}Ga_{0.7}As$ materials by molecular beam epitaxy on prepatterned (100) GaAs substrates. Details of sample preparation and description of devices were reported in [6]. Samples with periodicity of dimples $d = 1\mu$m and 0.3μm have been studied. The mobility of the 2 DEG is 30–70 m^2/Vs, and the density 5.5×10^{11} cm^{-2}. The phase coherence length L_f at $T = 50$ mK is 1-2 μm, which is comparable with the sample size (1.5–2 μm). Samples have a cross shape (see insert to Fig. 1) and four-terminal measurements of the magnetoresistance were carried out at temperatures $T = 50$ mK.

When placed in a magnetic field parallel to substrate, the electrons in the heterojunction move in sign alternating effective magnetic field [6]. In this case the total magnetic flux through the area of the steps of the dimpled surface is close to zero. Since the interference effects and universal conductance fluctuations are caused by the enclosed

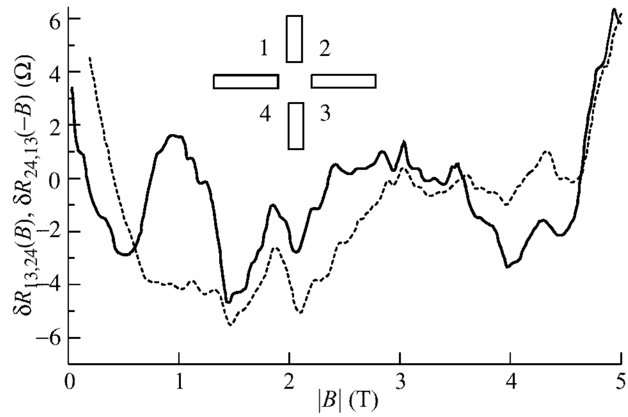

Fig 1.

flux through the electron trajectories, no influence of the sign alternating magnetic field on the UCF is therefore expected. However, because the electron motion imposed by the impurity disorder, a "random" number of flux is enclosed by the electron loops, in spite of the periodical nature of the dimple lattice that causes the spatial variation of the magnetic field. In [5] we considered the random walk model and obtained second order corrections to the total flux enclosed by all electron trajectories involved in the interference. This gives the correlation magnetic field in a parallel external field $B_c = 2hcb/eL_f$, where b is the height of the dimples 0.1 μm, which agrees well the experimental observations.

The Hall resistance together with B-linear background reveals aperiodical reproducible fluctuations. Fig. 1 shows these fluctuations in detail, after subtraction of the linear part R_{xyl}. The Hall resistance was measured while interchanging the current and voltage leads. It is clearly seen that Hall resistance fluctuations does not obey the symmetry law. The cross correlation for the two traces $R_{1324}(B)$ and $R_{2413}(-B)$ is 60%, and correlation for traces ander the same conditions (reproducibility) is 95%.

The demonstration of an antisymmetric Hall-component fluctuation may have further implications for the possibility of extended states in a 2 DEG experiencing a random magnetic field.

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