Anisotropic Transport of Unidirectional Lateral Superlattice in High Landau Levels

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Abstract

We report anisotropic transport observed in unidirectional lateral superlattices (LSL) with period *a*=92 nm, at high ($6 \geq N \geq 1$) Landau levels (LLs). Near the half filling of the LLs (up to filling factor ν=25/2), sharp peaks are observed in the resistance traces when current is along the grating that defines the superlattice, which are not present (sometimes dips appear) for current across the grating. The peaks show alternating intensities with magnetic field: higher-magnetic-field branch spin sublevels in each LL tend to display more distinct peaks. Since the period *a* of LSL is close to the theoretically predicted period of the stripe phase in half-filled high LLs, the observed peaks probably represent the response of the stripe to the external periodic modulation.

Key words: lateral superlattice; magnetotransport; anisotropy; CDW

The ground state of two-dimensional electron gas (2DEG) near half-filling of high ($N \geq 2$) Landau levels (LLs) has theoretically been predicted to be unidirectional charge density wave (CDW) or stripe state [1]. Anisotropic resistivity observed only in 2DEGs with exceptionally high mobility ($\mu \geq 1000$ m^2/Vs) [2] is currently interpreted as manifestation of the stripe phase in transport properties, although the mechanism in the first place that introduces the anisotropy in a plain 2DEG is still not well understood. In a unidirectional lateral superlattice (LSL), external periodic modulation can be an obvious source of the anisotropy. Moreover, when the period *a* is close to the period a_{CDW} (30-150 nm in the magnetic field range of interest) of the stripe, it is natural to expect that the external modulation assists the spontaneous forming or aligning of the stripe, which would otherwise be prohibited by impurities in moderate mobility 2DEGs. In the present paper, we report anisotropic transport observed in high ($N \geq 1$) LLs in LSL with *a*=92 nm, which probably represents the response of the stripe to the external modulation.

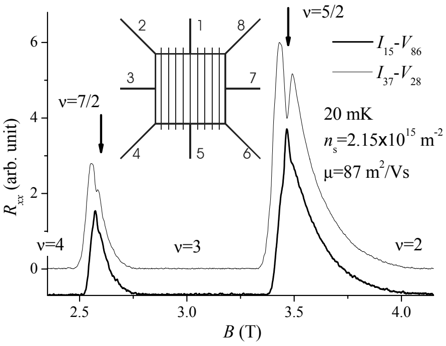

Fig. 1. Magnetoresistance traces of LSL for *N*=1 LL. Current is along (thick trace) or across (thin trace, vertically shifted for clarity) the grating. Arrows mark the observed anisotropic features (peaks/dips) near ν=5/2 and 7/2. Inset: schematic drawing of the sample.

Fig. 1 demonstrates anisotropic magnetoresistance observed in *N*=1 LL. The LSL sample is made by placing a grating of electron-beam resist on the surface of a 2DEG wafer [3], and has a square geometry with eight probe arms [4], which allows anisotropy measurements with a *single* sample. A sharp peak or dip appears near half-filling (ν=5/2 and 7/2) depending on whether the current is along or across the grating. The peak here happens to coincide with the

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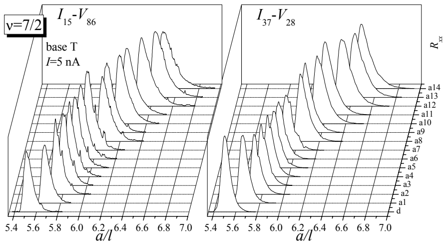

Fig. 2. Evolution with n_e of the region between ν=3 and 4 plotted against a/l. Current is along (left) or across (right) the grating. n_e's (in 10^{15} m^{-2}) are d: 1.97, a1: 2.11, a2: 2.16, a3: 2.20, a4: 2.22, a5: 2.24, a6: 2.26, a7: 2.29, a8: 2.42, a9: 2.44, a10: 2.55, a11: 2.60, a12: 2.71, a13: 2.77, a14: 2.84.

inter-LL transition maximum and rather difficult to be distinguished (pointed protrusion on top of otherwise smooth maximum). In general, the peak occurs at the slope of the transition region and more readily discernible (see below and [5]). The ground state of N=1 LL at half-filling is known to be *isotropic* even-denominator fractional quantum Hall state. However, transition to anisotropic states by the application of in-plane magnetic field has been reported for ultrahigh mobility 2DEGs [6,7]. A theoretical study shows that a slight modification in electron interaction potential suffices to cause this transition [8]. In our case, it is the external modulation that seems to be playing the role of making the anisotropic state energetically favorable, in addition to assisting the stripe phase to manifest itself in transport.

In order to search for the optimum ratio a/a_{CDW}, we tuned a/l=$a\sqrt{2\pi n_e/\nu}$ by varying electron density n_e over the range 1.97-2.84$\times10^{15}$ m^{-2} via IR-LED illumination, since a_{CDW} is reported to scale with magnetic length l=$\sqrt{\hbar/eB}$ [9,10]. For ν=5/2 [5], the anisotropic features appear only in a narrow n_e range 2.11-2.29 $\times10^{15}$ m^{-2}, with most conspicuous features appearing with n_e=2.16 $\times10^{15}$ m^{-2} at a/l=6.7. Therefore 6.7l seems to be representing some optimum length scale for our present 2DEG, a_{CDW} being one possible candidate (see [5] for detailed discussion). For ν=7/2 (Fig. 2), the features are less clear and more complicated, and seems to appear in the whole n_e range investigated. However, the features become relatively more pronounced in the same n_e range where ν=5/2 features are observed.

Fig. 3 shows magnetoresistance traces for higher LLs. Peaks are observed around half-filling of each LLs for current along the grating. The peaks are absent (and with closer look, shallow dents are occasionally observed) for current across the grating. The observed anisotropic features are consistent with our previous observation at ν=9/2 using Hall bar LSLs [11]. The peaks are observed up to ν=25/2, as marked by ellipses (larger peaks) or arrows (smaller peaks). As can readily be noticed, the peaks show alternating intensities with magnetic field: higher-magnetic-field branch spin sublevels in each LL tend to display more distinct peaks. Similar alternating nature has also been observed for anisotropy in ultrahigh mobility plain 2DEGs [2]. This, although still remains unexplained, suggests the common origin of the observed anisotropy.

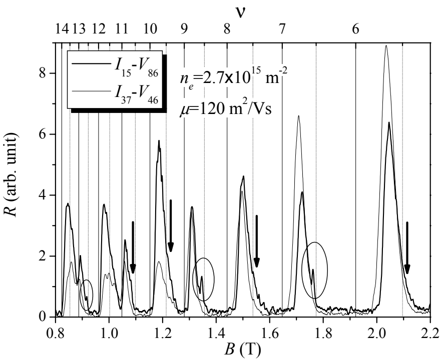

Fig. 3. Magnetoresistance traces for higher LLs. Peaks are observed for current along the grating (thick trace) up to ν=25/2, as marked by ellipses (larger peaks) and arrows (smaller peaks).

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