Comment on “Possible Spin Polarization in a One-Dimensional Electron Gas” PACS numbers: 73.20.Dx, 73.23.Ad, 73.40.Kp.

In a 1996 letter K.J. Thomas et al. report on the discovery of a conductance anomaly at 0.7 (2e²/h) observed in quantum ballistic transport in split-gate quantum point contacts [1]. Independently, Tscheuschner and Wieck observed a similar structure at 0.5 (2e²/h) in quantum ballistic transport in focused-ion-beam written in-plane-gate transistors [3]. Actually, both observations were presented at NANOMES 96 in May 96. However, signals showing this type of structure were recorded earlier, but passed uncommented on so far [8]. Indeed, the structure was already recorded in measurements involving focused-ion-beam written in-plane-gate transistors as well [2].

It should be emphasized that the observations of both groups are fully compatible. Whereas the Cavendish group scanned a temperature range from 70 mK to 1.5 K observing a weakening in the definition of the quantization for higher temperatures, the team at Bochum, due to experimental limitations, was only able to perform experiments in the 1.3 - 4 K temperature range. Both groups attribute the new effect to a manifestation of spin-polarized transport, the polarization being of spontaneous nature here. The crucial test is an application of an in-plane magnetic field which makes the 0.7 (2e²/h) structure discovered by K.J. Thomas et al. continuously approach 0.5 (2e²/h) for high magnetic field strengths [1]. This is in correspondence to the behavior seen in in-plane-gate transistors (cf. Fig 7 of Ref. [3]), where an external magnetic field in transport direction stabilizes the 0.5 (2e²/h) structure. The new quasi-plateau is comparatively robust in that it remains stable even when all the quantized plateaux are washed out, e.g. for high temperatures as well as high density of impurities. In other words, the new quasi-plateau is probably due to a many-body effect showing some rigidity similar to itinerant ferromagnetism reflecting the idea of Gold and Calmels [1].

Recent measurements in a different type of quantum wire by Ramvall et al. observed anomalies at 0.2 (2e²/h) [7].

It is the purpose of this comment to discuss the question whether the observed non-integer quantization by K.J. Thomas et al. [1], which was always found at 0.7 (2e²/h), is universal or, rather, related to the physics of the set-up. We propose that, despite its very special peculiarities [11] and serious flaws such as wide lateral spreading of the implanted ions [1], which spoils the quality of quantization at low temperatures, energetically carefully tuned focused ion beam lithography could shed some light on this fundamental question. In addition, to test the magnetic character of this many body effect an obvious strategy would be to use the focused-ion-beam set-up to implant a few magnetic ions such as Mn, Er, Yb.

Essentially, there may be three main points to be discussed depending on the interpretation of the factor 0.7, namely as fractional quantization, as orientation polarization, or as an impurity effect.

The first interpretation suggests an interpretation in terms of a fractionalization of charge analogous to the fractional quantum Hall effect. There is an interesting result by Alekseev, Cheianov, and Fröhlich [8], who, starting from the ideas of Landauer and Büttiker and adapting ideas of current algebra, analyze in detail how the system in question can be coupled to external reservoirs determining the renormalization of the quantized conductance. In particular, their parallel treatment of the quantum wire and the fractional Hall effect problem reveals that, due to the fact that physical electrons are to be identified with different types of excitations, the wire does not allow for fractional quantization in sharp contrast to the FQHE system. However, a thorough quantum-field-theoretical treatment of the quantum wire should include the spin-statistics of the interacting electrons giving rise to a transported-spin-basis gauge structure [2] not present in Luttinger-type models which enforce a certain kind of non-abelian bosonization. In this sense it is not clear at all how the elementary excitations of the wire are related to physical electrons. Hence, the possibility of fractional quantization remains, though it is improbable.

The second interpretation points towards an oblique orientation polarization of a current of magnetic dipoles which is supported by the field distribution in split-gate set-up as compared to the idealized in-plane-gate set-up (see Figures 1+2).

On the one hand an obliquely polarized state should approach a longitudinally or in-plane polarized state smoothly under the influence of an increasing in-plane external magnetic field which is in accordance with the experimental observations [11]. On the other hand a current of obliquely polarized magnetic dipoles naturally induces an effective Hall-type voltage perpendicular both to transport and polarization direction which, as a part of electrodynamic response, tends to compensate the oblique electric field components induced by the top split gate geometry. In an fairly idealized situation, in-plane-gates produces only field components which are in-plane, such that the only symmetry axis of the problem is the transport direction.

Note that the oblique-polarization picture is inti-

![Figure 1: Split-gate set-up](Image)
mately related to the semi-relativistic spin-orbit interaction picture. More precisely, in electrodynamics the force on a moving magnetic dipole in an external electrostatic field is dual to the Lorentz force on a charged particle in an external magnetic field in the sense of electromagnetic duality. For example, if the Hall effect expresses a balance between a transverse electromotive force and a Lorentz force, the appearance of an induced voltage transverse to a plane, in which off-plane oriented magnetic dipoles or vortices move, balances the spin-orbit interaction. Hence, the latter depends on the geometry of the contact. In fact, for a symmetric idealized "open X" in-plane-gate transistor we would have no spin-orbit interaction in contrast so a set-up using sufficient asymmetric top gates, which break inversion symmetry. However, in our view the primary in-plane effect is always due to spontaneous polarization, which exhibits some rigidity which cannot be explained by spin-orbit interaction.

Figure 2: In-plane-gate set-up

Unfortunately, we do not know at all to what extent real-world focused-ion-beam written in-plane-gate transistors reflect the pretension of its inventors. To date, there is no theory of the density of states of the focused ion beam implanted lines whose microscopic structure is fairly fractal and dirty, in the mesoscopic regime "open X" and "open T" are not too different. It is a careful variation of the implantation energy which could provide us with information about this point and should have some influence of the quantization parameter.

The third interpretation seems to be the most natural. As shown by several authors impurities in a narrow channel alter the quality of the quantization of the conductance [3, 4]. Chu and Sorbello showed that for s-like scatterers the value is lowered [4]. Haanappel and Marel studied the deformation of the quantization staircase function within the framework of quantum mechanical model calculations [4, 12]. In Ref. 2 the strong deviation of the standard \(2h/e^2\) plateau was attributed to this effect, however, the new state seems to be more stable against the influence of impurities. This is in harmony with the work of K.J. Thomas et al. Future study should focus on the different behavior of the impurity dip for the conventional and the novel plateaux. In particular, the magnetic character of this many-body effect could be traced by implanting a few magnetic (Kondo-type) impurities.

In conclusion, it cannot be overemphasized that unlike standard ballistic quantization the effect in question shows up clearly not only in ultra-clean long quantum wires (find the tiny sharp bend at 0.6 \((2e^2/h)\) in Fig. 1 at of Ref. [16]) but also in ‘quick and dirty’ prepared systems such as focused-ion-beam written in-plane-gate contacts. This is reminiscent of the robustness of superconductivity and other many-body phenomena. To study the fundamental nature of the value of the new quantization step it is proposed to vary carefully the implantation energy. Finally we remark, that would be interesting to implant a few magnetic ions to test the many-body character of this magneto-electronic mesoscopic effect.

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Received

The authors would like M. Dinter and R.L. Stuller for discussions. One of us (R.D.T.) would like to thank H. Schulz and K.J. Thomas for email correspondence.

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