Spontaneous Bunching of *e*/5 Quasiparticles in ν=2/5 FQHE Regime

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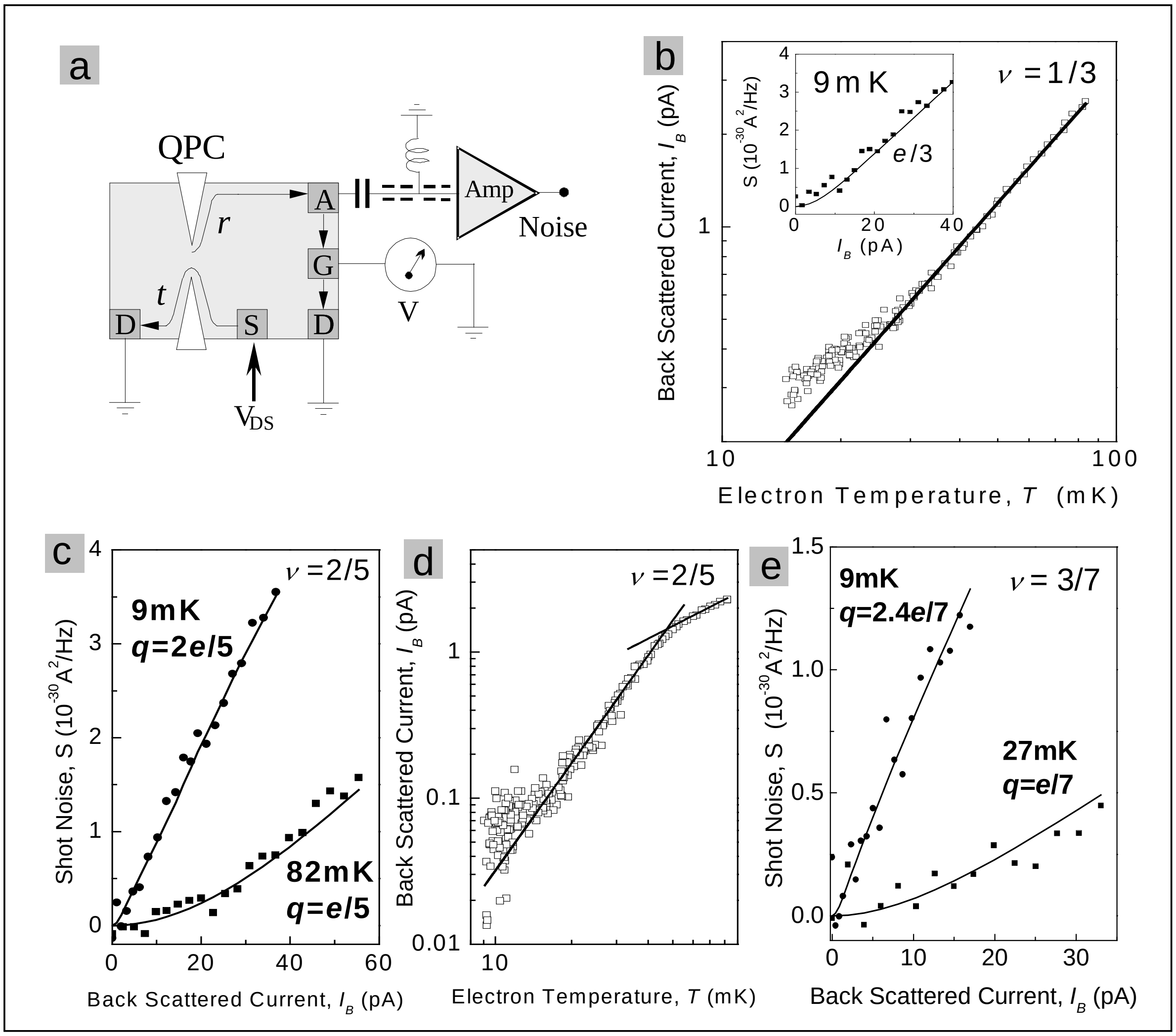
Fractionally charged quasiparticles were proposed by Laughlin to explain the fractional quantum Hall effect (FQHE). For example, quasiparticles were predicted to have charge $q=e/m$ with m odd, $q=e/3$, $e/5$, and $e/7$ (*e* is the electron charge) at filling factors ν=1/3, 2/5, and 3/7 (of type $\nu=p/m$), respectively. These predictions were confirmed experimentally via measurements of quantum shot noise, which was induced by artificial weak backscattering, with determined charge $e/3$ at ν=1/3 [1] and $e/5$ at ν=2/5 [2] at temperature 50-80mK. We report here new and surprising findings at exceptionally low electron temperature (T<10mK). In the very weak backscattering limit we measured quasiparticles with charge $q=\nu e=e/3$, $2e/5$, and ~$3e/7$, namely, a correlated backscattering of *p* quasiparticles.

Measurements were done at the above filling factors in a high mobility 2DEG. A quantum point contact (QPC) served as a voltage controlled backscatterer, hence partitioning the beam and generating shot noise (**figure a**). The spectral density of the noise, *S*, was measured at terminal **A** at a center frequency 1.4MHz and a bandwidth ~30kHz as a function of the DC current. Adding the terminal **G** allowed the thermal noise measured by the amplifier to stay constant and independent of the transmission of the QPC. For a highly open QPC (t~1, r~0.02), the backscattering events are very rare leading to Poissonian shot noise [3], namely, noise proportional to the reflected current and the scattered charge. The inset of **figure b** provides an example of the measured shot noise at ν=1/3 and 9mK, with charge $e/3$ as expected. However, as shown in **figure c**, at ν=2/5 the low temperature partitioned charge was found to be $2e/5$ rather than $e/5$. This charge though, dropped to the familiar $e/5$ charge as the temperature was increased to ~80mK. Measuring the temperature dependence of the backscattered current, as shown in **figure d**, we found, in contract to **figure b**, two distinct temperature regimes, each corresponds to the different measured charge, with a transition temperature ~45mK. A similar behavior of the charge had been observed at ν=3/7, with a charge $e/7$ at high temperature increasing to $2.4e/7$ at 9mK (**figure e**). These observations suggest the existence of two scattering states, each one with its characteristic charge and temperature. The lower temperature state is that of *p* quasiparticles, each with charge e/m, being scattered in a highly correlated manner. A slightly higher temperature seems to be sufficient to dissolve the correlated state of the bunched quasiparticles, leading to the scattering of individual Laughlin quasiparticles.

It should be noted that the current bunching of *p* Laughlin's quasiparticles at low temperatures is quite different from the already observed bunching of quasiparticles into an electron via strong backscattering potentials [4]. In the latter case the FQHE state does not exist in the high barrier regions, preventing thus the existence of elementary quasiparticles in the barrier regions and *forces* only electrons to tunnel. Here, however, the FQHE state is only very slightly perturbed in the extremely weak backscatterer region, still allowing the existence of Laughlin quasiparticles. Hence, the *spontaneous* bunching of *p* quasiparticles might result from the *partly Bosonic* nature of the quasiparticles (due to their fractional statistics) - encouraging them to bunch upon scattering.

[1] R. de-Picciotto et al., *Nature* **389**, 162 (1997).
[2] M. Reznikov et al., *Nature* **399**, 238 (1999).
[3] C. L. Kane and M. P. A. Fisher, *Phys. Rev. Lett.* **72**, 724 (1994).
[4] T. Griffits et.al., *Phys. Rev. Lett*. **85**, 3918 (2000).



(a) The measurement set up of shot noise and differential conductance. The noise generated by the QPC passes through a resonant circuit tuned to 1.4HMz and is amplified by a cryogenic amplifier. The small capacitance at **A** allows only the high frequency component to pass. The multiple-terminal geometry kept the conductance seen from **S** and **A** constant. **(b)** The backscattered current as function of electron temperature at ν=1/3. The curve can be fitted with a single slope. Inset: Shot noise due to a weakly pinched off QPC (t~0.97) at an electron temperature 9mK. Noise is Poissonian and quasiparticle charge is *e*/3. **(c)** Shot noise measured at ν=2/5 for two different temperatures. The backscattered quasiparticle charge is 2*e*/5 at 9mK and *e*/5 at 82mK. The QPC was set to reflect some 2% of the impinging current at the two temperatures. **(d)** Backscattered current as function of the electron temperature at ν=2/5. Two distinct slopes are observed with a transition temperature of about 45mK. **(e)** Shot noise at filling factor ν=3/7 at two different temperatures. The backscattered quasiparticle charge is ~2.4*e*/7 at 9mK and *e*/7 at 27mK.