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Non-locality of the gapless plasma excitations in the QHE

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Abstract. Edge magnetoplasma excitations in a two-dimensional electron system (2DES) have been studied in radio-frequency experiments. The plasmon frequency is shown to be governed by length l which characterizes the spatial distribution of the plasma charge oscillations in the direction perpendicular to the plasmon wavevector and demonstrates a nonlocal behaviour in the QHE regime.

The collective excitations spectrum of an electronic system at large wavevectors q is governed by the well known nonlocal effects. Here we report about a very different nonlocal effect which is an unique property of a finite size 2DES when the edges become important. We have observed this nonlocal effect in the QHE experiments on 2DES of macroscopic size ($1 \times 1\,\mathrm{cm}^2$) for the low frequency ($\omega \ll \omega_c$) branch of the plasma excitations, i.e., the edge magnetoplasmons (EMP). The nonlocal effect arises at low values of the length l which is shown to govern the spatial extent of the plasma charge oscillations in the direction perpendicular to the q direction, i.e., to the edge of a 2DES.

The EMP frequency ω_{EMP} has been calculated by different authors [1, 2] and is shown to be essentially proportional to the Hall conductivity σ_{xy} and the wavevector q:

$$\omega_{\mathrm{EMP}} = (2q\sigma_{xy}/\varepsilon) \ln (2e/ql), \tag{1}$$

where ε is the effective dielectric function of the surrounding medium. The interesting quantity in the logarithmic term is l which in [1] is

$$l = 2\pi\sigma_{xx}/\varepsilon\omega, \tag{2}$$

where σ_{xx} is the diagonal conductivity. However no significant influence of the logarithmic term with l has ever been observed in the previous experiments [3].

We have studied the EMP in a GaAs-AlGaAs heterostructure with electron density $n = 3\ 10^{11}\,\mathrm{cm}^{-2}$ and mobility $\mu = 2\ 10^5\,\mathrm{cm}^2/\mathrm{V\,s}$ in a non-resonant radio-frequency (1–1000 MHz) measurement cell [3].

The filling factor dependence $\omega_{\mathrm{EMP}}(\nu)$ (for an arrangement with a large ε) demonstrates a very unusual behaviour. ω_{EMP} decreases and strongly oscillates with ν while the EMP damping γ_{EMP} has correspondingly deep minima. With increasing

temperature this behaviour becomes less pronounced. In the temperature regime where we observe in dc transport measurements an activated conductivity, that at $\nu = 2$ and $\nu = 4$ the frequencies ω_{EMP} exhibit a linear dependence on the inverse temperature $1/T$.

These novel results clearly demonstrate that EMP excitations are governed not only by σ_{xy} but also strongly influenced by σ_{xx}. Moreover, we have shown that ω_{EMP} depends on σ_{xx} via a logarithmic factor as follows from (1).

Finally we would like to discuss the relevant length l in our experiments. With decreasing T the plasmon "width", i.e., l, decreases as coincides with (2). However at low T ($T \leqslant 2K$) l approaches a saturation value which is extremely small and is $\approx 0.05\ \mu$m at $\nu = 1$ and $\nu = 2$ while the magnetic length is $\approx 0.01\ \mu$m. That means that in this regime of the strong localization of the EMP we have reached the limits of the local approximation for $\sigma_{\alpha\beta}$ which is used in [1]. The length l now characterizes the non-local effects which govern the dynamical transport in the edge region of a 2DES in the QHE. We can suggest that in this case l corresponds to the variation of the electron density near the edge of a 2DES or a localization length in the QHE.

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