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**Autor:** Grodnensky, I. / Heitmann, D. / Klitzing, K. von  
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# Non-locality of the gapless plasma excitations in the QHE

By I. Grodnensky<sup>1</sup>, D. Heitmann<sup>2</sup> and K. von Klitzing<sup>2</sup>

<sup>1</sup>Institute of Radioengineering and Electronics of the Academy of Sciences of the USSR,  
Marx avenue 18, 103907, GSP-3, Moscow, USSR.

<sup>2</sup>Max-Planck Institut für Festkörperforschung, Heisenbergstrasse 1, D-7000 Stuttgart 80,  
Federal Republic of Germany

*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 ( $1 \times 1 \text{ cm}^2$ ) 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  $\omega_{\text{EMP}}$  has been calculated by different authors [1, 2] and is shown to be essentially proportional to the Hall conductivity  $\sigma_{xy}$  and the wavevector  $q$ :

$$\omega_{\text{EMP}} = (2q\sigma_{xy}/\epsilon) \ln(2e/ql), \quad (1)$$

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

$$l = 2\pi\sigma_{xx}/\epsilon\omega, \quad (2)$$

where  $\sigma_{xx}$  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  $n = 3 \cdot 10^{11} \text{ cm}^{-2}$  and mobility  $\mu = 2 \cdot 10^5 \text{ cm}^2/\text{V s}$  in a non-resonant radio-frequency (1–1000 MHz) measurement cell [3].

The filling factor dependence  $\omega_{\text{EMP}}(\nu)$  (for an arrangement with a large  $\epsilon$ ) demonstrates a very unusual behaviour.  $\omega_{\text{EMP}}$  decreases and strongly oscillates with  $\nu$  while the EMP damping  $\gamma_{\text{EMP}}$  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  $\omega_{\text{EMP}}$  exhibit a linear dependence on the inverse temperature  $1/T$ .

These novel results clearly demonstrate that EMP excitations are governed not only by  $\sigma_{xy}$  but also strongly influenced by  $\sigma_{xx}$ . Moreover, we have shown that  $\omega_{\text{EMP}}$  depends on  $\sigma_{xx}$  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  $T$  ( $T \leq 2K$ )  $l$  approaches a saturation value which is extremely small and is  $\approx 0.05 \mu\text{m}$  at  $\nu = 1$  and  $\nu = 2$  while the magnetic length is  $\approx 0.01 \mu\text{m}$ . 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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