# HIGH-FREQUENCY TRANSPORT IN GaAs/AlGaAs HETEROSTRUCTURES IN THE EXTREME QUANTUM LIMIT: ACOUSTIC STUDY

I.L. Drichko, I. Yu. Smirnov (Ioffe PTI, St.-Petersburg, Russia); A.V. Souslov (NHMFL); D.R. Leadley (University of Warwick, UK)

## Introduction

A powerful way to investigate localization in 2D systems is the acoustics [1,2] especially as this is a *non-contact* measurement: it does not require a Hall-bar to be configured and there is no need for carrier injection at the low-dimensional interface from contact areas. Simultaneous measurements of the attenuation and velocity of Surface Acoustic Waves (SAW) provides a *unique* way to determine the *complex* ac conductivity $\sigma_{xx}(\omega)=\sigma_1(\omega)-i\sigma_2(\omega)$ as a function of magnetic field $H$, temperature $T$ and SAW frequency $\omega$. These dependences provide information on both the extended and localized states. The objective of this study was to clarify the ac transport mechanisms in 2D electron systems in the quantum limit.

## Experimental and Results

Acoustoelectric effects - the SAW attenuation $\Gamma$ and velocity $\Delta V/V$, associated with interaction of SAW with the 2DEG in the heterostructure GaAs/AlGaAs (electron density $n\cong 2\times10^{11}$ cm$^{-2}$; mobility $\mu\cong 2\times10^{6}$ cm$^2$/Vs) have been studied in the ultra-quantum limit at different SAW intensities for SAW frequencies of 30-250 MHz, for temperatures $0.3<T<4.2$ K and fields of up to 18 T. The measurements have been performed in the *hybrid* configuration when the sample and piezoelectric substrate on which SAW propagates are separated by a thin gap not permitting a strain from the wave to be transmitted in the sample.

The absorption coefficient and the velocity change both undergo Shubnikov-de Haas type oscillations in magnetic field (Fig.1). In high fields there are very strong features corresponding to the FQHE. Both the real $\sigma_1$ and imaginary $\sigma_2$ components of the ac-conductivity have been determined. Fig. 2 illustrates field dependences of $\sigma_1$ and $\sigma_2$, obtained from SAW measurements at different frequencies at $T$=0.3 K. One can see that $\sigma_1$ also demonstrates SdH-type oscillations. It is evident that $\sigma_1$ is not affected by varying the SAW frequency in the low magnetic field region and near half-integer filling factors $\nu$ where the electron states are delocalized. However, at small $\nu$, where the states are strongly localized, $\sigma_1$ exhibits a frequency dispersion. $\sigma_2$ is very small near half-integer $\nu$ and at low fields, while it has appreciable magnitude near to $\nu$=1; 2 and 2/3. It is actually an order of magnitude higher than $\sigma_1$, which points to a manifestation of 2D ac hopping conductivity. The hops occur between the states close in energy localized in the random potential generated by charged impurities. Fractions 5/3, 4/3, 3/5 and 1/2 are weakly dependent on a frequency within our experimental error. Along with the fact that in these regions $\sigma_1>\sigma_2$ it proves these states to be metallic-like at the temperature used.

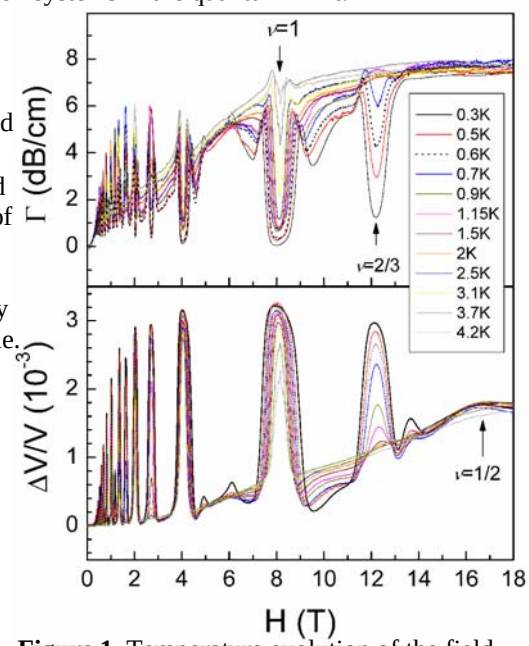


**Figure 1.** Temperature evolution of the field dependences of SAW attenuation $\Gamma$ and velocity change $\Delta V/V$, frequency $f$=30 MHz.

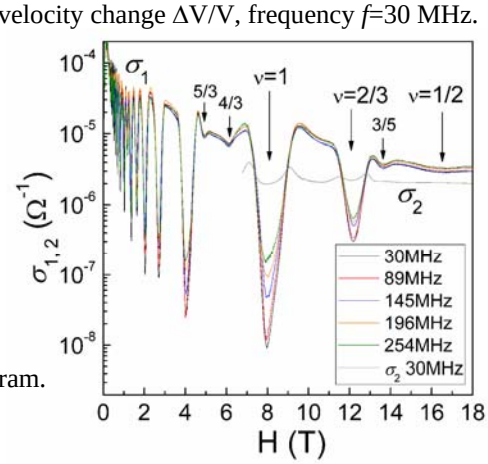


**Figure 2.** Real $\sigma_1$ and imaginary $\sigma_2$ components of the ac conductivity vs. magnetic field at different SAW frequencies, $T$=0.3K.

## Acknowledgements

Ultrasonic research at the NHMFL is supported by the In-House Research Program.

## References

[1] Willet, R.L., *et al*., Phys. Rev. Lett., **71**, 3846-3849 (1993).
[2] Drichko, I.L., *et al*., Phys. Rev. B, **71**, 045333 (2005).