Frictional magnetodrag between spatially separated two-dimensional electron gases mediated by virtual phonon exchange

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Theoretical model

- The model consists of two spatially separated 2DEGs with densities \( n_1 \) and \( n_2 \) and layer thicknesses \( d_1 \) and \( d_2 \). Both electron sheets are exposed to the perpendicular magnetic field \( B \).
- Frictional magnetodrag manifests itself when a current driven along layer 1 induces, via momentum transfer, a drag voltage in the layer 2.

Drag scattering rate

The drag scattering rate, which can be derived for instance from either the Boltzmann linearized equation or Kubo formula, is given by

\[
\frac{1}{\tau_{q,\ell}} = \frac{1}{\tau_{q,\ell}^{(0)}} + \frac{1}{\tau_{q,\ell}^{(1)}}
\]

where \( \tau_{q,\ell}^{(0)} \) is the transferred momentum, \( q(\ell) \) is the screening function in the RPA, \( q(\ell) \) is the polarization function, \( \tau_{q,\ell}^{(1)} \) is the transition probability of two electrons from the states \( |1\rangle, |2\rangle \) into \( |1'\rangle, |2'\rangle \). To avoid unphysical jumps and singularities, we use a Gaussian density of states \( \rho_{\ell}(\omega) \). The phonon propagator \( G(\omega) \) is a delta-function.


Magnetic field, temperature, and interlayer spacing dependence of the drag scattering rate due to piezoelectric acoustic phonons

In many experiments, magnetic field \( B \approx 0, \approx T, B \approx T \) and electron transitions in each layer are in the partially filled Landau levels. Therefore, the drag is realized due to exchange of phonons with zero energy and finite momenta. The phonon propagator \( D(\omega) \) is never on the ‘mass surface’ since \( \varepsilon_0 \) and \( \varepsilon_0 \), magnetodrag is only mediated by virtual phonons. Magnetodrag can be due to exchange of acoustic and optic phonons. Two factors determine their relative contributions: the optic phonon propagator \( D(\omega) \) is smaller at \( \varepsilon_0 \) while the vertex part \( J \) is larger than that of acoustic phonons.

Conclusions

- We have calculated the magnetodrag scattering rate between spatially separated 2D electron layers due to virtual phonon exchange with and without screening effects.
- The drag rate as a function of magnetic field shows the Shubnikov-de Haas oscillations without the screening effects. The screening effects result to the double-peaked structure, firstly revealed for the Coulomb magnetodrag by Bensager et al. [1] and observed by Rubel et al. [2,3].
- The drag rate as a function of temperature has a peak without the screening effects. At small \( T \) it increases as a power-law function and at high \( T \) it decreases as \( T^{-\gamma} \). At half-filling the drag rate diverges at \( T=0 \). The screening eliminates this divergence and results to its monotonic increase in \( T \).

References

[1] M. C. Bensager, K. Flensberg, B. Yu-Kuang Hu, and A.-P. Jauho, Phys. Rev. B 56, 10 314 (1997).
[2] H. Rubel, A. Fisher, W. Dietsche, K. von Klitzing and K. Eberl, Phys. Rev. Lett. 78, 1763 (1997).
[3] X. G. Feng, S. Zelinkevicz, H. Nish, T. J. Raguacci, T. J. Gramila, L. N. Pfeiffer, and K. W. West, Phys. Rev. Lett. 81, 3219 (1998).