Confined surface electrons on liquid Helium

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The surface of liquid helium provides a very well-defined and nearly ideal substrate for studying electrons in 2 dimensions as a model system: perpendicular to the surface the electrons are localized in a potential well formed by the long-range attractive image potential of the liquid and a short-range repulsive interaction due to the Pauli principle; parallel to the surface the elctrons are free to move. Compared to the well-known 2D electron systems in semiconductor structures the electron density on bulk helium is rather low, being limited to values below $2x10^9$ cm^2 by an electrohydrodynamic instability of the liquid surface. On helium films, however, due to the additionally stabilizing van der Waals forces, distinctly higher densities can be achieved.

Most experiments with electrons on liquid helium – including studies of magnetoconductivity, weak localization and Wigner crystallization – have so far been carried out in a regime where the Fermi energy is small compared to the thermal and/or the Coulomb energy. For infinite geometry, the transport properties are dominated by the scattering of the electrons from gas atoms for temperatures T > 1K and from quantized surface waves (ripplons) at T < 1K. Experiments with electrons above helium in laterally confined geometry are rather sparse up to now [1], but various projects are under preparation. We discuss here the benefits, problems and challenges of these systems and consider transport in 1D “wires” and 2D “dot” arrays, as well as the possible use of electrons of helium for quantum computing.

[1] J. Klier, I. Doicescu, P. Leiderer: "First dc measurements of electrons on liquid He: the helium-FET", J. Low Temp. Phys. vol. 121, p. 603 (2000)