Nonlinear Transport of the Wigner Crystal in a Confinement Geometry

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We investigate the nonlinear transport of a quasi-one-dimensional (Q1D) electron system formed on the ultra-clean surface of superfluid ^{4}He, in a microchannel 10 μm-wide and 100 μm-long. By applying voltages to electrodes at the microchannel edges and beneath the helium surface, the confinement potential, and therefore electron density, can be controlled. A detailed finite-element analysis of the microdevice was performed in order to calculate the confinement potential. This electrostatic model was found to explain many features of the electron transport through the microchannel. Under certain conditions, we were able to observe reentrant melting of the Q1D Wigner crystal as the number of electron rows formed in the microchannel varied. The number of electron rows observed experimentally agreed well with the number predicted by the electrostatic model. The nonlinear response of the system to an increased driving force was also investigated. It was found that the sliding of the Q1D Wigner crystal on the helium surface, which occurs due to the decoupling of the electrons from the underlying dimple lattice (deformation of the helium surface), depends on both the positional order of electron rows and temperature of the electron system. With increasing driving fields, the sliding transition occurs for higher electron densities in the microchannel, and the features of the sliding transition become sharper. In addition, the sliding of the Wigner crystal loses its dependence on the reentrant melting.

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