Oscillatory frequency dependence of ballistic mobility

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In very short semiconductor structures, the electron transport becomes ballistic and collisions with impurities and crystal vibrations are not important [1]. When the 25 nm node of the International Technology Roadmap for Semiconductors is reached in 2009, nearly all transistors will operate in the ballistic or near-ballistic regime.

As was shown in [2-4], at low voltages, the dc current-voltage characteristic in the ballistic regime is still linear and can be described using the so-called "ballistic mobility" with the effective electron relaxation time on the order of the electron transit time, $\tau = L/v$, where L is the distance between the contacts and v is the Fermi velocity for the degenerate electrons and the thermal velocity for the non-degenerate electrons. The electric current is determined by the difference between the electron fluxes injected from the opposite contacts, so that the current is essentially contact limited.

In this work, we derive a general expression for the dc ballistic mobility in two-dimensional structures (for an arbitrary degeneracy level) and investigate its dependence on frequency, f. We show that the current-voltage characteristic is an oscillatory function of the $f\times\tau$ product. This oscillatory dependence is caused by the phase difference between the electrons injected from the opposite contacts. The physics of this effect is similar to that of the oscillatory frequency conductivity behavior previously predicted for quantum ballistic wires [5].

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