Origin of Huge Anisotropic Mobility in Quantum Wire Arrays

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Recently, a new periodic quantum-wire array (QWA) was formed during growth of a GaAs/AlAs heterointerface on GaAs (775)B substrate by molecular beam epitaxy [1]. Under suitable growth condition, a zigzag heterointerface comes into being instead of a flat plane. Transport experiments were started quite recently and high anisotropy of the electron mobility has been observed [2,3]. A recent self-consistent calculation of the subband structure in QWA gives an almost circular and isotropic Fermi line for the usual electron density because $2k_F < 2\pi/a$, where k_F is the Fermi wave vector of two-dimensional (2D) electrons and a is the period of QWA [4]. This seems to show that Bragg reflection due to the periodic variation of the well thickness cannot give rise to considerable effects on the electron mobility. The purpose of this paper is to demonstrate that diffusive Bragg scattering due to the presence of a small disorder in the QWA period is responsible for the anisotropic mobility.

One important conclusion obtained in the self-consistent calculation [4] is that effects of the interface corrugation can be fully incorporated as an effective potential for 2D electrons as in the case of interface roughness [5]. Therefore, effective scattering potential can be obtained by treating fluctuations as an interface roughness and therefore its effect can be described fully by a correlation function of fluctuating interface positions. The correlation function is calculated analytically (although approximately) in the limit of weak disorder and also numerically in a model that the peak and valley height fluctuate but the corresponding terrace angles are fixed.

The resulting correlation function has a sharp but broadened peak in the vicinity of the fundamental Bragg peak corresponding to the array period. These diffuse Bragg peaks give rise to a huge backscattering for electron waves moving in the direction perpendicular to the quantum wire even when $2k_F < 2\pi/a$. The anisotropic mobilities are calculated by exactly solving a Boltzmann transport equation in the absence of a magnetic field. The large anisotropy in the conductivity in the presence of a strong magnetic field is calculated also using a center migration theory [6,7].

References

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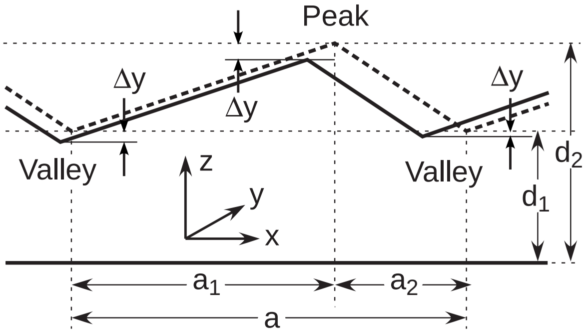


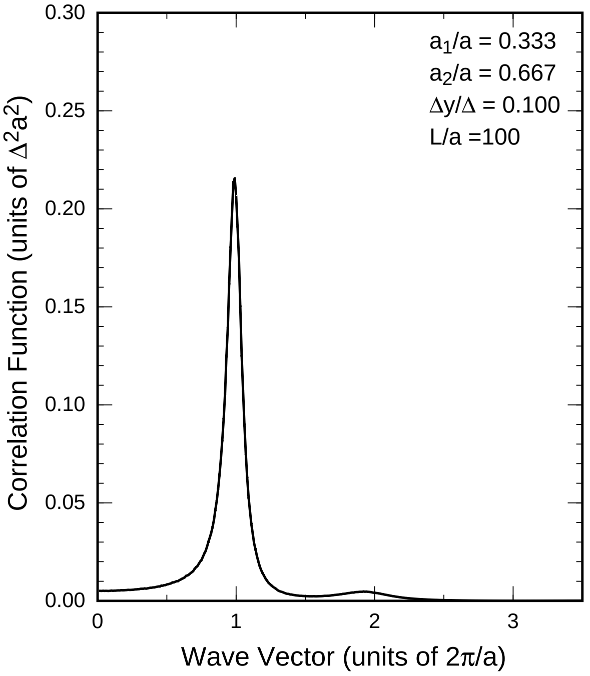
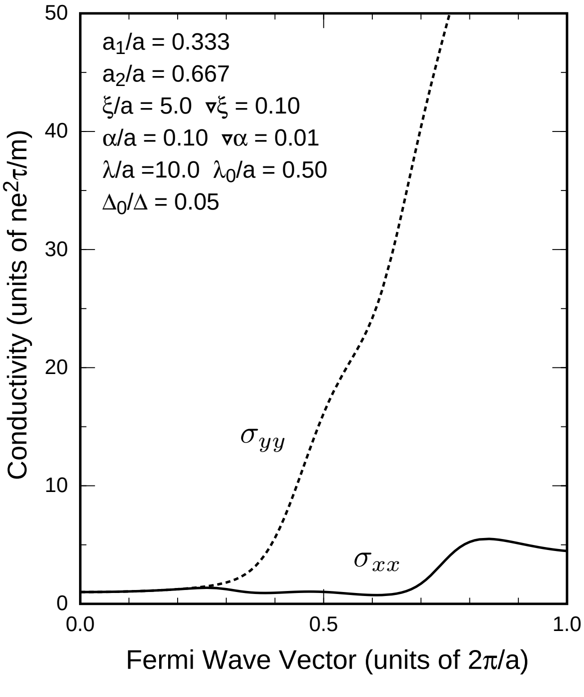


Fig. 1 (Left) A schematic illustration of a periodic quantum-wire array both in the absence and presence of fluctuations in the peak and valley height.

Fig. 2 (Right) An example of a Fourier transform of a correlation function of interface position in the direction perpendicular to the wire direction.



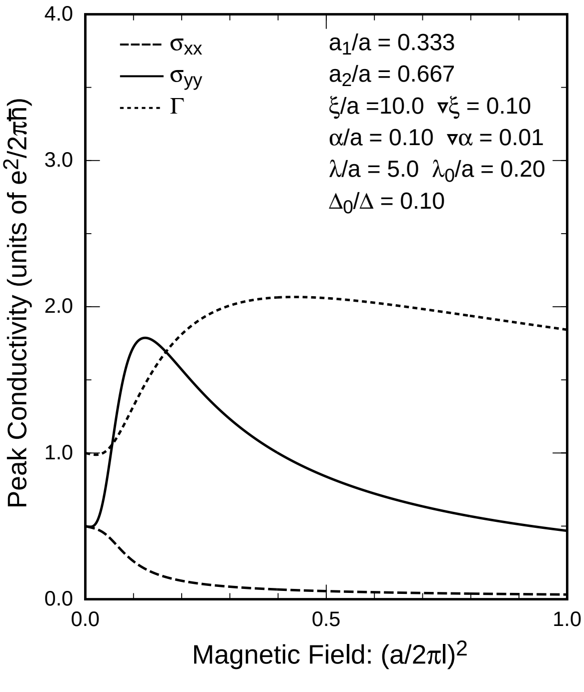


Fig. 3 (Left) An example of calculated conductivity in two directions in a model of QWA with weak randomness, as a function of the Fermi wave vector.

Fig. 4 (Right) An example of calculated diagonal conductivity (the peak value of the lowest Landau level) in strong magnetic fields. The horizontal axis represents $(a/2\pi l)^2$, proportional to the magnetic-field strength, where l is the magnetic length.