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Tuneable, Strongly Non-Parabolic Confinement in a Quasi One Dimensional Electron Gas Formed by Epitaxial Regrowth

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In the presence of a strongly non-parabolic lateral confining potential, dramatic changes in the far-infrared (FIR) response of quasi one-dimensional electron gases (Q1DEGs) have been predicted. New absorption modes should appear which do not correspond to the electron centre of mass motion, a single mode typically seen for parabolic or weakly non-parabolic confinement. Recent development in epitaxial regrowth on patterned substrates now allows strongly non-parabolic, even non-symmetric, tuneable confining potentials to be fabricated for the first time. In this Q1DEG, an electron gas on a (100) GaAs facet is confined in one lateral direction by hole gas sidegates on adjacent (311)A facets, forming a p-n-p structure (Fig. 1)

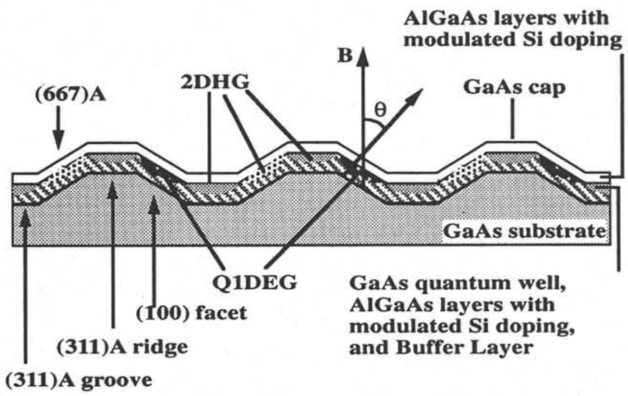

Fig. 1 Cross sectional schematic diagram of the device structure.

The confining potential may be tuned by a bias (V_h) applied between separate ohmic contacts to the electron channel and hole gases. Cross section electron beam induced current (EBIC) imaging is used to map the magnitude of the electric field in this structure, and explicitly demonstrate the non-symmetric nature of the potential (Fig. 2).

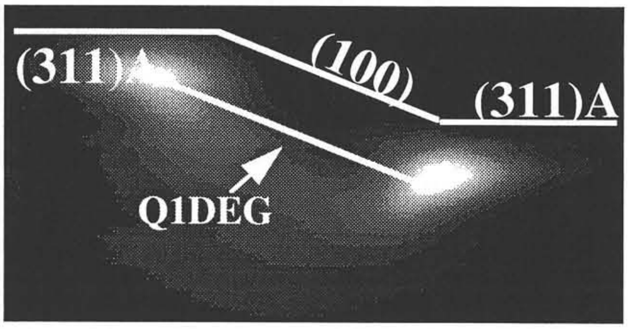

Fig. 2 EBIC measured at V_h =-1.0 V. The brighter regions are associated with higher electric field. The picture shows a non-symmetric profile along the confinement direction. The strong non-parabolicity which results is responsible for the new mode ν_4 in the FIR spectra.

FIR cyclotron resonance (CR) spectra of this structure contain up to four modes; a fundamental ($\nu 1$) associated principally with the centre of mass excitation, plus harmonics (ν_2, ν_3; see Fig. 3).

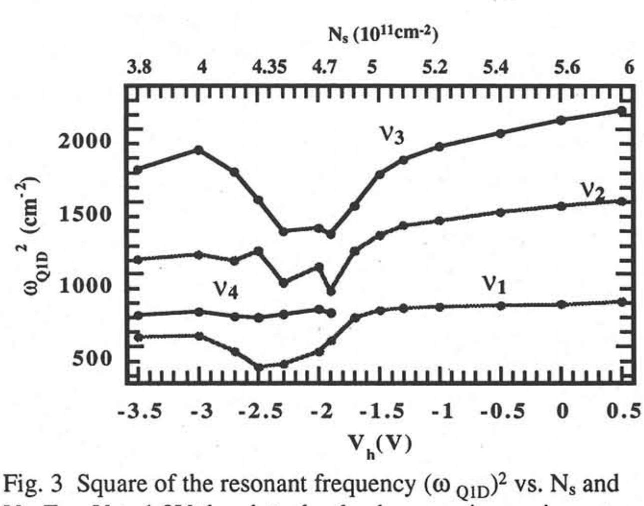

Fig. 3 Square of the resonant frequency $(\omega_{Q1D})^2$ vs. N_s and V_h. For V_h>-1.9V the plot clearly shows an increasing rate of change of $(\omega_{Q1D})^2$ for decreasing V_h while the carrier density decreases linearly. This is explained by increase in non-parabolicity of the confining potential. This is also supported by the appearance of the new mode ν_4 for V_h<-1.9V.

The number of harmonics observed, as well as their high absorption intensity, are consistent with the strong non-parabolicity suggested by the EBIC image.

The confined plasmon model (CPM), which has been shown accurately to predict the FIR frequency ω_{Q1D} of the modes for Q1DEGs, reproduces the frequency of the fundamental and harmonics for V_h>-1.9 V, yielding a lateral width W=1500nm which is constant with bias, also consistent with the EBIC images. However, the CPM model predicts a $(\omega_{Q1D})^2$ proportional to N_s, where N_s is the areal carrier density. By contrast, the data in Fig. 3 clearly show that the slope of $(\omega_{Q1D})^2$ vs. N_s increases rapidly with decreasing V_h. This is consistent with theoretical predictions for a non-parabolic potential in which the slope increases as higher-order anharmonic terms become more important. Further evidence of an increasingly non-parabolic potential with decreasing V_h is provided by the dramatic change in the spectra for V_h -1.9 V. A new mode ν_4 appears, and the CPM model no longer predicts ω_{Q1D} of the modes accurately, again suggesting a dramatic increase in the non-parabolicity. To our knowledge, this is the first demonstration of a non-symmetric potential with strongly tuneable anharmonicity.

References

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