Low Temperature Physics Laboratory

RIKEN

Quantum Oscillations in a Nondegenerate 2D Electron System on He

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Introduction

Shubnikov de Haas effect in degenerate 2DEG

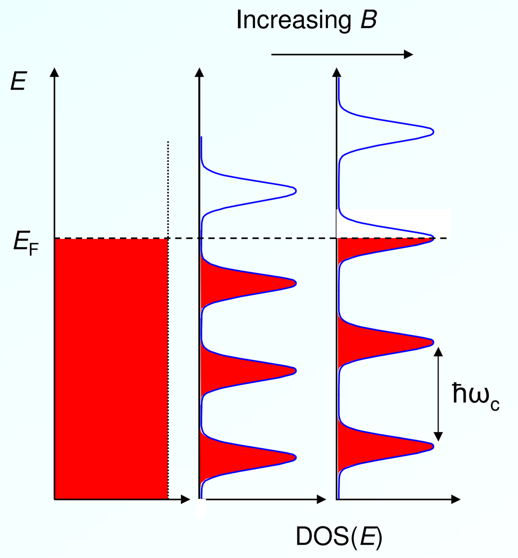
Quantum degenerate electron gas:

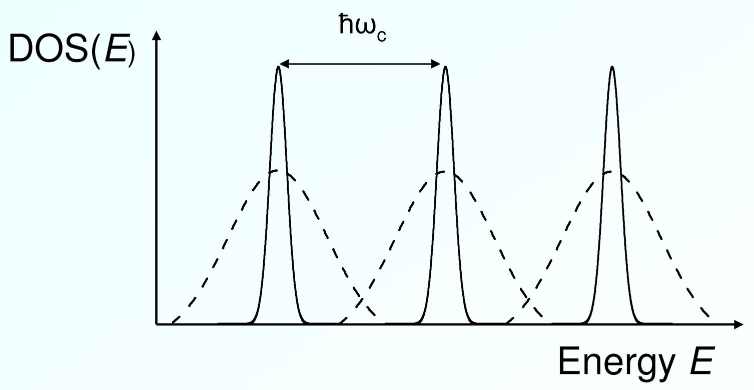
$$E_F = \frac{\pi \hbar^2 n_s}{m_e} >> k_B T_e$$

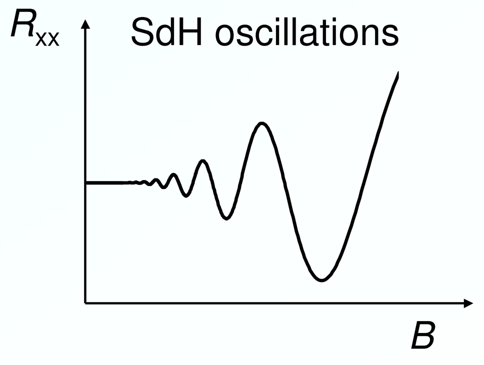
In *B*-field perpendicular to 2D-plane:

$$E = \hbar\omega_c (l + \frac{1}{2}), \quad l = 0, 1, 2, \ldots$$

Modulated density of states (DOS)

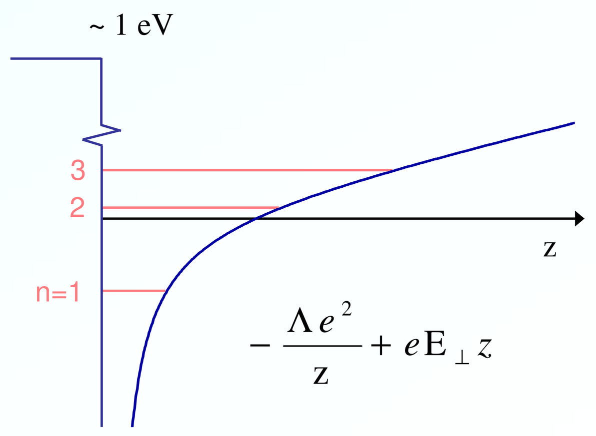




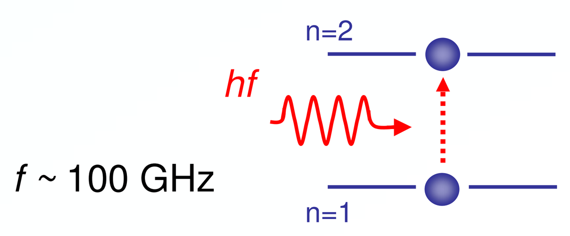


Inter-subband oscillations in electrons on He

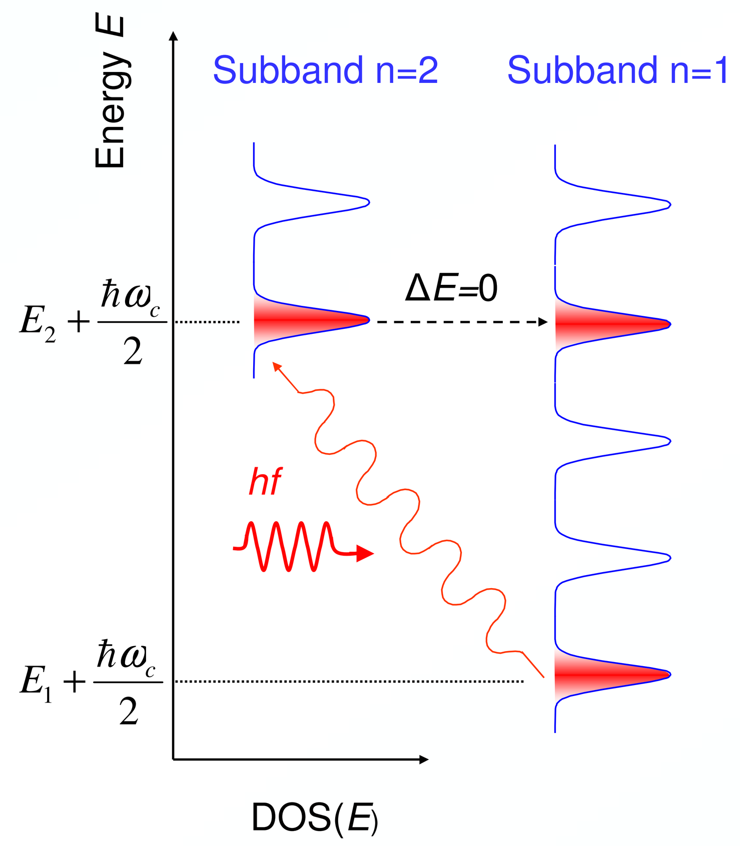
Surface states form subbands:



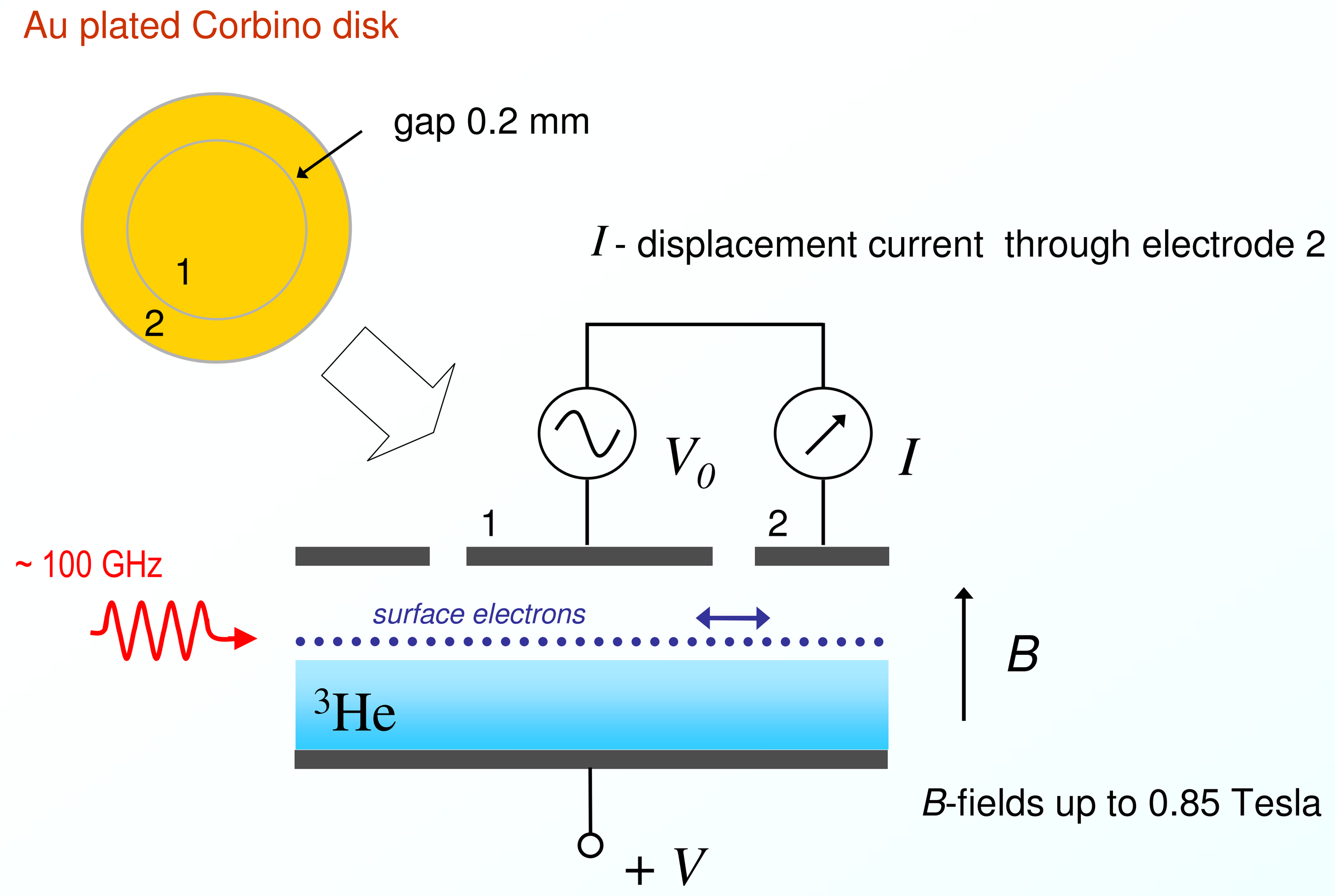
Inter-subband absorption:



In *B*-field: $E = E_n + \hbar\omega_c (l + \frac{1}{2})$



Experimental

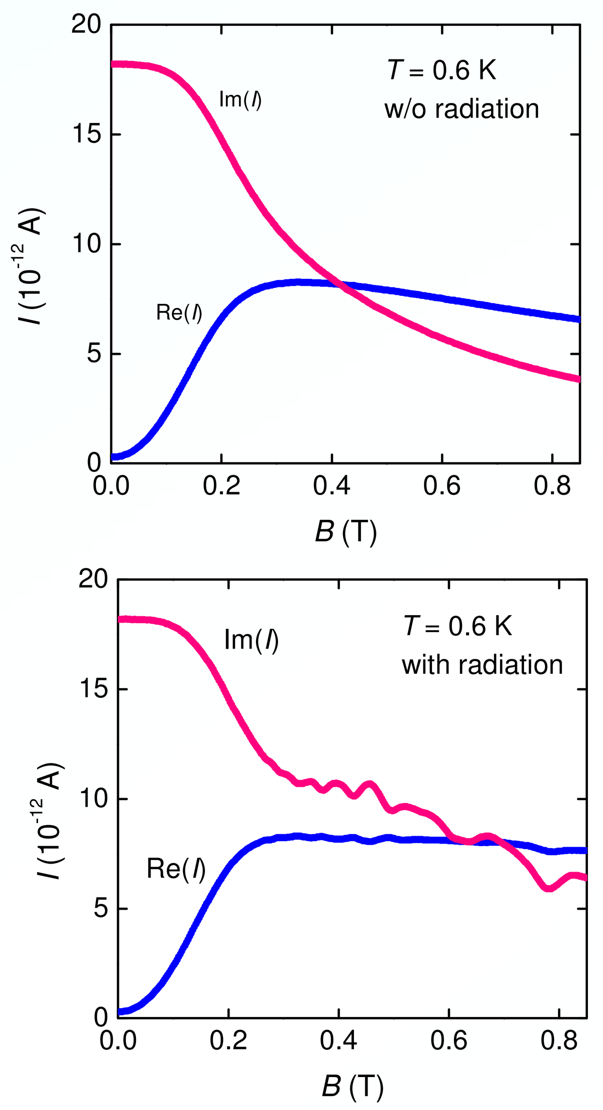


$I = (\mathrm{Re}(G) + j\,\mathrm{Im}(G)) \times V_0$ - measure complex admittance *G*

Need to find relationship between *G* to σ_{xx}!

Method

Measured current



Data analysis

Solve Maxwell equations to find field distribution:

$$G = I/V = \sum_{i=1}^{\infty} \frac{A_i}{\chi_1 - j\left(\frac{m\omega_p^2}{2\pi f_1 e^2 n_a} - \chi_2\right)}$$

where $\chi_1 + j\chi_2 = \sigma_{xx}^{-1}$

$$A_i = \frac{4\pi \sinh^2(\lambda_i d / R_e)}{\sinh^2(\lambda_i D / R_e)} \times$$

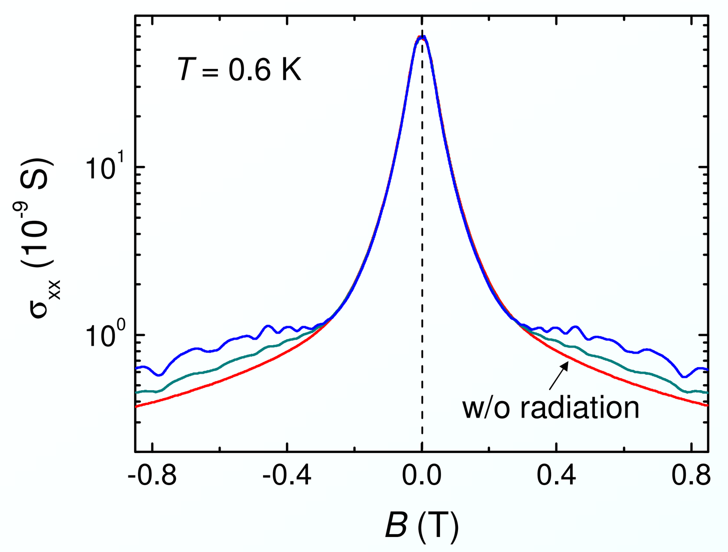
$$\times \frac{R_1 J_1(\lambda_i R_1 / R_e)[R_2 J_1(\lambda_i R_2 / R_e) - R_1 J_1(\lambda_i R_1 / R_e)]}{R_e^2 J_0^2(\lambda_i)}$$

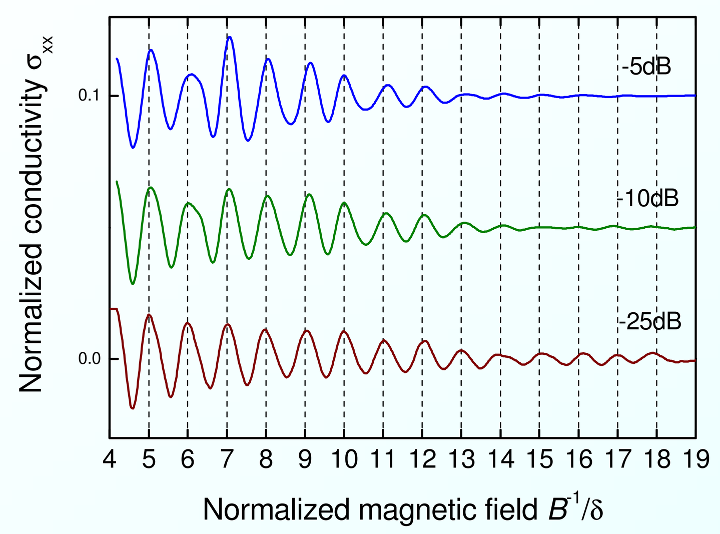
and

$$\omega_p = \frac{4\pi\, n_a \lambda_i}{m R_e [\coth(\lambda_i (D-d)/R_e) + \varepsilon \coth(\lambda_i d / R_e)]}$$

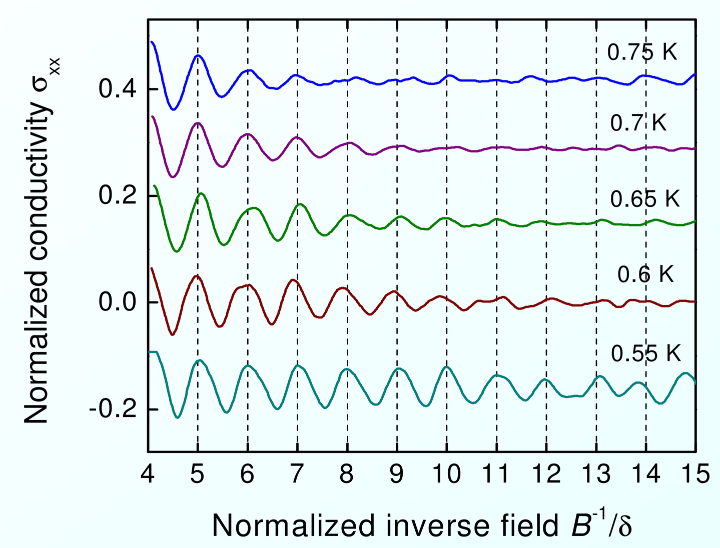
Results

High-T oscillations

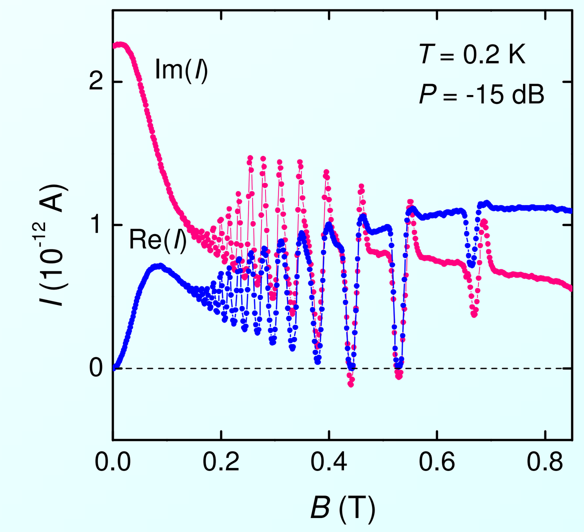




T-dependence



Current oscillations at T=0.2 K



Summary

○ Novel magneto-oscillations are demonstrated in nondegenerate quasi-2D electrons subjected to perpendicular magnetic fields

○ The effect is governed by resonant inter-subband excitation and scattering mediated transitions between Landau levels of two subbands

○ At *T*=0.2 K system shows intriguing behavior which suggests the existence of zero-resistance states