Cyclotron Resonance of Wigner Crystal on Liquid Helium

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The cyclotron resonance (CR) of 2D correlated electrons on liquid helium in high magnetic fields and low temperatures is investigated on the basis of the newly developed theory. Electrons are assumed to form a Wigner crystal in which the electrons are localized and oscillate around their equilibrium positions, and the electron correlation effect which characterizes the width of the dynamic structure function (DSF) is taken into account through the Wigner phonons. This method is in contrast from the previous theory in which the correlation effect is considered phenomenologically by the Doppler shift of fast moving electrons. Indeed the analytic structure of the DSF when the electron correlation is considered is different each other.

The scattering effects on electrons are assumed to be due to electron-ripplon and electron-vapor atom scatterings. The DSF then takes the explicit form:

$$S(q,\omega) = \frac{2\sqrt{\pi}\hbar}{\Gamma}\sum_{n=0}^{\infty}\frac{x^{n-\frac{1}{2}}}{n!}e^{\hbar(\omega-n\omega_c)/2T}\exp\left[-x\left(1+\left(\frac{\Gamma}{4T}\right)^2\right)-\frac{\hbar^2(\omega-n\omega_c)^2}{x\Gamma^2}\right], \qquad (1)$$

where $\omega_{\rm c}$ is the cyclotron frequency, $x = \hbar q^2/2m\omega_c$, and Γ is called the broadening parameter given by $\Gamma = \sqrt{\Gamma_{\rm e}^2+\Gamma_{\rm r}^2+\Gamma_{\rm v}^2}$, and $\Gamma_{\rm e}$, $\Gamma_{\rm r}$ and $\Gamma_{\rm v}$ are the contributions coming from the electron-electron, electron-riplon and electron-vapor atom scattering, respectively and are given explicitly by

$$\Gamma_{\rm e} = \eta\hbar\omega_0(T/\hbar\omega_c)^{1/2}, \quad \Gamma_{\rm r} = \sqrt{\frac{T}{\pi\alpha}}e(E_z+E_R), \quad \Gamma_{\rm v} = \hbar(2\nu_0\omega_c/\pi)^{1/2}, \qquad (2)$$

where $\eta \simeq 1.21$ is a numerical constant, ω_0 is related to the 2D plasma frequency, E_z and E_R are the holding field and the effective electric field caused by the polarization of helium, repectively, α is the surface tension constant of liquid helium and ν_0 the collision frequency of vapor helium. The final expression for the line-width of the CR line shape is given by

$$\gamma = \frac{1}{8\hbar\Gamma}\frac{1}{(1+\frac{\Gamma^2}{16T^2})^{\frac{3}{2}}}\left[\frac{e^2(E_z+E_R)^2T}{\alpha}+\frac{3\hbar^2{\rm e}\nu_0}{1+\frac{\Gamma^2}{16T^2}}\right]+\text{(background terms)}.$$

Based on this expression, numerical calculations are performed, and they show the good agreement with the experiment by Eldeman[1] without any fitting parameters.

[1]V. S. Edel'man, Sov. Phys. JETP **50**, 338 (1979).

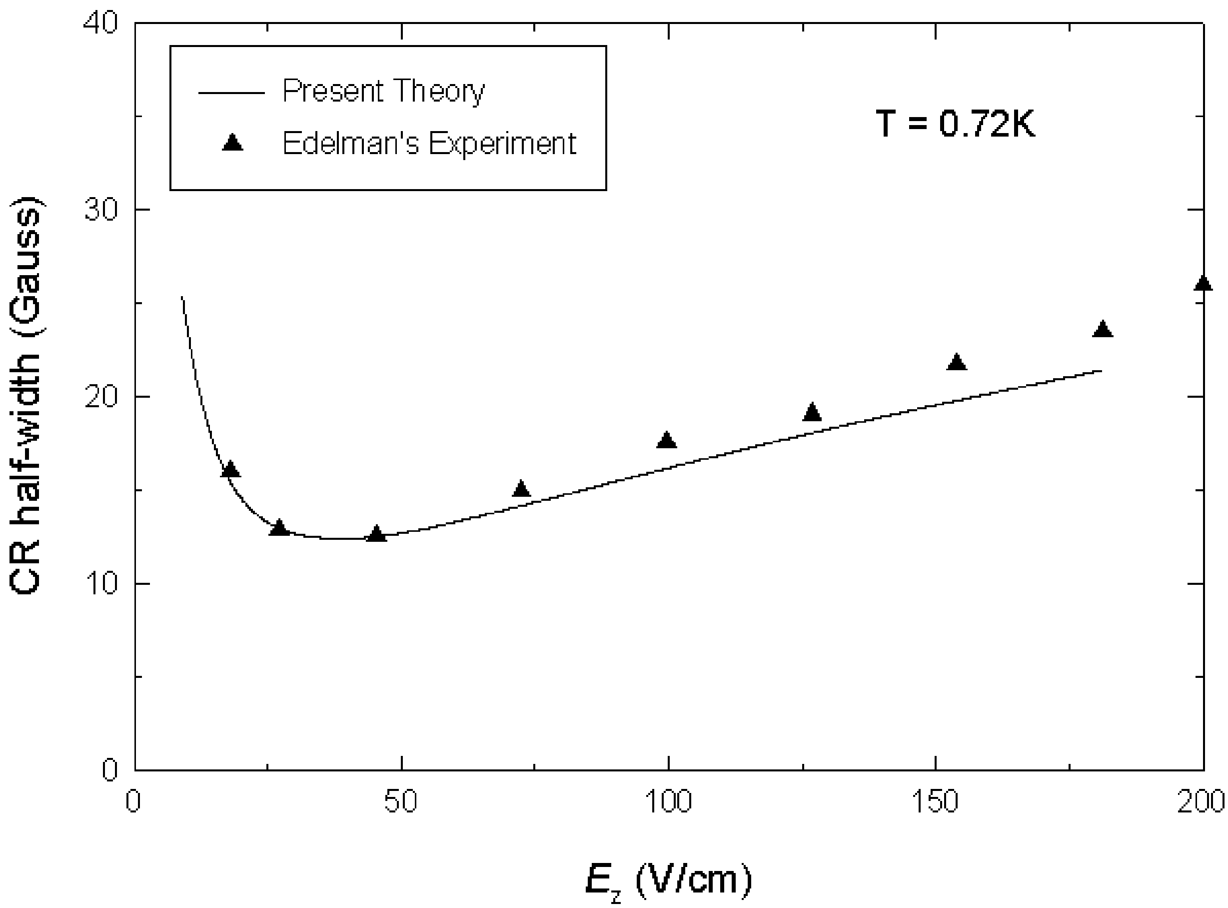

Figure 1: CR half-linewidth vs. holding field with the saturation condition at $T = 0.72\text{K}$.