Microwave Spectroscopy of Wigner crystals in 2DES and Bilayer Systems: Many-body correlation in electronic quantum solids\textsuperscript{1}
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It is generally known that in high quality two dimensional electron systems (2DES, similarly for 2D hole systems and bilayer systems) under sufficiently large perpendicular magnetic field $B$, the quantum Hall (QH) states terminate into an electronic solid — a Wigner crystal (WC) pinned by disorder. After a brief review of solid phases in QH systems (including several recently discovered ones \cite{1}) as known from microwave spectroscopy (measuring a characteristic pinning mode resonance of the solid), I will discuss two of our experiments that highlight the importance of many-body quantum correlation in the high-$B$ WC. In one experiment \cite{2}, we measured the melting temperature ($T_c$) of the high-$B$ WC at many different $B$ and densities $n$ and in multiple 2DES samples. The data show unambiguously that in a given sample, $T_c$ is controlled by Landau filling $\nu=nh/eB$ instead of by $n$. This demonstrates the quantum nature of the high-$B$ WC and that its melting is dependent on many-body quantum correlation (via $\nu$). Such behavior contrasts with any other known solids (in particular, a classical electron solid), whose $T_c$ are determined by $n$. In addition, we found that stronger pinning disorder in samples with tighter vertical confinement led to an enhancement of $T_c$. In another experiment \cite{3}, we studied bilayer WC (BWC) in bilayer hole systems (in low inter-layer tunneling limit). We found that in samples with a bilayer exciton condensate (BEC) QH state at $\nu=1$, the pinning mode frequency of the BWC ($\nu\ll1$) is systematically enhanced from what would be expected from two classically interacting single-layer WC. The enhancement decreases with increasing effective layer separation and is not observed for samples without the $\nu=1$ state. We suggest that our results give evidence for a pseudospin (layer index) ferromagnetic BWC, which possesses interlayer quantum correlation and long range in-plane phase coherence similar to that in the $\nu=1$ BEC state and can experience enhanced pinning \cite{4} in the presence of interlayer spatial correlation of disorder. \cite{1} Yong P. Chen \textit{et al.}, Phys. Rev. Lett. \textbf{93}, 206805 (2004); Phys. Rev. Lett. \textbf{91}, 016801 (2003); \cite{2} Yong P. Chen \textit{et al.}, Nature Physics \textbf{2}, 452 (2006); \cite{3} Z. Wang \textit{et al}, submitted; \cite{4} Yong P. Chen, Phys. Rev. B \textbf{73}, 115314 (2006).

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