# Electronic Phase Transition and Multiband Conduction in the Landau Levels of Few-layer $MoS_2$

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## Introduction

Atomically thin transition metal dichalcogenides (TMDCs) is revealed to be a unique system with strong electron interactions. Previously, we have investigated the interaction enhanced g-factor in few-layer $WSe_2$ [1], and also studied the carrier density dependent spin susceptibility enhancement in both few-layer $WSe_2$ [2] and layer-polarized bilayer $MoS_2$ [3] by Landau level crossings. However, the quantum transport study of TMDCs at both low and high carrier density regime still remains scarce due to the challenge on achieving good electrical contact. The investigation is now accessible with our high-quality few-layer $MoS_2$ device and the high fields provided by NHMFL.

## Experimental

hBN-sandwiched few-layer $MoS_2$ devices with standard Hall bar structure was fabricated. Both $R_{xx}(B)$ and $R_{xy}(B)$ were measured simultaneously in Cell 9 at 1.5K up to 32 T [Fig.1].

## Results and Discussion

In our few-layer $MoS_2$ device with field-effect mobility 23000$cm^2$/Vs at 1.5K, filling factor 1 in quantum Hall regime is firstly reached at carrier density as low as $0.78*10^{12}/cm^2$ [Fig.1a]. By varying the temperature, two crossing points are observed at 1.5T and 21T, which may hint the existence of magnetic-field-tuned metal-insulator transitions. Scaling analysis for the transition around 19.92T [Fig.1b] gives the critical exponent zv~2.13, which is close to the quantum critical value 7/3 of the universality class for spin-split Landau levels in integer quantum Hall effect. Such transitions result from a background conduction of the disorders at low carrier densities modulated by the Landau levels and quantum Hall effect.

At high density, for example $V_g$=70V, a clear beating pattern in the oscillation can be seen in Fig.1c, which is the evidence of multiband conduction. Further Fourier transform analysis confirms that the upper spin-orbit-coupling split band mixes in the conduction at high gating regime and shares the total carrier density.

## Conclusions

We have studied quantum oscillations in few-layer $MoS_2$ under high magnetic fields in both low and high carrier density regimes. In low carrier density regime, a quantum Hall modulated phase transition is observed around the lowest Landau level. In high carrier density regime, multiband conduction is present, shown as a beating pattern in quantum oscillations.

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## References

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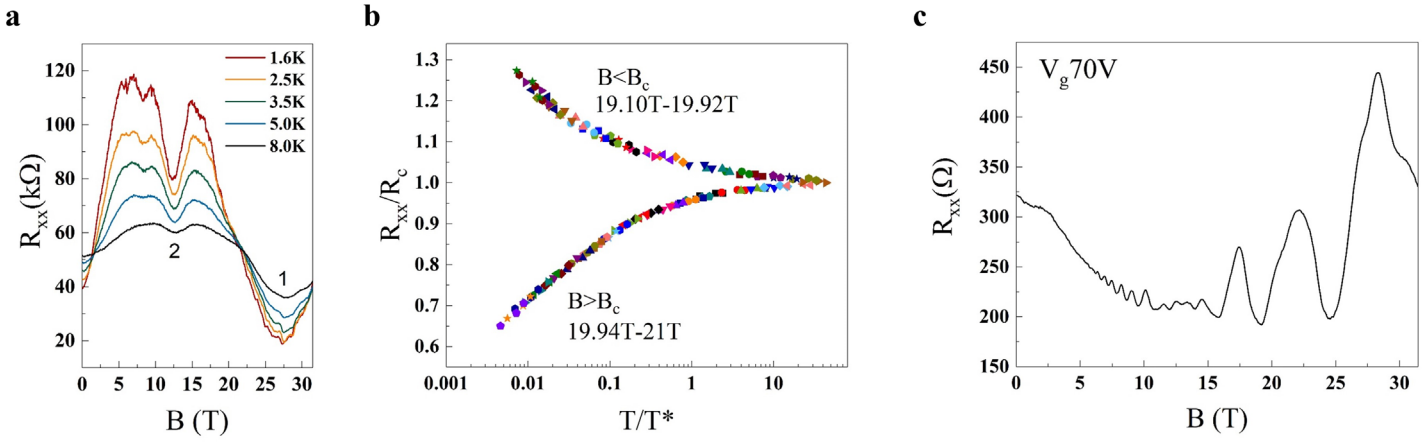


Fig.1 Magnetoresistance measured in a few-layer $MoS_2$ sample. (a) temperature dependent magnetoresistance at lowest carrier density, numbers indicating the filling factors; (b) scaling analysis for phase transition around 21T; (c) quantum oscillations with beating pattern at high carrier density.