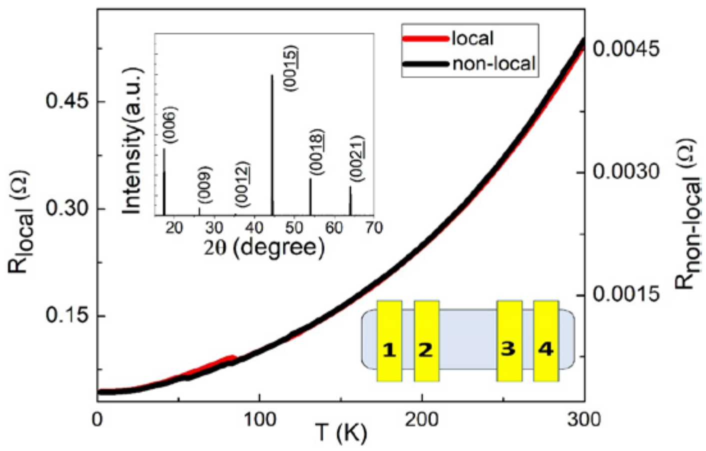
The quantum oscillations in different probe configurations in the BiSbTe3 topological insulator macroflake

Shiu-Ming Huang[1,3*], Chien Lin[1], Sheng-Yu You[1], Wei-Cheng Lin[1], You-Jhih Yan[2], Shih-Hsun Yu[2] and Mitch M. C. Chou[2,3]
1 Department of Physics, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan.
2 Department of Materials and Optoelectronic Science, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan.
3 Center of Crystal Research, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan.

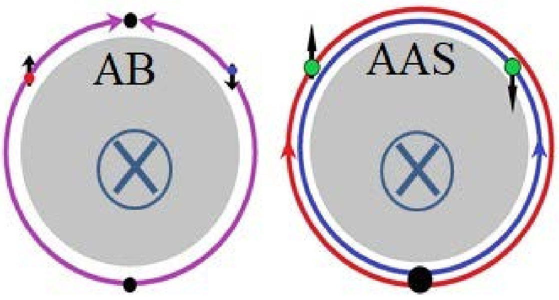
Background

- Quantum interference such as universal conductance fuctuations, Aharonov–Bohm (AB) oscillation and Altshuler–Aronov–Spivak (AAS) oscillation, is a wave characteristic of carrier transport. These oscillations originate from a magnetic field flux, through a close loop by two carrier transport trajectories with the same phase in clockwise and counterclockwise directions.
- The oscillation periodicity of AB and AAS oscillations are related to the of flux quanta, h/e and h/2e, where the h and e are the Planck's constant and electron charge, respectively.
- The intrinsic mechanism between AB and AAS oscillations are different and the magnetic flux quantum are h/e and h/2e for AB and AAS interference, respectively which result to half oscillation frequency difference between AB and AAS interference. These two interferences coexist in carrier transports. It is curious that whether one could individually demonstrate the AAS-like oscillation in a mesoscopic system.
- In this work, we individually realize the experimental demonstration of AB-like and AAS-like oscillations in different probe configurations in the BiSbTe3 topological insulator macroflakes.
- Our experimental result revealed that the Shubnikov-de Haas oscillation frequency was the same but oscillation peaks revealed a π phase shift in the local and non-local configurations. The Berry phase is π in the local configuration and 0 in non-local configuration.

Results and Discussions

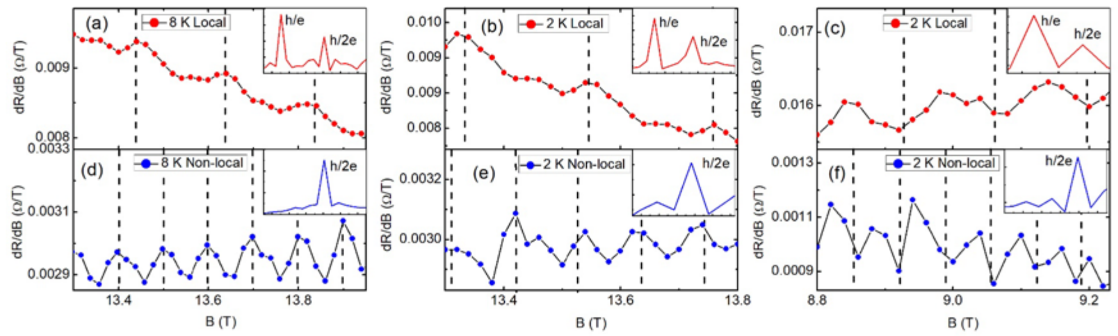


- The top-left inset shows the XRD spectrum revealing sharp peaks testifying high quality BiSbTe3 crystal.
- The bottom-right inset shows the probe configuration in this work.
- The applied current, I_{14}, flows through the electrode 1 and 4, and the voltage difference, V_{23}, is detected at the electrode 2 and 3 in the local configuration. The applied current, I_{21}, flows from the electrode 2 to electrode 1, and the voltage difference, V_{34}, is detected at the electrode 3 and 4 in the non-local configuration.
- The resistance, R, is determined by the ratio of the detected voltage difference to the applied current in both two configurations. The measured resistances in two configurations follow the same temperature dependence from 300 to 2 K. The residual resistance ratio, R(2K)/R(300 K), reaches 0.07.

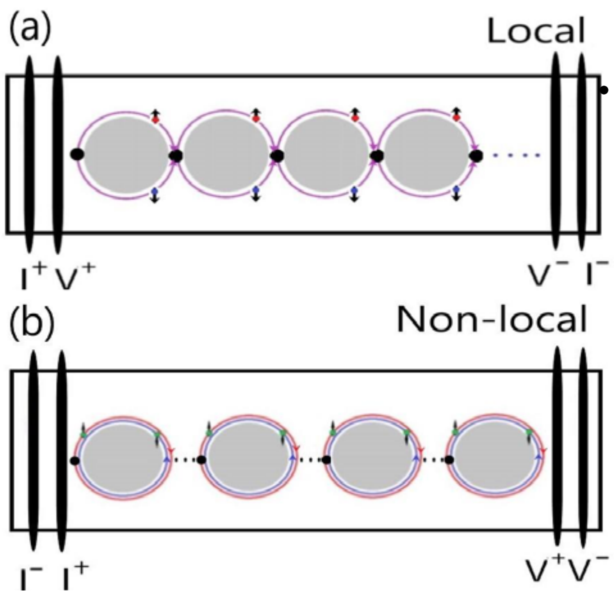


- The cartoon of AB and AAS oscillations. Carriers travel half loops and form quantum interference at the other side of the loop in the AB oscillation. Carriers travel a whole loop and form quantum interference at the original position in the AAS oscillation.

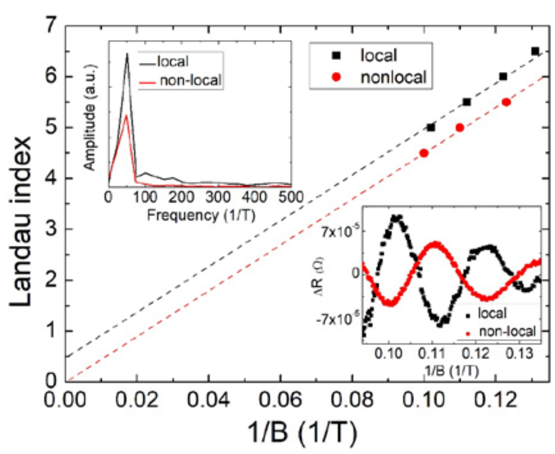
Results and Discussions



- The magnetoresistance as a function of magnetic fields. (a–c) The dR/dB in local configuration, and (d–f) the dR/dB in nonlocal configuration. The oscillation period in the local configuration is double of that in the nonlocal configuration.



- The cartoons of AB-like and AAS-like interferences.
(a) The AB-like interference is dominant in the local configuration.
(b) the AAS-like interference is dominant in the nonlocal configuration.



- The bottom-right inset shows the extracted SdH oscillations in both configurations. The oscillation shifts a π phase in the two configurations.
- The top-left inset shows the FFT of SdH oscillation in two configurations. The oscillation peak positions are the same.
- The Landau level fan diagram of two SdH oscillation. The Berry phase are π in the local configuration and 0 in the nonlocal configuration.

Conclusions

We demonstrate quantum oscillations in BiSbTe3 topological insulator macroflakes in different probe configurations. The oscillation period in the local configuration is twice compared to the non-local configuration. The Aharonov–Bohm-like (AB-like) oscillation dominates the transport property in the local configuration and the Altshuler–Aronov–Spivak-like (AAS-like) oscillation dominates the transport property in the non-local configuration. The AB-like oscillation period is 0.21 T and the related loop diameter is 156 nm which is consistent with the reported phase coherence length in topological insulators. The Shubnikov–de Haas oscillation frequency is the same but oscillation peaks reveal a π phase shift in the local and non-local configuration. The Berry phase is π in the local configuration and 0 in non-local configuration.