An integrated quantum material testbed with multi-resolution photoemission spectroscopy

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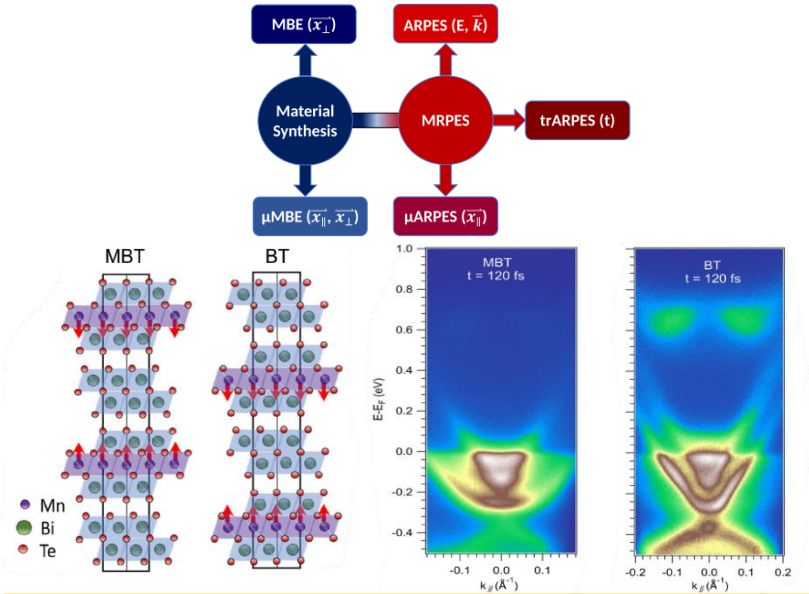
Project Summary: Angle-resolved photoemission spectroscopy (ARPES) has been established as a powerful tool to directly reveal electronic band structures of materials and played a critical role in discovering various topological materials such as topological insulators, Dirac semimetals, and Weyl semimetals. Investigations on quantum materials often require the combination of different modalities in photoemission spectroscopy. However, multi-modal ARPES measurements are remarkably challenging due to the limited access to multiple facilities and the potential sample degradations during transportation. Recently, Prof. Yang's group at University of Chicago set up a new integrated platform for multiresolution photoemission spectroscopy (MRPES) that integrates a helium discharge lamp, a narrow bandwidth 6 eV laser, and a tunable ultrafast laser, which effectively combines static ARPES, time-resolved ARPES (trARPES), and micro-ARPES (*μ*ARPES). This setup provides a first-time all-in-one solution for multi-modal photoemission spectroscopy. By using single crystals of Bi_2Se_3, $MnBi_2Te_4$, $MnBi_4Te_7$, and FeSe/$SrTiO_3$ thin films, his group demonstrated an energy resolution of <4 meV in static laser-based ARPES, a time resolution of 35 fs in trARPES, and a spatial resolution of ~10 μm in μARPES. Remarkably, their time resolution sets a new record for trARPES setups with probe pulses generated by solid-state nonlinear crystals. The detailed findings are published in *Review of Scientific Instruments* **92**, 113907 (2021).

2DCC Role: A part of this research benefits from a close collaboration between 2DCC and Prof. Yang who is an external user. The single crystals of $MnBi_2Te_4$ and $MnBi_4Te_7$ used in this work were grown using a flux method at the 2DCC Bulk Growth facility.



The MRPES platform combines all elements of traditional electronic structure characterizations in connection with a customized molecular beam epitaxy (MBE). $MnBi_4Te_7$ crystal structures corresponding to the two possible terminations: $MnBi_2Te_4$ (MBT) and Bi_2Te_3 (BT). Spectra taken with the trARPES module at 120 fs near Γ, showing the unoccupied band structures of the MBT termination and the BT termination.