Layer-by-layer engineering and deciphering of topological orders in magnetic topological insulators

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The advent of intrinsic magnetic topological insulators enables us to envisage various low-dimensional topological orders, such as the quantum anomalous Hall insulators and the axion insulators, at realistic cryogenic temperatures. These materials are represented by $MnBi_2Te_4$ and its derived superlattices $MnBi_{2n}Te_{3n+1}$. However, it has been controversial whether these materials exhibit the key ingredient for magnetic topological phases: an energy gap due to the time-reversal symmetry breaking. Moreover, the construction of high-quality magnetic topological insulators at the ultrathin limit has met significant challenges. In this talk, I will present a new technique, layer-encoded frequency-domain photoemission spectroscopy, which allows us to decipher the layer origins of various electronic states. By encoding layer indices with intralayer phonon frequencies, we measure the strengths of coupling with layer-specific phonons. This experiment reveals that the topological surface states on antiferromagnetic $MnBi_4Te_7$ are partially relocated to the nonmagnetic layers, reconciling the mystery of vanishing broken-symmetry gaps [1]. Moreover, I will present our recent progress on the "carpet-growth" of Bi_2Te_3 ultrathin films and $MnBi_2Te_4/Bi_2Te_3$ heterostructures using molecular beam epitaxy. These thin films extend coherently across a millimeter spatial scale without disruptions by substrate step edges. Angle-resolved photoemission spectroscopy studies yield unprecedentedly sharp electronic structures in agreement with first-principles calculations layer-by-layer, and suggest opportunities to realize the quantum spin Hall effect and quantum anomalous Hall effect at near-ambient temperatures [2].

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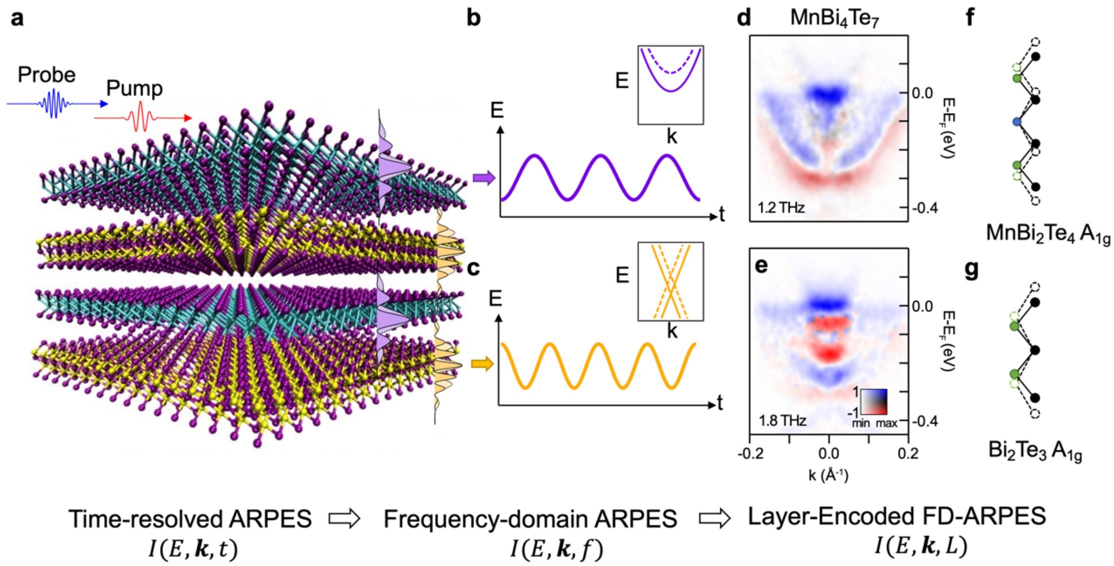

Figure 1. Resolving the layer origins of electronic states in $MnBi_4Te_7$ using layer-encoded, frequency-domain ARPES. (a) Schematic of pump-probe setup on a superlattice material. (b,c) Different electronic states are coupled to layer-specific coherent phonon oscillations. (d,e) Frequency-domain (FD) ARPES allows us to resolve the electronic states coupled to the $MnBi_2Te_4$ A_{1g} mode and the Bi_2Te_3 A_{1g} mode, respectively. The layer-frequency correspondence leads to layer-encoded FD-ARPES. The mode configurations are shown in panels (f) and (g).