Equilibrium and Ultrafast Response of Topological Matter to Optical Excitation

Jaime Sánchez-Barriga[a]

[a] *Helmholtz-Zentrum Berlin für Materialien und Energie, Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany*

Keywords: Topological materials, topological surface states, topological quantum phase transitions, spin- and angle-resolved photoemission, time-resolved photoemission, synchrotron radiation, ultrafast optical excitation.

In this talk, I will provide an overview of my research activity on spin-based phenomena in topological materials primarily using time-, spin- and angle-resolved photoemission as well as synchrotron-radiation methods. In the first part of the talk, I will concentrate on the spin-dependent properties of topological surface states (TSSs) in equilibrium by highlighting previous and recent results obtained using synchrotron-based photoemission at the RGBL-2 end-station permanently installed at the U125/2 undulator beamline of the synchrotron source BESSY-II in Berlin. This includes the first commissioning results concerning the spin texture manipulation of emitted photoelectrons from TSSs, the direct observation of magnetic and non-magnetic gaps at the Dirac point of TSSs and hedgehog spin textures, as well as the realization of topological quantum-phase transitions between topological crystalline insulators and strong topological insulators.

In the second part of the talk, I will focus on dynamical aspects such as observation of ultrafast spin-polarized electrical currents in energy-momentum space, the emergence of anisotropic coherent-phonon oscillations on topological insulator surfaces or the electron relaxation dynamics near the critical point of a trivial to topological quantum-phase transition. Finally, I will discuss the impact of ultrafast carrier transport on the dynamics of TSSs following laser excitation, and describe how the complex and alternating transient spin textures observed above the Fermi level on sub-picosecond time scales affect the ultrafast channels of charge and energy transfer that are relevant for the relaxation of carriers.

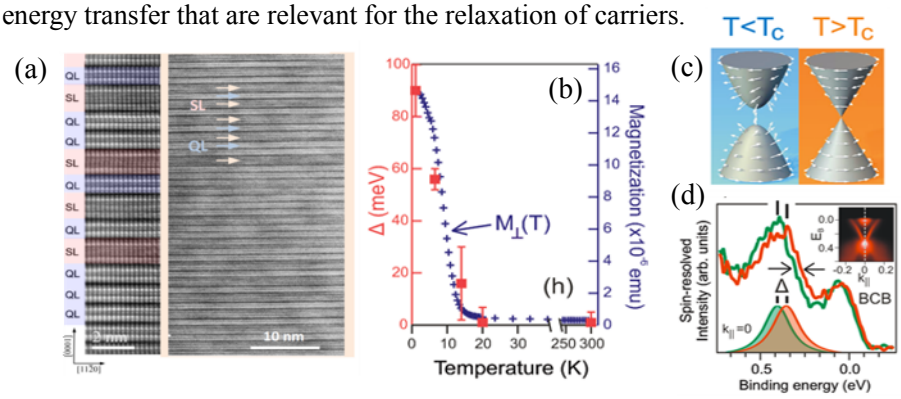

FIGURE 1. Example of a large magnetic gap at the Dirac point in Mn-doped Bi_2Te_3. The system exhibits (a) a self-organized alternating sequence of $MnBi_2Te_4$ septuple and Bi_2Te_3 quintuple layers, (b) an out-of-plane magnetic anisotropy which correlates with a band gap opening at the Dirac point of the topological surface state only below the Curie temperature T_c, and (c),(d) a ferromagnetic out-of-plane spin texture which can be resolved using spin- and angle-resolved photoemission [3].

REFERENCES

1. O. J. Clark, F. Freyse, I. Aguilera, A. Ionov, S. Bohzko, L. V. Yashina and J. Sánchez-Barriga, *submitted* (2021)
2. A. Varykhalov, F. Freyse, I. Aguilera, M. Krivenkov, D. Marchenko, G. Bihlmayer, S. Blügel, O. Rader and J. Sánchez-Barriga, *Physical Review Research* **2**, 013343 (2020)
3. E. Rienks*, S. Wimmer*, J. Sánchez-Barriga*, O. Caha*, P. S. Mandal, J. Ruzicka, A. Ney, H. Steiner, V. V. Volobuev, H. Groiss, M. Albu, G. Kothleitner, J. Michalicka, S. Khan, J. Minár et al., *Nature* **576**, 423 (2019).
4. P. S. Mandal, G. Springholz, V.V. Volobuev, O. Caha, A. Varykhalov, E. Golias, G. Bauer, O. Rader, and J. Sánchez-Barriga , *Nature Communications* **8**, 968 (2017)
5. J. Sánchez-Barriga *et al.*, M. Battiato, M. Krivenkov, E. Golias, A. Varykhalov, A. Romualdi, L. V. Yashina, J. Minár, O. Kornilov, H. Ebert, K. Held, J. Braun, *Physical Review B* **95**, 125405 (2017)
6. J. Sánchez-Barriga, A. Varykhalov, G. Springholz, H. Steiner,R. Kirchschlager, G. Bauer, O. Caha, E. Schierle, E. Weschke, A. A. Ünal, S. Valencia, M. Dunst, J. Braun, H. Ebert, J. Minár et al., *Nature Communications* 7, 10559 (2016)