Special seminar

Wednesday, July 30, 2025
1:30 pm
ZQE, Seminar room EG 003
Exclusively in person

"Creating semimetals from semiconductors"

Our decade-long journey to a 'true' Weyl semimetal and next-generation low-dissipation interconnects

The synthesis of new materials drives computing and electronics technology. For example, breakthroughs in the synthesis of the semiconductor GaN in the early 1990s gave us the blue LED and higher-performance power electronics [1]. Over the last two decades, physicists have been fascinated by semimetals, notably Weyl semimetals hosting emergent Weyl fermions. What would it take for semimetals to have the same technological impact as semiconductors? One problem is that our best Weyl materials to date all exhibit conventional metallic conductivity, arising from irrelevant conduction electrons which coexist with the Weyl fermions, shunt the electric current and obscure the unique Weyl properties [2-6]. I have now instead used molecular beam epitaxy to create a Weyl semimetal by doping the topological semiconductor Bi2Te3 with ferromagnetic Cr [7]. I find that (Cr,Bi)2Te3 exhibits a record bulk anomalous Hall angle > 0.5 (the key figure of merit for a magnetic Weyl semimetal) along with non-metallic conductivity, sharply distinct from earlier Weyl materials and conventional ferromagnets. Together with theory, our experiments suggest that (Cr,Bi)2Te3 has a 'truly semimetallic' Fermi surface composed entirely of emergent Weyl fermions, without irrelevant conduction electrons, giving us the first 'true' Weyl semimetal. Our design principle may serve as a bridge to commercial semiconductor technologies, and we expect that improving the crystalline quality should increase the figure of merit. Our results may enable low-dissipation Weyl interconnects superior to conventional metals [8] and offer a path to the three-dimensional quantum anomalous Hall insulator, which could allow bulk dissipation-less interconnects for efficient, high-density electronics.

[1] I. Akasaki, H. Amano & S. Nakamura. Nobel Prize in Physics (2014)
[2] Su-Yang Xu, I.B. *et al*. *Science* 349, 613 (2015)
[3] D. S. Sanchez, I.B. *et al*. *Nature* 567, 500 (2019)
[4] I.B. *et al*. *Nature* 604, 647 (2022)
[5] I.B. *et al*. *Science* 365, 1278 (2019)
[6] I.B. *et al*. *Phys. Rev. Lett.* 127, 256403 (2021)
[7] I.B. *et al*. *Nature* 637, 1078 (2025)
[8] A.I. Khan *et al. Science* 387, 62 (2025)

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About the speaker: As an undergraduate I developed detectors at the Laser Interferometer Gravitational Wave Observatory in Hanford, Washington (years before the binary black hole merger which won the Nobel Prize!). Then, during a year abroad at the Ecole Polytechnique in Paris I was captivated by the lectures of Antoine Georges on the quantum physics of crystals. So, I switched from astrophysics to condensed matter physics and pursued my Ph.D. at Princeton University with Zahid Hasan. I soon found myself at the frontier of the explosion of interest in Weyl semimetals, driven in part by our group's discovery in 2015. To broaden my scientific perspective, after my Ph.D. I escaped to Tokyo to work with the renowned Yoshinori Tokura and Naoto Nagaosa, acquiring a new passion for creating quantum materials. I have been honored by the Richard L. Greene Award of the American Physical Society (2021), as well as the Spicer Young Investigator Award of SLAC (California, 2021). I hope to inspire future scientists and make the world a better place through quantum.