THE CHINESE UNIVERSITY OF HONG KONG

Department of Physics

SEMINAR

Incommensurate Transverse Peierls Transition and Chiral Charge Density Waves in Topological Semimetal $EuAl_4$

by

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ALL INTERESTED ARE WELCOME
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Abstract

In one-dimensional quantum materials, conducting electrons and the underlying lattices can undergo a spontaneous translational symmetry breaking, known as Peierls transition [1]. For nearly a century, the Peierls transition has been understood within the paradigm of electron-electron interactions mediated by longitudinal acoustic phonons. This classical picture has recently been revised in topological semimetals, where transverse acoustic phonons can couple with conducting *p*-orbital electrons and give rise to an unconventional Fermi surface instability, dubbed the transverse Peierls transition (TPT) [2]. Most interestingly, the TPT induced lattice distortions can further break rotation or mirror/inversion symmetries, leading to nematic or chiral charge density waves (CDWs). In this talk, I will present experimental observation of an incommensurate TPT in tetragonal Dirac semimetal $EuAl_4$ [3]. We observed the complete softening of a transverse acoustic phonon at the CDW wave vector upon cooling, whereas the longitudinal acoustic phonon is nearly unchanged. The first-principles calculations show that the incommensurate CDW wave vector matches the calculated charge susceptibility peak and connects the nested Dirac bands with Al $3p_x$ and $3p_y$ orbitals. Our second harmonic generation measurements show that the CDW induced lattice distortions break all vertical and diagonal mirrors whereas the four-fold rotational symmetry is retained below the CDW transition. These observations strongly suggest a chiral CDW in $EuAl_4$ and highlight the TPT as a new avenue for chiral quantum states.

[1] Frohlich, H. On the Theory of Superconductivity: The One-dimensional Case, Proc. of the Royal Soc. A 233, 296 (1954).
[2] Luo, K. F. & Dai, X. Transverse Peierls Transition, *Phys. Rev. X* **13**, 011027 (2023).
[3] Yang, F. Z. et al., Incommensurate Transverse Peierls Transition, arXiv: 2410.10539 (2024).

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