9th International Workshop on 2D Materials

Title of the Presentation: Population inversion and Dirac fermion cooling in 3D Dirac semimetal Cd_3As_2

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Short Biography:

After receiving the B.S. degree of Mathematics and Physics from department of physics in Tsinghua university in 2016, he began Ph. D. in Prof. Shuyun Zhou's group in Tsinghua University. He focuses on studying the novel electronic structure and light-matter interaction in two-dimensional and topological materials by utilizing state-of-the-art angle-resolved photoemission spectroscopy (ARPES) including time-resolved ARPES and Nano/Micro-ARPES. He has been awarded *Top 10 Graduate Students Award* in Tsinghua university (2021) and *Young Scientist Prize* in RPGR (2019).

Abstract:

Revealing the ultrafast dynamics of three-dimensional (3D) Dirac fermions is critical for both fundamental science and device applications [1]. So far, how the cooling of 3D Dirac fermions differs from that of two-dimensional (2D) and whether there is population inversion are fundamental questions to be answered. Time- and angle-resolved photoemission spectroscopy (TrARPES) is a powerful technique for revealing the ultrafast dynamics, however, TrARPES study of 3D Dirac fermions has been missing so far due to the lack of tunable probe photon energy, which is required to scan through the conical dispersion at the desired out-of-plane momentum. Here we develop a novel TrARPES system with a widely tunable probe photon energy from 5.3 to 7.0 eV [2] and reveal the ultrafast dynamics of 3D Dirac fermions for the first time in a model 3D Dirac semimetal Cd_3As_2 [3]. The energy- and momentum-resolved relaxation rate shows a linear dependence on the energy, suggesting Dirac fermion cooling through intraband relaxation. Moreover, a population inversion is reported based on the direct observation of accumulated photoexcited carriers in the conduction band with a lifetime of 3.0 ps. Our work provides direct experimental evidence for a long-lived population inversion in a 3D Dirac semimetal, which is in contrast to 2D graphene with a much shorter lifetime.

[1] C. Bao *et al.*, Nat. Rev. Phys. 4, 33 (2022).
[2] C. Bao *et al.*, Rev. Sci. Instrum. 93, 013902 (2022).
[3] C. Bao *et al.*, Nano Lett. (2022) doi: 10.1021/acs.nanolett.1c04250

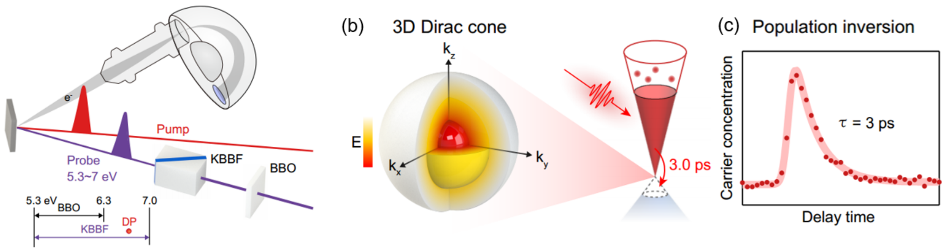

Fig. 1. (a,b) Schematics for TrARPES with tunable probe photon energy and photoexcited 3D Dirac cone. (c) The ultrafast temporal evolution of carrier concentration in conduction band.