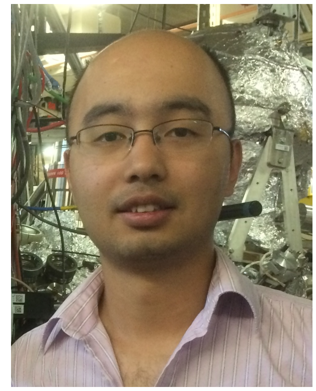
Postdoctoral Fellowship Highlight

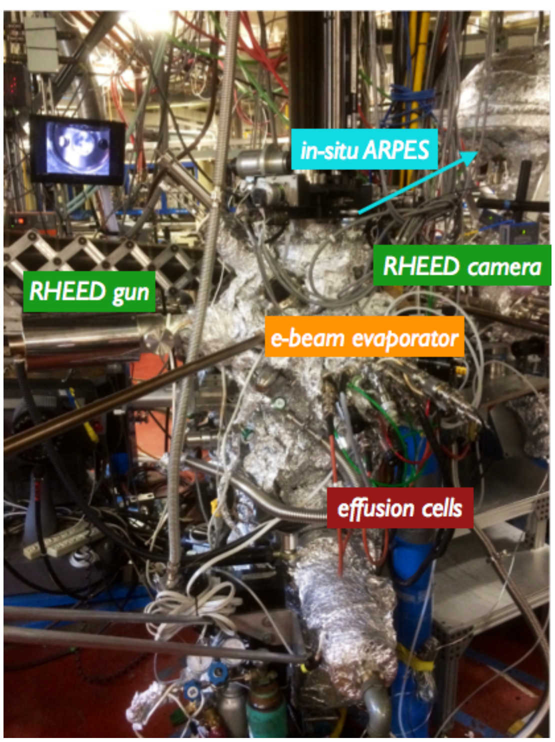


Yi Zhang, Ph.D., Physics

Years of Fellowship: 2011–present (03/2014)
Collaborating Institution: Stanford University
Currently: Postdoc Fellow, Advanced Light Source

Project: **Development of MBE thin film growth capability at Beamline 10.0.1**

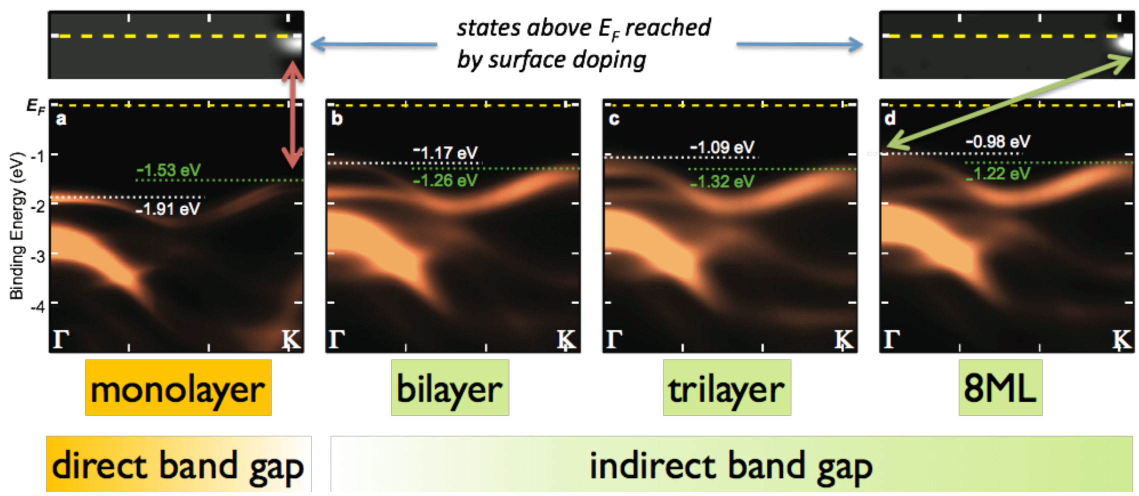
Understanding, controlling, and tailoring material properties at the level of electrons are the ultimate goals of today's material science and condensed matter physics research, as addressed by the Department of Energy's Grand Challenges for Basic Energy Science report. Owing to the complex nature of the problems, tackling them requires a multi-nodal approach in synthesis, characterization, and theory/computation. A useful contribution to this grand challenge could be derived from a combined effort of atomically controlled thin film growth with in situ spectroscopic characterization utilizing powerful synchrotron light sources.



MBE system at the beamline 10.0.1 combined with *in situ* ARPES

Since he joined the ALS in October 2011, Dr. Yi Zhang has developed and commissioned a molecular-beam epitaxy (MBE) thin film growth chamber in connection with the pre-existing angle-resolved photoemission (ARPES) endstation at ALS Beamline 10.0.1. The growth chamber is equipped with a four channel e-beam evaporator with separate flux monitors, four effusion cells optimized for different temperatures, a silicon evaporator, a crystal-thickness monitor, a reflection high-energy electron diffraction (RHEED) system, an Argon sputter gun, a low energy electron diffraction (LEED) system, and a sample stage capable of heating up to 1500 ˚C. Thin-film samples grown in this chamber can be easily transferred in ultrahigh vacuum to the ARPES system for in-situ characterization and investigation of electronic structure.

Using the unique combination of MBE and in-situ synchrotron ARPES, Dr. Yi Zhang has been studying new types of topological quantum materials and transition metal dichalcogenides. Of particular importance, he has successfully grown thin-film samples of $MoSe_2$ with well-controlled thickness from a single layer to 2-, 3-, 8-layers and directly observed the transition from a direct band gap semiconductor to indirect band gap semiconductors. This makes a good example of band gap engineering by thickness control, and opens a potential route towards thin, flexible, and more efficient optoelectric and spintronic devices.



Dr.
Yi

ARPES investigation of the electronic structure of epitaxial $MoSe_2$ thin films. A distinct direct-indirect band gap transition is observed.

Zhang's effort not only produces novel and exciting science, but also benefits the users working at the beamline. In the process of developing the MBE system at the beamline, he has upgraded the existing sample surface preparation chamber significantly and maintains it in a excellent working condition. Yi's contribution is very timely and beneficial to the user community as evidenced by the growth over the last seven years in the number of users from 10% to 40%. The MBE system is also open to users. Due the nature of the work involved in thin film growth, we expect it to be based on long-term collaborations and we are looking forward to them.

Publications related to this highlight:

1. Y. Zhang, T.-R. Chang, B. Zhou, Y.-T. Cui, H. Yan, Z. Liu, F. Schmitt, J. Lee, R. G. Moore, Y. L. Chen, H. Lin, H.-T. Jeng, S.-K. Mo, Z. Hussain, A. Bansil and Z.-X. Shen, "Direct observation of the transition from indirect to direct band gap in atomically thin epitaxial $MoSe_2$", *Nature Nanotechnology* **9**, 111 (2014).

2. Z. K. Liu, B. Zhou, Y. Zhang, Z. J. Wang, H. M. Weng, D. Prabhakaran, S. -K. Mo, Z. X. Shen, Z. Fang, X. Dai, Z. Hussain and Y. L. Chen, "Discovery of a Three-dimensional Topological Dirac Semimetal, Na_3Bi", *Science* **343**, 864 (2014).