The 1st International Conference on the Electronic Structure of Complex Quantum Matter and Microstructure

Program & Abstract Book

May 30th - June 2nd, 2015
Shanghai, China
Accommodation

Take a taxi to Fu Xuan Hotel: No.400 Guo-ding Road, at the cross traffic light of Han-dan Rd. and Guo-ding Rd. It’s a gray 21-floor building.

复宣酒店（复旦大学新闻培训中心）：上海杨浦区国定路400号，就在邯郸路和国定路的交叉口，21层灰色的高楼，如下图所示。

If you need any help, please contact us.
Ms. Miao: Cell Phone: 18121202026; Office: +86-21-51630206
Prof. Feng: Cell Phone: 13764276009; Office: +86-21-51630266
Meeting Venue

Room 103, East Sub-building, GuangHua Tower, Fudan University
(marked with 3, the tallest (100m) twin-tower in the surrounding area)

Brief Schedule

Day 1: Saturday, May 30
14:00-18:00  Registration @ Fu-Xuan Hotel Lobby
   (Address: 上海国定路 400 号，复宣酒店，marked with 1)
18:00-20:30  Welcome Reception @Café mix, Crowne Plaza Hotel
   (Address: 复旦皇冠假日酒店，上海邯郸路 199 号, marked with 2)

Day 2: Sunday, May 31
8:50-12:40  Meeting @Room 103, East Sub-building, GuangHua Tower, Fudan University (marked with 3)
12:40-13:40 Lunch @ Room "庐山村", 3F, "且苑" Canteen, marked with 4
14:30-18:00 Meeting @ 3
18:30-20:30 Banquet @ Room 511, WH Ming Hotel
   (Address: 佳木斯路777号，小南国花园酒店，511包房)

Day 3: Monday, June 1
9:00-12:30 Meeting @ 3
12:30-13:30 Lunch @ 4
13:45 - 21:00 Conference Excursion& Dinner [Please come to the assembly station (the parking lot outside the canteen) after lunch]
### Scientific Program

*(Each presentation includes 20 minutes talk plus 5 minutes Q&A)*

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**June 1, 2015 (Mon.)**

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Sharper and sharper experimental tools are often crucial for understanding of novel physical phenomena and making new discoveries. Today in condensed matter physics we are experiencing need for revolutionary new instrumentation for understanding interplay of many degrees of freedom interacting at different energy, length and time scales. These interactions lead to new phases of matter and emergent phenomena such as high temperature superconductors, topological insulators and thermoelectric materials, to name a few. My talk will focus, through various examples, upon the necessity for advanced techniques and instrumentation to elucidate the basic physics in the arena of soft x-ray synchrotron radiation and free electron laser.
Shining (low frequency) light on quantum magnets: Ising spin chains, quantum spin ice, and spin-orbital liquids

N. Peter Armitage

Institute of Quantum Matter, Dept. of Physics and Astronomy, The Johns Hopkins University, Baltimore MD, 21210

Although typically we regard optical spectroscopies as probes of electronic degrees of freedom in materials, light's time-varying magnetic field allows one to couple to magnetic degrees of freedom. This talk will review recent advances in the area of time-domain THz spectroscopy and its application to "quantum" magnets. Our high signal to noise, routinely excellent energy resolution, and unique ability to measure complex response functions gives unique insight into the magnetic response of quantum materials and gives several distinct advantages in these matters over neutron scattering. I will give examples of the use of the technique on quantum magnet systems as diverse as 1D Ising spin chains, quantum spin ices, and spin-orbital liquids.
Two-Dimensional Topological Insulator films with Large Energy Gap

Dong Qian
Department of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China

One of the fundamental properties of the mobile electrons in the topological edge states of topological insulators (TI) is the spin–momentum locking that will be extremely useful in relation to possible applications in spintronics. In this sense, 2D TI can be advantageous over 3D TI in transport applications because electrons can only move along two well-defined directions in a 2D TI’s 1D metallic edges. However, unlike the relatively rich family of 3D TI systems, in some sense, the HgTe and GaSb related quantum wells are the only two well-defined 2D TI with very small energy gap (~ 10 meV). Several other 2D TIs with large energy gap have been proposed. In this talk, I will discuss our experimental efforts on fabrication of new 2D TI films. Using molecular beam epitaxy, ultrathin films with large spin-orbital coupling were successfully grown including single bilayer Bi and Sn. The atomic and electronic structures of those possible 2D TI films were systematically studied by scanning tunneling microscopy and angle-resolved photoemission with the help of LDA calculations.
Superconductivity and nematicity in FeSe thin film

Y. Zhang\textsuperscript{1,2}, J. J. Lee\textsuperscript{1,3}, W. Li\textsuperscript{1}, M. Yi\textsuperscript{1,3}, R. G. Moore\textsuperscript{1}, Z.-K. Liu\textsuperscript{1,3}, M. Hashimoto\textsuperscript{4}, S.-K. Mo\textsuperscript{2}, Z. Hussain\textsuperscript{2}, T. P. Devereaux\textsuperscript{1,3}, D.-H. Lee\textsuperscript{5,6}, D. H. Lu\textsuperscript{4,*}, Z.-X. Shen\textsuperscript{1,3,*}

\textsuperscript{1}Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025, USA
\textsuperscript{2}Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
\textsuperscript{3}Geballe Laboratory for Advanced Materials, Departments of Physics and Applied Physics, Stanford University, Stanford, California 94305, USA
\textsuperscript{4}Stanford Synchrotron Radiation Lightsource, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025, USA
\textsuperscript{5}Department of Physics, University of California at Berkeley, Berkeley, California, 94720, USA
\textsuperscript{6}Material Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

Superconductivity in one monolayer (1ML) FeSe thin film has attracted great interest recently due to its intriguing interfacial properties and possibly high superconducting transition temperature ($T_c$) over 77 K. Here, we report angle-resolved photoemission spectroscopy (ARPES) studies on the superconductivity and nematicity in FeSe thin film. In 1ML FeSe thin film, we found that (1) the glide plane symmetry is nearly unbroken despite the asymmetry induced by the substrate, and (2) the superconducting gap is nodeless but moderately anisotropic, with four gap minima along the iron-selenium-iron bond directions. Detailed fitting of superconducting gaps suggests that there is no sign change of the gap on the electron pockets, hence is consistent with simple s-wave pairing. On the other hand, in 35ML FeSe thin film, without the complexities induced by co-existing long-range magnetic order, we clearly delineate the electronic signature of nematic state. It is characterized by an orbital splitting between $d_{xz}$ and $d_{yz}$, whose splitting energy is only pronounced near the Brillouin zone corner. Such nontrivial momentum dependence suggests that the orbital anisotropy does not occur on-site in a ferro-orbital manner. Instead, the anisotropy occurs in the nearest-neighbor hopping of $d_{xz}$ and $d_{yz}$. The more important question may be whether there exist strong nematic fluctuations in 1ML FeSe with the complete suppression of nematic order. The answer to this question is intimately related to the pairing mechanism in 1ML FeSe. Further investigations are required to elucidate these issues.
Observation of universal strong orbital-dependent correlation effects in iron chalcogenides

Ming Yi\textsuperscript{1,2}, Zhongkai Liu\textsuperscript{1,2}, Yan Zhang\textsuperscript{1,3}, Rong Yu\textsuperscript{4,5}, Qimiao Si\textsuperscript{5}, Zhi-Xun Shen\textsuperscript{1,2}, and Donghui Lu\textsuperscript{6}

\textsuperscript{1}SIMES, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA
\textsuperscript{2}GLAM, Stanford University, Stanford, California 94305, USA
\textsuperscript{3}ALS, Lawrence Berkeley National Lab, Berkeley, California 94720, USA
\textsuperscript{4}Department of Physics, Renmin University of China, Beijing 100872, China
\textsuperscript{5}Department of Physics and Astronomy, Rice University, Houston, Texas 77005, USA
\textsuperscript{6}SSRL, SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA

Establishing the appropriate theoretical framework for unconventional superconductivity in the iron-based materials requires correct understanding of the electron correlation strength. This fundamental issue becomes especially relevant with the discovery of the iron chalcogenide superconductors \(A_x\text{Fe}_{2-y}\text{Se}_2\) (\(A = \) alkali metal), the first iron-based superconductor family in proximity to an insulating phase, suggesting stronger electron correlation in this family. In this talk, I will present ARPES study on three representative iron chalcogenide superconductors, \(\text{FeTe}_{0.56}\text{Se}_{0.44}\), \(\text{K}_{0.76}\text{Fe}_{1.72}\text{Se}_2\), and monolayer FeSe film grown on \(\text{SrTiO}_3\). Our results demonstrate that the iron chalcogenides are in a strongly correlated regime, with an orbital-selective strong renormalization in the \(d_{xy}\) bands. Furthermore, raising temperature drives all three compounds from a metallic superconducting state to an orbital-selective Mott phase, where the \(d_{xy}\) orbital loses all spectral weight while other orbitals remain itinerant [1]. These observations establish universal orbital-selective strong correlation behaviors in iron chalcogenides and highlight the importance of orbital-physics in iron-based superconductors.

Figure 1: Calculated phase diagram of the OSMP.

*This work supported by the Local Organizing Committee.
Comparison of Ce-based and other high-Tc superconductors

Filip Ronning¹

¹Los Alamos National Lab, Los Alamos, NM 87545 USA

Ce-based heavy fermions offer a rich playground within which to explore unconventional superconductivity. Because of the small energy scales present in heavy fermions, they are often ideal model systems through which to explore the interplay between magnetism and superconductivity, which are present in many classes of unconventional superconductors. I will give a brief survey of heavy fermion superconductivity and highlight some similarities and differences to other high-Tc superconductors. Then, I will highlight some of our recent work which focuses on understanding the parent compound CeRhIn₅, including inelastic neutron scattering to reveal the spin wave spectrum, and high field magnetotransport data illustrating a field induced density wave akin to what has been observed in the cuprates.
I have been enjoying a lot of fruitful collaborations with current and former group members of Prof. Zhi-xun Shen. What I can offer have been single crystals; ranging from transition-metal oxides having strong electron correlations (including high-$T_c$ cuprates) to heavy-metal chalcogenides having strong relativistic effects (including topological insulators and superconductors). It is noted that, upon request, our crystals can be accompanied by not only the results of the experimental characterization but also the predictions of the electronic structures from first principles calculations. In my talk, with some examples, I would like to discuss “Seeds” and “Needs” in our future collaborations.

Figure 1: Single crystals grown in my group.
Several transition-metal dichalcogenides exhibit a striking crossover from indirect to direct band gap semiconductors as they are thinned down to a single monolayer. Here, we demonstrate how an electronic structure characteristic of the isolated monolayer can be created at the surface of a bulk MoS2 crystal. This is achieved by intercalating potassium in the interlayer van der Waals gap, expanding its size while simultaneously doping electrons into the conduction band. Our angle-resolved photoemission measurements reveal resulting electron pockets centered at the $K_g$ and $K'_g$ points of the Brillouin zone, providing the first momentum-resolved measurements of how the conduction band dispersions evolve to yield an approximately direct band gap of $\sim 1.8$ eV in quasi-freestanding monolayer MoS2. As well as validating previous theoretical proposals, this establishes a novel methodology for manipulating electronic structure in transition-metal dichalcogenides, opening a new route for the generation of large-area quasi-freestanding monolayers for future fundamental study and use in practical applications [1].

*This work supported by hai and Research Fund, Suranaree University of Technology (TRF Grant RSA5680052), Office of Higher Education Commissions under NRU project, the U.K. EPSRC (EP/I031014/1) and ERC (207901).
Doped Mott Insulators may be conducting, but they are usually not well described by the standard theory of metals. These compounds, particularly 3d transition metal oxides, are among the most studied compounds in condensed matter physics with properties such as high temperature superconductivity, colossal magnetoresistance, and metal-insulator transitions. However, in many cases the basic ground states are not known. Early theory for doped Mott insulators predicted that the doped charges should segregate leaving charge-rich conducting regions and charge-poor insulators. When such behaviour was not initially seen, the idea lost favour. However, many reports surfaced concerning short length scale charge inhomogeneity. More recently, our group has focused charge doping transition metal oxides through controlling the concentration of oxygen, and compared these compounds to those produced by the usual method of cation substitution. For two quite different systems, a high temperature superconductor and a magnetic perovskite, we have found similar behavior. Samples doped via cation substitution, where the dopant ions are immobile, show continuously varying phases and glassy electronic response. However, samples doped using highly mobile oxygen defects segregate into large charge-rich and charge-poor regions with distinct electronic properties. We are working to fully characterize the separate regions with an eye toward understanding what makes some charge states particularly stable. This work will allow us to identify more precisely the inherent ground state of doped Mott insulators.

*This work on superconductors supported by USDOE-BES through contract DE-FG02-00ER45801. Work on ferromagnetic oxides is supported by the United States NSF through grant DMR-0907197.
In this talk, I will report our angle-resolved photoemission work on the electronic structure and superconductivity of FeSe/SrTiO$_3$ films [1-4], as well as some latest results on quantitative determination of fluctuations for high temperature superconductivity in cuprates. I will also briefly report on the electronic structure and spin texture of Bi$_2$Se$_3$ topological insulator [5] and latest result on direct observation of Dirac cones in single-layer silicene[6].

1) Defa Liu, Wenhao Zhang, Daixiang Mou, Junfeng He, Xucun Ma, Qikun Xue and X. J. Zhou et al., Nature Communications 3, 931 (2012);
2) Shaolong He, Junfeng He, Wenhao Zhang, Lin Zhao, Xucun Ma, Qikun Xue and X. J. Zhou et al., Nature Materials 12, 605 (2013);
3) Xu Liu, Defa Liu, Wenhao Zhang, Junfeng He, Xucun Ma, Qikun Xue and X. J. Zhou et al., Nature Communications 5, 5047 (2014);
4) Junfeng He, Xu Liu, Wenhao Zhang, Lin Zhao, Xucun Ma, Qikun Xue and X. J. Zhou et al., PNAS. 111, 18501 (2014).
5) Zhuojin Xie, Shaolong He and X. J. Zhou et al., Nature Communications 5, 3382 (2014).
Self-energy and mass renormalization of strongly-correlated vanadium oxides SrVO₃ revealed by ARPES and inverse ARPES

T. Yoshida¹, S. Yamamoto¹, D. Shimonaka¹, A. Fujimori², H. Sato³, H. Namatame³, M. Taniguchi³, H. Kumigashira⁵, K. Ono⁵, S. Miyasaka⁶, S. Tajima⁶, and S. Biermann⁷

¹Graduate School of Human and Environmental Studies, Kyoto University,
²Department of Physics, University of Tokyo, Japan
³Hiroshima Synchrotron Radiation Center, Hiroshima University, Japan
⁴Graduate School of Science, Hiroshima University, Japan
⁵Photon Factory, Institute of Materials Structure Science, KEK, Japan
⁶Graduate School of Science, Osaka University, Japan
⁷Centre de Physique Théorique, Ecole Polytechnique France

SrVO₃ is one of the perovskite-type light transition-metal oxides and is a prototypical Mott-Hubbard-type system with d¹ electron configuration. Therefore, SrVO₃ is an ideal system to study the fundamental physics of electron correlation and has been extensively studied by photoemission spectroscopy. Also, the electronic structure of this system has been studied by a dynamical mean-field theory (DMFT) calculation, because the system is ideal for the realistic modeling of correlated materials.

Detailed ARPES measurements have been achieved by the growth of high-quality films using the pulsed laser deposition technique. In our ARPES study of SrVO₃ with thin-film sample, we have revealed the self-energy with “kink” structure, which is similar to the high-Tc cuprates [1]. Also, the self-energy in a wide energy range has been deduced using the Kramers-Kronig (KK) relation.

On the other hand, a recent theoretical study by GW+DMFT calculation has pointed out that the mass renormalization is asymmetric between the occupied and unoccupied electronic states [2]. Therefore, we have studied of the unoccupied band of SrVO₃ by angle resolved inverse photoemission spectroscopy (ARIPES). As shown in Fig. 1, compared with a band-structure calculation, one can find that the effective electron mass is enhanced in both sides. Moreover, the mass renormalization in the unoccupied state is smaller than that of the occupied states, qualitatively consistent with the result of GW+DMFT calculation [2]. The observed asymmetric mass renormalization provides new insight into understanding of strongly correlated electronic structure.

Figure 1: Image plots deduced by taking second derivative of the ARPES and ARIPES spectra for SrVO₃.

Electronic structure evolution from metal to ininsulator in iron-selenides and bilayer manganites

Zhe Sun
National Synchrotron Radiation Laboratory, University of Science and Technology of China

In correlated electron systems, electronic structures show evident changes as the electronic systems evolve from metal to insulator, which leads to various fascinating physical properties. We will show the unusual changes of electronic structures in $A_xFe_{2-y}Se_2$ and $La_{2-2x}Sr_{1+2x}Mn_2O_7$. In iron-selenide superconductor $A_xFe_{2-y}Se_2$, the isovalent doping of S and Te can suppress the superconducting transition temperatures with either positive or negative chemical pressures and drive the system into metal and insulator, respectively. From metal to insulator with the variation of S/Se/Te, the bandwidth of Fe 3d bands decreases and eventually the coherent bands disappear in the insulating phase. In these materials, the electronic structure evolution can be fit into a prototypical phase diagram of bandwidth-controlled Mott system, which indicates that iron-based superconductors can be considered to be a derivative of Mott insulator and it might be unified with cuprate superconductors in the framework of Mott physics. In $La_{2-2x}Sr_{1+2x}Mn_2O_7$, we have studied in the overdosed region how the low-energy spectral weight changes as a function of temperature or doping, when the system approaches an insulating phase. Near the nodal region, as expected, the quasiparticle effective mass increases and Fermi velocity decreases. In contrast, near the antinodal region, the quasiparticile effective mass and Fermi velocity remain basically unchanged when the insulating phases are approached. Nevertheless, the reduction of low-energy spectral weight is the common behavior that is closely connected to MIT.
Charge order in cuprates: from hole to electron doping

Andrea Damascelli$^{1,2}$

$^1$Department of Physics & Astronomy, UBC, Vancouver, British Columbia V6T 1Z1, Canada
$^2$Quantum Matter Institute, UBC, Vancouver, British Columbia V6T 1Z4, Canada

Charge ordering has resurged as a prominent phenomenon in the physics of high-$T_c$ cuprates. In this talk I will review our recent results from Bi2201 [1,2] and YBCO hole-doped cuprates [3,4], as well as electron doped NCCO [5]. With the early discovery of stripe-like order in La-based cuprates, this establishes charge ordering instabilities to be omnipresent in all cuprate families. I will discuss the connection between charge ordering and pseudogap phenomenology [2,5], similarities and asymmetries between hole and electron doping [2,5], and the native local symmetry of charge modulations [3,4].

Photoelectron spectroscopy: From UHV to Liquid-Solid interface

Zhi Liu¹,², Zahid Hussain²

1. Shanghai Institute of Microsystem and Information Technology, CAS, Shanghai 200050
2. Advanced Light Source, Lawrence Berkeley National Lab, Berkeley, CA 94305

The application of photoelectron spectroscopy (PES) to catalysis and environmental science has long driven the advancement of PES to function at higher pressure¹². While such systems have been developed for the past 30 years, there has been a resurgence of ambient pressure PES(AP-PES) in the past decade due to advanced construction of electron analyzers and the exploitation of synchrotron facilities with high brightness, tunable, monochromatic light with small spot size.

Several new facility are currently being planned or constructed at US and international synchrotron light sources. ALS has pioneered the development of new AP-PES both at soft and hard X-ray³⁵. By using X-ray up to 5 keV, we can perform AP-XPS at a pressure up to 110 torr. By using hard X-ray and increasing the probing depth of photoelectrons to >10 nm, it enables us to study not only the gas-solid interface but also the liquid-solid interface. In this talk, I will give an overview of science projects in heterogeneous catalysis and electro-chemistry using these new systems. Furthermore, I will present results of in-situ study on the solid-liquid interface of a working model electrochemical cell.

The continuous improvements of soft and hard X-ray AP-PES technique are providing many research communities a powerful in-situ tool to directly study the gas-solid and liquid-solid interfaces.

* This work is supported by US Department of Energy under contract No. DE-AC02-05CH11231. Z. L. is supported by Natural Science Foundation of China (No. 11227902).
Transfer of spectral weight across the gap of $\text{Sr}_2\text{IrO}_4$
induced by La doping


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$^2$Laboratoire des Solides Irradiés, Ecole polytechnique, 91128 Palaiseau cedex, France
$^3$Synchrotron SOLEIL, L’Orme des Merisiers, Saint-Aubin-BP 48, 91192 Gif sur Yvette, France
$^4$CNR-IOM, TASC Laboratory, AREA Science Park - Basovizza, I-34149 Trieste, Italy
$^5$Geballe Laboratory for Advanced Materials and, Stanford University, Stanford, California 94305-4045, USA

I will present an Angle Resolved PhotoElectron Spectroscopy (ARPES) study of the evolution of the electronic structure of $\text{Sr}_2\text{IrO}_4$, when holes or electrons are introduced, through Rh or La substitutions. At low dopings, the added carriers occupy the first available states, at bottom or top of the gap, revealing an anisotropic gap of 0.7eV in good agreement with STM measurements. At further doping, we observe a reduction of the gap and a transfer of spectral weight across the gap, although the quasiparticle weight remains very small. We discuss the origin of the in-gap spectral weight as a local distribution of gap values$^1$.

Figure 1: Energy positions of the J=1/2 peak at X (blue points) and J=3/2 peak at □ (red points) measured around 50K for different samples of $\text{Sr}_2\text{IrO}_4$ (middle), $\text{Sr}_2\text{IrO}_4$ doped with Rh (left) and La (right). The axis roughly corresponds to different dopings, ranging from 10 to 15% in the case of Rh and 1 to 4% in the case of La.

1) V. Brouet et al., cond-mat/1503.08120
Epitaxial growth and \textit{in-situ} angle-resolved photoemission spectroscopy study of novel artificial iridate systems

Z. T. Liu,\textsuperscript{1} M. Y. Li,\textsuperscript{1} H. F. Yang,\textsuperscript{1} C. C. Fan\textsuperscript{1}, J. S. Liu\textsuperscript{1} and D. W. Shen\textsuperscript{1,\*}

\textsuperscript{1} State Key Laboratory of Functional Materials for Informatics, SIMIT, Chinese Academy of Sciences, Shanghai, 200050, China
\textsuperscript{*} dwshen@mail.sim.ac.cn

In this talk, I will introduce how to synthesize and study the artificial 5d iridate thin films by the combo of oxide molecular beam epitaxy (OMBE) and angle-resolved photoemission spectroscopy (ARPES) techniques. We will report \textit{in-situ} ARPES measurements on the electronic structure of epitaxial pseudocubic-structured SrIrO\textsubscript{3} thin films, in which the unique spin-orbit coupling induced semi-metallic properties were comprehensively investigated. Moreover, we successfully synthesized a series of high-quality [(SrIrO\textsubscript{3})\textsubscript{m}/(SrTiO\textsubscript{3})\textsubscript{n}]\textsubscript{m}/SrTiO\textsubscript{3}(100) superlattices (Fig. 1) using OMBE, and realized the metal-insulator transition (MIT) by artificial dimensionality control of the iridates. The mechanism of this MIT was then investigated by both transports and our combined OMBE and ARPES system.

Figure 1: Sketch drawings of the artificial epitaxial [(SrIrO\textsubscript{3})\textsubscript{m}/(SrTiO\textsubscript{3})\textsubscript{n}]\textsubscript{m}/SrTiO\textsubscript{3}(001) superlattices. Note the m =\infty superstructure evolves to the pseudocubic -structured SrIrO\textsubscript{3} thin film.
Electron Dynamics in Cuprate Superconductors

Dan Dessau¹, Ted Reber¹², Stephen Parham¹, Haoxiang Li¹, Xiaoqing Zhou¹, N. Plumb¹, Tom Nummy¹, Justin Waugh¹, Justin Griffith¹, Gerald Arnold¹, H. Iwasawa², J. S. Wen³, Z. J. Xu³, Genda Gu³, Y. Yoshida⁴, H. Eisaki⁴, Y. Aiura⁴

¹Department of Physics, University of Colorado, Boulder, CO USA
²Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hiroshima, Hiroshima 739-0046, Japan.
³Condensed Matter Physics and Materials Science Department, Brookhaven National Labs, Upton, New York, 11973 USA.
⁴AIST Tsukuba Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki 3058568, Japan.

We have developed a number of new ways to extract the intrinsic (homogeneous) electronic self-energies of the cuprate superconductors. The first of these was the TDoS (Tomographic Density of States) method of ARPES analysis, in which we showed ARPES scattering rates that are up to an order of magnitude smaller than that obtained from the standard MDC or EDC peak analysis, with the new TDoS scattering rates consistent with results from other probes. Detailed studies using the new TDoS method enables us to extract the temperature and k-dependence of the scattering rates and pairing energies across the phase diagram, showing an especially strong temperature dependence of the electron self energy as well as uncovering critical new scalings, and we connect to STM disorder, thermodynamics experiments, etc. We obtain complementary information of the electron dynamics from time-resolved pump-probe ARPES, with good agreement of the uncovered parameters from the various techniques.
Switching quantum materials properties with light

Alessandra Lanzara$^{1,2}$

$^1$Physics Department, University of California, Berkeley
$^2$Materials Science Division, Lawrence Berkeley National Laboratory

The recent advancements in laser technology have dramatically expanded the applications of lasers to table top experiments in condensed matter physics. Femtosecond time-resolved spectroscopy techniques are emerging tools in the study of quantum materials, offering new paths to disentangle coexisting phases with similar energy scale, selectively tune a specific phase across a quantum critical point and create hidden states that do not exist in equilibrium, to name a few.

In this talk I will present some of our recent work where ultrafast light is used to manipulate electron charges, spin and lattice to reveal underlying properties in quantum materials, to drive metal insulator transition, to depin a charge density wave, to destroy superconductivity and to control spin texture in topological insulators. Future direction in the field will be discussed.
Atomic-scale Control of Emergent Phenomena in Correlated Oxide Heterostructures

Kyle M. Shen

Department of Physics, Cornell University, Ithaca NY 14853, USA

Our ability to control the electronic properties of materials, for instance at semiconductor interfaces, has had enormous scientific and technological implications. Recently, this concept has been extended to complex transition metal oxides which possess inherently strong quantum many-body interactions, such as correlated transition metal oxides, allowing us to synthesize artificial heterostructures which can harbor novel electronic or magnetic properties. I will describe some examples of our recent work in creating such heterostructures using oxide molecular beam epitaxy and using knobs such as dimensionality or biaxial strain to control their properties, while employing high-resolution angle-resolved photoemission spectroscopy (ARPES) to probe the effects on their electronic structure. In particular, I will describe how dimensional confinement at interfaces can be used to drive a metal-insulator transition in both superlattices of colossal magnetoresistive manganites and ultrathin films of correlated nickelates, and describe our recent work using epitaxial strain to control the electronic structure and properties of other correlated oxides.
Understanding Quantum Materials Microscopically using Time-Resolved Photoemission

Shuolong Yang\textsuperscript{1,2}, Jonathan A. Sobota\textsuperscript{1,3}, Dominik Leuenberger\textsuperscript{1,2}, Hadas Soifer\textsuperscript{1,2}, Patrick S. Kirchmann\textsuperscript{1}, and Zhi-Xun Shen\textsuperscript{1,2}

\textsuperscript{1}Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94025, USA
\textsuperscript{2}Geballe Laboratory for Advanced Materials, Departments of Physics and Applied Physics, Stanford University, Stanford, CA 94305, USA
\textsuperscript{3}Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Time- and angle-resolved photoelectron spectroscopy (trARPES) is a powerful technique for studying non-equilibrium properties of quantum materials. The access to electronic band structure upon optical excitation enables a detailed investigation of the temporal evolution of photo-excited carriers \cite{1,2}. However, it remains challenging to extract microscopic information on electronic interactions from trARPES data. With our state-of-the-art trARPES setup \cite{1,3}, we address this issue on both the copper- and iron-based high temperature superconductors. In optimally doped Bi\textsubscript{2}22\textsubscript{1}2, we find that the trARPES-derived population lifetimes deviate from the ARPES-derived single-particle lifetimes by one to two orders of magnitude \cite{4}. This disparity can only be understood if processes beyond electron-phonon interactions play a significant role in the electron dynamics. In FeSe/SrTiO\textsubscript{3} systems, we observe an abrupt phonon frequency renormalization in the monolayer FeSe as compared to thicker films \cite{5}. This result sets the basis to quantitatively understand the interfacial lattice strain. These examples demonstrate some unique microscopic insights on electronic and phononic properties which can only be accessed by trARPES.

Figure 1: photoemission spectrum as a function of energy, momentum, and time.

4) Yang et al., under review (2015).
5) Yang et al., submitted (2015).
Recent discovery of new superconductors containing pnictogen atoms

Akira Iyo¹, Hijiiri Kito¹, Tatsuya Kinjo², Taichirou Nishio², Shigeyuki Ishida¹, Nao Takeshita¹, Kunihiro Oka¹, Izumi Hase¹, Hiroshi Eisaki¹, Yoshiyuki Yoshida¹

¹ National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, Japan.
² Tokyo University of Science, Shinjuku, Tokyo, Japan.

Since the discovery of iron-based high-$T_c$ superconductors, compounds containing pnictogen atoms are attracting much attention as candidates for new superconductors. Recently, we have found several new superconductors containing Bi, P or Sb.

SrBi₃ with a AuCu₃-structure exhibits superconductivity below $T_c$ of 5.6 K. We demonstrate that a large amount of Na substitution (40 %) into Sr site is possible when the samples are synthesized under the combination of high pressure (3 GPa) and low temperature (350°C) synthesis conditions. $T_c$ of resultant (Sr,Na)Bi₃ increases with the Na substitution up to 9.0 K.

$AP_{2-x}X_x$ ($A = Zr, Hf; X = S, Se$) have a PbFCl-type structure with $x$ greater than 0.3. We have succeeded in synthesizing a series of the intermetallic ternary phosphide chalcogenide superconductors under high-pressure. $T_c$ changes systematically with $x$, yielding dome-like phase diagrams. The maximum $T_c$ of 6.3 K is achieved at $x = 0.75$ for ZrP₂₀Se₇.

Ba₂Bi₃ contains planar anionic Bi ribbon nets with four- and three-bonded Bi separated by cationic Ba layers. Ba₂Bi₃ is found to be a superconductor with a $T_c$ of 4.4 K.
Visualizing Electronic Structures of Topological Quantum Materials

Yulin Chen
Physics Department, University of Oxford

The discovery of materials with novel properties is one of the most fascinating aspects of physics, and such findings have always played important roles in the development of science and human life. Two recent examples are graphene and topological insulators. Interestingly, both materials possess 2D Dirac fermions; and topological insulators further show distinct topology in their electronic band structures. With the swift development in both fields, two questions have been naturally raised:

i). Does there exist a 3D counterpart of graphene, or a “3D graphene”?
ii). Besides topological insulators, can one find other materials that have unusual topology in their electronic structures?

Remarkably, the answer to both questions can lie on a same type of novel quantum matter – the topological Dirac semi-metal - which not only processes 3D Dirac fermions in the bulk (in contrast to the 2D Dirac fermions in graphene and topological insulators), but also shows unusual topology in its electronic structures.

In this talk, I will show that by using photoemission spectroscopy, we were able to directly visualize the non-trivial electronic structures in topological insulators and topological Dirac semi-metals recently discovered\(^1\)\(^-\)\(^6\).

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3) Y. Chen, Frontiers of Physics, 7, 175 (2012)
4) Y. Chen, et. al., Nature Physics, 9, 704 (2013)
Some Reflections on New Experimental Developments

Zhi-xun Shen

Departments of Physics and Applied Physics, Stanford University, Stanford, CA 94305, USA
BL-1000
Lab-based VUV Source
Ultra-High Intensity/Variable Gas

Specification:

<table>
<thead>
<tr>
<th>MAX Flux</th>
<th>~10^{18} photons/sr sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orders of Magnitude</td>
<td>Higher than any commercial lab-based VUV source</td>
</tr>
<tr>
<td>Typical Line Width</td>
<td>&lt;1 meV with Xe @8.436 eV</td>
</tr>
<tr>
<td>Working Gas</td>
<td>He/Ne/Ar/Kr/Xe</td>
</tr>
<tr>
<td>Photon Energy Range</td>
<td>8.436~40.8 eV</td>
</tr>
<tr>
<td>Easy to Switch between Gases/Photons</td>
<td>Ideal for Electronic Structure 3D Mapping</td>
</tr>
<tr>
<td>Connection Flange</td>
<td>DN40CF</td>
</tr>
<tr>
<td>Gas In</td>
<td>3mm SS Tube</td>
</tr>
<tr>
<td>Cooling</td>
<td>Water (&gt;5 L/min)</td>
</tr>
<tr>
<td>Weight</td>
<td>&lt;4 kg</td>
</tr>
<tr>
<td>Easy to be Adapted to Existing Monochromators</td>
<td></td>
</tr>
</tbody>
</table>

Test Spectrum taken by R-4000 Analyzer
0.5c, Ep=2eV, step=1meV
30 sweeps

Applications:

- Photoemission Spectroscopy
- UV Spectroscopy
- Mass Spectroscopy
- UV Lithography
<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber</td>
<td>Made from SS304 with UHV standard</td>
</tr>
<tr>
<td>Pumps</td>
<td>Edwards STP1003 Mag-Lev Turbo Pump, EXT75DX turbo pump as the second stage backing pump and differential pumping, nxDS10i as the forevacuum pump; TSP with Liquid Nitrogen Cooling Shroud</td>
</tr>
<tr>
<td>Base Pressure</td>
<td>&lt;1E-10 mbar after 48 hours bakeout at 150 °C</td>
</tr>
<tr>
<td>4-axis Manipulator</td>
<td>X/Y(±8mm), Z(150mm), θ (+/-180°)</td>
</tr>
<tr>
<td></td>
<td>Temperature Range: Liquid Nitrogen Cooling Module, 150~1200K</td>
</tr>
<tr>
<td>QCM</td>
<td>INFICON XTC/3s with 150mm Linear Shift</td>
</tr>
<tr>
<td>RHEED</td>
<td>STAIB 15 KeV RHEED &amp; Phosphor Screen; Data acquisition and Analysis.</td>
</tr>
<tr>
<td>High Purity Ozone System</td>
<td>High purity Ozone source, up to 90% purity; capable to oxidize most material at 1E-6 mbar Ozone atmosphere; Max 16 g/hour Ozone generation capability and storage of 8g liquid Ozone (supporting up to 8 hours of growth process).</td>
</tr>
<tr>
<td>Evaporator Cells</td>
<td>Up to 16 Evaporators</td>
</tr>
<tr>
<td></td>
<td>Temperature Range : up to 2000°C (with K-cells)</td>
</tr>
<tr>
<td></td>
<td>up to 3000°C (with E-beam Evaporator)</td>
</tr>
<tr>
<td></td>
<td>Temperature Stability : ±0.1°C</td>
</tr>
<tr>
<td></td>
<td>Flange : DN40CF / DN63CF</td>
</tr>
<tr>
<td></td>
<td>Pneumatic Siftters with Controller &amp; Software</td>
</tr>
<tr>
<td>Gate Valve</td>
<td>VAT DN63/40CF UHV Manual Gate Valve</td>
</tr>
<tr>
<td>Other Accessories</td>
<td>Load Lock, RDC, High Stability Chiller</td>
</tr>
</tbody>
</table>
Cubic-200 MBE System, of which chamber is made from one piece of SS304, no welding part guarantees the lowest possibility of leaking; including 6 DN100CF and 8 DN40CF flanges.

With 300L/s Turbo Pump and oil-free scroll pump, wide range gauge (or Ion gauge), Inficon QCM with linear shift, 4-axis manipulator with temperature controller, up to 7 Evaporators. This system satisfies the demands of different thin films growth.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Basic</th>
<th>Upgrade Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber</td>
<td>Made from one piece of SS304</td>
<td>SS316 / Ti Alloy available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DN40CF: 8; DN100CF: 6;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DN40CF: 8; DN100CF: 4; DN150CF: 2;</td>
</tr>
<tr>
<td>Flanges</td>
<td>DN40CF: 8; DN100CF: 6;</td>
<td>Edwards STP301 Mag-Lev TMP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Edwards nXDS10i</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;5E-10 mbar (or additional Ion Pump/NEG/TSP, base pressure up to 5E-11 mbar)</td>
</tr>
<tr>
<td>Turbo Pump</td>
<td>Pfeiffer Hi Pace 300</td>
<td></td>
</tr>
<tr>
<td>Forevacuum Pump</td>
<td>Edwards nXDS6i</td>
<td></td>
</tr>
<tr>
<td>Base Pressure</td>
<td>&lt;5E-10 mbar</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-axis Manipulator</td>
<td>X/Y(±8mm), Z(75mm), Θ (±180°)</td>
<td></td>
</tr>
<tr>
<td>Temperature Range</td>
<td>RT~1200K</td>
<td>Liquid Nitrogen Cooling Module; E-beam Heating Module</td>
</tr>
<tr>
<td></td>
<td>INFICON STM-2 100mm Linear Shift</td>
<td>INFICON XTC/3s 100mm Linear Shift</td>
</tr>
<tr>
<td>QCM</td>
<td>INFICON STM-2 100mm Linear Shift</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INFICON XTC/3s 100mm Linear Shift</td>
<td></td>
</tr>
<tr>
<td>Evaporator Cells</td>
<td>Medial Temperature Cells: 3 sets</td>
<td>Up to 7 Evaporators</td>
</tr>
<tr>
<td></td>
<td>Temperature Range: 80-1100°C</td>
<td>Temperature Range: up to 2000°C</td>
</tr>
<tr>
<td></td>
<td>Temperature Stability : ±0.1°C</td>
<td>Pneumatic Shutter with Controller &amp; Software</td>
</tr>
<tr>
<td></td>
<td>Flange: DN40CF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crucible Volume: ∼10cc</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manual Shutters and Water Cooling</td>
<td></td>
</tr>
<tr>
<td>Gate Valve</td>
<td>HTC DN63CF Manual Gate Valve</td>
<td>VAT DN63CF Manual Gate Valve</td>
</tr>
<tr>
<td>Other Accessories</td>
<td>Load Lock, Sample Transfer, High Stability Chiller</td>
<td></td>
</tr>
</tbody>
</table>
Advanced Technology Liquefiers
Automated 80 and 160 Liter Capacity Helium Liquefiers

Quantum Design's Advanced Technology Liquefiers (ATL) along with its innovative Helium Recovery, Storage & Purification Systems allow you to recover the helium gas currently being lost from the normal boil off and helium transfers of your cryogenic instruments.

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New! ATL160+
Now with a Liquefaction Rate of 30+ liters/day!

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Integrated Compressor

*Liquefaction rates vary based on input helium quality and pressure.

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Direct Recovery: Most Simple System
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- Hassle-free tip and sample exchange
- Ultra low noise < 1 pm with cryostat running
- Interruption free, maintain cryogenic temperatures indefinitely
- Atomic resolution from 15 K to 300 K
- Not only STM, but also q-Plus AFM
- Extremely low drift
- Superb STS in LT

CCC stability at 18K Si image courtesy of B. Choi (RHK)