International Symposium

on Frontier of Superconductivity Research (VII)

Optical Spectroscopy on Unconventional Superconductors

Program and Abstracts

October 26-29, 2017

National Lab for Superconductivity

Index

Organizing Committee:

Chair: Prof. Zhong-xian ZHAO
Chairman of Academic Committee,
National Lab for Superconductivity

Co-Chair: Prof. Xingjiang ZHOU
Director, National Lab for Superconductivity

Co-Chair: Prof. Xianggang Qiu
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Secretaries: Prof. Beiyi ZHU, Ms. Lingqian WANG

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Brief Schedule:

Friday, October 27
Registration and Opening (M-building Room 234)
Scientific program

Saturday, October 28
Scientific program
11:50 Closing remarks

Welcome

The International Symposium on Frontier of Superconductivity Research (VII) Optical Spectroscopy on Unconventional Superconductors, organized by the National Lab for Superconductivity, will be held on the campus of Institute of Physics, Chinese Academy of Sciences, Beijing, China, between Oct. 26 and 29, 2017.

The National Lab for Superconductivity at the Institute of Physics, Chinese Academy of Sciences, Beijing (http://nlsc.iphy.ac.cn/), established in 1991, is a national premier base for superconductivity research in China and an important hub for academic exchange among domestic and foreign scholars in this field. Current research projects include searching for new superconductors, investigating the superconductivity mechanism and related physics problems, thin films synthesis as well as superconducting devices development and their applications.

Aiming to strengthen international scientific exchange and foster international scientific collaboration, the National Lab for Superconductivity initiated
on Frontier of Superconductivity s a series of symposiums held once a year. We have successfully organized the symposium
(2011), and ARPES (2012), Neutron Scattering (2013), STM (2014), Transport and Thermodynamic Properties (2015) and NMR and μSR (2016) on Unconventional Superconductors. This year marks the 7th symposium that focuses on
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We hope to make the Symposium informative, encouraging and inspiring, particularly to young scientists and graduate students.

Scientific Program

(Each presentation includes 40 minutes talk plus 10 minutes Q&A)

October 27, 2017, Friday, M234, IOP			
Morning Session			
Chair: Prof. Nanlin Wang			
09:00- 09:05	Zhongxian Zhao	Institute of Physics, Beijing	Welcome Speech
09:05- 09:15	Xingjiang Zhou	Institute of Physics, Beijing	Brief Introduction to National Lab for Superconductivity and the Symposium
09:15- 10:05	S. Uchida	University of Tokyo	Physics of Josephson Plasma Modes in High-Tc Copper Oxides
10:05- 10:30	Break & group photo		
Chair: Prof. Rudolf Ulrich Hackl			
10:30- 11:20	Nanlin Wang	Peking University	Light-induced new collective modes in $La_{1.905}Ba_{0.095}CuO_4$ superconductor
11:20- 12:10	Setsuko Tajima	Osaka University	Fermi surface development with doping and the superconductivity in the pseudo-gapped state in the high T_c cuprates
12:10-14:00	Lunch		
Afternoon Session			
Chair: Prof. Wei-Sheng Lee			
14:00 -14:50	Rudi Hackl	Walther Meissner Institute	Light scattering on electronic and magnetic excitations in unconventional superconductors
14:50 -15:40	Qingming Zhang	Renmin University of China	Raman scattering in FeSe-based superconductors
15:40-16:00	Break		
Chair: Prof. Thomas Timusk			
16:00 -16:50	Wei-Sheng Lee	Stanford University	X-ray studies of CDW and excitations in high-Tc cuprate
16:50 -17:40	Jimin Zhao	Institute of Physics	Ultrafast Quasiparticle Dynamics in Single-Layer FeSe/SrTiO3 and $(Li_{0.84}Fe_{0.16})OHFe_{0.98}Se$
17:40 -	Dinner		

Scientific Program

(Each presentation includes 40 minutes talk plus 10 minutes Q&A)

October 28, 2017, Saturday, M234, IOP			
Morning Session			
Chair: Prof. S. Uchida			
09:00 -09:50	Thomas Timusk	McMaster University	Search for the mechanism of superconductivity using optical spectroscopy
09:50 -10:40	Yuan Li	Peking University	Light scattering from correlated electrons: a glimpse at symmetry-breaking mechanisms
10:40 -11:00	Break		
Chair: Prof. Yuan Li			
11:00 -11:50	Xiang Gang Qiu	Institute of Physics	Infrared Spectroscopic Studies of the Phonon Dynamics in Iron-based Superconductors
11:50 -12:10		Summary & Closing remarks	
12:10 -14:00	Lunch		
Afternoon Session			
14:00 -18:00	Lab Tour		

October 29, 2017
Free discussion

Physics of Josephson Plasma Modes in High-T_c Copper Oxides

S. Uchida[1, 2, 3]

[1] *Department of Physics, University of Tokyo, Tokyo, Japan*
[2] *National Institute of Advanced Science and Technology (AIST), Tsukuba, Japan*
[3] *Institute of Physics, Chinese Academy of Sciences, Beijing, China*

In the normal state of high-T_c copper oxides (cuprates), the charge transport in the interlayer *c*-axis direction is highly incoherent. Below the superconducting transition temperature T_c the *c*-axis transport becomes coherent, because Cooper pairs formed within each CuO_2 layer can tunnel between layers via Josephson coupling. Associated with the establishment of the interlayer phase coherence of the superconducting order parameter, a collective phase fluctuation mode, called (longitudinal) Josephson plasma mode, appear in the THz frequency range of the *c*-axis optical spectrum[1)]. The Josephson plasma mode can thus be used as an experimental evidence of superconductivity[2)].

The Josephson plasma mode can, in principle, be observed for other layered superconductors, such as organic[3)] and Fe-based compounds when the interlayer coupling is weak enough. However, it is clearly seen only for the cuprates. in which quite fortuitous situations are realized; i) the interlayer coupling strength is severely suppressed due to their crystal structures and the presence of a pseudogap in the electronic excitation spectrum, and ii) the plasma frequency is located deep inside the wide superconducting gap region.

For cuprates, particularly for multilayer cuprates, additional Josephson plasma modes, so-called transverse (or optical) plasma modes[4)], emerge at much higher frequencies which arise from interlayer Josephson coupling within a multilayer. The transverse modes persist well above T_c, signalling a pair formation within a layer or multilayer even when the inter-multilayer phase coherence is lost[5)]. Furthermore, the intra-multilayer Josephson coupling appears responsible for the enhanced T_c values in multilayer cuprates[6)]. Therefore, the Josephson plasma modes, both longitudinal and transverse, provide unique insight into the physics and T_c of high-T_c cuprates.

1) K. Tamasaku, Y. Nakamura, and S. Uchida, Phys. Rev. Lett. **69**, 1455 (1992).
2) S. Kaiser, A. Cavalleri *et al*., Phys. Rev. B **89**, 184516 (2014).
3) T. Shibauchi, S. Tajima *et al*., Phys. Rev. B **55**, 11977 (R) (1997).
4) D. van der Marel and A. Tsvetkov, Czech. J. Phys. **46**, 3165 (1996).
5) A. Dubroka, C. Bernhard *et al*., Phys. Rev. Lett. **106**, 047006 (2011).
6) Y. Hirata, K.M. Kojima, S. Uchida *et al*., Phys. Rev. B **85**, 054501 (2012).

Presenting author: Prof. S. Uchida
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Light-induced new collective modes in $La_{1.905}Ba_{0.095}CuO_4$ superconductor

S. J. Zhang[1], Z. X. Wang[1], G. D. Gu[2], T. Dong[1], **N. L. Wang**[1]

[1]*International Center for Quantum Materials, School of Physics, Peking University, Beijing 100871, China*

[2]*Condensed Matter Physics and Materials Science Department, Brookhaven National Lab, Upton, New York 11973, USA*

Strong field midinfared pump - terahertz (THz) probe spectroscopy has been proven as a powerful tool for light control of different orders in strongly correlated materials. We present our recent work on the construction of an ulstrafast broadband infrared (ranging from 1.2 μm - 15 μm and beyond) pump - THz probe system in a reflection geometry and its application to the c-axis charge dynamics of a cuprate superconductor $La_{1.905}Ba_{0.095}CuO_4$ with T_c=32 K. Our measurement reveals that the pump-induced change occurs predominantly at the Josephson plasma edge position below T_c. Most significantly, the Josephson plasma edge is suppressed to lower energy and a new longitudinal mode emerges at the plasma edge with increasing the pump fluence. The effect is stronger when the electric field of pump beam is polarized along the c-axis, but becomes much weaker when the field is perpendicular to the c-axis. The new mode and effect induced by ultrafast optical excitations will shed new insight into the nature of the Josephson coupling in cuprate superconductor.

Presenting author: Prof. N. L. Wang

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Fermi surface development with doping and the superconductivity in the pseudo-gapped state in the high T_c cuprates

Setsuko Tajima

Dept. of Physics, Osaka University, Toyonaka 560-0043, Osaka, Japan

In my talk, I will address the two issues to which optical spectroscopy has made a big contribution in the study of high temperature superconducting cuprates. One is the Fermi surface development with carrier doping from a Mott insulator to a Fermi liquid metal, which was revealed by optical spectra[1]. The electronic picture drawn by the optical data in the very beginning of high T_c research was consistent with the angle-resolved photoemission data reported about ten years later. Recently we have revisited the phase diagram problem in electron-doped cuprates, because the new reduction process enables us to obtain high T_c samples even at very low doping levels. Recalling the characteristic spectral change with carrier doping, we found a pronounced electron-hole asymmetry in the cuprates[2].

The other issue is the problem how superconductivity develops in the pseudo-gapped state. The c-axis polarized optical spectra could clearly distinguish the gap features due to the pseudogap and to the superconductivity[3]. The former one is of insulating nature. Moreover, a precise analysis of the spectra has revealed a precursor of superconductivity at very high temperatures above T_c[4]. Such a precursor of superconductivity is peculiar to the system near the BCS-BEC crossover, and thus our observation turns to suggests that the cuprates are in this crossover regime. The strong electron-electron interaction is a key ingredient here.

References:

[1] S. Uchida *et al*., Phys.Rev.B**43** (1991)7942
[2] R. Ohnishi *et al*., submitted.
[3] E. Uykur *et al*., J. Phys. Soc. Jpn. **82**, 033701 (2013).
[4] E. Uykur et al., Phys. Rev. Lett. **112**, 127003 (2014).

Presenting author: Prof. Setsuko Tajima

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Light scattering on electronic and magnetic excitations in unconventional superconductors

Rudi Hackl

Walther Meissner Institut, Walther-Meissner-Str. 8, 85748 Garching, Germany

Light scattering provides insight into most of the excitations of a solid. After the discovery of the cuprates and ferro-pnictides the interest in the electronic and magnetic properties was fueled by the interrelation of superconductivity, charge and spin order. I provide an introduction into the light scattering from electrons and spin excitations and summarize the latest results. In particular I address the results from gap spectroscopy in BKFA and magnetism in FeSe and try to provide a critical comparison of the results in the various compounds in the Fe pnictides and chalcogenides. The main focus will place on the hierarchy of pairing states and SDW versus local magnetic order.

Presenting author: Prof. Rudi Hackl

Email of presenting author: hackl@wmi.badw.de

Raman scattering in FeSe-based superconductors

Qingming Zhang

Department of Physics, Renmin University of China, Beijing, China

Recently there has tremendous interest in exploring FeSe-based superconductors, since many intriguing properties, such as high superconducting transition temperatures and various structural and magnetic phases, have been revealed in the compounds. In this talk, we will briefly review the existing Raman scattering results in FeSe-based superconductors, with particular emphasis on the topics of structure and superconductivity, electron and magnetic excitations, and spin/electron-phonon coupling, etc.

Presenting author: Prof. Qingming Zhang

Email of presenting author: qmzhang@ruc.edu.cn

X-ray studies of CDW and excitations in high-Tc cuprate

Wei-Sheng Lee

Stanford Institute for Materials and Energy Sciences,
SLAC National Accelerator Lab. And Stanford University

I Charge density wave modulations have now been widely reported in high temperature superconducting cuprates, raising questions about their nature and relationship with superconductivity and the mysterious pseudogap state. In this presentation, I will briefly cover the background of CDW in cuprates. I will also give a flavor of some novel x-ray scattering techniques that are enabled by technology advances and X-ray free electron laser. Most of the presentation will focus on the investigation of the CDW ground state in $YBa_2Cu_3O_{6+x}$ by suppressing the superconductivity with a pulsed magnetic field of ~ 30 T [1, 2], the observation of CDW and its excitations in $Bi_2Sr_2CaCu_2O_{8+x}$ using high resolution resonant inelastic x-ray scattering [3], and the implications of these observations.

[1] S. Gerber *et al.*, Charge Density Wave in $YBa_2Cu_3O_{6.67}$ at High Magnetic Fields, Science **350**, 949 (2015).
[2] H. Jang *et al.*, Ideal charge density wave order in the high-field state of the YBCO superconductors, Proc. Nat. Acd. Sci. **113**, 14645 (2016).
[3] L. Chaix *et al.*, Dispersive charge density wave excitations in underdoped cuprates $Bi_2Sr_2CaCu_2O_{8+x}$. Nature Physics, in print. Published advance online: doi:10.1038/nphys4157

Presenting author: Prof. Wei-Sheng Lee
Email of presenting author: leews@slac.stanford.edu

Ultrafast Quasiparticle Dynamics in Single-Layer FeSe/SrTiO3 and $(Li_{0.84}Fe_{0.16})OHFe_{0.98}Se$

Jimin Zhao

Institute of Physics, Chinese Academy of Sciences

Ultrafast spectroscopy of quantum materials such as high-*T*c superconductors is at the heart of the

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the single-layer $FeSe/SrTiO_3$ [2] and the $(Li_{0.84}Fe_{0.16})OHFe_{0.98}Se$, respectively. Other than the evidence and characterization of the superconductivity, we also report the important electron-phonon coupling constant measured through the quasiparticle lifetime. Further we show the coherent phonons in such unconventional systems.

[1] Q. Wu, Jimin Zhao, et al. *Ultrafast optical spectroscopy of high-temperature superconductors (in Chinese)*, Chin Sci Bull, 2017, doi: 10.1360/N972017-00816
[2] Y. C. Tian, Jimin Zhao, et al. *Ultrafast Dynamics Evidence of High Temperature Superconductivity in Single Unit Cell FeSe on SrTiO3*, PRL 116, 107001 (2016).

Presenting author: Prof. Jimin Zhao
Email of presenting author: jmzhao@iphy.ac.cn

Search for the mechanism of superconductivity using optical spectroscopy

Thomas Timusk

Department of Physics and Astronomy, McMaster University, Hamilton, ON, L8S 4M1, Canada

Originally, tunneling spectroscopy was used to unravel the detailed mechanism of superconductivity. In lead for example a comparison of tunneling spectra with inelastic neutron scattering spectra established phonons as the excitations responsible for superconducting pairing. In the new high temperature superconductors optical spectroscopy has taken the place of tunneling as the premier reliable spectroscopic tool. I will illustrate this with two examples.

In the cuprate materials where large single crystals are available one uses reflectance spectroscopy over a wide range of energies to obtain the optical constants of the material. Using maximum entropy methods one can then calculate the electron-boson spectral function ^{2} compare it with the density of states of phonons or magnons. A second example is the recently discovered 200 K superconductor, H_3S, which becomes superconducting at 200 GPa pressures generated in a diamond anvil cell. This experimental environment presents several challenges. The transparent at all the relevant frequencies. Here we use the opposite approach, we start with a theoretical spectral function ^{2} (calculated from density functional theory), calculate the optical constants and compare our observed spectral features with predictions from theory with various assumptions for the spectral function. To gain sufficient sensitivty we use a synchrotron source.

Presenting author: Prof. Thomas Timusk

Email of presenting author: timusk@mcmaster.ca, timusk@gmail.com,

Light scattering from correlated electrons: a glimpse at symmetry-breaking mechanisms

Yuan Li

School of Physics, Peking University, China

Unconventional superconductors are intriguing not only for their superconducting properties, but also for their rich phase behaviors describable from a symmetry point of view, the most prominent examples being the simultaneous breaking of rotational and/or lattice translational symmetries. In this talk, I will present some of our recent efforts in using photon scattering experiments, including Raman and X-ray spectroscopy, to detect symmetry breaking (and sometimes 'symmetry recovery') in correlated-electron materials. The same techniques also allow us to elucidate the underlying mechanisms that triggers the phase transitions. As examples, I will discuss spin-orbital interplay in Fe-based superconductors, spin-singlet formation in spin-1/2 chains, and the importance of lattice soft modes in some other materials.

Presenting author: Prof. Yuan Li

Email of presenting author: yuan.li@pku.edu.cn

Infrared Spectroscopic Studies of the Phonon Dynamics in Iron-based Superconductors

X.G. Qiu, R. Yang, B. Xu

National Laboratory for Superconductivity, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

The temperature dependence optical reflectivity has been measurement on iron-based superconductors of different families. The optical conductivity has been obtained by using the two-Drude component model. It has been found that the phonons show red- or blue-shift in different samples. Interestingly, the phonon conductivity exhibits a Fano lineshape, suggesting possible coupling between phonon and electrons or spin. Based on the temperature evolution of the lineshape and peak shift, we discuss the possible role played by electron-phonon and spin fluctuation in the occurrence of superconductivity in iron-based superconductors.

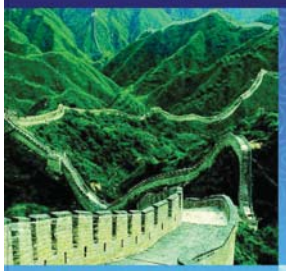
Presenting author: Prof. Xiang Gang Qiu

Email of presenting author: xgqiu@iphy.ac.cn

International Symposium
on Frontier of Superconductivity Research (I)

Exploration of Novel Superconductors

Beijing, China, November 4-7, 2011



Scope:

The National Lab for Superconductivity at the Institute of Physics, Chinese Academy of Sciences, Beijing, is a national premier base for superconductivity research in China and an important hub for academic exchange among domestic and foreign scholars in this field. Aiming to strengthen international scientific exchanges and collaborations, the National Lab for Superconductivity plans to hold "International Symposium on Frontier of Superconductivity Research" once a year.

This first 2011 symposium will focus on "Exploration of Novel Superconductors". Leading experts will provide overview, personal experience, latest results and future perspectives on various novel superconductors, including cuprate superconductors, iron-based superconductors, heavy Fermion superconductors, C60-based and organic superconductors, and more. We hope to make the Symposium informative, encouraging and inspiring, particularly to young scientists and graduate students.

http://nlsc.iphy.ac.cn/scis/

List of invited speakers:

Jun Akimitsu (Kanagawa, Japan)
Eric D. Bauer (Los Alamos, USA)
Ernst Bauer (Wien, Austria)
Xianhui Chen (Hefei, China)
Ming-Hu Fang (Hangzhou, China)
Hideo Hosono (Yokohama, Japan)
Kai-Qing Jin (Beijing, China)
Dirk Johrendt (München, Germany)
Kazushi Kanoda (Tokyo, Japan)
Yoshihiro Kobayashi (Okayama, Japan)
Kosmas Prassides (Durham, UK)
You-Guo Shi (Beijing, China)
Frank Steglich (Dresden, Germany)
Li-Ling Sun (Beijing, China)
Hai-Hu Wen (Nanjing, China)
Zhu-An Xu (Hangzhou, China)

Conference organizers:
Chairs: Zhong-xian ZHAO
Co-Chair: Xingjiang ZHOU
Local organizing committee:
Dongning ZHENG Fang ZHOU

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(II)

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This second symposium in 2012 will focus on "Angle-Resolved Photoemission Spectroscopy (ARPES) on Unconventional Superconductors". Leading experts will provide overview, personal experience, latest results and future perspectives on ARPES studieses es tAlan Goldma
Martin Greven (Minnesota, USA)
Bernhard Keimer (Stuttgart, Germany)
Yuan Li (Beijing, China)
Christopher Stock (Edinburgh, UK)
John M. Tranquada (Brookhaven, USA)
Fangwei Wang (Beijing, China)
Jinsheng Wen (Nanjing, China)
Kazuyoshi Yamada (Tohoku, Japan)

Arun Bansil (Boston, USA)
Sergey V. Borisenko (Dresden, Germany)
Juan Carlos Campuzano (Argonne, USA)
Hong Ding (Beijing, China)
Dong-Lai Feng (Shanghai, China)
Atsushi Fujimori (Tokyo, Japan)
Peter D. Johnson (Brookhaven, USA)
Adam Kaminski (Ames, USA)
Makoto Hashimoto (Stanford, USA)
Kozo Okazaki (Tokyo, Japan)
Zhe Sun (Hefei, China)
Shan-Cai Wang (Beijing, China)
Xing-Jiang Zhou (Beijing, China)

Zhong-Xian ZHAO
Xing-Jiang ZHOU
Dong-Ning ZHENG Fang ZHOU
Bei-Yi ZHU Ling-Qian WANG
Shao-Peng CUI

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This third symposium in 2013 will focus on "Neutron Scattering on Unconventional Superconductors". Leading experts will provide overview, personal experience, latest results and future perspectives on Neutron Scattering studies of unconventional superconductors, including cuprate superconductors, iron-based superconductors and other unconventional superconductors. We hope to make the Symposium informative, stimulating and fruitful, particularly to young scientists and graduate students.

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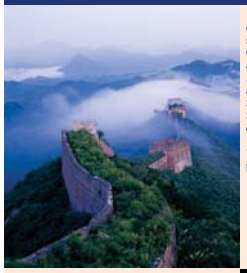

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This fourth symposium in 2014 will focus on "STM on Unconventional Superconductors". Leading experts will provide overview, personal experience, latest results and future perspectives on Scanning Tunneling Microscopy(STM) studies of unconventional superconductors, including cuprate superconductors, iron-based superconductors and other unconventional superconductors. We hope to make the Symposium informative, stimulating and fruitful, particularly to young scientists and graduate students.

Zhong-Xian ZHAO
Xing-Jiang ZHOU
Lei SHAN
Dong-Ning ZHENG Fang ZHOU
Bei-Yi ZHU Ling-Qian WANG

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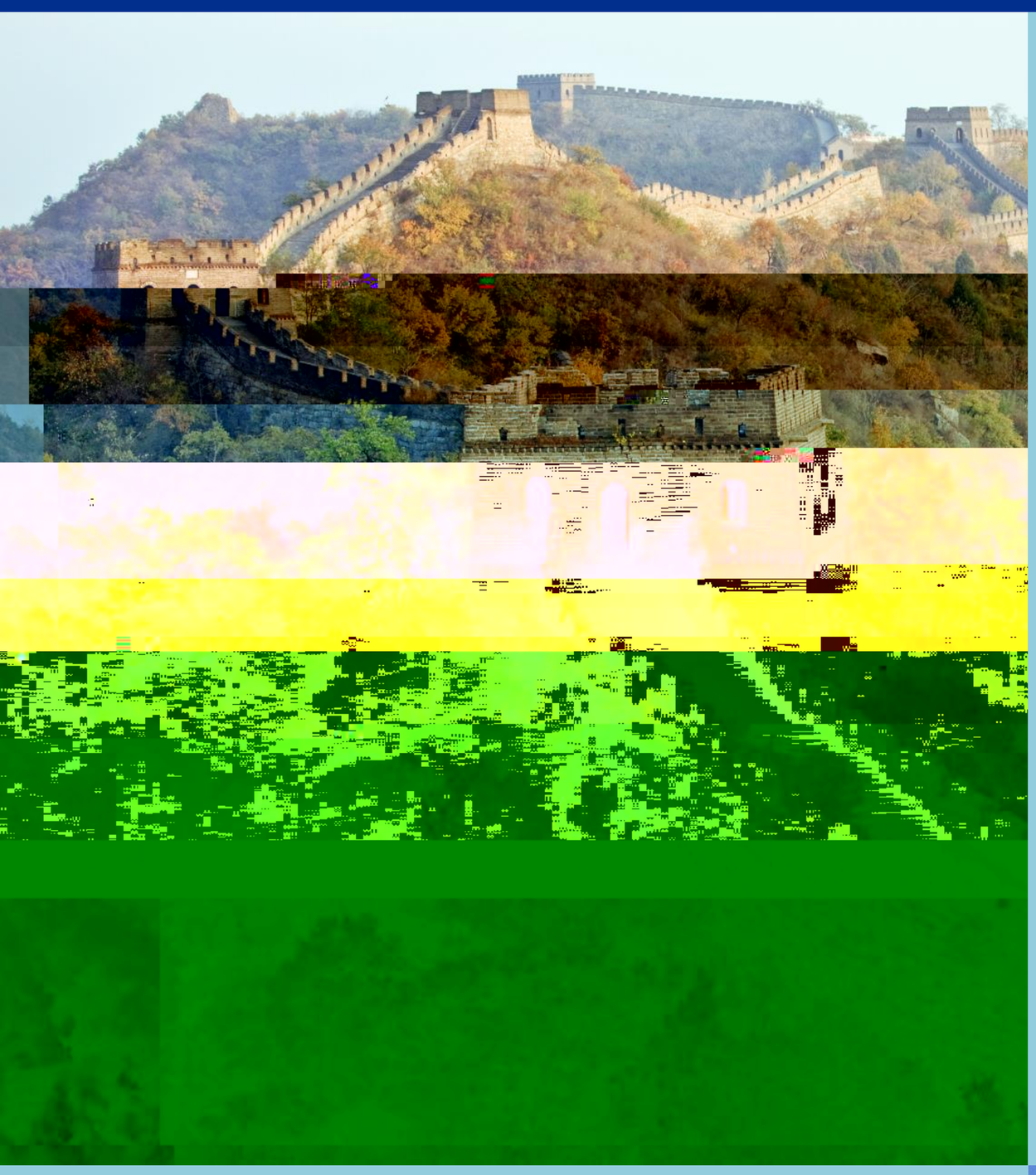
(V)

Clement Collignon (Paris, France)
Yoram Dagan (Tel Aviv, Israel)
Nigel Hussey (Bristol, UK)
Kui Jin (Beijing, China)
Shiyan Li (Shanghai, China)
Ying Liu (Shanghai, China)
Yuji Matsuda (Kyoto, Japan)
Cyril Proust (Toulouse, France)
Jeffery Tallon (Wellington,(P ¯ ã Ï j ↔ a an ú)

International Symposium
on Frontier of Superconductivity Research (VII)

Optical Spectroscopy on Unconventional Superconductors

Beijing, China, October 26 - 29, 2017



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This seventh symposium in 2017 will focus on “Optical Spectroscopy on Unconventional Superconductors”. Leading experts will provide overview, personal experience, latest results and future perspectives on optical spectroscopy studies of unconventional superconductors, including cuprate superconductors, iron-based superconductors and other unconventional superconductors. We hope to make the Symposium informative, stimulating and fruitful, particularly to young scientists and graduate students.

List of Invited Speakers

Rudi Hackl (Garching, Germany)
Weisheng Lee (Stanford, USA)
Yuan Li (Beijing, China)
Xianggang Qiu (Beijing, China)
Thomas Timusk (Hamilton, Canada)
Setsuko Tajima (Osaka, Japan)
Shinichi Uchida (Tokyo, Japan)
Nan-Lin Wang (Beijing, China)
Qingming Zhang (Beijing, China)
Jimin Zhao (Beijing, China)

Conference organizers:

Chair: Zhong-Xian ZHAO
Co-Chair: Xing-Jiang ZHOU
Co-Chair: Xiang-Gang QIU

Conference Secretaries:
Bei-Yi ZHU Ling-Qian WANG

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