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1999 – 2001: Associate Professor, Department of Physics, Boston University, Boston, USA
1995 – 1999: Research Associate, Department of Physics, University of California Berkeley, USA
1993 – 1995: Senior Research Staff, Applied Physics Department, Hamburg University, Germany
1991 – 1993: Postdoc Fellow, Department of Physics, Basel University, Switzerland

Research interests:

Scanning Tunnelling Microscopy/Spectroscopy; Strongly Correlated Electron Systems; Superconductivity

Selected Publications:

1. *Evidence for topological edge states in large energy gap near the step edges on the surface of* $ZrTe_5$
   R. Wu, J.-Z. Ma, L.-X. Zhao, S.-M. Nie, X. Huang, J.-X. Yin, B.-B. Fu, P. Richard, G.-F. Chen, Z. Fang, X. Dai, H.-M. Weng, T. Qian, H. Ding, and S. H. Pan
   Phys. Rev. X 6, **20**, 021017 (2016)
2. *Observation of a Robust Zero-energy Bound State in Iron-based Superconductor Fe(Te/Se)*
   J.-X. Yin, Zheng Wu, J.-H. Wang, Z.-Y. Ye, Jing Gong, X.-Y. Hou, Lei Shan, Ang Li, X.-J. Liang, X.-X. Wu, Jian Li, C.-S. Ting, Z. Wang, J. -P. Hu, P.-H. Hor, H. Ding, S. H. Pan
   Nature Physics **11**, 543-546, (2015).
3. *Microscopic Electronic Inhomogeneity in the High-*T_c *Superconductor* $Bi_2Sr_2CaCu_2O_{8+\delta}$
   S. H. Pan, J. P. O'Neal, R. L. Badzey, C. Chamon, H. Ding, J. R. Engelbrecht, Z. Wang, H. Eisaki, S. Uchida, A. K. Gupta, K.-W. Ng, E. W. Hudson, K. M. Lang, and J. C. Davis
   Nature **413**, 282-285, (2001)
4. *STM Studies of the Electronic Structure of Vortex Cores in* $Bi_2Sr_2CaCu_2O_{8+\delta}$
   S. H. Pan, E. W. Hudson, A. K. Gupta, K-W Ng, H. Eisaki, S. Uchida, and J. C. Davis
   Phys. Rev. Lett. **85** (7), 1536 (2000)
5. *Imaging the Effects of Individual Zinc Impurity Atoms on Superconductivity in* $Bi_2Sr_2CaCu_2O_{8+\delta}$
   S. H. Pan, E. W. Hudson, K. M. Lang, H. Eisaki, S. Uchida, and J. C. Davis,
   Nature **403**, 746-750, (2000)

Phase Coherence Dominated Superconducting Transition in $Fe_{1+x}(Te,Se)$

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Abstract: This talk will report our STM/S studies on the iron-based superconductor $Fe_{1+x}(Te,Se)$. Earlier, we reported the discovery of a zero-energy mode localized at each interstitial Fe impurity sites (Nature Physics **11**, 543-546, 2015). Further study has shown that, in addition to the novel localized effects, these interstitial magnetic impurity atoms also collectively destroy the superconducting condensate by decoherence, not by reduction of the pairing strength (energy-gap). This phenomenon is inconsistent with the Abrikosov-Gor'kov description of the effects of magnetic impurities on superconductivity. With a quantitative analyses of our STM/S results, we show that the linear reduction of T_c with increasing of the impurity concentration displayed by the magnetic susceptibility measurements is also consistent with the decoherence effect. In addition, we will show the results of the temperature dependent STS measurements to demonstrate that the interstitial Fe impurity atoms collectively drive a quantum phase transition from the coherence dominated superconducting state to an unknown quantum state.

Coherent Electron Imaging Based on a Single-Atom Electron Source

Ing-Shouh Hwang 黃英碩
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Over the past several years, we have been developing low-voltage (80–5000 V) coherent electron imaging techniques. An advantage of this approach is that there is a possibility to achieve diffraction-limited resolution without the need to fabricate a high-quality lens. Coherent diffractive imaging has been successfully demonstrated in optical microscopy and x-ray microscopy. There are relatively fewer experiments in electron microscopy mainly because optical lasers and synchrotron light sources are usually considered to possess better coherence than electron sources. Now we have demonstrated full spatial coherence for single-atom electron sources. Thus coherent imaging based on single-atom electron sources is very promising to reach atomic resolution even for nonperiodic structures such as biological molecules. Our ultimate goal is to achieve high-contrast and high-spatial-resolution imaging of two-dimensional materials and organic molecules under low-dose conditions.

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EDUCATION

1993 Applied Physics, Division of Applied Science, Harvard University
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1984 Department of Electrical Engineering, National Taiwan University, Taiwan
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EXPERIENCE

2005– Adjunct Professor, Department of Material Sciences and Engineering, National Tsing-Hua University
2000– Research Fellow, Institute of Physics, Academia Sinica
2000– Adjunct Associate Professor, Department of Physics, National Tsing-Hua University
1998– Associate Research Fellow, Institute of Physics, Academia Sinica.
1994– Assistant Research Fellow, Institute of Physics, Academia Sinica
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AWARD

1999 Young Investigator Award, Academia Sinica.
2000 Outstanding Research Award, National Science Council.
2006 Outstanding Nano-tech Research Award, Taiwan Nanotechnology Industry Development Association.

The main research interests of Dr. Ing-Shouh Hwang are on surface and interface sciences, scanning probe microscopy, electron/ion beam techniques, development of new instrumentation techniques.

Applications of field emission resonances on nano-scale measurements

Wei-Bin Su 蘇維彬
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Field emission resonances (FERs) in scanning tunneling microscopy (STM) is a phenomenon in which the field emission electrons emitted from the microscope tip couple into the quantized standing-wave states within the STM tunneling junction. Although FERs originate from the quantized states in vacuum, they actually can contain the information associated with physical properties of the surface and the STM tip. We demonstrate that FER energies can be used to measure the local work function of the surface. FER intensities can reflect the local electron transmissivity of the reconstructed surface. The zero valley intensities appearing around the FER can indicate that the observed material has the band gap above the vacuum level. FER energies combining with Z-V spectroscopy can be utilized to characterize the potential form in STM junction. Characterization of the potential form can be applied to measure the barrier width of the field emission, and quantify the sharpness and the field enhancement factor of an STM tip.

Determination of Spin-Orbit Scattering Lifetime at the Interface of $LaAlO_3/SrTiO_3$ from the Superconducting Upper Critical Fields

Dr. Wei-Li Lee 李偉立
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The intrinsic mechanism of the spin-orbit coupling at the $LaAlO_3$ / $SrTiO_3$ interface remains a debatable issue. Rashba-type spin-orbit coupling is an appealing candidate that has been demonstrated by several magnetotransport results. On the other hand, the atomic spin-orbit coupling was also shown to play an important role, particularly when the Fermi level is close to the Lifshitz point. Unlike previous works, we focus on the measurements of the anisotropic and superconducting upper critical fields in gated $LaAlO_3$ / $SrTiO_3$ devices. By rigorous fittings of the H_{c2}-T curves using both the Werthamer-Helfand-Hohenberg theory and Klemm-Luther-Beasley model, the spin-orbit scattering lifetime can be determined with high precision in superconducting state. We found that the extracted spin-orbit scattering lifetime monotonically increases with the transport lifetime that spanned over two orders of magnitude in the regime with sheet density higher than that at Lifshitz point. Those results suggest the dominant role of Elliott-Yafet type spin-relaxation. The comparison to the weak localization fittings on magnetoconductance reveals a striking difference, suggesting the model dependence on the determination of the spin-orbit scattering lifetime.

Spin-Orbital Angular Momentum Coupling in Cold Atoms

Sungkit Yip 葉崇傑
Institute of Physics, Academia Sinica

I shall describe briefly my collaboration with the experimental group of Dr. Yu-Ju Lin (Institute of Atomic and Molecular Sciences, Academia Sinica) on spin-orbital angular momentum coupling in Rb87 bosons. We show how this coupling can be used to create non-trivial vortices, spin textures, and an artificial gauge field. Utilizing the last, a Hess-Fairbank type of experiment has also been performed.

If time permits, I would also briefly mention my theoretical investigation of spontaneous thermal Hall conductivity of chiral superconductors with gap nodes.

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1997 – 2006:	Physicist & Beamline Scientist, Dept. of Applied Physics and Stanford Synchrotron Radiation Laboratory, Stanford University, Stanford, CA94305 & Advanced Light Source, Lawrence Berkeley National Lab, Berkeley, CA94720.
1995 – 1997:	Humboldt Research Fellow, Max-Planck-Institute for Solid State Research, Heisenbergstrasse 1, D-70569, Stuttgart, Germany

Research interests:

Electronic structure of unconventional superconductors and other quantum materials: high-temperature cuprate superconductors, iron-based superconductors, low-dimensional and nanoscale materials, topological insulators and topological superconductors.

Selected Publications:

1. *Orbital Origin of Extremely Anisotropic Superconducting Gap in Nematic Phase of FeSe Superconductor*
   Defa Liu, Cong Li, Jianwei Huang, X. J. Zhou et al.,
   Physical Review X **8**, 031033(2018).

2. *Electronic Evidence of Temperature-Induced Lifshitz Transition and Topological Nature in* $ZrTe_5$
   Yan Zhang, Chenlu Wang, Guodong Liu, X. J. Zhou et al.,
   Nature Communications **8**, 15512 (2017)

3. *Quantitative Determination of the Pairing Interactions for High Temperature Superconductivity in Cuprates*
   Jin Mo Bok, Han-Yong Choi, Chandra M. Varma, X. J. Zhou et al.,

Science Advances **2**, e1501329 (2016)

4. *Common Electronic Origin of Superconductivity in (Li,Fe)OHFeSe Bulk Superconductor and Single-Layer FeSe/SrTiO$_3$ Films*
   Lin Zhao, Aiji Liang, Dongna Yuan, X. J. Zhou et al.,
   Nature Communications **7**, 10608 (2016)

5. *Direct Evidence of Interaction-Induced Dirac Cones in Monolayer Silicene/Ag(111) System*
   Ya Feng, Defa Liu, Baojie Feng, X. J. Zhou et al.,
   PNAS **133**, 14656(2016)

Laser ARPES on High Temperature Superconductors and Topological Materials

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Abstract. We have studied electronic structure of high temperature superconductors and other quantum materials by high resolution laser-based angle-resolved photoemission spectroscopy (ARPES). In this talk, I will first introduce our latest progress in developing vacuum ultra-violet laser-based angle-resolved photoemission systems [1]. Then I will report our recent results on studying high temperature superconductors and topological materials including: (1). Distinct electronic structure and superconducting gap in single-layer FeSe/$SrTiO_3$ films [2,3], (Li,Fe)OHFeSe [4] and bulk FeSe superconductors [5]; (2). Quantitative determination of pairing interactions in high-Tc cuprate superconductors [6]; and (3). Electronic structure of topological materials including Bi_2Se_3 [7], silicence [8], WTe_2 [9] and $ZrTe_5$ [10].

1. X. J. Zhou et al., Reports on Progress in Physics 81, 062101 (2018);
2. Defa Liu et al., Nature Communications 3, 931 (2012);
3. Shaolong He et al., Nature Materials 12, 605 (2013);
4. Lin Zhao et al., Nature Communications 7, 10608 (2016);
5. Defa Liu et al., Physical Review X 8, 031033 (2018);
6. Jinmo Bok et al., Science Advances 2, e1501329 (2016);
7. Zhuojin Xie et al., Nature Communications 5, 3382 (2014);
8. Ya Feng et al., PNAS 133, 14656(2016)
9. Chenlu Wang et al., Phys. Rev. B 94, 241119(R) (2016)
10. Yan Zhang et al., Nature Communications 8, 15512 (2017).

Magneto-optics of electrons in conical bands

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Intriguing analogies to relativistic systems have largely helped to understand the electronic properties of various solid-state systems. These include, for instance, 2D graphene, surfaces of topological insulators as well as novel 3D Dirac/Weyl semimetals, as well as certain narrow gap semiconductors. In this talk, I will brifly discuss how the relativistic-like dispersion of electrons in solids impacts their magneto-optical properties, and in turn, how can magneto-optical spectroscopy visualize their electronic bands, or in general, contribute to our understanding of physical phenomena related to these systems.

Topological Materials

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Topological materials host various novel quantum phases of electrons which are characterized by band topology and topologically protected surface/edge states. [1] Despite recent progress, intense world-wide research activity in search of new classes of topological materials is continuing unabated. This interest is driven by the need for materials with greater structural flexibility and tunability to enable viable applications in spintronics and quantum computing. We have used first-principles band theory computations to successfully predict many new classes of 3D topologically interesting materials, including Bi_2Se_3 series, [2] the ternary half-Heusler compounds, [3] $TlBiSe_2$ family, [4] Li_2AgSb-class, and $GeBi_2Te_4$ family as well as topological crystalline insulator (TCI) SnTe family [5] and Weyl semimetals TaAs, [6,7] $SrSi_2$, [8] $(Mo,W)Te_2$, [9] Ta_3S_2, [10] and LaAlGe family. [11,12] I will also highlight our recent work on unconventional chiral fermions in RhSi, [13] cubic Dirac points in $LiOsO_3$, [14] and rotaional symmetry protected TCIs. [15] A brief discussion on Kramer-Weyl fermions in non-magnetic chiral cyrstals will be given. [16]

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[3] H. Lin, L. A. Wray, Y. Xia, S. Xu, S. Jia, R. J. Cava, A. Bansil, and M. Z. Hasan, Nat. Mater. **9**, 546 (2010).
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[10] G. Chang *et al.*, Sci. Adv. **2**, e1600295 (2016).
[11] S.-Y. Xu *et al.*, Sci. Adv. **3**, e1603266 (2017).
[12] G. Chang *et al.*, Phys. Rev. B **97**, 041104 (2018).
[13] G. Chang *et al.*, Phys. Rev. Lett. **119**, 206401 (2017).
[14] W. C. Yu *et al.*, Phys. Rev. Mater. **2**, 051201 (2018).
[15] X. Zhou *et al.*, ArXiv:1805.05215 (2018).
[16] G. Chang *et al.*, Nat. Mater. *in press* (2018).

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Education:

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Professional Employment:

1994 – 1996:	Postdoctor, Institute of Physics, Chinese Academy of Sciences
1996 – 1997	Associate Professor, Institute of Semiconductors, Chinese Academy of Sciences
1998 – 2001:	Visiting scholar, Tohoku University (Japan), University of New Orleans (USA), and Trinity College Dublin (Ireland) etc.
2002–Present:	Professor, Institute of Physics, Chinese Academy of Sciences

Research interests:

His present main research field is Spintronics Materials, Physics, and Devices.

His specialties and research content include: (1) Magnon Valve, Magnon Junction, and Magnonics; (2) Magnetic tunnel junction (MTJ) and tunneling magnetoresistance (TMR) materials, physics and devices; (3) Spin-Orbit Torque effect, Spin Hall effect and spin Seebeck effect in magnetic heterostructures ; (4) Hybrid MTJs based on ferromagnetic, multiferroic, semiconductor and organic materials etc., and their spin transport properties; (5) New designed spintronic devices of Magnetic Random Access Memory (STT-MRAM, SOT-MRAM), TMR magnetic Sensors, Magnetic Logic & Spin Logic, Spin Nano-Oscillator, Spin Diode, Spin Transistor and Spin Field Effect Transistor, etc.

Selected Publications:

[1] *Fabrication of high-magnetoresistance tunnel junctions using* $Co_{75}Fe_{25}$ *ferromagnetic electrodes.*
X. F. Han, M. Oogane, H. Kubota, Y. Ando, and T. Miyazaki.
Appl. Phys. Lett. **77** (2000) 283.

[2] *First-principles theory of quantum well resonance in double barrier Magnetic Tunnel Junctions.*
Y. Wang, Z.Y. Lu, X.G. Zhang, and **X. F. Han***,
Phys. Rev. Lett. **97** (2006) 087210.

[3] *Probing spin flip scattering in ballistic nanosystems.*
Z. M. Zeng, J. F. Feng, Y. Wang, **X. F. Han***, W. S. Zhan, X. G. Zhang, and Z. Zhang.
Phys. Rev. Lett. **97** (2006) 106605.

[4] Patterned nanoring magnetic tunnel junctions.
Z. C. Wen, H. X. Wei, and **X. F. Han***
Appl. Phys. Lett. **91** (2007) 122511.

[5] Nanoring MTJ and its application in MRAM demo devices with spin-polarized current switching.
X. F. Han, Z. C. Wen, and H. X. Wei,
J. Appl. Phys. **103** (2008) 07E933 **(Invited paper**).

[6] *Long range phase coherence in double barrier MTJs with large thick metallic quantum well.*
B. S. Tao, H. X. Yang,Y. L. Zuo, X. Devaux, G. Lengaigne, M. Hehn, D. Lacour, S. Andrieu, M. Chshiev, T. Hauet, F. Montaigne, S. Mangin, **X. F. Han***, Y. Lu*.
Phys. Rev. Lett. **115** (2015) 157204.

[7] *Observation of magnon-mediated electric current drag at room temperature*.
H. Wu, C. H. Wan, X. Zhang, Z. H. Yuan, Q. T. Zhang, J. Y. Qin, H. X. Wei, **X. F. Han***, S. Zhang.
Phys. Rev. B **93** (2016) 060403(R).

[8] *Experimental demonstration of programmable multi-functional spin logic cell based on spin Hall effect.*
X. Zhang, C. H. Wan, Z. H. Yuan, C. Fang, W. J. Kong, H. Wu, Q. T. Zhang, B. S. Tao, **X. F. Han***.
J. Magn. Magn. Mater. **428** (2017) 401–405 (**Letter to Editor**).

[9] *Magnon valve effect between two magnetic insulators.*
H. Wu, L. Huang, C. Fang, B. S. Yang, C. H. Wan, G. Q. Yu, J. F. Feng, H. X. Wei, and **X. F. Han***.
Phys. Rev. Lett. **120** (2018) 097205, (**Editors' Suggestion** & **Featured in Physics**).

[10] *Magnon Valves Based on YIG/NiO/YIG All-Insulating Magnon Junctions*
C. Y. Guo, C. H. Wan, X. Wang, C. Fang, P. Tang, W. J. Kong, M. K. Zhao, L. N. Jiang, B. S. Tao, G. Q. Yu, and **X. F. Han***.
Phys. Rev. B **---** (2018) ----, (LU16420, accepted and at print).

Magnon Valve and Magnon Junction

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Abstract. Compared with the electron based spintronic devices, the magnon based spintronic devices have many attractive features, including minimization of Joule heating, much longer magnon coherence length and additional phase degree of freedom. It has been expected that a device, used a core structure of Magnetic insulator [MI_1]/Space [S]/Magnetic insulator [MI_2], can also operate by method of magnon current similar to a classical spin valve (SV) and a magnetic tunnel junction (MTJ). Here, we first demonstrated a magnon valve (MI_1/S/MI_2, YIG/Au/YIG) which consists of two magnetic insulators (MI=YIG) and a nonmagnetic spacer (S=Au). Instead of regulating transport of spin- polarized electrons, the magnon valve regulates flow of magnons. We used the temperature gradient to excite the magnon current in YIG, and inverse spin Hall effect (ISHE) to detect the magnon current across the magnon valve by the electrical method. Our results show that the magnon current transmission between two magnetic insulating layers (YIG) mediated by a nonmagnetic metal (Au) has high efficiency, and the transmission of the magnon current in a magnon valve becomes high (low) as magnetizations of the two magnetic insulators are parallelly (anti-parallelly) configured. We interpret the Magnon Valve Effect (MVE) by the angular momentum conversion and propagation between magnons in two YIG layers and conduction electrons in the Au layer. The temperature dependence of Magnon Valve Ratio (MVR=11% at room temperature) shows approximately a power law, supporting the above magnon-electron spin conversion mechanism. This work conceptually proves the possibility of using magnon valve structures to manipulate the magnon current in magnetic insulators, which has potential applications in magnon based devices. [1-4]

Then, we designed and manufactured an all-insulating magnon junction with sandwich structure MI_1/S/MI_2 (S=AFI, Anti-Ferromagnetic Insulator, such as YIG/NiO/YIG), in order to achieve pure magnon transport. The devices were made on magnetron sputtering system which is a technique used for industrial large-scale production. Necessarily, the transport and manipulating properties of magnon were investigated. When the temperature gradient was applied, the magnon current would flow from one MI to the other MI through the AFI. So, the magnon current in any MI are easily influence by the other MI layer. Then setting a heavy metal Pt on the top MI layer for detecting magnon, one could find an effect that the signal of ISHE is related to the magnetization structure of both MI layers, similar to the TMR effect in an MTJ. Furthermore, the magnon valve ratio (MVR) in such magnon junctions can be increase to 100%. Hence, the electric-insulating magnon junctions can be used for developing magnon-based circuits, including non-Boolean logic, memory, diode, transistors, magnon waveguide and switches with sizable on-off ratios in near future. [5]

References:

[1] H. Wu and X. F. Han et al., Phys. Rev. Lett. 120 (2018) 097205.
[2] H. Wu and X. F. Han et al., Phys. Rev. B. 93 (2016) 060403(R).
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[4] H. Wu and X. F. Han et al., Phys. Rev. B. 92 (2015) 054404.
[5] C.Y. Guo, C.H. Wan and X. F. Han et al., Phys. Rev. B. (Accepted, 2018, at print).

Spin Transfer Torque, Spin Orbit Torque and pure spin current

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In Spintronics, spin transfer torque (STT) and spin orbit torque (SOT) play active role to manipulate local magnetizations, which are controlled by external magnetic field traditionally. The advantage of these spin torque effects is that the required current is scalable with magnetization dimension. The STT refers to the effect by spin polarized charge current in magnetic materials when there is magnetization spatial gradient. The SOT results from pure spin currents, with no net charge currents, which are generated by the spin Hall effect, the spin pumping effect, the spin Seebeck effect, magnon transport etc.

We will present our experimental works on the STT in magnetic micron and sub-micron structures; the spin pumping effect in Topological Insulator/magnetic material bilayers; the generation and propagation of spin wave (SW); and some simulation about the SOT of SW acting on magnetic domain walls.

Employing a micro-focused Brillouin light scattering spectroscopy (BLS) setup, we experimentally realize a spin-wave (SW) generator, capable of frequency modulation, in a magnonic waveguide. The emission of spin waves was produced by the reversal or oscillation of nanoscale magnetic vortex cores in a NiFe disk array. The vortex cores in the disk array were excited by an out of plane radio frequency (rf) magnetic field. The dynamic behaviors of the magnetization of NiFe were studied. In addition to the discrete ferromagnetic resonance (FMR) signals above external dc saturation magnetic field, we observed clear signals at zero magnetic field where vortex cores are present.

We performed simulations in a quasi-one-dimensional ferromagnetic strip and have found that the SW shows highly anisotropic transmission through different orientations of magnetization inside a domain wall (DW) at a relatively low frequency. When the SW amplitude is large, it induces an effective field torque leading to the rotation of the DW plane and the DW motion. The forward DW motion is a contribution of the demagnetization field due to the increase of the transverse components of magnetization in the DW region, and thus yields an increase of the magnetization orientation of $\delta\varphi$. The backward motion is attributed to the conservation of the spin angular momentum. The transmission ratios of the SW are in turn determined by $\delta\varphi$ of the DW and show complicated dependence at low frequencies. We can thus manipulate the DW motion by selecting the SW frequency and/or controlling the SW amplitude through adjusting the DW angles.

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2010 – 2016:	Associate Professor, Institute of Physics, Chinese Academy of Sciences
2007 – 2010:	Assistant Professor, Japan Advanced Institute of Sciences and Technology
2005 – 2007:	Postdoctor, Institute for Materials Research, Tohoku University

Research interests:

First-principles calculation; Transition-metal Oxide; Topological Materials; Magneto-optics

Selected Publications:

1. *Weyl Semimetal Phase in Noncentrosymmetric Transition-Metal Monophosphides*
   Hongming Weng*, C. Fang, Z. Fang, B. A. Bernevig, X. Dai
   Phys. Rev. X 5, 011029 (2015)
2. *Topological node-line semimetal in three-dimensional graphene networks*
   Hongming Weng*; Liang Y.; Xu Q.; Yu R.; Fang Z.; Dai X.; Kawazoe, Y.
   Phys. Rev. B 92, 045108 (2015)
3. *Dirac semimetal and topological phase transitions in A_3Bi (A = Na, K, Rb)*
   Wang Zhijun, Sun Yan, Chen Xing-Qiu, Franchini Cesare, Xu Gang, **Hongming Weng***, Xi Dai, Zhong Fang*
   Phys. Rev. B 85, 195320 (2012)
4. *Topological Crystalline Kondo Insulator in Mixed Valence Ytterbium Borides*
   Hongming Weng, JZ Zhao, ZJ Wang, X. Dai, Z. Fang

   Phys. Rev. Lett. 112 , 016403 (2014)

5. *Transition-Metal Pentatelluride $ZrTe_5$ and $HfTe_5$: a Paradigm for Large-gap Quantum Spin Hall Insulators*
   Hongming Weng, X. Dai*, Z. Fang*

   Phys. Rev. X 4 , 011002 (2014)

6. *Topological semimetals with triply degenerate nodal points in θ-phase tantalum nitride*
   Hongming Weng*, Chen Fang*, Zhong Fang, and Xi Dai
   Phys. Rev. B 93, 241202(R) (2016)
7. *Topological semimetals predicted from first-principles calculations*

   Hongming Weng *, Xi Dai* and Zhong Fang*

   J. Phys.: Condens. Matter 28, 303001 (2016)

Prediction of Topological Semimetals

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Abstract. Topological semimetals (TSMs), characterized by Weyl/Dirac nodes in the bulk and Fermi arcs on their surfaces, are new states of three-dimensional quantum matters. They represent the extension of the topological classification of matters from insulator to metal. The low energy excitation in Dirac/Weyl semimetals (WSM) behaves in the similar way as the massless Dirac/Weyl fermions described by Dirac/Weyl equation. The Weyl fermions have certain chirality and have not been discovered since Hermann Weyl proposed them nearly 88 years ago. The recent discovery of their quasiparticles in solids has inspired broad and intensive studies in the field of TSMs. Notably, the Lorentz invariance assumed in high-energy field theory is broken in solids, which leads to more unconventional quasiparticles beyond the traditional classification of Dirac-Weyl-Majorana fermions. This greatly enriches the quantum states of TSM family, including Node-Line semimetal, type-II WSM, multiple-degenerate nodal point semimetal, etc. The precise prediction of materials hosting these novel quantum states is highly needed for further studies, while it is also very challenge when facing countless materials. In this talk, I will introduce our theoretical predictions of them to show the physical pictures, experimental features and practical design. These successful stories have led to the first time realization of several TSM family members. Each of them and their relationship with each other are discussed and summarized.