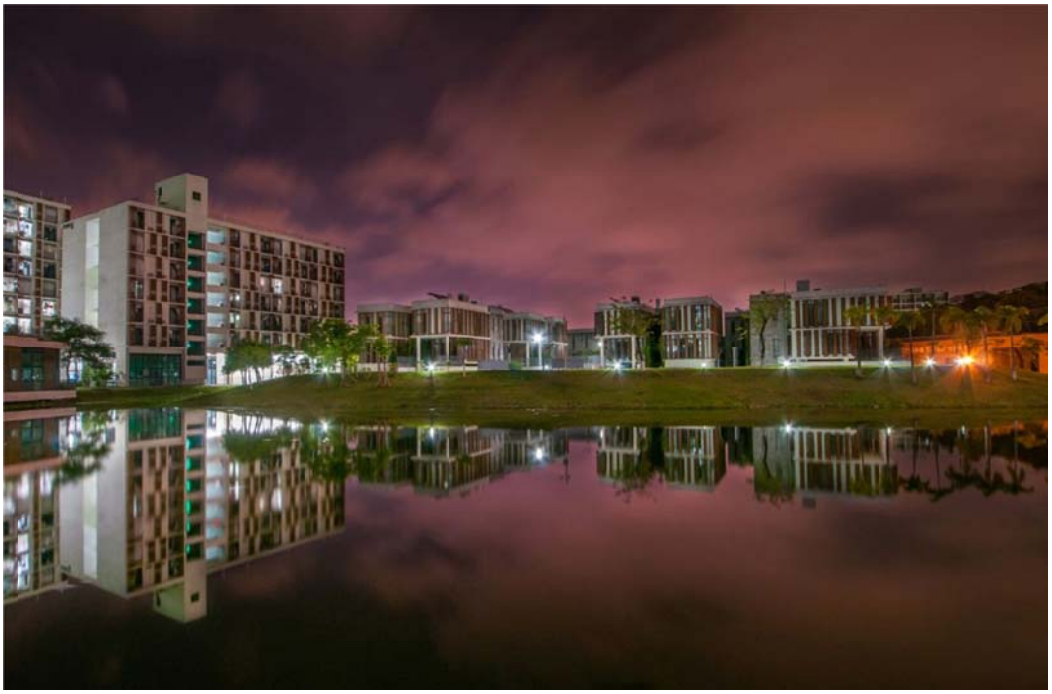
南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

“量子与信息科学”南科大高峰论坛

报告摘要手册



大会主席：俞大鹏　潘建伟

执行主席：赵予生　何佳清

主办单位：南方科技大学 物理系

“量子科学与工程”研究所

2016 年 11 月 4 日-6 日

南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

目　录

大会主题报告

南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

大会分会场报告（以姓氏笔画为序）

后摩尔时代新器件研究进展

黄如

北京大学

摘要：随着大规模集成电路技术的持续发展，来自短沟效应、量子隧穿以及寄生效应等问题的挑战使得传统微电子器件技术越来越难以满足 IC 技术持续推进的要求，特别是日益严峻的能耗问题已经成为延续摩尔定律的最大瓶颈，在后摩尔时代采用新器件技术成为必然。面向不同集成电路应用如何发展适合未来微电子产业需求的纳米尺度新器件成为当前热点问题。报告简单介绍后摩尔时代 IC 技术存在的挑战、发展趋势和特点，重点介绍面向不同应用的器件在结构材料和工作机理上发生和可能发生的变化，讨论新器件技术在高能效智能化电路系统发展中发挥的作用。

报告人简介：黄如，中国科学院院士，北京大学教授。1991 年毕业于东南大学电子工程系，1994 年获该校硕士学位，1997 年于北京大学获博士学位。现任北京大学信息科学技术学院院长，微纳电子研究院院长。研究方向：SOI 技术、纳米量级新结构器件及制备工艺技术，射频电路技术研究，模型模拟。

集成电路发展的挑战及应对策略

刘明

中科院微电子所

摘要：集成电路经过 60 年的快速发展，已经成为电子信息产业的基础和国家信息安全的根本保障。集成电路在不断缩小尺寸、提高性能和降低成本的发展道路日趋成熟，Scaling Down 严峻面临挑战； 未来集成电路进一步发展呈多元化趋势。本报告将讨论微电子的发展、现在、面临挑战及机遇。

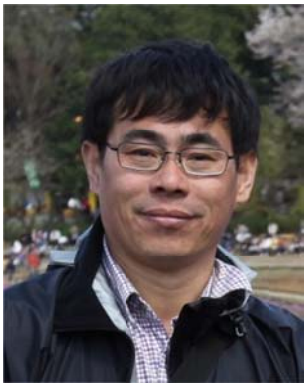
报告人简介：刘明，中国科学院院士，中国科学院微电子研究所研究员，从事微电子科学与技术的研究，研究兴趣主要是存储器机理模型、材料结构、核心共性技术和芯片集成等。973项目首席科学家、国家杰出青年基金获得者和基金委创新群体负责人。担任 “Applied Physics A” 的编辑、《中国科学》编委、Scientific Reports 的编委会委员等。

量子物理的新视野－从信息、能源到生命科学

孙昌璞

北京计算科学研究中心

摘要：本报告结合报告人个人的研究工作，系统地评述近年来量子物理基础研究的前沿问题和发展趋势：一方面，量子力学基本问题的研究已经走出原来的哲学逻辑思辨的层面，在面临着被实验全面检验的同时，正在突破哥本哈根诠释的窠臼，孕育着观念的变革；另一方面，量子物理与信息、生命和能源科学交叉，产生学科新的生长点。例如，生命体系量子效应的研究可能会成为一个蓬勃发展的前沿科学领域。深入研究光合作用过程中的量子相干效应机，将有助于设计具有高效光电转换仿生功能的固体人工器件， 超越传统硅基太阳能电池的光电转换效率；生物指南针的研究可以启发重大需求方面的量子感知和量子陀螺研究。



报告人简介：孙昌璞，中国科学院院士，发展中国家科学院院士，中国工程物理研究院北京计算科学研究中心教授。毕业于东北师大本科，于南开大学获博士学位。曾任东北师大教授， 中科院理论所研究员。获得过国家自然科学二等奖和美国ISI“经典引文奖”等奖励以及全国先进工作者和等荣誉称号，多次被评为中科院“优秀导师”，指导的研究生有2人

获全国“百篇优秀博士学位论文”、多人获得“中国科学院优秀博士论文”和科学院院长特别奖等. 他长期从事量子物理、数学物理及量子信息基础理论研究，发表论文300余篇，被引用10000余次，h因子53。有不少工作得到国际承认，如 q-变形玻色子工作是国际上本领域开创性工作之一 《科学》评述中国科学发展提及了这个工作。他预言的量子临界系统动力学不稳定效应和人工循环原子结构得到德国等多个实验证实。他还研究了低维纳米结构中单光子的传输和探测，近期开始探索生命过程中的量子相干效应，如人工光合作用和生物迁徙的量子指南针。

量子计算

郭光灿

中国科学技术大学

摘要：本报告将简述量子计算机诞生背景、基本原理、量子编码与容错编码以及量子芯片发展状况，最后对我国发展现状作个评述。

报告人简介：郭光灿，第三世界科学院院士，中国科学院院士，中国科学技术大学教授。现任中国科学院量子信息重点实验室主任、中国物理学会理事，中国光学学会理事，全国量子光学专业委员会主任；国家科技部973项目“量子通信与量子信息技术”首席科学家，中科院重要方向项目首席科学家，国家基金委创新群体学术带头人。国家科技部中长期规划“量子调控”重大项目－“量子通信与量子计算的物理实现”首席科学家；荣获国家自然科学二等奖，何梁何利奖，安徽省自然科学一等奖，安徽省2007年重大科技成就奖，被评选为中国科学院先进工作者、教育部全国优秀教师。主要从事量子光学、量子密码、量子通信和量子计算的理论和实验研究。

远距离量子通信进展

潘建伟

中国科学技术大学

摘要：量子力学是近代自然科学技术和社会经济发展的支柱。作为量子调控的第一个系统性应用，量子信息科学（包括量子通信、量子计算与模拟和量子精密测量等）可以在确保信息安全、提高运算速度、提升测量精度等方面突破经典信息技术的瓶颈，为社会经济发展所面临的多个重大问题提供革命性的解决途径。量子调控和量子信息技术的迅速发展标志着第二次量子革命的兴起。在量子通信方面，利用成熟的光纤技术和丰富的光纤资源，目前的量子通信技术已可以实现城域范围内的实用化，世界各国也已建设了多个量子通信网络。

我国在量子通信技术和应用方面处于国际领先地位，在国际上率先实现了安全通信距离突破100公里的光纤量子通信、建成国际上首个全通型量子通信网络、首个规模化城域量子通信网络，并初步应用于国防、政务、金融等领域的信息安全。

今年底，总长约 2000 公里的远距离光纤量子通信骨干网络“京沪干线”将建成，实现不同应用模式的示范。利用卫星对自由空间光量子传输进行中转，是实现远距离量子通信的另一有效途径；目前，我国已成功发射国际上首颗量子科学实验卫星，将首次实现星地量子通信，以及地面城域量子通信网络在卫星中转下的互联，结合京沪干线将初步构建我国天地一体的广域量子通信网络基础设施。

报告人简介：潘建伟，1992 年毕业于中国科学技术大学近代物理系，1995 年获该校理论物理硕士学位，1999 年获得奥地利维也纳大学博士学位，2005 年加入九三学社，2008 年入选中组部首批“千人计划”，2011 年当选为中国科学院院士。长期从事量子光学、量子信息和量子力学基础问题检验等方面的研究，对量子通信等研究有创新性贡献，是该领域的国际著名学者，有关实现量子隐形传态的研究成果入选美国《科学》杂志“年度十大科技进展”，并同伦琴发现 X 射线、爱因斯坦建立相对论等影响世界的重大研究成果一起被《自然》杂志选为“百年物理学 21 篇经典论文”。其研究成果曾 6 次入选两院院士评选的“中国年度十大科技进展新闻”、5 次入选欧洲物理学会评选的“年度物理学重大进展”、4 次入选美国物理学会评选的“年度物理学重大事件”。

量子材料发展与展望

俞大鹏

南方科技大学/北京大学

摘要：以能带理论为代表的固体物理学帮助人们打开了认识一系列纷繁多样的量子材料的大门。量子材料的研究把人们探索自然、创造知识的能力延伸到介于宏观和微观物体之间的中间领域。

2004 年英国的 Geim 和 Novoselov 等人发现石墨烯不仅可以稳定地存在于衬底上，而且表现出优越的物理性质[1]。石墨烯是由碳原子组成的二维蜂窝状单原子层材料，是目前发现的最薄、最硬、最强、最导热、最导电的一种新型量子材料，是“新材料之王”。在石墨烯及类石墨烯二维材料的所有可能应用中，电子芯片是真正体现石墨烯独特而优异性质的颠覆性应用。要真正把石墨烯做成未来电子芯片材料，还需要将石墨烯单晶的尺寸做得足够大，将石墨烯单晶的生长速度提高[2]，将 CVD 方法制备的石墨烯缺陷密度降到最低，保证其超高迁移率，将石墨烯可控打开合适的带隙（300 meV 以上，开关比>10^5）。

外尔费米子的一个重要性质是手型异常[3]。我们通过研究三维狄拉克材料 Cd3As2 的热电势，发现平行磁场下的负磁热电势行为，且伴随着高场下的变号，分析表明这是手性异常的表现，从而给出了外尔费米子这一奇异行为的热电势证据[4]。针对理论预言的外尔费米子的诸多奇特性质，通过对外尔半金属多种性质的研究，揭示其手性异常等效应，将是未来研究的重点。同时发现更多的外尔半金属，以及第二类外尔半金属。

二维晶体材料展现出丰富多彩的性质。最近，超导电性、电荷密度波等集体效应也在二维晶体中被观察到[5]。然而，凝聚态物理中的一些重要现象，如二维拓扑绝缘体，磁性等，尽管被大量理论预言在二维晶体中存在，但还未能在得到实验证实。a）拓扑绝缘体是近年来人们关注的热点之一，三维拓扑绝缘体，已经被大量发现。二维拓扑绝缘体的材料却局限于少数复杂的异质结构。在预言的许多基于二维晶体的拓扑绝缘体中，$ZrTe_5$ 受到广泛关注[6]。有证据表明 $ZrTe_5$

块材具有三维狄拉克的能带。我们首次研究了薄膜的电输运行为，证明其中有两个能带，且伴随厚度的减小，体系经历一个能带相对移动的变化。未来研究将主要集中在寻找和证实基于二维晶体的二维拓扑绝缘体，尤其是具有较大能隙且载流子浓度低的材料。在此基础上研究一维边缘态的性质并构建自旋电子学器件。**b**）磁性材料在当代科技中有广泛应用，二维磁性更是凝聚态物理发展进程中的一个关键问题。因此，在二维晶体中实现磁性，无论从应用还是基础物理角度都有重大意义。我们通过对过渡金属硫族化合物 V_5S_8 的反常霍尔效应的研究，发现厚度的减小导致一个反铁磁到铁磁的转变，证明少层 V_5S_8 在低温下具有铁磁性，该项研究打开了磁性二维晶体的一扇门。

我们相信，未来研究将会发现更多性质更优异的量子材料。同时受益于量子材料的可调控性，期望将会在自旋电子学方面有重要应用。量子材料这个全新的领域必将主导未来数十年的技术创新路径，深刻影响科技发展进程。

References:

[1] Novoselov K S, Geim A K, Morozov S V et al. Electric field effect in atomically thin carbon films. **Science** 306, 666-669. 2004.

[2] Xu X, Zhang Z, Qiu L et al. Ultrafast growth of single-crystal graphene assisted by a continuous oxygen supply. **Nature Nanotechnology**, DOI:10.1038/nnano.2016.1132. 2016.

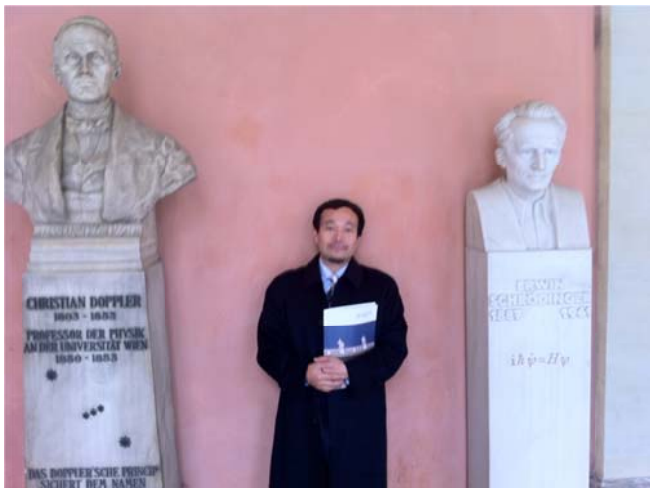
[3] P. Hosur and X. Qi, Recent developments in transport phenomena in Weyl semimetals, **C. R. Phys**. 14, 857-870 (2013).

[4] Li, Cai-Zhen; Wang, Li-Xian; Liu, Haiwen; et al., Giant negative magnetoresistance induced by the chiral anomaly in individual Cd3As2 nanowires, **Nature Communications** 6: 10137，2015；Li-Xian Wang,Cai-Zhen Li,Da-Peng Yu，Zhi-Min Liao，Aharonov–Bohm oscillations in Dirac semimetal Cd3As2 nanowires, **Nature Communications** 7, 10769，2016 ；Z. Jia, C. Li, X. Li, J. Shi, Z. Liao, D. Yu, and X. Wu, Thermoelectric signature of the chiral anomaly in Cd3As2, **Nature Communications** 7, 13013(2016).

[5] J. M. Lu, O. Zheliuk, I. Leermakers, N. F. Q. Yuan, U. Zeitler, and etc., Evidence for two-dimensional Ising superconductivity in gated MoS2, **Science** 350, 1353 (2015).

[6] H. Weng, X. Dai, and Z. Fang, Transition-Metal Pentatelluride ZrTe$_5$ and HfTe$_5$: A Paradigm for Large-Gap Quantum Spin Hall Insulators, **Phys. Rev. X** 4, 011002 (2014).

报告人简介：俞大鹏，



1959 年 3 月 16 日出生于宁夏中卫;法国南巴黎大学(Université de Paris, Orsay）固体物理实验室 (Laboratoire de Physique des Solides)博士；2000 年获得国家杰出青年科学基金； 2002 年获得教育部“长江学者”特聘教授；2005 年获得教育部长江学者与创新团队计划--“准一维纳米结构与低维物理”项目支持；2015 年当选为中国科学院技术学部院士。

俞大鹏院士长期从事纳米线材料中关键基础科学问题的研究，为我国纳米线材料科学研究进入国际先进行列做出了重大贡献：包括解决了规模、可控制备半导体量子线材料的难题、深入揭示了半导体量子线结构特有的新颖物理现象、系统发掘了半导体量子线的若干重大应用特性，发现了若干重要的纳米线器件效应，发明了一系列纳米加工与精确操控技术，申请国家发明专利 20 余项（含多项国际 PCT 专利），引领了半导体纳米线材料的应用基础研究。近十年来，俞大鹏院士把研究的重点放在量子材料的可控制备，特别是量子输运性质研究方面，并且取得长足的研究进展。

基于所取得的研究成果，俞大鹏院士共计发表 300 余篇论文，含 Nature 子刊、Physical Review Letters、Applied Physics Letters、Advanced Materials、Nano Letters 等顶级专业刊物论文 100 余篇，被同行参考他引一万余次，h 因子为 69。俞大鹏院士曾以第一完成人获得了 2004 年度教育部提名自然科学一等奖和 2007 年获国家自然科学二等奖、2016 年中国真空科技成就奖等。在世界著名出版公司 Elsevier 发布的 2014、2015 年度在全球具有重要学术影响力的中国高被引学者（Most Cited Chinese Researchers）榜单中，俞大鹏院士连续进入“物理与天文学科”前三名；被评选为 2015 年度北京大学研究生“十佳导师”。

俞大鹏团队近期代表性论文目录：

1. Xiaozhi Xu, Zhihong Zhang, Lu Qiu, Jianing Zhuang, et al., Ultrafast Growth of Large Single-crystal Graphene Assisted by Continuous Oxygen Supply, **Nature Nanotechnoloy** , in press，2016.
2. Thermoelectric signature of the chiral anomaly in Cd3As2, Zhenzhao Jia, Caizhen Li, Xinqi Li, Junren Shi, Zhimin Liao, et al., **Nature Communications** 7, accepted and in press，2016.
3. Aharonov–Bohm oscillations in Dirac semimetal Cd3As2 nanowires,Li-Xian Wang, Cai-Zhen Li, Da-Peng Yu，Zhi-Min Liao，**Nature Communications** 7, 10769，2016 .
4. A polymer scaffold for self-healing perovskite solar cells，Zhao, Yicheng; Wei, Jing; Li, Heng et al., **Nature Communications** 7 : 10228，2016 .
5. Giant negative magnetoresistance induced by the chiral anomaly in individual Cd3As2 nanowires，Li, Cai-Zhen; Wang, Li-Xian; Liu, Haiwen; et al., **Nature Communications** 6: 10137，2015.
6. Electrical control of intervalley scattering in graphene via the charge state of defects, Yan, Baoming; Han, Qi; Jia, Zhenzhao et al., **Physical Review B** 93: 041407,2016.
7. Vibrational spectroscopy at electrolyte/electrode interfaces with graphene gratings，Bie, Ya-Qing; Horng, Jason; Shi, Zhiwen et al., **Nature Communications** 6: 7593,2015.
8. Chen, Jing-Jing; Meng, Jie; Zhou, Yang-Bo; et al., Layer-by-layer assembly of vertically conducting graphene devices, **Nature Communications** 4, 1921, 2013.
9. Yu, Haiming; Granville, S.; Yu, D. P.; et al., Evidence for Thermal Spin-Transfer Torque, **Physical Review Letters** 104, 146601, 2010.
10. Zhu, X. L.; Ma, Y.; Zhang, J. S.; et al., Confined Three-Dimensional Plasmon Modes inside a Ring-Shaped Nanocavity on a Silver Film Imaged by Cathodoluminescence Microscopy, **Physical Review Letters** 105, 127402, 2010.
11. Liao, Zhi-Min; Wu, Han-Chun; Kumar, Shishir; et al.,Large Magnetoresistance in Few Layer Graphene Stacks with Current Perpendicular to Plane Geometry, **Advanced Materials** 24: 1862-1866, 2012.
12. Han, Xiaobing; Kou, Liangzhi; Zhang, Zhuhua; et al., Strain-Gradient Effect on Energy Bands in Bent ZnO Microwires, **Advanced Materials** 24: 4707-4711, 2012.
13. Bie, Ya-Qing; Zhou, Yang-Bo; Liao, Zhi-Min; et al., Site-Specific Transfer-Printing of Individual Graphene Microscale Patterns to Arbitrary Surfaces, **Advanced Materials** 23: 3938, 2011.
14. Bie, Ya-Qing; Liao, Zhi-Min; Zhang, Hong-Zhou; et al., Self-Powered, Ultrafast, Visible-Blind UV Detection and Optical Logical Operation based on ZnO/GaN Nanoscale p-n Junctions. **Advanced Materials** 23: 649, 2011.
15. Bie, Ya-Qing; Liao, Zhi-Min; Wang, Peng-Wei; et al., Single ZnO Nanowire/p-type GaN Heterojunctions for Photovoltaic Devices and UV Light-Emitting Diodes, **Advanced Materials** 22: 4284, 2010.
16. Zhu, Xinli; Zhang, Yang; Zhang, Jiasen; et al., Ultrafine and Smooth Full Metal Nanostructures for Plasmonics，**Advanced Materials** 22: 4345, 2010.
17. Han, Xiaobing; Kou, Liangzhi; Lang, Xiaoli; et al., Electronic and Mechanical Coupling in Bent ZnO Nanowires, **Advanced Materials** 21: 4937, 2009.
18. Li, Heng; Zhao, Qing; Wang, Wei; et al., Novel Planar-Structure Electrochemical Devices for Highly Flexible Semitransparent Power Generation/Storage Sources, **Nano Letters** 13: 1271-1277, 2013.
19. He, Li; Liao, Zhi-Min; Wu, Han-Chun; et al., Memory and Threshold Resistance Switching in Ni/NiO Core-Shell Nanowires, Nano Letters 11: 4601-4606, 2011.
20. Zhu, Xinli; Zhang, Jiasen; Xu, Jun; et al., Vertical Plasmonic Resonant Nanocavities, **Nano Letters** 11: 1117-1121, 2011.

1. 蔡建明: Dynamically Decoupling Protected Interrogation for Quantum Metrology

Yu Liu[1], Zijun Shu[1], Martin B. Plenio[2] and **Jianming Cai（蔡建明）**[1*]
[1]School of Physics & Center for Quantum Optical Science,
Huazhong University of Science and Technology, Wuhan 430074, P. R. China
[2]Institut fuer Theoretische Physik & IQST, Albert-Einstein Allee 11, Universitaet Ulm,
89069 Ulm, Germany

Abstract: Quantum enhanced sensing and metrology provides a powerful tool for the precise measurement of physical parameters that is applicable in many areas of science and technology. The achievable sensitivity in quantum enhanced metrology scales as a function of the number N of employed quantum systems. Quantum mechanics allows to achieve a 1/N-scaling known as Heisenberg limit that surpasses the $1/\sqrt{N}$ shot noise limit of classical statistics. Here, we propose a combination of adiabatic quantum state preparation and dynamically decoupling protected readout to demonstrate theoretically that it can achieve the Heisenberg limit in sensing and metrology applications, without resorting to quantum entanglement for quantum resource. The proposed protocol benefits from the energy gap protection against noise, and is feasible with the current state-of-art quantum engineering technology.

2. 曹俊诚: 太赫兹成像与通信应用研究

曹俊诚
中国科学院太赫兹固态技术重点实验室，
中国科学院上海微系统与信息技术研究所，上海，200050
E-mail: jccao@mail.sim.ac.cn

摘要:近些年来，太赫兹（THz）成像技术、通信技术以及光谱技术发展迅速。THz 成像技术在公共安全、生物医学、工业监控和无损检测分析等方面的应用研究引起了科研人员广泛关注。利用 THz 波可以穿透许多在可见和红外波段不透明的材料，以及成像分辨率高等特点，开发可在无损检测、质量控制和国家安全等领域获得实际应用的成像系统，成为研究的主要目标。同时，THz 波也适合于信息领域的大容量信号处理、与宽带高保密的数据通信等。

THz 辐射源与探测器是 THz 频段应用的关键器件。在众多 THz 辐射的产生方式中，基于半导体的 THz 量子级联激光器（QCL）由于其能量转换效率高、体积小、轻便和易集成等优点，成为本领域的研究热点之一。THz 量子阱探测器（QWP）是红外量子阱探测器向 THz 波段的延伸，是一类重要的 THz 辐射探测器。近年来，我们从理论上和实验上深入研究了 THzQCL 和 THzQWP 器件物理、材料生长、器件制备和表征，并实现了基于 THzQCL 和 THzQWP 的成像及通信演示。同时，我们在国家重大科学仪器设备开发专项的支持下，研制了基于 THz 技术的 THz 成像、成谱技术的危险品分析仪。本文重点报道了上述进展。

3. 常　凯: Semiconductor interface engineering towards topological phases

Kai Chang(常凯）
1SKLSM, Institute of Semiconductors, Chinese Academy of Science Beijing 100083

Abstract: Topological insulating and semimetal phases have aroused intense interests in condensed mattered physics in recent years. However, the reported materials possess topological phases are majorly composed of heavy elements with rare abundances. It has been proposed that the intrinsic polarization of GaN/InN/GaNheterostructures can be utilized to simultaneously reduce the energy gap, enhance the SOI,and finally driving the system to a TI state [1]. Inspired by this proposal, we promoted investigate objectives into commonly-used semiconductors, and demonstrated that, utilizing giant electric fields generated by charge accumulation at GaAs/Ge/GaAs opposite semiconductor interfaces and band folding, the interface engineering can reduce the sizable gap in Ge, induce large spin-orbit interaction, and drive Ge into a topological insulating phase [2]. In addition, the similar design can be applied in two-dimensional materials. We investigated Graphene/BN in-planeheterostructures by systematically considering possible interface configurations. Our results reveal that interface has significant impact on electronic properties. Specifically, for heterostructures with a zigzag type of interface, electronic states are found to be spin-polarized, and a half-metallic phase emerged. For heterostructures with an armchair type of interface, electronic states display a robust semiconducting behavior [3]. Very recently, we found out that, the interface engineering can not only induce topological insulator phase with a 50 meV nontrivial band gap but also Dirac semimetal phase in semiconductor heterostructures and superlattices [4]. The interface engineering provides a unique way to realize novel phase transitions in commonly-used semiconductors and suggests broad promising applications of well-understoodsemiconductors in virginal areas in the future.

References:

[1].M. S. Miao, Q. Yan, C. G. Van de Walle, W. K. Lou, L. L. Li, and K. Chang, ***Phys. Rev. Lett. 109***, 186803 (2012).

[2].Dong Zhang, Wenkai Lou, Maosheng Miao, Shou-cheng Zhang, and Kai Chang, ***Phys. Rev. Lett. 111***, 156402 (2013).

[3]. Dong Zhang, Dong-Bo Zhang, Fuhua Yang, Hai-Qing Lin, Hongqi Xu and Kai Chang, ***2D MATERIALS 2***, 041001 (2015).

[4]. J. P. Sun, J. J. Zhu, Dong Zhang, Kai Chang, submitted.

4. 但亚平：Self-Assembly of Macromolecules for Single Atoms Control

Yaping Dan（但亚平）
UM-SJTU Joint Institute, Shanghai Jiao Tong University

Abstract: Researchers at IBM first demonstrated the manipulation of xenon atoms at nickel substrate by using scanning tunneling microscope (STM) in 1995. In recent years, this technology was applied to control single dopant atoms at the surface of silicon substrates, forming transistors and quantum computing circuits. However, the technology does not fit for mass production of single atom devices and circuits. In this talk, I propose to control single dopant atoms at large scale by self-assembly of macromolecules. Each of the synthesized macromolecules carries only one phosphorus atom. The molecules are immobilized on the patterned silicon surface by forming covalent bonds with silicon. The molecule-carried phosphorus dopants are thermally driven into the silicon substrate and electrically activated by rapid thermal annealing. Low temperature Hall measurements and deep level transient spectroscopy are employed to investigate the electronic properties of doped substrates. The realization of single dopant atoms at large scale is still in progress.

Bio

Bio.: Dr. Yaping Dan is currently a tenure-track associate professor at UM-SJTU Joint Institute, Shanghai Jiao Tong University. He received the Bachelor from Xi'an Jiaotong University, Master's degree from Tsinghua University and PhD degree from the University of Pennsylvania. He joined the UM-SJTU Joint Institute as a faculty member in 2012 after finishing his postdoctoral research at Harvard University. He won the "1000 Young Scholars" award and Shanghai "Pujiang Talent Program" Award.

5. 段文晖: Parameter-Free Universality In Two-Dimensional Materials

Zeyu JIANG[1], Zhirong LIU[2], Yuanchang LI[3], Wenhui DUAN（段文晖）[1]
[1] Department of Physics, Tsinghua University, Beijing 100084, China
[2]Colledge of Chemistry and Molecular Engineering, Peking University, Beijing 100871, China
[3]National Center for Nanoscience and Technology of China, Beijing 100190, China

Abstract: Parameter-free universal phenomena are amazing while rare in the material science which are usually associated with profound physics behind, e.g., the topology for quantized conductance, the fine structure constant for opacity, the self-organized criticality for 1/*f* noise. Here we show that there exists such a material parameter-free behavior in two-dimensional (2D) semiconductors. That is a robust linear scaling law between the band gap (E_g) and the exciton binding energy (E_b), namely, $E_b = E_g/4$, regardless of their lattice configuration, bonding characteristic, as well as the topological property, which is never observed in their three-dimensional counterparts. The underlying mechanism is revealed based on the fact that both E_b and E_g can be generally expressed as a simple function of the 2D polarizability. This work adds an example to the rare universal phenomena in condensed matter physics and materials science that do not depend on material parameters, and even the fundamental constants.

6. 范　桁: Quantum Coherence And Uncertainty Relations: Theory And Experiment

Heng Fan（范桁）
[1]Institute of Physics, Chinese Academy of Sciences, Beijing 100190

Abstract: Quantum coherence is the fundamental reason for the significant phenomena differing from our everyday life such as uncertainty principle, entanglement and contextuality in quantum mechanics. By quantifying coherence, we observe that quantum coherence as resource should satisfy relations due to uncertainty principle in entropic representation. Experimentally, we demonstrate the coherence resource and entropic uncertainty relations in three measurements bases by a natural three-dimensional solid-state system: the nitrogen-vacancy (NV) center in pure diamond. The experimental data agrees well with theoretical expectation. The natural indivisible three dimension of spin-1 quantum state shows the principle of coherence and superposition not resulting from entanglement or non-locality. The entanglement-enhanced phase estimation in NV-diamond system will also be reported.

References:

[1]. G. Q. Liu, Y. R. Zhang, Y. C. Chang, J. D. Yue, Heng Fan* and X. Y. Pan*, ***Nature Communications 6***, 6726 (2015).

[2]. F. Franchini*, J. Cui, L. Amico, Heng Fan*, M. Gu, L. C. Kwek, V. Korepin* and V. Vedral,***Phys. Rev. X 4***, 041028 (2014).

[3]. Heng Fan, Y. N. Wang, L. Jing, J. D. Yue, H. D. Shi, Y. L. Zhang, and L. Z. Mu, ***Phys. Rep.*** 544, 241-322 (2014).

[4]. D. Wang, Z. Liu*, J. P. Cao and Heng Fan*, ***Phys. Rev. Lett. 111***, 186804 (2013).

[5].J. Cui, M. Gu, L. C. Kwek, M. F. Santos, Heng Fan and V. Vedral, ***Nature Communications 3***, 812 (2012).

7. 冯　军: Synthesis Of Novel Photocathode And Surface Study Using In-Situ Atomic Force Microscope

Jun Feng（冯军）
Advanced Light Source, Lawrence Berkeley National Laboratory, University of California at Berkeley

Abstract: The development of high performance photocathodes is a key challenge for next generation light sources such as high repetition rate Free Electron Laser (FEL), energy recovery linac (ERL), linac-based inverse Compton sources, and high brightness electron beam, detectors application, etc. Among various photocathodes such as traditional metal photocathodes, plasmon-enhanced photocathodes, and surface-state emitted electron cathodes, the synthetic alkali antimonide photocathodes have shown great promise for the next generation light source application because of their high quantum efficiency (QE), low thermal emittance, fast response time and response in the visible light wavelength range. It is well-known that the fabrication of multi-alkali cathodes is difficult and complicated. We have developed a new method using simultaneous element evaporation to grow green sensitive, low emittance and highly efficient photocathodes. In my talk, I will introduce our photocathode lab and report on the cathode fabrication, QE, transverse emittance measurement and the study of cathode surface using in-situ atomic force microscope.

8. 龚新高: Computational Studies of Novel Energy Materials: From interface to Extrinsic Properties

X.G. Gong（龚新高）
Key Laboratory for Computational Physical Sciences, Department of Physics, Fudan University

Abstract: With the rapid development of the modern computational techniques, computational studies on the condensed matter, simulating specific dynamics processes and designing desired materials, becomes feasible task and actually have played a more and more important role in materials science. In this talk, I will report our recent progress on the interface in the solar cell of the quaternary semiconductor alloy. By carefully analyzing the intrinsic defects, we propose Cu grading with Ag near the interface in the CZTS solar cell, which would increase the output voltage. By proposing the self-passivation rule, we clearly understand how to passivate defect state in the grain boundary, which would eliminate the recombination center and thus increase the current. Finally, I will briefly report our new results on the recombination rate in the solar cell by developing a new algorithm which makes the calculation feasible in the realistic materials.

References:

[1]. Z.K. Yuan, et al., ***ADVANCED FUNCTIONAL MATERIALS***, 25, 6733(2015)
[2]. C.Y. Liu, et al., P***HYSICAL REVIEW B***, 90, 205426(2016)
[3]. Z.K. Yuan, et al. ***ADVANCED ENERGY MATERIALS***, 1601191(2016)
[4]. C.Y. Liu, et al. ***ADVANCED ENERGY MATERIALS***, XXX(2016)
[5]. Z.Q. Li, et al., Unpublished.

9. 郭国平: 半导体量子芯片实验研究

郭国平

中国科学技术大学

摘要：作为现代信息科技的核心，半导体芯片由于尺寸等导致的量子效应已越来越明显，信息从编码、传送到处理与测量等也呈现出明显的量子化趋势。半导体量子芯片在继承现有半导体产业技术的基础上采用全量子化的信息编码和处理模式，构建新型的量子计算单元。本次报告将重点介绍我们在半导体量子芯片基本逻辑单元超快单比特量子逻辑门[1,2,3]、两比特量子受控非门[4]、长程量子比特的耦合和量子数据总线等方面的实验研究进展[5,6]，同时讨论石墨烯与类石墨烯 TMDS 等新半导体材料单电子晶体管和量子点的设计与调控问题。

References:

1. Ultrafast universal quantum control of a quantum-dot charge qubit...
Nature Commun. 4, 1401 (2013)
2. Detection and Measurement of Spin-Dependent Dynamics in Random...
Phys. Rev. Letter 111, 126803 (2013)
3. Tunable hybrid qubit in a GaAs double quantum dot.
Phys. Rev. Letter 116, 086801 (2016)
4. Conditional rotation of two strongly coupled semiconductor charge qubits
Nature Commun. 6, 7681 (2015)
5. Charge number dependence of the dephasing rates of a graphene double ...
Phys. Rev. Letter 115, 126804 (2015)
6. Coupling two distant double quantum dots with a microwave resonator
NanoLetter 16, 5456 (2016)

10. 何　林: Emergent Phenomena in Graphene

Lin He(何林)
Center for Advanced Quantum Studies, Department of Physics, Beijing Normal University, Beijing, 100875, People's Republic of China
helin@bnu.edu.cn

Abstract: In this talk, I will introduce several emergent states of graphene, including localized magnetic moments [1], non-Abelian-gauge-field-induced-localization [2-5], and topological edge states [6,7], induced by atomic defects and stacking orders. Our results demonstrate that STM is a powerful technique to direct image and characterize these novel electronic states in graphene.

References:

[1] Y. Zhang, S.-Y. Li, H. Huang, W. T. Li, J. B. Qiao, W.-X. Wang, L.-J. Yin, W. H. Duan, and **L. He***, "Direct experimental evidence of π magnetism of a single atomic vacancy in graphene". **Phys. Rev. Lett.** Vol: 117, PP. 166801 (2016).
[2] W. Yan, M. Liu, R.-F. Dou, L. Meng, L. Feng, Z.-D. Chu, Y. F. Zhang, Z. F. Liu, J.-C. Nie, and **L. He***, "Angle Dependent Van Hove Singularities in a Slightly Twisted Graphene Bilayer". **Phys. Rev. Lett.** Vol: 109, PP. 126801 (2012).
[3] W. Y. He, Z.-D. Chu, and **L. He***, "Chiral tunneling in a twisted graphene bilayer". **Phys. Rev. Lett.** Vol: 111, PP. 066803 (2013).
[4] L.-J. Yin, J. B. Qiao, W. J. Zuo, W. T. Li, and **L. He***, "Experimental evidence for non-Abelian gauge potentials in twisted graphene bilayers". **Phys. Rev. B** Vol: 92, PP. 081406(**Rapid Communications**) (2015).
[5] L.-J. Yin, J. B. Qiao, W.-X. Wang, W. J. Zuo, W. Yan, R. Xu, R.-F. Dou, J.-C. Nie, and **L. He***, "Landau Quantization and Fermi Velocity Renormalization in Twisted Graphene Bilayers". **Phys. Rev. B** Vol: 92, PP. 201408(**Rapid Communications**) (2015).
[6] L.-J. Yin, H. Jiang, J. B. Qiao, and **L. He***, "Direct imaging of topological edge states at a bilayer graphene domain wall". **Nature Commun.** 7, 11760 (2016).
[7] S.-Y. Li, H. Jiang, J.-J. Zhou, H. W. Liu, F. Zhang, and **L. He***, "Corrugation induced stacking solitons with topologically confined states in gapped bilayer graphene". **arXiv:1609.03313.**

11. 何　亮: The Quasi-2D Quantum Oscillations of Topological Insulator ZrTe5

Liang He（何亮）[1], Wang Wei[1], Xiaoqian Zhang[1], Yongbing Xu[1]
[1]York-Nanjing Joint Center (YNJC) for Spintronics and Nano Engineering, School of Electronics Science and Engineering, Nanjing University, Nanjing, 210093, China

Abstract: The layered material ZrTe5 who has large thermopower has attracted many attentions after being predicted as a topological insulator with 0.4 eV bulk direct band gap in 2014. Here we report the quantum oscillations in ZrTe5 bulk crystals, with mobility larger than 10000 cm2/Vs. The observed Fermi surface is shown to be two-dimensional, with a Berry phase 0.67. This suggests that ZrTe5 is a topologically non-trivial material. More importantly, the transport properties are dominated by a collective behavior of individual ZrTe5 single layer, evidenced by the quantized Hall resistance.

12. 贾金锋: Observation of Majorana fermions in the vortex

Jinfeng Jia（贾金锋）
[1]Key Laboratory of Artificial Structures and Quantum Control (Ministry of Education), Department of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China
[2]Collaborative Innovation Center of Advanced Microstructures, Nanjing 210093, China
*Email address: jfjia@sjtu.edu.cn

Abstract: Majorana fermion (MF) whose antiparticle is itself has been predicted in condensed matter systems. MFs can be used in fault-tolerant quantum computation relying on their non-Abelian braiding statistics, therefore, lots of efforts have been made to find them. Signatures of the MFs have been reported as zero energy modes in various systems. As predicted, MF in the vortex of topological superconductor appears as a zero energy mode with a cone like spatial distribution. Also, MF can induce spin selective Andreev reflection (SSAR), a novel magnetic property which can be used to detect the MFs. Here, all the three features are observed for the MFs inside vortices in Bi2Te3/NbSe2 hetero-structure [1-4], in which topological superconductivity was previously established [2,3]. Especially, by using spin-polarized scanning tunneling microscopy/spectroscopy (STM/STS), we observed the spin dependent tunneling effect, which is a direct evidence for the SSAR from MFs, and fully supported by theoretical analyses [4]. More importantly, all evidences are self-consistent. Our work provides definitive evidences of MFs and will stimulate the MFs research on their novel physical properties, hence a step towards their statistics and application in quantum computing.

References:

[1] M. X. Wang, et al., ***Science 336***, 52-55 (2012).
[2] J. P. Xu, et al., ***Phys. Rev. Lett.*** 112, 217001 (2014).
[3] J. P. Xu, et al., ***Phys. Rev. Lett.*** 114, 017001 (2015).
[4] H. H Sun, et al., ***Phys. Rev. Lett.*** 116, 257003 (2016).

13. 江　颖: Exotic quantum states of protons in water probed by STM

Ying Jiang（江颖）
International Center for Quantum Materials,
School of Physics, Peking University, Beijing 100871, P. R. China.

Abstract: Quantum behaviors of protons in terms of tunneling and zero-point motion have significant effects on the macroscopic properties, structure, and dynamics of H-bonded materials even at room temperature or higher. In spite of tremendous theoretical and experimental efforts, accurate and quantitative description of the quantum motion of protons is still challenging. The main difficulty lies in that the nuclear quantum effects (NQEs) are extremely susceptible to the structural inhomogeneity and local environments, especially when interfacial systems are concerned. Using a cryogenic scanning tunneling microscope (STM), we are able to achieve submolecular-resolution imaging [1,2] and single-bond vibrational spectroscopy [3] of water molecules on a NaCl(001) surface via controlling tip-water coupling, which allows us to access the quantum degree of freedom of protons both in real and energy space. In this talk, I will discuss how those techniques are used to directly visualize the concerted quantum tunneling of protons within the H-bonded network [4] and quantify the impact of nuclear quantum fluctuation on the strength of H bonds [3]. Our work opens up the new possibility of exploring the exotic quantum states of light nuclei with STM besides electrons, as well as the quantum coupling between the electrons and nuclei.

References:

[1] J. Guo, X. Z. Meng, J. Chen, J. B. Peng, J. M. Sheng, X. Z. Li, L. M. Xu, J. R. Shi, E. G. Wang*, Y. Jiang*, ***Nature Materials*** 13, 184 (2014).
[2] J. Chen, J. Guo, X. Z. Meng, J. B. Peng, J. M. Sheng, L. M. Xu, Y. Jiang*, X. Z. Li*, E. G. Wang, ***Nature Communications*** 5, 4056 (2014).
[3] J. Guo, J.-T. Lü, J. Chen, J. Peng, X. Meng, Z. Wang, Z. Lin, X.-Z. Li*, E.-G. Wang*, Y. Jiang*, ***Science*** 352, 321 (2016).
[4] X. Meng, J. Guo, J. Peng, J. Chen, Z. Wang, J. R. Shi, X. Z. Li, E. G. Wang*, Y. Jiang*, ***Nature Physics*** 11, 235 (2015).

14. 金贤敏: Writing Photonic Lattice Chip and Quantum Simulation

Jun GAO[1], Hao TANG[1], Xiaofeng LIN[1], Zhen FENG[1], **Xianmin JIN**（金贤敏）[1]
[1]Department of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China

Abstract: Photon can be generated, manipulated and detected comparatively easier than other quantum particles, and can be transferred in a long distance without coupling into environment. Photon therefore is a promising candidate for realising quantum information processing, including quantum enhanced communication, computation, simulation and metrology. However, a few limitations including phase stability, mode matching and loss that were thought to be only technical problems have become fundamental bottlenecks preventing quantum technology from realising in large scale and practical applications.

Integrated photonics is an elegant way to solve the aforementioned problems. In this talk, I will introduce the progress of building femtosecond laser writing 2.0 in Shanghai Jiao Tong University. We targeted at the key demands on devices in order to develop quantum communication and quantum computing. We have thoroughly studied the physical mechanism of waveguide writing in loss, precision and three-dimensional topological structures. With our laser-written integrated chip, it is feasible to manipulate quantum states in a high phase stability as well as highly complex interferometer, i.e. two-dimensional physics system, where little experimental demonstration has been achieved. I will present the result of non-classical correlation of two identical photons in a fully coupled two-dimensional photonic lattice [1]. I will also present new results of quantum walk both in a large-scale genuine two-dimensional structure [2], a graphene-like photonic lattice [3] and first experimental quantum percolation [4]. We are now developing fullly 3D fabrication capacity to reach the fascinating goal of simulating two-dimensional physics system and large-scale quantum information processing.

References:

[1] Gao, J. et al. Non-classical photon correlation in a two-dimensional photonic lattice. ***Opt. Express*** 24, 12607-12616 (2016)

[2] Lin, X.F. et al. Single walker quantum walk in a large-scale genuine two-dimensional structure. In preparation

[3] Tang, H. et al. Experimental quantum walk in a graphene-like photonic lattice. In preparation

[4] Feng, Z. et al. Experimental quantum percolation. In preparation

15. 李永庆: Nanoscale spin correlations and colossal magnetoresistance in $HgCr_2Se_4$

Yongqing Li（李永庆）
Institute of physics, Chinese Academy of Sciences, Beijing 100190, China

Abstract:$HgCr_2Se_4$ has been known as a magnetic semiconductor for five decades. It was however predicted to be a candidate for ferromagnetic Weyl semimetals in 2011. We have carried out a set of magnetization and transport measurements of n-type HgCr2Se4 single crystals to probe the nature of their electronic structure. For the samples with carrier densities on the order of 1018 cm-3, our magnetization and Andreev reflection spectroscopy measurements suggest a half-metallic ground state. Near the Curie temperature, pronounced critical behaviors have been observed in transport and magnetic properties. This can be attributed to strong spin fluctuations near the critical point and strong exchange coupling between low density conduction electrons and a 3D Heisenberg-type lattice of Cr3+ spins. The colossal magnetoresistance observed in a wide range of temperatures in the paramagnetic phase will be discussed in a context of magnetic polarons, nanoscale spin correlations, and the strong coupling between the conduction electrons and the lattice spins.

References:

[1] T. Guan, C. J. Lin, C. L. Yang, Y. G. Shi, C. Ren, Y. Q. Li, H. M. Weng, X. Dai, Z. Fang, S. S. Yan, and P. Xiong, *Evidence for half-metallicity in n-type $HgCr_2Se_4$*. ***Phys. Rev. Lett. 115***, 087002 (2015).
[2] C. J. Lin, C. J. Yi, L. Zhang, Y. G. Shi, G. M. Zhang, J. Müller, and Y. Q. Li, *Spin correlations and colossal magnetoresistance in $HgCr_2Se_4$*. ***arXiv:1610.00556.***

16. 廖志敏: 低维狄拉克材料的电子输运性质

廖志敏[1, 2*] 李彩珍[1] 王礼先[1] 俞大鹏[1,2, 3]
[1]北京大学物理学院，北京，邮编 100871；
[2]量子物质科学协同创新中心，北京，邮编 100871
[3]南方科技大学 物理系，深圳，邮编 518055
*Email:liaozm@pku.edu.cn

摘要:狄拉克电子材料中的载流子有效质量为零，能量和动量之间为线性色散关系，这种独特的狄拉克锥形电子能带结构导致许多新奇的量子输运性质。本报告我将汇报我们关于低维狄拉克电子材料（包括石墨烯、拓扑绝缘体 Bi_2Se_3 纳米结构、狄拉克半金属 Cd_3As_2 纳米结构）的制备和量子输运性质方面的工作:（1）石墨烯垂直结构的构筑，以及在电流垂直于石墨烯平面的情况下，温度、磁场、门电压对载流子输运的调制作用；（2）在高迁移率的 Bi_2Se_3 纳米结构中观测到来源于 Bi_2Se_3 纳米带侧面表面态的 Shubnikov-de Haas (SdH) 振荡，通过圆偏振光选择性激发拓扑绝缘体的表面态，增强了体系的光热电效应；（3）在狄拉克半金属 Cd_3As_2 纳米线中观测到负磁电阻效应和 A-B 效应，给出了外尔费米子手性反常效应以及表面态输运的实验依据。

参考文献:

[1] Li-Xian Wang, Cai-Zhen Li, Da-Peng Yu, Zhi-Min Liao*, "Aharonov–Bohm oscillations in Dirac semimetal Cd_3As_2 nanowires", ***Nature Communications*** 7, 10769 (2016).

[2] Cai-Zhen Li, Li-Xian Wang, Haiwen Liu, Jian Wang, Zhi-Min Liao*, Da-Peng Yu, "Giant negative magnetoresistance induced by the chiral anomaly in individual Cd_3As_2 nanowires", ***Nature Communications*** 6, 10137 (2015).

[3] Jing-Jing Chen, Jie Meng, Yang-Bo Zhou, Han-Chun Wu, Ya-Qing Bie, Zhi-Min Liao*, Da-Peng Yu*, "Layer-by-layer assembly of vertically conducting graphene devices", ***Nature Communications*** 4, 1921 (2013).

[4] Zhenzhao Jia, Caizhen Li, Xinqi Li, Junren Shi, Zhimin Liao*, Dapeng Yu, Xiaosong Wu*, "Thermoelectric signature of the chiral anomaly in Cd3As2", ***Nature Communications*** 7, 13013 (2016).

[5] Yuan Yan, Zhi-Min Liao*, Xiaoxing Ke, Gustaaf Van Tendeloo, Qinsheng Wang, Dong Sun, Wei Yao, Shuyun Zhou, Liang Zhang, Han-Chun Wu, Dapeng Yu*, "Topological Surface State Enhanced Photothermoelectric Effect in Bi2Se3 Nanoribbons", ***Nano Letters*** 14, 4389 (2014).

[6] Zhi-Min Liao*†, Han-Chun Wu*†, Shishir Kumar, et al, "Large Magnetoresistance in Few Layer Graphene Stacks with Current Perpendicular to Plane Geometry", ***Advanced Materials*** 24, 1862 (2012).

17. 刘　畅: ARPES investigation of selected topological materials

Chang Liu（刘畅）
Department of Physics, Southern University of Science and Technology, Shenzhen 518055, China

Abstract: The discovery of topologically non-trivial states of matter opens up a new realm of knowledge for fundamental condensed matter physics. Opposed to conventional materials, the so-called "topological insulators (TIs)" maintain an insulating bulk electronic structure, while exhibiting topologically-protected metallic surface states governed by the Dirac equation. The newly-discovered topological semimetals possess such linear dispersive pattern in all three dimensions, yielding pairs of Fermi dots and exotic Fermi arc surface states between the dots in a pair. In this talk, I will give an overview of our works in this field, including the discovery of the Dirac semimetallic state and the finding of 3D HgTe surface as a tunable topological insulator.

References:

[1] Chang Liu *et al.*, Tunable spin helical Dirac quasiparticles on the surface of three-dimensional HgTe. ***Phys. Rev. B* 92**, 115436 (2015)

[2] Su-Yang Xu*, Chang Liu* *et al.*, Observation of Fermi arc surface states in a topological metal. ***Science* 347**, 294 (2015)

18. 刘开辉: 原位纳米光谱学技术的发展和应用

刘开辉

北京大学

摘要:当材料的大小由宏观减小到低维尺度（约 1-10 nm）后，会出现很多新的物理现象:如量子受限、增强的多体相互作用、强的范德华耦合。由于低维材料单元中只有为数不多的原子，其物理性质强烈依赖于它的结构。为了研究其中新颖的物理规律，我们需要一种能直接把同一个低维材料结构和性质直接对应起来的技术。在本报告中我将介绍我们最近发展出的原位透射电镜、纳米光谱学、化学气相沉积生长结合技术，该技术具有测量同一个低维材料结构单元原子结构和物理性质的功能。我们利用该技术研究了一维碳纳米管、二维石墨烯和二硫化钼体系中一些低维物理和材料生长机理问题。

报告人简介: 刘开辉博士，北京大学物理学院研究员、博士生导师、中组部青年千人、基金委“优青”。本科毕业于北京师范大学物理学系（2004）；博士毕业于中科院物理所（2009）；2009-2014 在美国加州大学伯克利分校物理系从事博士后研究工作；2014 年回北京大学工作。

主要研究方向是:低维材料结构与物理。主要研究手段是:发展单个低维材料单元水平的原位透射电镜、纳米光谱学、化学气相沉积结合技术，以研究单个低维材料的生长、结构和性质的直接对应关系，从而揭露低维凝聚态物理中的新颖规律和材料生长机理。目前刘博士把该技术成功应用到一维碳纳米管、二维石墨烯等体系，取得了一些研究成果。发表 SCI 论文 40 余篇，其中包括第一作者和通讯作者的 ***Nature Nanotechnology*** (3 篇), ***Nature Physics, Nature Communications*** (3 篇), PNAS, JACS (2 篇), ***Advanced Materials, Nano Letters, ACS Nano, PRB, APL***。

19. 刘雄军: Chiral Majorana modes protected by an emergent 4D topological invariant

刘雄军

北京大学

Abstract: The search for topological superconductors and non-Abelian Majorana modes ranks among the most fascinating topics in condensed matter physics. There now exist several fundamental superconducting phases which host symmetry protected or chiral Majorana modes. The latter, namely the chiral Majorana modes are protected by Chern numbers which are topological invariants in even dimensions. Here we propose to observe a new type of chiral Majorana modes by realizing Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state in a Weyl semimetal which breaks time-reversal symmetry. Without symmetry protection, the 3D gapped FFLO phase is topologically trivial. However, we find that a vortex line generated in such phase can host chiral Majorana modes, which are shown to be protected by an emergent 4D topological invariant, namely the second Chern number of a synthetic 4D system generalized from the current FFLO phase. We further show that these chiral modes in the vortex rings obey non-Abelian statistics like the vortices in a p+ip superconductor. This work opens a new avenue in the study of new type Majorana modes and non-Abelian statistics of loop braiding which can be applied to topological quantum computation.

20. 刘玉玺: 基于超导磁通量子比特电路的新物理

刘玉玺

清华大学微电子学研究所
微电子和纳电子学系
清华大学信息科学与技术国家实验室（筹）

摘要:经过近 20 年的发展，基于量子计算的超导量子相干电路（也称超导人工原子）取得了巨大的发展。超导量子比特相干时间从最初的纳秒级大幅度地提升到百微秒。达到了量子计算纠错的阈值条件并具有了容错功能。电路扩展到包括 10 多个同种量子比特单元的规模，逻辑相干操控达到上千次。新设计的原型器件和相关的新物理现象接连涌现。

本报告将基于可控超导磁通量子比特电路，阐述其与天然原子不同的新的跃迁选择定则，以及由此导致的新物理和在量子计算中的应用。主要讲解磁通量子比特与微波电场的横向与纵向耦合的机制，纵场引起的电磁透明，纵场控制的量子比特和横向量子电场耦合的开关。三能级超导量子电路中量子态的绝热转变和关联激光器等理论，以及近来与这些理论相关的实验研究。

参考文献

[1] Yu-xi Liu, J. Q. You, L. F. Wei, C. P. Sun, and F. Nori, ***Phys. Rev. Lett.*** 95, 087001 (2005)

[2] Yu-xi Liu, C. X. Yang, H. C. Sun and X. B. Wang, ***New J. Phys.*** 16, 015031 (2014)

[3] Z. H. Peng, Yu-xi Liu, J. T. Peltonen, T. Yamamoto, J. S. Tsai, and O. Astafiev, ***Phys. Rev. Lett***. 115, 223603 (2015)

[4] H. K. Xu, C. Song, W. Y. Liu, G. M. Xue, F. F. Su, H. Deng, Ye Tian, D. N. Zheng, Siyuan Han, Y. P. Zhong, H. Wang, Yu-xi Liu, and S. P. Zhao, ***Nat. Commun***. 7, 11018 (2016).

[5] Yulin Wu, Li-Ping Yang, Yarui Zheng, Hui Deng, Zhiguang Yan, Yanjun Zhao, Keqiang Huang, William J. Munro, K. Nemoto, Dong-Ning Zheng, C. P. Sun, Yu-xi Liu, Xiaobo Zhu, and Li Lu，An efficient and compact quantum switch for quantum circuits，***arXiv:1605.06747***

21. 龙桂鲁: Quantum Secure Direct Communication: Principles and Current Status

Gui-Lu Long（龙桂鲁）
State Key Laboratory of Low-dimensional Quantum Physics and Department of Physics, Tsinghua University, Beijing 100084, China
The Innovative Center of Quantum Matter, Beijing 100084, China
Tsinghua National Laboratory of Information Science and Technology, Beijing 100084, China
gllong@tsinghua.edu.cn

Abstract: Quantum communication holds promise for absolutely security in secret message transmission. Quantum secure direct communication (QSDC), quantum key distribution and quantum secret sharing are the three major directions of secure quantum communication. In QSDC secret messages are sent directly over a quantum channel with security [1]. QSDC offers higher security and instantaneousness in communication [2]. It is also a powerful basic quantum communication primitive for constructing many other quantum communication tasks such as quantum bidding, quantum signature and quantum dialogue and so on. Since the first QSDC protocol proposed in 2000 [1], it has become one of the extensive research focuses in recent years. In this talk, I will introduce the basic ideas of QSDC, and major QSDC protocols such as the efficient-protocol[1], the two-step protocol[3], the DL04 protocol[4], the high-dimensional protocol [5]. I also will review the experimental progress. In particular, the quantum DL04 protocol[4] equipped with frequency coding has recently been successfully demonstrated experimentally[6]. An experimental demonstration of entanglement-based QSDC has been realized recently with the use of the state-of-the-art quantum memory [7]. A brief perspective will be also given. It is likely to be a major form of quantum secure communication in future all-quantum communications.

References:

[1] G L Long and X S Liu, ***Phys. Rev. A*** 65 , 032302 (2002)
[2] Z. C. Zhu, A. Q. Hu, A. M. Fu. Int. J. ***Theo. Phys.*** , 2014, 53(5): 1495-1501.
[3] Fu-Guo Deng, Gui Lu Long, Xiao-Shu Liu, ***Phys. Rev. A***68, 042317 (2003)
[4] Fu-Guo Deng and Gui Lu Long, ***Phys.Rev. A*** 69, 052319 (2004)
[5]Cuan Wang et al, ***Phys. Rev. A*** 71 , 044305 (2005)
[6] Jianyong Hu et al, ***Light: Science & Applications*** (2016) 5, e16144
[7] Zhang W, Ding D S, Sheng Y B, Zhou L, Shi B S and Guo G C 2016 preprint ***arXiv:1609.09184***

22. 卢海舟: Anomalous Phase Shift of Quantum Oscillations in 3D Topological Semimetals

Chunming WANG[1,2], Hai-Zhou LU（卢海舟）[1], Shun-Qing SHEN[3]

[1]Department of Physics, Southern University of Science and Technology, Shenzhen 518055, China

[2]School of Physics and Electrical Engineering, Anyang Normal University, Anyang 455000, China

[3]Department of Physics, The University of Hong Kong, Pokfulam Road, Hong Kong, China

Abstract: Berry phase physics is closely related to a number of topological states of matter. Recently discovered topological semimetals are believed to host a nontrivial Berry phase to induce a phase shift of in the quantum oscillation (+ for hole and - for electron carriers).We theoretically study the Shubnikov–de Haas oscillation of Weyl and Dirac semimetals, taking into account their topological nature and inter-Landau band scattering. For a Weyl semimetal with broken time-reversal symmetry, the phase shift is found to change nonmonotonically and go beyond known values of and , as a function of the Fermi energy. For a Dirac semimetal or paramagnetic Weyl semimetal, time-reversal symmetry leads to a discrete phase shift of or . Different from the previous works, we find that the topological band inversion can lead to beating patterns in the absence of Zeeman splitting. We also find the resistivity peaks should be assigned integers in the Landau index plot. Our findings may account for recent experiments in Cd2As3 and should be helpful for exploring the Berry phase in various 3D systems.

References:

[1]. C. M. Wang, Hai-Zhou Lu*, and Shun-Qing Shen, ***Physical Review Letters*** 117, 077201 (2016).

23. 卢明辉: 光、声拓扑态研究

卢明辉

南京大学

摘要:发现新的物相是凝聚态物理研究的重要内容。不同于传统的基于局域序参量的郎道相变理论，科学家陆续发现了整数量子霍尔、分数量子霍尔效应，以及量子自旋霍尔效应等基于全局的拓扑序参量的新物相，并陆续提出了拓扑绝缘体以及拓扑半金属等新的材料体系，使得拓扑序参量成为物相分类的新的序参量。这些概念首先在高能物理中提出，并在费米子凝聚态物理的准粒子系统中实现，电子传输受到对称性破缺或者时间反演对称性的保护，具有鲁棒性。最近几年来，玻色系统的拓扑性质也引起了人们的极大关注。本报告我将着重讨论我们课题组在对称性原理的框架下，基于人工带隙材料的研究平台，进行一系列关于光子和声子拓扑态的研究工作。不仅为量子模拟提供新的研究思路和材料平台，同时为光、声新型器件的设计提供了新的原理。

报告人简介:卢明辉 教授

南京大学现代工程与应用科学学院教授，南京大学首批登峰 B 人才、 首批“万人计划”青年拔尖人才，江苏省杰出青年，国家杰出青年（公示中）。2007 年于南京大学材料科学与工程系获博士学位,后留校任教。研究领域涉及光学、声学、凝聚态物理等相关领域及其交叉学科领域，主要研究方向为人工带隙材料、超构材料，人工微结构光电功能材料以及热电材料。迄今申请及授权中外专利 10 余项,，在 Science, Nature Materials, PRL,PRB, Sci. Rep. APL, OL/OE 等刊物上发表论文一百余篇，文章他引 2200 余次，H-index 21。2007 年获得《中国基础研究十大新闻》，2010 面获得全国优秀博士学位论文奖等荣誉。作为第二完成人获得 2013 年度高等学校科学研究优秀成果奖教育部自然科学一等奖, 2015 年度国家自然科学二等奖。目前，卢明辉还兼任中国声学学会物理声学分会委员。

24. 鲁大为: Twelve-Coherence Creation Supervised By A Quantum Computer

Dawei LU（鲁大为）1, Keren LI1,2, Jun LI3, Hemant KATIYAR1, Annie Jihyun PARK4, Guanru FENG1, Hang LI1,2, GuiLu LONG1,2, Aharon BRODUTCH5, Jonathan BAUGH1, Bei ZENG1,6, Raymond LAFLAMME1,7

1Institute for Quantum Computing, University of Waterloo, Waterloo N2L 3G1, Ontario, Canada

2State Key Laboratory of Low-Dimensional Quantum Physics and Department of Physics, Tsinghua University, Beijing 100084, China

3Beijing Computational Science Research Center, Beijing 100084, China

4Max-Planck-Institutfür Quantenoptik, D-85748 Garching, Germany

5Center for Quantum Information and Quantum Control, University of Toronto, Toronto M5S 3H6, Ontario, Canada

6Department of Mathematics & Statistics, University of Guelph, Guelph N1G 2W1, Ontario, Canada

7Perimeter Institute for Theoretical Physics, Waterloo N2L 2Y5, Ontario, Canada

Abstract: Quantum computers promise to outperform the classical counterparts in a myriad of applications. However, there is still a long way to go in building a universal quantum computer physically, despite the rapid experimental progress1. One primary reason is that the experimental control field of a large quantum system is difficult to be optimised using classical computers2,3, in order to satisfy the requirements of quantum computing about gate errors and quantum bit (qubit) lifetime. Based on the measurement-based quantum feedback control (MBQFC) approach4, here we report the experimental creation of a 12-coherent state with the essential control pulse completely designed on a 12-qubit nuclear magnetic resonance (NMR) quantum computer. Our results preliminarily show two superiorities in efficiency and performance beyond classical computing. First, the time of our control field optimisation via MBQFC is only linear to the number of qubits, and thus efficient; in fact, our 12-qubit quantum computer has already beat a prevailing computer configured with 2.7 GHz CPU and 4 GB memory regarding to this 12-coherence creation task. Furthermore, the fidelity of our prepared 12-coherence using MBQFC is 6.7 per cent higher than the best one using classical optimisation, demonstrating that MBQFC can inherently correct unknown errors of a quantum process to a certain extent. As the MBQFC approach is readily to be transferred to many other quantum systems, we anticipate to open up a way in precisely and efficiently controlling quantum systems and emerging more classical-outperforming experiments.

References:

[1]. Ladd, T. D. et al. Quantum computers. ***Nature*** 464, 45–53 (2010).

[2]. Gradl, T., Spörl, A., Huckle, T., Glaser, S. J. & Schulte-Herbrüggen, T. Parallelising matrix operations on clusters for an optimal control-based quantum compiler. In European Conference on Parallel Processing, 751–762 (***Springer***, 2006).

[3]. Lu, D. et al. Experimental estimation of average fidelity of a Clifford gate on a 7-qubit quantum processor. ***Phys. Rev. Lett.*** 114, 140505 (2015).

[4]. Li, J., Yang, X., Peng, X. & Sun, C.-P. Physical realization of a quantum oracle machine. ***arXiv:1608.00677*** (2016).

25. 陆朝阳: Creating Perfect Single Photons For The Demonstration Of Quantum Supremacy

Chao-Yang Lu（陆朝阳）

University of Science and Technology of China, Hefei, P.R. China

Abstract: In this talk, I will report two routes towards experimental boson sampling with many photons. We developed SPDC two-photon source with simultaneously a brightness of ~12 MHz/W, a collection efficiency of ~70% and an indistinguishability of ~91% between independent photons. With this, we demonstrate genuine and distillable entanglement of ten photons under different pump power [1]. Such a state-of-the-art multi-photon platform will provide enabling technologies for challenging optical quantum information tasks such as teleportation of three degrees of freedom of photons [2] and scattershot boson sampling.Self-assembled InGaAs QDs are promising solid-state emitters with near-unity quantum efficiency and fast decay rate. Using a QD coupled to a micropillar, we produced single photons with high purity, near-unity indistinguishability [3], and high extraction efficiency, compatibly and simultaneously [4]. Long streams of >1000 single photons separated by tens of microseconds maintain a >92% indistinguishability, which are shown to be near transform limit [5]. The single photons are time-bin encoded and interfered in an electrically programmable loop-based network [6].With further refinement, the two approaches may be feasible to be scaled up to≥20-boson sampling to outperform classical computers, and thus provide experimental evidence against the Extended Church-Turing Thesis.

References:

[1]. X.-L. Wang et al. Experimental ten-photon entanglement, ***arXiv:1605.08547.***

[2]. X.-L. Wang *et al.* Quantum teleportation of multiple degrees of freedom of a single photon, ***Nature 518***, 516 (2015).

[3]. Y.-M. He *et al.* On-demand semiconductor single-photon source with near-unity indistinguishability ***Nature Nanotechnology 8***, 213 (2013).

[4]. X. Ding *et al.* On-demand single photons with high extraction efficiency and near-unity indistinguishability from a resonantly driven quantum dot in a micropillar, ***Phys. Rev. Lett. 116,*** 020401 (2016).

[5]. H. Wang *et al.* Near transform-limited single photons from an efficient solid-state quantum emitter, ***Phys. Rev. Lett. 116,*** 213601 (2016).

[6]. Y. He *et al.* Boson sampling with a single-photon device, ***arXiv:1603.04127***

26. 马雄峰: From entanglement to quantum cryptography

Xiongfeng Ma（马雄峰）
Center for Quantum Information, Institute for Interdisciplinary Information Sciences,
Tsinghua University, Beijing, China

Abstract: Entanglement, “the spooky action at a distance”, plays a crucial role in the foundation test of quantum mechanics. In quantum information processing, entanglement becomes an important resource for various tasks, such as teleportation, quantum computation, and cryptography. Intuitively, entanglement means a strong nonlocal correlation between distant parties, which essentially offers a secure key generation tool. Various Bell’s inequality test experiments have proved that eavesdropping (as a local hidden variable) can be fundamentally ruled out. In this talk, I shall link the basic concept of entanglement with the security of key distribution.

27. 吕　力: Search For Majorana Zero Modes In Josephson Devices Constructed On Bi2Te3 Surface

Yuan Pang[1], Jie Shen[1], Fanming Qu[1], Zhaozheng Lyu[1], Junhua Wang[1], Junya Feng[1], Jie Fan[1], Guangtong Liu[1], Zhongqing Ji[1], Xiunian Jing[1,2], Changli Yang[1,2], Qingfeng Sun[2,3], X. C. Xie[2,3], Liang Fu[4] and Li Lu（吕力）[1,2]

1 Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, People's Republic of China

2 Collaborative Innovation Center of Quantum Matter, Beijing 100871, People's Republic of China

3 International Center for Quantum Materials, Peking University, Beijing 100871, People's Republic of China

4 Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Abstract: Recently, much attention has been paid to search for Majorana fermions in solid-state systems. Among various searching proposals there is one category of experiments based on proximity-effect-induced Josephson devices and phase-sensitive detections, in which a 4π-perioded current-phase relation is expected to occur if Majorana fermion states exist. In this talk I will report the observations of fully transparent quasiparticle transport and gap-closing in single Josephson junctions as well as in radio-frequency superconducting quantum interference devices (rf-SQUIDs) constructed on the surface of three-dimensional topological insulator Bi_2Te_3. The results support that Majorana fermions exist in these devices.

References

[1] Y. Pang, et al., arXiv:1503.00838v2.
[2] Y. Pang, et al., arXiv:1603.04540v1.

28. 毛金海: Manipulating Charge And Spin At A Vacancy Site In Graphene

Jinhai Mao
Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854, USA

Abstract: Graphene in its pristine form has transformed our understanding of 2D electron systems leading to fundamental discoveries and to the promise of important applications. New and surprising phenomena emerge when the perfect honeycomb lattice of graphene is disrupted. I have investigated the effect of single atom vacancies on graphene`s electronic and magnetic properties as revealed by scanning tunneling microscopy and spectroscopy. I will show that it is possible to deposit positive charge at the vacancy site in a controlled fashion and that the charge is stable. In this system we discovered that it is possible to charge the vacancy site into the supercritical regime where an artificial atom forms consisting of the central positive charge and surrounded by a sequence of quasi-bound states which are analogous to atomic collapse states in super-critical nuclei. We have further demonstrated that the magnetic moment of the vacancy can be screened by the conduction electrons, providing evidence of intriguing Kondo screening in this pseudogap system. Moreover I will show that the screening of the magnetic moment can be controlled by an external electric field.

29. 缪　峰: Electronic Transport and Device Applications of 2D Materials

Feng MIAO（缪峰）
School of Physics, Nanjing University, Nanjing 210093

Abstract: During the last decade, tremendous research efforts have been focused on two-dimensional (2D) materials due to their rich physics and great potentials for many applications. Our group at Nanjing University is now focusing on electronic transport, electro-mechanical properties, optoelectronic properties, and related device applications of various 2D materials. My talk will mainly cover our recent studies on transition-metal dichalcogenides (TMD) with low lattice symmetry. In a predicted type-II Weyl semimetal (WSM) material, tungsten ditelluride (WTe_2), we observed notable angle-sensitive negative longitudinal magnetoresistance (MR) and the strong planar orientation dependence which reveal important transport signatures of chiral anomaly. By applying a gate voltage, we further demonstrated that the Fermi energy can be tuned through the Weyl points via the electric field effect; this is the first report of controlling the unique transport properties *in situ* in a WSM system. [1]

We also studied atomically thin rhenium disulfide (ReS_2) flakes exhibiting interesting in-plane anisotropic transport and mechanical properties, as well as excellent optoelectronic properties. We fabricated mono- and few-layer ReS_2 field effect transistors, which exhibit competitive performances and record-high anisotropic ratio. We further successfully demonstrated an integrated digital inverter with good performances by utilizing two ReS_2 anisotropic field effect transistors, suggesting the promising implementation of large-scale two-dimensional logic circuits. [2] Our latest results on the ultra-high responsivity phototransistors based on few-layer ReS_2, broadband photovoltaic detectors based on an atomically thin heterostructure and the positive piezoconductive effect observed in suspended multi-layer graphene will also be presented. [3-4]

References:

[1] Wang, *et al*. “Gate-Tunable Negative Longitudinal Magnetoresistance in the Predicted Type-II Weyl Semimetal WTe2”, ***Nat. Comm.*** 7, 13142 (2016).

[2] Liu, *et al*. “Integrated Digital Inverters Based on Two-dimensional Anisotropic ReS_2 Field-effect Transistors”, ***Nat. Comm.*** 6, 6991 (2015).

[3] Liu, *et al*. “Ultra-high responsivity phototransistors based on few-layer ReS_2 for weak signal detection”, ***Adv. Func. Mater.*** 26, 1938 (2016); Long, *et al*. “Broadband photovoltaic detectors based on an atomically thin heterostructure”, ***Nano Lett.*** 16, 2254 (2016).

[4] Xu, *et al*. “The positive piezoconductive effect in graphene”, ***Nat. Comm.*** 6, 8119 (2015).

30. 石兴强: Tuning The Spintronic Properties At Organic/Magnetic Metal Interfaces

Xingqiang Shi (石兴强)

Department of Physics, South University of Science and Technology of China, Shenzhen, China, Email address: shixq@sustc.edu.cn

Abstract: Large magnetoresistance has been reported for C_{60}-based vertical spin valves. But for the underlying organic/magnetic interfacial atomistic structures, both experimental and theoretical works have assumed unreconstructed atomic structures for the magnetic surfaces, although organic molecule (e.g., fullerene and thiolate) adsorption frequently induces surface reconstruction. Here we report that C_{60} adsorption can induce prototype magnetic surfaces, Ni(111) [1], Fe(001) [2], and antiferromagnetic Cr(001) [3] reconstruction via thorough structural search from first-principles calculations, which can effectively tune the interface spintronic properties.

For the C_{60}/Ni(111) spinterface [1], surface reconstruction drastically modifies the magnetic properties at both sides of C_{60}/Ni(111): 1) the C_{60} spin polarization and conductance around the Fermi level are enhanced simultaneously, which can be important for read-head sensor miniaturization; 2) localized spin-polarized states appear in C_{60} with a spin-filter functionality, and 3) magnetocrystalline anisotropic energy (MAE) and magnetic exchange coupling in the outermost Ni layer are reduced enormously. Reconstruction solidifies the C_{60}/metal interface bonding and enhances C_{60} spin-polarization. More importantly, only our reconstructed structure can explain the experimental observation of an inversion of C_{60} spin-polarization around Fermi-level relative to that of the Fe substrate [2], which can be explained by a simple model.

Understanding these complex interface phenomena is a crucial step for their device applications.

References:

1. R. Pang, et al., J. Am. Chem. Soc. 2016, 138, 4029.
2. Z. H. Yang, et al., J. Phys. Chem. C 2015, 119, 10532.
3. In preparation

31. 宋凤麒:

拓扑绝缘体表面态的量子霍尔效应和普适电导涨落实验研究

张帅 1，李兆国 1，潘星辰 1，皮雳 2，王伯根 1，宋凤麒 1
1 南京大学物理学院，南京市汉口路 22 号，南京
2 中科院合肥强磁场中心，合肥
Email: songfengqi@nju.edu.cn

摘要:拓扑绝缘体的体相能带具有一个奇异的拓扑数，其与真空邻接的界面存在一个表面态。此处介绍我们课题组在拓扑绝缘体表面态低温输运研究的两个结果。拓扑绝缘体实际材料中存在体相、表面平庸、表面拓扑载流子等多种输运组分，如何确认拓扑表面态的输运特征？我们在此展示三元拓扑绝缘体 Bi_2Te_2Se 器件拓扑表面态的普适电导涨落（UCF）的例子。包含四方面证据:1）在磁电阻曲线中观察到一系列不规则的可重复的量子噪音，其幅度为 e^2/h 量级。2）所有量子噪音只与磁场的垂直分量有关，这指出了信号的二维特征。3）施加一系列固定的平行场，量子噪声的特征和参数保持不变，这排除了准二维体态的贡献。4）信号幅度与拓扑态预言接近，并且随着磁场增加出现了一个量子平台。

我们优化生长了四元拓扑绝缘体 BiSbTeSe2 的单晶样品，实现了主导的和高迁移率的表面态输运。其特征表现为量子霍尔效应的出现。我们在样品中观察到了量子霍尔效应的台阶，在 27.4 特斯拉的强场下，我们可以观察到多个霍尔平台。利用背门可以将下表面的朗道指数从 1/2 调节到-5/2，利用表面颗粒修饰则可以将上表面的朗道指数从-1/2 调节到 1/2。我们还进行了器件弱反局域化和 Shubnikov de Haas 振荡的分析，尝试探索 Co 纳米团簇修饰对拓扑器件的影响。

32. 宋祎璞: Coulomb Oscillations In A Gate-Controlled Few-Layer Graphene Quantum Dot

宋祎璞
IIIS, Tsinghua University

Abstract: Graphene quantum dots could be an ideal host for spin qubits, and thus have been extensively investigated based on graphene nanoribbons and etched nanostructures, however, edge and substrate-induced disorders severely limit device functionality. Here, we report the confinement of quantum dots in few-layer graphene with tunable barriers, defined by local strain and electrostatic gating. Transport measurements unambiguously reveal that confinement barriers are formed by inducing a band-gap via the electrostatic gating together with local strain induced constriction. Numerical simulations according to the local top-gate geometry confirm the band-gap opening by a perpendicular electric field. We investigate the magnetic field dependence of the energy-level spectra in these graphene quantum dots. Experimental results reveal a complex evolution of Coulomb oscillations with the magnetic field, featuring kinks at level crossings. The simulation of energy spectrum shows that the kink features and the magnetic field dependence are consistent with experimental observations, implying the hybridized nature of energy-level spectrum of these graphene quantum dots.

33. 孙麓岩: Superconducting circuits for quantum information processing

Luyan Sun (孙麓岩)
IIIS, Tsinghua University

Abastract: Superconducting quantum circuits, particularly circuit Quantum Electrodynamics (circuit QED), have become a promising platform for quantum information processing (QIP) because of their long coherence times, fast quantum manipulation, and ease of scale up. In this talk, I will first talk the recent progress based on this system towards QIP, in particular quantum error correction. Then I will focus on our two recent experiments with this system at Tsinghua University, although not particular for the purpose of QIP. In the first experiment, we demonstrate a unique two-fold quantum delayed-choice experiment, enabled by a which-path detector with further unprecedented controllability to test of wave-particle complementarity. In the second experiment, we demonstrate a new method to generate arbitrary Fock-state superpositions. As examples, we generate high-fidelity phase eigenstates under various Hilbert-space dimensions and squeezed states, which are useful for quantum walk and high-precision measurements, respectively.

34. 万贤纲: Novel properties of 5d transition metal compounds

Xiangang Wan（万贤纲）
Department of Physics, Nanjing University, Nanjing 210093, China

Abstract: In 5d transition metal oxides, novel properties arise from the interplay of electron correlations and spin-orbit interactions. In this talk, I will discuss our theoretical progress relating to 5d compounds. We focus on describing the anisotropic unscreened Coulomb interaction in ferroelectric metal LiOsO□, the interesting spin texture in WTe2 and the pressure-induced dome-shape like superconductivity in WTe2。

35. 万义顿: Experimental Identification of Non-Abelian Topological Orders on a Quantum Simulator

Keren Li[1,2], Yidun Wan（万义顿）[3,4], Ling-Yan Hung[3], Tian Lan[4], Guilu Long[1], Dawei Lu[2], Bei Zeng[2,5,6], Raymond Laflamme[2,4,6]

[1]State Key Laboratory of Low-Dimensional Quantum Physics and Department of Physics, Tsinghua University, Beijing 100084, China

[2]Institute for Quantum Computing and Department of Physics and Astronomy, University of Waterloo, Waterloo N2L 3G1, Ontario, Canada

[3]Department of Physics and Center for Field Theory and Particle Physics, Fudan University, Shanghai 200433, China

[4]Perimeter Institute for Theoretical Physics, Waterloo N2L 2Y5, Ontario, Canada

[5]Department of Mathematics & Statistics, University of Guelph, Guelph N1G 2W1, Ontario, Canada

[6]Canadian Institute for Advanced Research, Toronto M5G 1Z8, Ontario, Canada

Abstract: Two-dimensional quantum systems with intrinsic topological orders can be used as media for topological quantum computing --- a promising quantum computation model against local errors. Conversely, a quantum simulator, often regarded as a special quantum computer, also offers a way of characterizing topological orders. Here, we show how to identify distinct topological orders via measuring their modular *S* and *T* matrices. We employ a nuclear magnetic resonance quantum simulator to study the properties of three topologically ordered matter phases described by the string-net model with two string types, including the Z_2 toric code, doubled semion, and doubled Fibonacci order. The latter---non-Abelian Fibonacci order---is notably expected to be the simplest candidate for universal topological quantum computing. Our experiment serves as the basic module, built on which one can simulate braiding of non-Abelian anyons and ultimately topological quantum computation via the braiding, and thus provides a new approach of investigating topological orders using quantum computers.

References:

[1]. Experimental Identification of Non-Abelian Topological Orders on a Quantum Simulator, Keren Li, Yidun Wan, Ling-Yan Hung, Tian Lan, Guilu Long, Dawei Lu, Bei Zeng, Raymond Laflamme, Under review in ***PRL.***

36. 汪子丹:Realizing And Manipulating Novel Topological Semimetal Bands With Superconducting Quantum Circuits

Xinsheng TAN[1], Y. X. ZHAO[2, 3], Qiang LIU[1], Guangming XUE[1], Haifeng YU[1], Z. D. WANG [2]（汪子丹）, Yang YU[1]
[1]National Laboratory of Solid State Microstructures, School of Physics, Nanjing University, Nanjing 210093
[2]Department of Physics, The University of Hong Kong
[3]Max-Planck-Institute for Solid State Research, D-70569 Stuttgart, Germany

Abstract: Symmetry and topology, as the two fundamentally important concepts in physics and mathematics, have not only manifested themselves in science, but also provided us with profound understanding of arresting natural phenomena. Recently, topological gapless systems, including Z_2 topological metals/semimetals [1-3], have stimulated significant research interests both theoretically and experimentally. In this talk, we will report experimental realization and manipulation of some novel topological semimetal bands in superconducting quantum circuits as well as the probe of exotic topological characters in these systems [4,5].

This work was partly supported by the GRF of Hong Kong (HKU173051/14P& HKU173055/15P) and the NKRDP of China (Grant No. 2016YFA0301802).

References:

[1]. Y. X. Zhao and Z. D. Wang, ***Phys. Rev. Lett.*** **110**, 240404 (2013).
[2]. Y. X. Zhao and Z. D. Wang, ***Phys. Rev. Lett***. **116**, 016401 (2016).
[3]. Y. X. Zhao and Z. D. Wang, ***Phys. Rev. Lett.*** **116**, 156402 (2016).
[4]. X. Tan *et al.*, to be published (2016).
[5]. X. Tan *et al.*, to be submitted (2017).

37. 王　干:Interfacial Superconductivity in Molecular Beam Epitaxy Grown Ultrathin Bi_2Te_3/FeTe Bilayers

Hailang Qin[1], Bochao Xu[1], Iamkeong SOU[2], **Gan WANG（王干）**[1]

[1]Department of Physics, Southern University of Science and Technology, Shenzhen 518055

[2]Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong S. A. R.

Abstract: In the past years, great efforts has been devoted to the study of Topological Insulator(TI) materials in the condense matter physics community, since the non-trivial gapless Dirac shape surface states owned by TI has shown great application potential in the study of spintronics and quantum devices. Recently, it also has been demonstrated that the interplay between superconductivity and TI surface state will pave the way to the realization of Majorana Fermions in solid state experimentally.[1] Thus, the growth of superconductor and topological insulator bilayer with an atomic sharp interface is quite essential for the further study of TI materials. In this study, we demonstrated the growth of ultrathin Bi_2Te_3/FeTe bilayers with an interfacial superconductivity of T_c=12K using Molecular Beam Epitaxy(MBE) technique.[2, 3] Through precisely epitaxial growth modulation, we proved that the interfacial superconductivity is strongly dependent on the thickness of Bi_2Te_3 layer. Via low temperature scanning spectroscopy study, we also found that the superconducting gap can be detected in the Bi_2Te_3 layer. All the results make the superconducting Bi_2Te_3/FeTe bilayer a promising platform for studying the interplay between topological surface states and superconductivity, as well as the unconventional superconductivity of iron chalcogenides.

References:

[1] H.H. Sun, K.W. Zhang, L.H. Hu, C. Li, G.Y. Wang, H.Y. Ma, Z.A. Xu, C.L. Gao, D.D. Guan, Y.Y. Li, C.H. Liu, D. Qian, Y. Zhou, L. Fu, S.C. Li, F.C. Zhang, J.F. Jia, Majorana Zero Mode Detected with Spin Selective Andreev Reflection in the Vortex of a Topological Superconductor, ***Physical Review Letters*** *116* (2016).

[2] Q.L. He, H.C. Liu, M.Q. He, Y.H. Lai, H.T. He, G. Wang, K.T. Law, R. Lortz, J.N. Wang, I.K. Sou, Two-dimensional superconductivity at the interface of a Bi2Te3/FeTe heterostructure, ***Nature Communications*** 5 (2014).

[3] G. Wang, Q.L. He, H.T. He, H.C. Liu, M.Q. He, J.N. Wang, R. Lortz, G.K.L. Wong, I.K. Sou, Formation Mechanism of Superconducting Fe1+xTe/Bi2Te3 Bilayer Synthesized via Interfacial Chemical Reactions, ***Crystal Growth & Design*** 14 (2014)

38. 王浩华: Solving Linear Systems of Equations with A Four-Qubit Superconducting Circuit

Haohua Wang (王浩华)
Department of Physics, Zhejiang University

Abstract: In this talk, I will review our recent activities with our collaborators on designing and fabricating various superconducting circuits for scalable quantum information processing. I will show that we are able to manipulate superconducting circuits with moderate complexity, which may integrate up to ten qubits and have decent coherence performance. As an example, I will introduce a circuit QED processor which consists of four individually-accessible Xmon qubits that are arranged in a chain. Neighboring qubit couplings can be flexibly turned on and off by tuning the qubits' resonance frequencies. With this processor we demonstrate a simplest instance of a quantum algorithm that promises an exponential speedup over classical algorithms in solving linear systems. The experimental sequence is one-microsecond long, which consists of 9 single-qubit gates and 9 two-qubit entangling gates in total. For eighteen input vectors, execution of the algorithm using our four-qubit circuit yields solutions with reasonably high fidelities ranging from 0.84 to 0.92.

Work in collaboration with Xiaobo Zhu at IOP and Chaoyang Lu at USTC.

39. 王建农: The Origin of Bias Independent Conductance Plateaus and Zero Bias Conductance Peaks in Bi2Se3/Nbse2 Hybrid Structures

Jiannong Wang（王建农）
Department of Physics, the Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, China
Email: phjwang@ust.hk

Abstract: Superconducting proximity effect (SPE) in topological insulator (TI) and superconductor (SC) hybrid structure has attracted intense attention in recent years in an effort to search for mysterious Majorana fermions (MFs) in condensed matter systems. Here we report on the SPE in a Bi2Se3/NbSe2 junction fabricated with an all-dry transfer method. Resulting from the highly transparent interface, two sharp resistance drops are observed at 7 K and 2 K, respectively, corresponding to the superconducting transition of NbSe2 flake and the SPE induced superconductivity in Bi2Se3 flake. Experimentally measured differential conductance spectra exhibit a bias-independent conductance plateau (BICP) in the vicinity of zero bias below 7 K. As temperatures further decrease a zero bias conductance peak (ZBCP) emerges from the plateau and becomes more enhanced and sharpened at lower temperatures. Our numerically simulated differential conductance spectra reproduce the observed BICP and ZBCP and show that the SPE in topological surface states (TSS) is much stronger than that in the bulk states of Bi2Se3. The SPE induced superconducting gap for the TSS of Bi2Se3 is comparable to that of NbSe2 and gives rise to the observed BICP below 7 K. In contrast, the SPE induced superconducting gap for the bulk states of Bi2Se3 is an order of magnitude smaller than that of NbSe2 and superconducting TSS. These weakly paired bulk states in Bi2Se3 give rise to the ZBCP below 2 K. Our study has clearly unveiled the different roles of TSS and bulk stats in SPE, clarified the physical origin of the SPE induced features, and shined light on further investigation of SPE and MF in TI/SC hybrid structures.

40. 王　健: Discovery Of Quantum Griffiths Singularity And Tip-Induced Topological Superconductivity

Jian Wang（王健）
International Center for Quantum Materials, School of Physics, Peking University, Beijing 100871, China

Abstract: By both in situ scanning tunneling microscopy/spectroscopy and ex situ transport and magnetization measurements, we find that the two-atomic-layer Ga film with graphene-like structure on wide band-gap semiconductor GaN is superconducting with Tc up to 5.4 K. [1] Furthermore, in three-atomic-layer Ga films, we firstly observe quantum Griffiths singularity in two dimensional (2D) system and superconductors.[2] As for the superconductivity in topological materials, we detect the tip-induced novel superconductivity in crystalline 3D Dirac semimetal Cd3As2 [3] by using hard point contact measurements with some signatures showing the possibility of topological superconductivity.[4]

References

[1] Huimin Zhang, et al., ***Physical Review Letters*** 114, 107003 (2015) (Editors' Suggestion).
[2] Ying Xing, et al., Science 350, 542 (2015) (with a perspective article: ***Science*** 350, 509)
[3] Yanfei　Zhao, et al., ***Physical Review X*** 5, 031037 (2015)
[4] He Wang, et al., ***Nature Materials*** 15, 38 (2016)
[4] Zhenzhao Jia, Caizhen Li, Xinqi Li, Junren Shi, Zhimin Liao*, Dapeng Yu, Xiaosong Wu*, "Thermoelectric signature of the chiral anomaly in Cd3As2", ***Nature Communications*** 7, 13013 (2016).
[5] Yuan Yan, Zhi-Min Liao*, Xiaoxing Ke, Gustaaf Van Tendeloo, Qinsheng Wang, Dong Sun, Wei Yao, Shuyun Zhou, Liang Zhang, Han-Chun Wu, Dapeng Yu*, "Topological Surface State Enhanced Photothermoelectric Effect in Bi2Se3 Nanoribbons", ***Nano Letters*** 14, 4389 (2014).
[6] Zhi-Min Liao*†, Han-Chun Wu*†, Shishir Kumar, Georg S. Duesberg, Yang-Bo Zhou, Graham L. W. Cross, Igor V. Shvets, and Da-Peng Yu, "Large Magnetoresistance in Few Layer Graphene Stacks with Current Perpendicular to Plane Geometry", ***Advanced Materials*** 24, 1862 (2012).

41. 王　宁: Observation Of The Quantum Hall States In Few-Layer Transition Metal Dichalcogenides

Ning Wang(王宁)
Department of Physics and the Center for 1D/2D Quantum Materials, the Hong Kong University of Science and Technology, Hong Kong, China.

Abstract: Atomically thin transition metal dichalcogenides (TMDCs) have opened new avenues for exploring physical property anomalies due to their large band gaps, strong spin-orbit couplings, and rich valley degrees of freedom. Although novel optical phenomena such as valley selective circular dichroism, opto-valley Hall effect, and valley Zeeman effect have been extensively studied in TMDCs, investigation of quantum transport properties has encountered a number of obstacles primarily due to the low carrier mobility and strong impurity scattering. Recently, we successfully fabricated ultrahigh-mobility few-layer TMDC field-effect transistors based on the boron nitride encapsulation method and observed a number of interesting transport properties, such as even-odd layer-dependent magnetotransport of Q-valley electrons and unconventional quantum Hall transport of Γ-valley hole carriers under a moderate strength magnetic field. For example, in few-layer TMDCs, the conduction bands along the ΓK directions shift downward energetically in the presence of interlayer interactions, forming six Q-valleys related by three-fold rotational symmetry and time reversal symmetry. In even-layers the extra inversion symmetry requires all states to be Kramers degenerate, whereas in odd-layers the intrinsic inversion asymmetry dictates the Q-valleys to be spin-valley coupled. In this talk, I'll demonstrate the prominent Shubnikov-de Hass (SdH) oscillations and the observation of the onset of quantum Hall (QH) plateaus for the Q-valley electrons and Γ-valley holes in few-layer TMDCs. Universally in the SdH oscillations, we observe a valley Zeeman effect in all odd-layer TMDC devices and a spin Zeeman effect in all even-layer TMDC devices. We observe a series of QH states following an unconventional sequence predominated by odd-integer states under a moderate strength magnetic field. By tilting the field and varying the temperature, remarkably, we discover Landau level crossings at very low coincident angles, revealing that the Zeeman energy is about three times as large as the cyclotron energy near the valence band top at Γ-valley.

42. 王　欣: Composite Pulses For Robust Control Of Spin Qubits

Wang Xin (王欣)
Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong SAR, China

Abstract: Spin qubits in semiconductor quantum dots are promising candidates for quantum information processing due to their demonstrated long coherence time, reasonably high control fidelity, and prospects for scalability. Despite these successes, there remain great challenges to overcome, with the major one being decoherence, the process through which the qubit loses the information it carries while interacting with its environment. Various techniques are proposed to combat decoherence, including the dynamically corrected gates using composite pulse sequences that are able to cancel both nuclear and charge noises simultaneously while performing a quantum gate operation. In this talk, I will present recent developments on these noise-compensating composite pulses for spin qubits, including gate sequences which are simultaneously resilient to nuclear and charge noises at both single- and two-qubit level. I will also present our attempt to improve the control fidelity of capacitively coupled spin qubits by making simple modifications to control sequences that are already used in the laboratory. With time permitting, I will discuss the possibility to achieve the same level of robustness using analytically designed smooth pulse instead of the square pulse traditionally used. These results mark an important step forward in using semiconductor spin qubits as the platform for scalable, fault-tolerant quantum computation.

Keywords: spin qubit, decoherence, robust control

References:

[1] X. Wang, L. S. Bishop, J. P. Kestner, E. Barnes, K. Sun, and S. Das Sarma, Composite pulses for robust universal control of singlet-triplet qubits, ***Nature Commun.*** 3, 997 (2012).

[2] J. P. Kestner, X. Wang, L. S. Bishop, E. Barnes, and S. Das Sarma, Noise-resistant control for a spin qubit array, ***Phys. Rev. Lett.*** 110, 140502 (2013).

[3] X. Wang, E. Barnes, and S. Das Sarma, Improving the gate fidelity of capacitively coupled spin qubits, ***npj Quantum Information*** 1, 15003 (2015).

[4] E. Barnes, X. Wang, and S. Das Sarma, Robust quantum control using smooth pulses and topological winding, ***Sci. Rep.*** 5, 12685 (2015).

43. 王欣然: Exploring Organic Semiconductors At The Two-Dimensional Limit

Xinran Wang（王欣然）
School of Electronic Science and Engineering, Nanjing University
xrwang@nju.edu.cn

Abstract: Since the debut of graphene, 2D layered materials have attracted tremendous interest. New physics and tuning capability emerges as the material thickness is reduced from bulk to monolayer limit, leading to many device applications including field-effect transistors, LEDs and van der Waals heterojunctions. However, most of the research focus on 2D atomic crystals (inorganic materials). It is well known that many small-molecule organic crystals are also layered in the bulk form, in a similar way as graphite. So it is possible to make organic semiconductors into 2D monolayer limit, where new physics is expected to emerge. Here we achieve such high-quality 2D molecular crystals using van der Waals epitaxy. This class of materials can not only make high-performance OFETs but also serve as a powerful platform to study intrinsic structure-property relationship. Precise control of epitaxy offers new possibilities in achieving well-defined heterojunctions based on organic materials.

44. 王雪华: Strong Light–Matter Interaction in Non-Cavity Plasmonic Nanosystem at Quantum Optics Limit

Renming Liu, Zhang-Kai Zhou, and **Xue-Hua Wang**（王雪华）
State Key Laboratory of Optoelectronic Materials and Technologies,
School of Physics, Sun Yat-sen University, Guangzhou 510275, China

Abstract: Strong light–matter interactions are not only significant from a fundamental quantum optics point of view [1,2], but also benefit for exploring advanced quantum optics devices, because it opens up a new frontier in controlling light at the single-photon level. Generally, two systems are applied to realize strong light–matter interactions. One is the cavity quantum electrodynamics (Cavity-QED) system including various optical and plasmonic cavities [3–7]. The other is the non-cavity plasmonic system [8,9]. To date, strong light–matter interactions in non-cavity plasmonic system at quantum optics limit is still lacking.

two challenges severely hinder the realization of such a limit. One is to integrate a single-exciton emitter with a plasmonic nanostructure. The other is to make the coupling strength at single-exciton level overcome the large damping of the plasmon mode. Here, we demonstrate the two hindrances can be removed by assembling individual J-aggregates to a single cuboid Au@Ag nanorod. In such a hybrid nanosystem, both an ultrasmall mode volume of ~42 nm3 and the ultrashort interaction distance of less than 0.9 nm make the coupling coefficient gdc between a single J-aggregate exciton and a nanorod as high as ~44.3 meV, which enables us achieve strong light–matter interaction at quantum optics limit in non-cavity plasmonic nanosystem.

References:

[1] P. Törmä, and W. L. Barnes, ***Rep. Prog. Phys.*** 78, 013901 (2015).

[2] R. Bose, T. Cai, K. R. Choudhury, G. S. Solomon, and E. Waks, ***Nat. Photonics 224***, 1 (2014).

[3] M. Nomura, N. Kumagai, S. Iwamoto, Y. Ota, and Y. Arakawa, ***Nat. Physics 6***, 279 (2010).

[4] A. Faraon, I. Fushman, D. Englund, N. Stoltz, P. Petroff, and J.Vučković, ***Nat. Photonics 4,*** 859 (2008).

[5] R. Chikkaraddy, B. de Nijs, F. Benz, S. J. Barrow, O. A. Scherman, E. Rosta, A. Demetriadou, P. Fox, O. Hess, and J. J. Baumberg, ***Natrue (London)*** doi:10.1038/nature17974 (2016).

[6] K. Santhosh, O. Bitton, L. Chuntonov, and G. Haran, ***Nat. Communications 7,*** 11823 (2016).

[7] A. E. Schlather, N. Large, A. S. Urban, P. Nordlander, and N. J. Halas, ***Nano Lett.***13,3281 (2013).

[8] P. Vasa, W. Wang, R. Pomraenke, M. Lammers, M. Maiuri, C. Manzoni, G. Cerullo, and C. Lienau, ***Nat. Photonics 7,*** 128 (2013).

[9] G. Zengin, M. Wersäll, S. Nilsson, T. J. Antosiewicz, M. Käll, and T. Shegai, ***Phys. Rev. Lett.*** 114, 157401 (2015).

45. 翁文康: Universal Bound of Sampling Boson and Unification of Gaussian Boson Sampling

Man-Hong Yung（翁文康）
Department of Physics, South University of Science and Technology of China, Shenzhen, 518055, China
*Email address:yung@sustc.edu.cn

Abstract: In linear optics, photons are scattered in a network through passive optical elements including beamsplitters and phase shifters, leading to many intriguing applications in physics, such as Mach-Zehnder interferometry, Hong-Ou-Mandel effect, and tests of fundamental quantum mechanics. Here we present a general analytic bound limiting the transition amplitudes in sampling bosons, through all realizable linear optics. Apart from boson sampling, this transition bound results in many other interesting applications, including behaviors of Bose-Einstein Condensates (BEC) in optical networks, counterparts of Hong-Ou-Mandel effects for multiple photons, and approximating permanents of matrices. Also, this general bound implies the existence of a polynomial-time randomized algorithm for estimating transition amplitudes of bosons, which represents a solution to an open problem raised by Aaronson and Hance in 2012.

On the other hand, motivated by molecular spectroscopy, we develop a hierarchical structure to show how the initial correlation in Vibronic Boson Sampling can be absorbed in Gaussian Boson Sampling with ancillary modes and in a scattershot fashion. Since every Gaussian state is associated with a thermal state, our result implies that every sampling problem in molecular vibronic transitions, at any temperature, can be simulated by Gaussian Boson Sampling associated with a product of vacuum modes.

References:

[1] Yung, M.-H., et al, Universal Bound on Sampling Bosons in Linear Optics. ***arXiv: 1608.00383 (2016)***

[2] Huh, J. & Yung, M.-H. Hierarchy in Sampling Gaussian-correlated Bosons. ***arXiv: 1608.03731 (2016)***

[3] Huh, J., et al Boson sampling for molecular vibronic spectra. ***Nat. Photonics*** 9, 615–620 (2015).

46. 吴孝松: Thermoelectric Signature Of The Chiral Anomaly In Cd3As2

贾振钊[1] 李彩珍[1] 李新祺[1] 施均仁[2,3] 廖志敏[1,3] 俞大鹏[1,3,4] 吴孝松[1,3*]
[1]北京大学人工微结构和介观物理重点实验室，北京，邮编 100871
[2]北京大学量子材料中心，北京，邮编 100871
[3]北京大学量子协同创新中心，北京，邮编 100871
[4]南方科技大学 物理系， 深圳，邮编 518055
[*]Email:xswu@pku.edu.cn

Abstract: Discovery of Weyl semimetals has revived interest in Weyl fermions which has not been observed in high energy experiments. It now becomes possible to study, in solids, their exotic properties. Extensive photoemission spectroscopy and electrical resistivity experiments have been carried out and important information has been obtained. However, many other properties remain unexplored. Here we report the thermoelectric study of Weyl fermions in a Dirac semimetal Cd3As2 under a magnetic field. We observe a strong suppression of the thermopower when a magnetic field parallel to the temperature gradient is applied [1]. The suppression follows a quadratic dependence in low fields. The coefficient of the dependence is nearly twice of that for the electrical conductivity. The thermopower reverses its sign in a high field. We show that all these intriguing observations can be understood in terms of the chiral anomaly of Weyl fermions. Our results reveal the anomalous thermoelectric property of Weyl fermions and provide insight into the chiral anomaly.

关键词: Dirac semimetal, Weyl fermions, chiral anomaly, thermoelectric

References:

[1]. Thermoelectric signature of the chiral anomaly in Cd3As2, Zhenzhao Jia et al., ***Nature Communications***, in press, 2016: http://www.nature.com/articles/ncomms13013.

47. 夏　钶: Computational spin caloritronics

Ke Xia（夏钶）
北京师范大学 物理系

Abstract: Magnetization dynamics can be excited and detected electrically and thermally by metal contacts, which makes it a wonderful spin energy material. The crucial parameter for ferromagnet(F)|normal metal(N) interfaces is the spin mixing conductance that governs the absorption of a transverse spin current and the spin transfer torque. However, the spin-mixing conductance is a purely nonrelativistic concept, while there is mounting evidence that spin-orbit interactions at interfaces generate additional spin-flips and spin-orbit torques. We have solved this issue by introducing an “effective” spin mixing conductance for weakly relativistic materials. First ab initio results on ferrite|metal interface indeed indicate an enhancement that can be very significant for selected crystal orientations.

Massive particles, i.e. the electrons, as well as quasi particles, i.e. magnons, can carry a thermal spin current that generates torques at the interfaces. Based on the same theoretical frame as effective mixing conductance, we compute both kind of torques for magnetic tunnel junctions from first principles in order to validate their spin transfer power e□ciency, switching speed, etc.

48. 肖　江: Magnetic Wafer Based Magnonics（自旋波电子学）

Jin Lan1, Weichao Yu[1], R. Q. Wu[1,2], and Jiang Xiao[1]（肖江）
[1]Department of Physics, Fudan University, Shanghai 200433, China
[2]Department of Physics and Astronomy, University of California, Irvine, California, USA

Abstract: Magnonics, which involves unified information storage and processing using magnons—spin waves that are collective quasi-particle excitations of magnetic moments—offers a promising platform for next-generation, energy-saving information technology. Many magnonic structures have been proposed and studied in a range of designs, but a unified and scalable magnonic platform is still lacking.

Here, we propose the design of magnonic integrated circuits that can in principle perform a large number of magnonic operations. [1, 2] We use domain walls and surface anisotropy stripes as two different spin wave waveguides. The magnonic integrated circuits that we design include a single square magnetic wafer, which is analogous to a silicon wafer. We experiment with yttrium iron garnet thin film magnetic wafers of several sizes (roughly a few thousand nanometers on a side). Since the magnetic texture of our circuits can be easily modified, our magnonic hardware architecture is reprogrammable, unlike most present-day information-processing architectures. Using this new architecture, we design the simplest magnonic component, a spin wave diode that admits only the unidirectional propagation of spin waves. We find that the bound spin wave states in a domain wall become chiral and are spatially separated depending on their propagation direction, which enables us to realize the diode effect for spin wave transport. Furthermore, we demonstrate that the function of the spin wave diode is easily altered from forward-transmitting to reverse-transmitting by simply moving domain walls via current-induced spin-transfer torque. Our magnonic architecture opens up new pathways for realizing a pure spin wave computer.

Reference:

[1]. Lan, J., Yu, W., Wu, R. & Xiao, J. Spin-Wave Diode. ***Phys. Rev. X*** 5, 041049 (2015).
[2]. Yu, W., Lan, J., Wu, R. & Xiao, J. Spin-Wave Fiber. ***ArXiv***:1603.05325 (2016) [to appear on Phys. Rev. B (Rapid Communications)].

49. 徐洪起: Topological Superconducting Quantum Devices Made from Semiconductor Nanostructures

徐洪起
北京大学 信息科学技术学院
hqxu@pku.edu.cn

Abstract: Topological superconducting systems are intriguing physical systems in which an elusive class of fermions—Majorana fermions, whose antiparticles are themselves, can be created and can be used to construct topological qubits for quantum computing. Here I report on the realization and quantum transport measurements of topological superconducting quantum devices made from semiconductor nanostructures. The talk will be divided into two parts. In the first part, our study of topological superconducting quantum devices made from InSb nanowires and s-wave Sb superconductors will be reported and discussed. In each of the devices, a quantum dot is fabricated between two topological superconducting InSb nanowires. Both a zero conductance peak arising from Majorana fermions located at two outer ends of the two nanowires and two side conductance peaks arising from the interaction between the two inner Majorana fermions in the vicinity of the quantum dot are observed. In the second part of my talk, our very recent work on topological quantum devices made from InSb nanoplates and s-wave Al superconductors will be reported and discussed. Here, I will show that it is possible to turn the semiconductor InSb nanoplates into two-dimensional topological insulators. As a consequence, in a Josephson junction made from an InSb nanoplate in the topological phase, the measured supercurrent as a function of magnetic field shows an interference pattern which is in accordance with the transport through the edges of the nanoplate. Finally, future directions of the field and perspective applications of topological superconducting quantum devices in the quantum information technology will be discussed.

50. 徐士杰: Distinctive Signatures of Photon Emission of Individual InGaN/GaN Quantum Dots

Shijie Xu（徐士杰）[1,2]
[1]Department of Physics, The University of Hong Kong, Pokfulam Road, Hong Kong
[2]Institute of Research and Innovation (SIRI), The University of Hong Kong, Pokfulam Road, Hong Kong

Abstract: In the talk, we present an experimental study of distinctive photoluminescence (PL) signatures of photon emission of individual InGaN/GaN quantum dots at room temperature. PL intensity intermittence, stochastic spectral jumping, strongly negative correlation etc. have been observed. Such peculiar behaviors actually reflect the distinct quantum nature of individual quantum dots and significant influence of surrounding environment.

51. 许金时: Experimental Simulation The Exchange Of Majorana Zero Modes

Jin-Shi Xu（许金时）[1,2], Yong-Jian Han[1,2], Chuan-Feng Li[1,2], Guang-Can Guo[1,2]
[1]Key Laboratory of Quantum Information, University of Science and Technology of China, CAS, Hefei, 230026
[2]Synergetic Innovation Center of Quantum Information and Quantum Physics, University of Science and Technology of China, CAS, Hefei 230026

Abstract: The realization of Majorana zero modes is in the center of intense theoretical and experimental investigations. Unfortunately, their exchange that can reveal their exotic statistics needs manipulations that are still beyond our experimental capabilities. Here we take an alternative approach. Through the Jordan-Wigner transformation, the Kitaev's chain supporting two Majorana zero modes is mapped to the spin-1/2 chain. We experimentally simulated the spin system and its evolution with a photonic quantum simulator. This allows us to probe the geometric phase, which corresponds to the exchange of two Majorana zero modes positioned at the ends of a three-site chain. Finally, we demonstrate the immunity of quantum information encoded in the Majorana zero modes against local errors through the simulator. Our photonic simulator opens the way for the efficient realization and manipulation of Majorana zero modes in complex architectures.

References:

[1]. J.-S. Xu et al. Simulating the exchange of Majorana zero modes with a photonic system. ***Nature Communications*** DOI:10.1038/ncomms13194 (2016).

52. 薛正远: Holonomic Quantum Computation All-Resonant Control

Zheng-Yuan Xue（薛正远）[1], Jian Zhou[2,1], Y.-M. Chu[3],Yong Hu[3], and Z. D. Wang[4]

[1]School of Physics & TE, South China Normal University, Guangzhou 510006
[2]Anhui Xinhua University, Hefei, 230088
[3]School of Physics, Huazhong University of Science and Technology, Wuhan 430074
[4]Department of Physics, The University of Hong Kong, Hong Kong

Abstract: The implementation of nonadiabatic holonomic quantum computation (NHQC) in superconducting quantum circuits is challenging as it requires controllable complicated coupling between multi-level systems [1]. We have proposed a scalable realization of NHQC [2] in a tunable and all-resonant way through a hybrid encoding of the logical qubits. Recently, we found that the transmon-resonator interaction induced polariton can be used to encode a qubit [3], where NHQC can also be implemented in an all-resonant way. Moreover, we expect that even a single transmon device can serve as a qubit that supports all-resonant NHQC [4]. Therefore, our schemes may pave a way towards the realization of high fidelity universal NHQC.

References:

[1]. Z.-Y. Xue, J. Zhou, and Z. D. Wang, Universal HQC in decoherence-free subspace on superconducting circuits, ***Phys. Rev. A* 92**, 022320 (2015).

[2]. Z.-Y. Xue, J. Zhou, Y.-M. Chu, and Y. Hu, NHQC with all-resonant control, ***Phys. Rev. A 94***, 022331 (2016).

[3]. Z.-Y. Xue *et al*., NHQC with polariton qubits, in preparation.

[4]. B.-J. Liu *et al*., NHQC without precise time control, in preparation.

53. 姚　望: Nano-Patterned Superstructures Of Topological Insulators In The Moire Superlattices Of Vdw Heterobilayers

Wang Yao（姚望）[1]
[1]Department of Physics and Center of Theoretical and Computational Physics, University of Hong Kong, Hong Kong, China

Abstract: In van der Waals heterobilayers, small twisting and/or lattice mismatch leads to the formation of long-period Moiré pattern where the atomic registry locally approximates commensurate bilayers but has local-to-local variation over long range. Such Moiré pattern forms a lateral superlattice modulation of the electronic properties because the form and strength of interlayer coupling is controlled by atomic registry. In heterobilayers of transition metal dichalcogenides, when the type-II band alignment is tuned into the inverted regime by an interlayer bias, we find the system can undergo a topological phase transition depending on the interlayer atomic registry. The Moire superlattice then leads to mosaic pattern of topological insulator (**T**I) regions and normal insulator regions in Moiré superlattices. This points to a new means of realizing programmable and electrically switchable topological superstructures from 2D arrays of TI nano-dots to 1D arrays of TI nano-stripes.

54. 游建强: Magnon Kerr Effect In A Cavity Quantum Electrodynamics System

Jian-Qiang You (游建强)
Quantum Physics and Quantum Information Division, Beijing Computational Science Research Center, Beijing 100193, China
Email: jqyou@csrc.ac.cn

Abstract: We report the experimental demonstration of the magnon Kerr effect in a cavity quantum electrodynamics system, where magnons in a small yttrium iron garnet (YIG) sphere are strongly but dispersively coupled to the microwave photons in a three-dimensional cavity. When considerable magnons are generated by pumping the YIG sphere, the Kerr effect gives rise to a shift of the cavity central frequency and yields more appreciable shifts of the magnon modes, including the Kittel mode (i.e., the ferromagnetic resonance mode), which holds homogeneous magnetization, and the magnetostatic (MS) modes, which have inhomogeneous magnetization. We derive an analytical relation between the magnon frequency shift and the pumping power for a uniformly magnetized YIG sphere and find that it agrees very well with the experimental results of the Kittel mode. In contrast, the experimental results of MS modes deviate from this relation owing to the spatial variations of the MS modes over the sample. This finding provides a method to characterize the deviations of MS modes from the homogeneous magnetization.

55. 翟　荟: Out-of-Time-Ordered Correlation and Entanglement Entropy

Hui Zhai (翟荟)
Institute for Advanced Study, Tsinghua University

Abstract: The out-of-time order correlation (OTOC) has recently emerged as a quantity that brings together interests from several different fields, which diagnoses chaotic behavior in the condensed matter systems, saturates an upper bound for systems with holographic duality to a black hole in the gravity physics and relates to information scrambling in the quantum information context. In this talk, we will first present a Quantum Critical Point (QCP) conjecture that the Lyapunov exponent defined from the OTOC displays a peak at the quantum critical regime, and we will present numerical evidence in the Bose-Hubbard model to support this conjecture. Then, we will consider the OTOC for a many-body localization (MBL) system and we will show that the OTOC can distinguish MBL from thermalized phase and the Anderson localized phase. Most importantly, we will present an OTOC-EE theorem that discovers a general relation between the OTOC in an equilibrium system and the entanglement entropy (EE) in a quenched system. Finally, we should present the first experimental measurement of OTOC using NMR quantum simulator.

References:

[1] Huitao Shen, Pengfei Zhang, Ruihua Fan and Hui Zhai, ***arXiv: 1608.02438***
[2] Ruihua Fam, Pengfei Zhang, Huitao Shen and Hui Zhai, ***arXiv: 1608.01914***
[3] Jun Li, Ruihua Fan, Hengyan Wang, Bingtian Ye, Bei Zeng, Hui Zhai, Xinhua Peng and Jiangfeng Du, ***arXiv: 1609.01246***

56. 张广宇: Zigzag-石墨烯纳米带的边缘态

张广宇（中科院物理研究所）

摘要：石墨烯是一个天然的量子材料，是研究很多新奇量子现象的理想载体。当把石墨烯裁成纳米带时，尺寸和维度的进一步降低，边缘效应凸显出来。其中，最引人关注的是 zigzag-边缘构型的石墨烯纳米带，自上个世纪 90 年代，就开始引起了理论家的关注，预测了很多和 zigzag-边缘相关的奇异物理性质。1996 年 Fujita 和 Dresselhaus 等就预言了在 zigzag-边缘构型的石墨烯纳米带中存在局域的金属性边缘态，可能会存在边缘电流。然而，这方面的实验的研究比较初步。过去的工作大多基于扫描隧道谱来研究局域态密度，相关的边缘电流的观测在输运上还没有被看到。本报告介绍我们针对这一问题在近 5 年来的研究结果，包括 zigzag-边缘构型的石墨烯纳米带的加工、表征、器件及边缘电流的实验观测等。

57. 赵建华: Perpendicularly Magnetized Mn-Based Binary Films Compatible With Semiconductor In Structure And Technique

Jianhua Zhao (赵建华)
State Key Laboratory of Superlattices and Microstructures, Institute of Semiconductors, Chinese Academy of Sciences, P.O. Box 912, Beijing 100083, China
Email: jhzhao@red.semi.ac.cn

Abstract: Ferromagnetic films with both high perpendicular anisotropy and good compatibility with semiconductors have great potential not only in semiconductor spintronic quantum devices, but also in high-density integration of metallic spintronic functional devices like nonvolatile magnetoresistive random access memory (MRAM) on semiconductor circuits.

In this talk, I will present our recent work on the high-quality Mn-based binary alloy, L10-MnGa and L10-MnAl single crystalline films with giant PMA grown on GaAs by molecular-beam epitaxy. These films show some fascinating room-temperature magnetic properties, with controllable magnetization from 130 to 700 emu/cc, and high magnetic energy product of 4.4 MGOe [2-6], close to theoretical predictions. Moreover, annealing studies revealed thermal stability of L10-MnGa up to at least 3500C in contact with GaAs, indicating its compatible with current semiconductor industry technique [4]. Following that, we unambiguously identified the pronounced influence of the chemical ordering on both the intrinsic and extrinsic contributions to the anomalous Hall effect (AHE) in L10-Mn1.5Ga [7]. Very recently, we observed the orbital two-channel Kondo (2CK) effect existing in ferromagnetic L10-MnAl and L10-MnGa, providing the first evidence for the presence of 2CK effect in a ferromagnet [8-10].

References:

[1] L. J. Zhu, and J. H. Zhao, ***Appl. Phys.* A 111** (2013) 379
[2] L. J. Zhu, S. H. Nie, and J. H. Zhao, ***Chin. Phys.* B 22** (2013) 118505
[3] L. J. Zhu, S. H. Nie, K. K. Meng, D. Pan, J. H. Zhao and H. Z. Zheng, ***Adv. Mater.* 24.** 4547
[4] L. J. Zhu, D. Pan, S.H. Nie, J. Lu and J. H. Zhao, ***Appl. Phys. Lett.* 102** (2013) 132403
[5] S. H. Nie, L. J. Zhu, J. Lu, D. Pan, H. L. Wang, X. Z. Yu, J. X. Xiao and J. H. Zhao, ***Appl. Phys. Lett.* 102** (2013) 152405
[6] S. H. Nie, L. J. Zhu, D. Pan, J. Lu, & J. H. Zhao, ***Acta. Phys. Sin***. 62 (2013) 178103
[7] L. J. Zhu, D. Pan and J. H. Zhao, ***Phys. Rev.* B 89** (Rapid Commun.) (2014) 220406(**R**)
[8] L. J. Zhu, S. H. Nie, P. Xiong, P. Schlottmann and J. H. Zhao, ***Nature Commun***. **7** (2016) 10817
[9] L. J. Zhu, S. H. Nie, and J. H. Zhao, ***Phys. Rev.* B 93** (2016) 195112
[10] L. J. Zhu, G. Woltersdorf, and J. H. Zhao, ***Sci. Rep.* 6** (2016) 34549

58. 赵巍胜: Engineering the Spin Orbit Interaction for Low Power Computing

K. H. Cao[1,2], S. Z. Peng[1,2], L. Su[1,2], M. X. Wang[1,2], X. X. Zhao[1,2], J. Q. Zhou[1,2], X. Y. Lin[1,2], Z. H. Wang[1,2], **W. S. Zhao**（赵巍胜）[1,2*]

1) Fert Beijing Institute, Beihang University, 100191, Beijing, P.R. China

2) School of Electronic and Information Engineering, Beihang University, 100191, Beijing, P.R. China, weisheng.zhao@buaa.edu.cn

Abstract: Low power is desirable for battery-powered electronics, such as mobile phone and internet of things (IOTs) devices etc. Spintronics is considered as an emerging technology that can offer this property based on its data non-volatility/fast operation/easy integration with CMOS. And spin transfer torque random access memory (STT-MRAM) has attracted much attention from academics and industries field. However, this technology has met some challenges in term of switching power, data stability and density etc. Spin orbit engineering may contribute of its improvement and this paper will give four examples: 1) heavy metal with strong spin orbit coupling for strong perpendicular magnetic anisotropy (PMA); 2) assistance of Spin-Hall Effect for fast Spin Transfer Torque; 3) Skyrmion racetrack memory with voltage control pinning; 4) all spin logic with weak spin orbit coupling channel. These could allow a full spin computing system with ultra-low power in the future.

References:

[1] S. Ikeda et al. "A perpendicular-anisotropy CoFeB–MgO magnetic tunnel junction", ***Nature Materials***, 9(9) 721-724, (2010).

[2] H. X. Yang et al, "First-principles investigation of the very large perpendicular magnetic anisotropy at Fe|MgO and Co|MgO interfaces", ***Physical Review B***, 84(5) 054401, (2011).

[3] S. Z. Peng et al, "Origin of interfacial perpendicular magnetic anisotropy in MgO/CoFe/metallic capping layer structures", ***Scientific reports,*** 5:18173, (2015).

[4] Z. H. Wang et al. "Perpendicular-anisotropy magnetic tunnel junction switched by spin-Hall-assisted spin-transfer torque", ***Journal of Physics D: Applied Physics,*** 48(6) 065001, (2015)

[5] W. Kang et al. "Voltage Controlled Magnetic Skyrmion Motion for Racetrack Memory", ***Scientific reports,*** 6:23164, (2016).

[6] L. Su et al, "Current-limiting challenges for all-spin logic devices", ***Scientific reports,*** 5:14905, (2015).

[7] L. Su et al, " Proposal for a graphene-based all-spin logic gate ", ***Applied Physics Letters,*** 106(7) 072407.

59. 赵　悦: Exploring the Physics of Graphene with Local Probes

Yue Zhao (赵悦)

Department of Physics, South University of Science and Technology, China

Abstract: Graphene is a two dimensional (2D) electron gas system exposed at the surface, which allows scanning tunneling microscopy (STM) to investigate the electron-electron interactions associated with the Dirac nature on a local scale. Because of the low density of states, electronic states in graphene (and other similar 2D materials) are susceptible to interactions with local probes. With a variety of tuning knobs, such as carrier density, spatially varying disorder potential, and applied magnetic field, I will discuss how the local STM probe creates and controls a circular pn junction and induce whispering gallery modes(WGM) resonances. The confined modes, revealed through characteristic resonances in the tunneling spectrum, originate from Klein scattering at pn junction boundaries[1]. In addition, with a small magnetic field, a Berry phase can be switched on and off, resulting in a sudden and giant increase in energy of angular momentum states in those WGM modes.

References:

1. Y. Zhao *et al.*, ***Science*** 348, 672(2015)

60. 周树云: New Topological Phases In Transition Metal Dichalcogenides

Shuyun Zhou（周树云）
Department of Physics, Tsinghua University, Beijing, P.R. China 100084

Abstract: Transition metal dichalcogenides have attracted extensive efforts in recent years due to the intriguing science and potential applications. So far most of the studies have been focused on the electronic, spin and valley physics, while little is known about their topological properties. In this talk, I will present our recent studies on the novel topological phases in transition metal dichalcogenide family. In particular, I will present the experimental realization of type-II Weyl fermions in MoTe2 [1,2] and type-II Dirac fermions in PtTe2 [3].

References:

[1] Ke Deng et al., "Experimental observation of topological Fermi arcs in type-II Weyl semimetal MoTe2", ***Nature Physics,*** DOI: 10.1038/NPHYS3871 (2016).
[2] Kenan Zhang et al, "Raman signatures of inversion symmetry breaking and structural phase transition in type-II Weyl semimetal MoTe2", ***arXiv:1603.08508***
[3] Mingzhe Yan et al., "Lorentz-violating type-II Dirac fermions in transition metal dichalcogenide PtTe2", ***arXiv:1607.03643.***

61. 周晓祺: The Simulation Of Boson Sampling With Qubit Systems

Xiaoqi Zhou(周晓祺)[1,2,3,4], He Lu[1,2,3], Xu-Fei Yin[1,2,3], Luo-Kan Chen[1,2,3], Yu-Ao Chen[1,2,3] and Jian-Wei Pan[1,2,3]

[1] Shanghai Branch, National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Shanghai 201315, China

[2] CAS Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, University of Science and Technology of China, Shanghai 201315, China

[3] CAS-Alibaba Quantum Computing Laboratory, Shanghai 201315, China

[4] State Key Laboratory of Optoelectronic Materials and Technologies and School of Physics, Sun Yat-sen University, Guangzhou 510275, China.

Abstract: A problem called boson sampling---sampling from the probability distribution of several identical bosons scattered by some linear unitary process---has raised strong interest recently. Despite the simplicity of its structure, boson sampling is a computational hard problem which cannot be efficiently simulated on classical computers. By now, several boson sampling experiments have been reported. However, in all of these experiments, boson sampling is realized by implementing the procedure literally instead of being simulated with other systems. It is well known that quantum processes, which are hard to be simulated on classical computers, can be efficiently simulated with controllable quantum devices. In this sense, boson sampling itself should be able to be well simulated with controlled quantum systems. Here we present a method to efficiently simulate boson sampling with qubit systems which are directly applicable to the standard quantum computing model. The two motivations to simulate boson sampling with qubit system are described below. Firstly, the standard quantum computing model is based on qubit system. By simulating boson sampling with qubits, one can run boson sampling on a quantum computer. Secondly, compared with the complex output quantum state that boson sampling process renders, the well-defined multi-qubit output quantum state our method provides is much easier for manipulation and processing. As our method makes the output state of boson sampling more usable, it might help theorists find some new applications for boson sampling. Besides presenting the theory, we have also experimentally demonstrate our scheme using photonic qubits. The experimental results reproduce the probability distribution of boson sampling quite well, which is in accordance with the theoretical expectation.

62. 朱诗亮: Maxwell Quasiparticles Emerged in Optical Lattices

Yan-Qing Zhu[1], Dan-Wei Zhang[2] ,Hui Yan[2], Ding-Yu Xing[1],Shi-Liang Zhu（朱诗亮）[1],

[1]National Laboratory of Solid State Microstructures and School of Physics, Nanjing University, Nanjing 210093

[2]Guangdong Provincial Key Laboratory of Quantum Engineering and Quantum Materials, SPTE, South China Normal University, Guangzhou 510006

Abstract: The discovery of new particles or new quasi-particles lies at the heart of the modern physics. One of the recent examples is the discovery of relativistic Dirac/Weyl fermions (spin-1/2) emerged in condensed matter or some artificial quantum systems. However, the particles with higher spin number are also fundamentally important but are rarely explored as for an emerged quasiparticles.

We have proposed an exotic quasiparticles emerged in the optical lattices. They are relativistic excitations with pesudospin-1 and should be described by the Maxwell equations--so called as the Maxwell quasiparticles. We first rewrite the Maxwell equations in the form of the Schrodinger equation and then construct 2D optical lattices, where the low energy excitations should be described by the Maxwell Hamiltonian. By tuning the parameter, the system is shown to have rich quantum phases, such as topological insulators/metals. The topological Maxwell metal is characterized with the threefold degeneracy points, the so-called Maxwell points. The low-energy excitations near the Maxwell point behave like photons described by the Maxwell equations. Furthermore, we find nontrivial edge states with spin-momentum locking in the topological Maxwell insulating phases, mimicking the circularly-polarized photons.

Reference:

[1]. Yan-Qing Zhu, Dan-Wei Zhang, Hui Yan, Ding-Yu Xing, and Shi-Liang Zhu, ***arXiv:1610.05993***.

63. 朱晓波: 纵场控制的量子开关和多比特量子芯片

朱晓波
中国科学技术大学

摘要:近年来，超导量子芯片方向进展迅速，人们关注的目光已经由少数比特的性能验证走向了多数量子比特的纠错容错实验阶段。在超导量子开关方面，我们实验演示了如何利用外加的纵向控制场连续地调整一个超导量子比特与一个超导量子谐振子的耦合大小。在特定幅度和频率的纵向控制场的作用下，量子比特和量子谐振子之间的真空拉比震荡完全停止，显示两个量子元件已经解耦合。我们还演示了如何利用脉冲的控制场动态地关断或打开量子比特与量子谐振子之间的耦合。值得注意的是在上述过程中量子比特与量子谐振子一直工作在同一个共振的频率，其中量子比特还保持工作在其相干时间最优的工作点。这可以解决传统的通过失谐实现量子退耦合方案所带来的一系列问题，是一种可以扩展到多数量子比特系统的量子开关方案。

我们还设计制备并测试了集成了六个量子比特的超导量子芯片，芯片上的超导比特的弛豫时间稳定的超过 10 微秒，最长达到 20 微秒以上。利用我们自行设计制备的 300MHz 带宽的量子极限约瑟夫森放大器，实现了对超导量子比特的多通道、单发高效率读取和多量子门操作。

*主要参与单位:中国科学院物理研究所、浙江大学、清华大学、北京计算科学研究中心、中国科学技术大学、日本 NTT 基础物性研究所、日本国立情报学研究所。