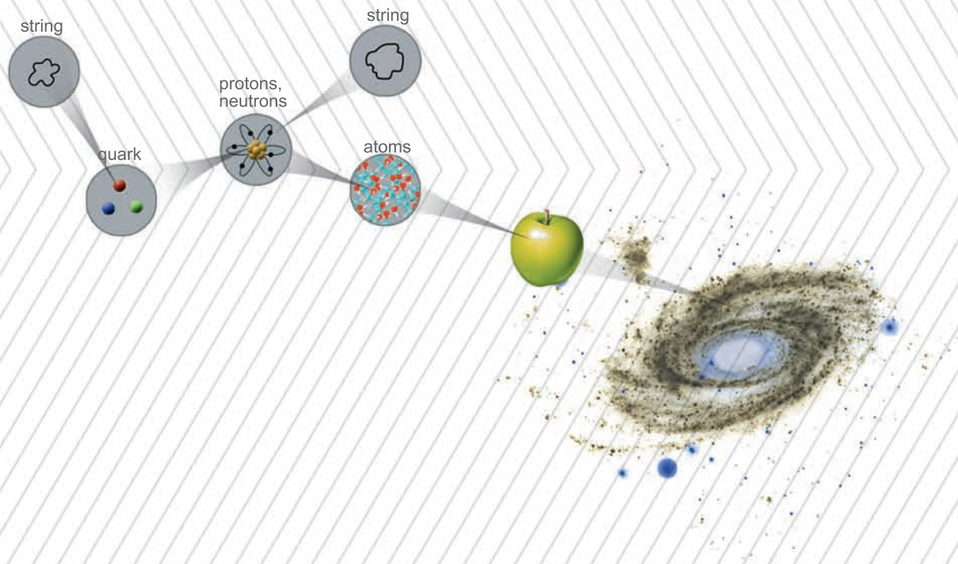
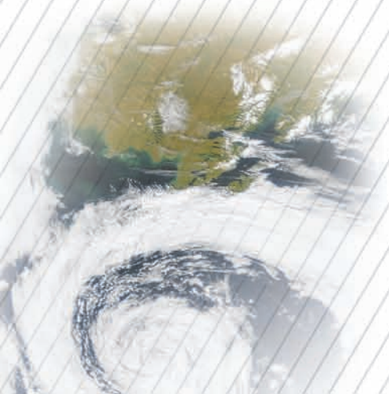
北京大学
物理学院



B 年报 2009-2010
i-annual Report



地址：北京市海淀区成府路209 邮编：100871
Add: 209 Chengfu Road, Haidian District, Beijing 100871, China

电话：86-10-62751732
Tel: 86-10-62751732

传真：86-10-62751615
Fax: 86-10-62751615

http://www.phy.pku.edu.cn/

School of Physics
Peking University

前言
The Dean's Address

北京大学是中国近代最早进行物理教育和研究的高等学府。自 1913 年设立物理学门起，北大物理已经走过将近一个世纪的风雨历程。近百年来，我们经历了创业初期的步步艰辛，创造出西南联大时的鼎盛辉煌；既目睹过国家解放后的蓬勃发展，更见证着改革开放以来的巨大进步。几代北大物理学人筚路蓝缕，矢志不移，苦心耕耘，艰难玉成，以自己的远见卓识、坚韧不拔和惟实创新铸就了中国物理乃至中国现代科学教育与研究的根基。时至今日，北京大学物理学院已经发展成为享誉海内外的物理学研究重镇和顶尖人才培养摇篮。

纵观世界一流的物理教育科研机构，无不都有历经久远、点滴积淀的独特传统，引领方向、特色鲜明的目标宗旨，科学合理、规范高效的管理体制，国际顶尖、各有所长的人才群体，宽松自由、协同共进的学术氛围，严谨缜密、执着求真的科学品质，追求卓越、开拓进取的创新精神以及所有这些因素的有机联系与共同作用。站在一个新的历史起点上，北京大学物理学院正向更高、更远的目标不断奋进。

科学研究是物理学院的立院之本。在我对北大，甚至对许多国内外大学的了解中，并不多见一个学院的科学研究领域在空间和时间的尺度上能像我们物理学院这样宽广——大到宇宙与星系，小到原子和夸克；快到阿秒，慢至亿年。北京大学物理学院始终面向国际一流、探索科学前沿；我们既鼓励原创性基础研究，也积极推进具有潜力的应用研究，更提倡不同学科之间的交叉拓展。我们努力寻求和把握物理研究的趋势和方向，期待在未来的竞争和发展中持续突破、有所作为。

物理学院一切工作的中心在于凝聚和培养人才。我们一直致力于发现、吸引、培养和使用具有国际竞争力的拔尖创新人才，他们不仅包括才华横溢的教授学者，还有壮志凌云的青年才俊和莘莘学子。我们为卓越人才全力准备的，不仅是良好的科研条件、完备的基础设施和优厚的生活保障，更在于自由活跃的学术气息、轻松愉悦的人文氛围和广阔持续的发展空间。我们深信，对浩瀚无际的未知世界的痴迷、执着和探求，是每个北大物理学人真正的生命意义与价值所在。

格物致知，薪火相传；百年物理，继往开来。今日的北京大学物理学院，将继续秉承近百年来积淀的优良传统，发扬“勤奋、严谨、求实、创新”的卓越精神，脚踏实地、同心同德、积极进取；努力向“将学院建设成为在国内物理学界起到骨干引领和带头示范作用，在国际物理学界具有重要影响的教学科研中心”的目标不断坚实迈进！

王恩哥
北京大学物理学院院长

Peking University is the first institute of higher learning in modern China to conduct physical education and research. It has been nearly a hundred years since Peking University established its physics division in 1913. One hundred years on, we have experienced the hardships of pioneering, the prime time of the National Southwest Associated University period, the vigorous development at the foundation of the new country, and the huge progress brought by the execution of the Reform and the Opening Up policy. Generations of scholars here have consolidated the foundation for the education and research of physical science and modern science in general in China with their combined vision, perseverance and innovation. Today, the School of Physics, Peking University has become a highly renowned research and talent cultivation center for physics.

As it embarks on its second century, the Peking University School of Physics establishes its new goal of developing into the world's first-class institution of physical education and academia. In order to achieve this goal, we will carry out our distinguished traditions, identify the specific target purpose, construct a scientific and sustainable mechanism, attract and train the outstanding talent groups, create a free and corporative environment, develop a rigorous and truth-seeking academic attitude, and cultivate an exceeding and innovative scholarly spirit.

The root of our work lies in promoting physical research. Based on my understanding of many colleges and universities at home and abroad, there are quite few whose fields of study can be as broad as ours—both spatially and temporally—as big as universes and galaxies, small as atoms and quarks, and as fast as attoseconds, slow as billion years. Research in the School of Physics is not only devoted to the frontiers of fundamental physics but also to the innovation of advanced technology as well as to the exploration of interdisciplinary collaborations. We strive to follow the development trend of physical research and expect to make continuous breakthroughs in the future.

The center of our work is attracting and cultivating talents. We have been engaging ourselves in discovering, attracting and training leading innovative talents, including distinguished scholars and outstanding young men and students. We seek to provide for them favorable research and living conditions, a free and friendly working environment and a sustainable room to develop. It is our belief that the true meaning of our lives here at Peking University the School of Physics lies in the infatuated and persistent exploration into the infinite world of the unknown.

To study the nature of things in order to acquire knowledge is a mission that the School of Physics, Peking University has undertaken for nearly a hundred years. Today, our school will continue to extend our great scholarly tradition of "Diligence, Rigorousness, Truth, and Innovation", make down-to-earth, united and active efforts in order to build our school into a leading institute of physical education and research that not only plays a leading role in China but also exerts an important impact on all over the world.

Enge Wang
Dean of School of Physics, Peking University

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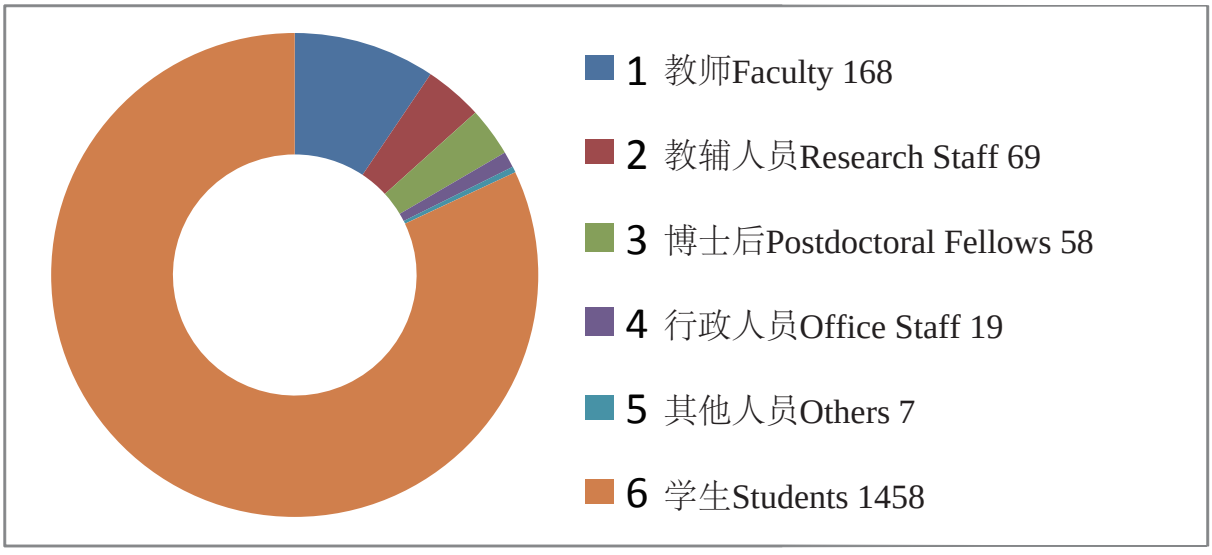

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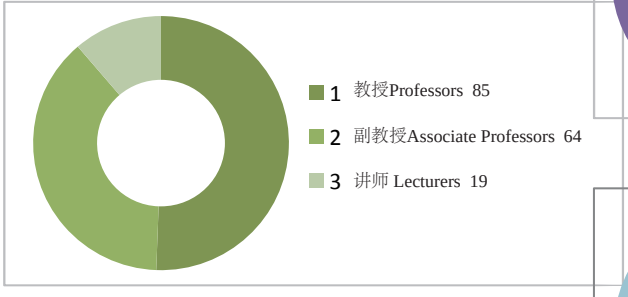

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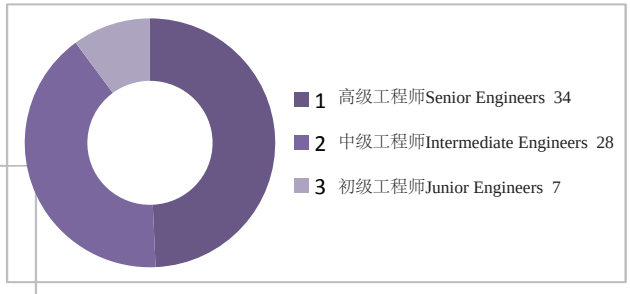

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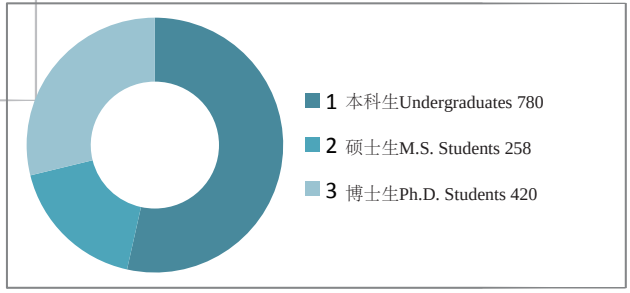

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下属机构
Divisions

- 理论物理研究所 Institute of Theoretical Physics
- 凝聚态物理与材料物理研究所 Institute of Condensed Matter and Material Physics
- 现代光学研究所 Institute of Modern Optics
- 重离子物理研究所 Institute of Heavy Ion Physics
- 等离子体物理与聚变研究所 Institute of Plasma Physics and Fusion Studies
- 技术物理系 Department of Technical Physics
- 天文学系 Department of Astronomy
- 大气与海洋科学系 Department of Atmospheric and Oceanic Sciences
- 普通物理教学中心 Teaching Center for General Physics
- 基础物理实验教学中心 Teaching Center for Experimental Physics
- 电子显微镜专业实验室 Electron Microscopy Laboratory
- 高能物理研究中心 Center of High Energy Physics
- 量子材料科学中心 International Center for Quantum Materials
- 科维理天文与天体物理研究所 Kavli Institute for Astronomy and Astrophysics

系所中心研究亮点
Highlights

01 理论物理研究所
Institute of theoretical physics

理论物理研究所现有教职工 15 人，其中教授 11 人，副教授 3 人，办公行政 1 人。主要研究领域包括：超弦与宇宙学、粒子物理、强子物理、核物理、凝聚态理论与统计物理等，涉及了自然界从宇观到介观直至微观基本粒子的各个尺度。

There are 15 members in the institute with 11 professors, 3 associate professors and one administrative staff. The research fields include: string and cosmology, particle physics theory, hadronic physics, nuclear physics, condensed matter and statistical physics which cover from the scale of the universe down to microscopic scales of elementary particles.

一、粲夸克偶素物理与 QCD 的研究

自 1974 年丁肇中等发现 J/ψ 粒子以来，粲夸克偶素物理一直是理论和实验非常关注的课题。由于粲偶素包含微扰和非微扰的多个能量标度，对它的研究有助于深入理解量子色动力学 (QCD) 与标准模型。特别是近十几年来在强子对撞机和正负电子对撞机上观测到的一些现象与原有的理论预言严重不符，极大地促进了理论研究的进展。

近年来，赵光达研究组（包括博士生张玉洁，马滟青，何志国，范莹，王凯等）对粲偶素的产生和衰变进行了系统研究，在 Physical Review Letters 上发表了四篇文章，从理论上解释了多个与粲偶素产生或湮灭相关的重要疑难问题，对这一前沿领域的发展起到了推动作用。

1. 正负电子湮灭中粲偶素的产生机制

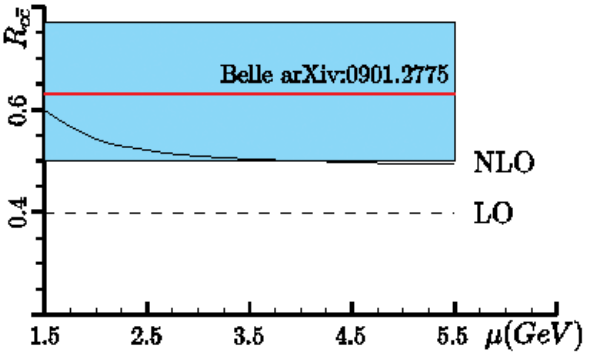
2002 年以来，日本 (Belle) 和美国 (BaBar) 两个正负电子对撞机 B 介子工厂发现，正负电子湮灭中粲偶素的产生实验与现有理论 NRQCD 预言存在尖锐矛盾：一对粲偶素遍举产生过程（如 e+e- → J/ψ ηc）的截面的理论预言值比实验值几乎小一个量级；单举产生过程 e+e- → J/ψ +c+cbar 的截面理论预言结果比实验值小至少 5 倍以上；e+e- → J/ψ +c+cbar 的截面与 J/ψ 单举产生总截面的比值 Rcc 与理论预言不符。上述理论与实验之间的矛盾引发了随后诸多的研究（如有人提出胶子球，超出标准模型的新物理机制，等）来探讨和解决这一问题，但都被新的实验测量所否定。理论与实验如此严重的差距长期未被解决，被认为是粲偶素物理中最具挑战性的热点问题。国际 Quarkonium Working Group 2005 年发表的 CERN 黄皮书中评论称之为“标准模型中理论与实验间的最大差距之一”。除了上述理论预言与实验数据的矛盾外，对于理论本身，以往 NRQCD 在产生过程中的因子化也并没有严格的证明。通过研究，我们发现，QCD 辐射修正和相对论修正效应是问题的关键所在。

1) 我们首先研究了遍举过程 e+e- → J/ψ ηc (Phys. Rev. Lett. 96,092001,2006) 和单举过程 e+e- → J/ψ +c+cbar (Phys. Rev. Lett.98, 092003, 2007) 的 QCD 辐射修正效应。在系统考虑所有单圈图的贡献后，首次证明了红外发散可以消除，因子化在次领头阶成立；进一步发现，次领头阶 QCD 效应对产生截面有很大的增强。 在进一步研究了相对论效应的贡献后，理论结果与实验测量的矛盾基

本上得到解决。

2) 研究了 J/ψ 伴随轻强子的产生。对于正负电子湮灭中 J/ψ 伴随两个胶子（e+e- → J/ψ+g+g）的色单态产生过程（Phys. Rev. Lett. 102， 162002，2009），发现次领头阶 QCD 辐射修正效应不仅能大大减小理论误差，而且使产生截面提高 20-30%。这一理论预言与 2009 年 Belle 实验组的 J/ψ 伴随轻强子的产生截面的新测量结果一致，从而得到结论：J/ψ 伴随轻强子的产生已被色单态过程 e+e- → J/ψ+g+g 所饱和，色八重态贡献基本上可以忽略。由于在 J/ψ 的其他产生过程（如 Tevatron 的强子 - 强子对撞过程）色八重态的贡献曾经被认为是最主要的，因此我们关于色八重态贡献的结论对于理解 NRQCD 和色八重态机制有重要意义。同时结合 e+e- → J/ψ+c+cbar 的研究结果，Rcc 的实验值也得到合理解释。

上述研究结果标志着 B 工厂正负电子湮灭中 J/ψ 产生问题已经基本解决，这一结论得到国际 Quarkonium Working Group，美国 SLAC 的 BaBar, 日本 KEK 的 Belle, 美国 Fermilab 的 CDF 等国际实验合作组的肯定。



图一：Rcc 在领头阶（LO）和次领头阶（NLO）的理论预言随重整化标度 μ 变化的曲线。阴影区域为 Belle 实验测量结果。

Figure 1: μ dependence of the predicted Rcc at LO and NLO. The shadow region represents the experimental result.

2. 粲偶素湮灭衰变的研究

为了澄清 BES 和 CLEO 两个实验组有关 D 波自旋三重态 ψ(3770) 粒子衰变实验结果的尖锐矛盾以及原有理论存在的红外发散问题，我们研究了 D 波粲偶素湮灭到胶子和轻夸克的衰变（Phys. Rev. Lett. 101, 112001，2008），通过引入色八重态贡献，消去了原有的 D 波衰变理论结果所存在的红外发散，在可因子化的条件下得到了衰变到轻强子的宽度，这是首次基于 NRQCD 对 D 波粲偶素衰变的研究。

我们进一步研究了 D 波自旋单态粲偶素 1D2 到轻强子的衰变，在考虑了次领头阶 QCD 效应之后，这些衰变道的宽度变得更加精确，这为实验寻找这一尚未发现的粲偶素态提供了理论依据。

代表性论文：

[1] QCD correction to e+e- → J/ψ+g+g at B Factories; Yan-Qing Ma, Yu-Jie Zhang, Kuang-Ta Chao，Phys.Rev.Lett.102， 162002（2009）.

[2] QCD radiative correction to color-octet J/ψ inclusive production at B Factories; Yu-Jie Zhang, Yan-Qing Ma, Kai Wang, Kuang-Ta Chao, Phys.Rev. D81，034015（2010）.

[3] Relativistic correction to e+e- → J/ψ+g+g at B factories and constraint on color-octet matrix elements; Zhi-Guo He, Ying Fan, Kuang-Ta Chao, Phys.Rev.D81，054036（2010）.

[4] Predictions of Light Hadronic Decays of Heavy Quarkonium 1D2 States in NRQCD; Ying Fan, Zhi-Guo He, Yan-Qing Ma, Kuang-Ta Chao, Phys. Rev.D80，014001(2009).

一、On Charmonium Physics and QCD

Since the J/ψ was discovered in 1974, charmonium physics has been playing an important role in understanding the fundamental aspects of QCD and the standard model. In particular, in recent years, experiments at the Fermilab Tevatron, and at the B factories on charmonium production have led to new

developments for the heavy quarkonium effective theory.

During the past years, Professor Kuang-Ta Chao and his group (including doctoral students Yu-Jie Zhang, Yan-Qing Ma, Zhi-Guo He, Ying Fan ,and Kai Wang et. al.) have studied the mechanisms of charmonium production and annihilation in QCD, and resolved several important puzzles in charmonium physics with 4 papers published in Physical Review Letters.

1.Charmonium production at electron-positron colliders

During 2002-2005, Belle and BaBar Collaborations found that charmonium production rates at B factories are much larger than theoretical predictions: NRQCD predictions are about one order of magnitude smaller than data for exclusive production of double charmonium (such as e+e- → J/ψ ηc) and for inclusive production of e+e- → J/ψ+c+cbar. Many attempts (e.g., invoking glueballs, and mechanisms beyond the standard model, etc.) were made but then ruled out by new measurements. These long-standing puzzles were called "the most challenging open problem" in heavy quarkonium physics, and regarded as "The discrepancies between theory and experiment in these measurements are among the largest in the standard model". By a thorough study for above problems, our group finds that the key effects are the QCD radiative corrections as well as relativistic corrections, with which these puzzles may be resolved.

1)Studies of the next-to-leading order (NLO) QCD radiative corrections to exclusive process e+e- → J/ψ ηc and inclusive process e+e- → J/ψ+c+cbar. With all one-loop contributions being considered, infrared divergences are found to be cancelled exactly, thus factorization at NLO is proven to hold. NLO effects can significantly enhance the cross sections. By combining the QCD radiative corrections with relativistic corrections, the large discrepancies between experiment and theory for these two processes are found to be almost removed.

2)Studies of J/ψ production accompanied with light hadrons. For J/ψ production accompanied with two gluons (e+e- → J/ψ+g+g), the NLO NRQCD effect significantly reduces theoretical uncertainties and enhances the cross section by about 20-30%. The result agrees well with new Belle measurements in 2009, which implies that the observed J/ψ production accompanied with light hadrons is saturated by e+e- → J/ψ+g+g, and the color octet contributions should be negligible. While J/ψ production in other processes, such as in hadron collisions at the Tevatron, is deemed to be dominated by color octet, the above conclusion is crucial in testing NRQCD and color octet mechanism. Moreover, combined with the study of e+e- → J/ψ+c+cbar, the experimental result of Rcc becomes well understood.

2.Studies of annihilation decays of charmonium

To resolve the problems of infrared divergence and experimental conflict between BES and CLEO, the annihilation decay to light hadrons of spin triplet D wave charmonium ψ(3770) is studied. A rigorous result is obtained based on NRQCD factorization by removing the infrared divergence. For the spin singlet D wave charmonium 1D2 state, the annihilation decay at NLO is also studied. The obtained better estimate of the hadronic decay width is certainly helpful in searching for this 1D2 charmonium state in future experiment.

Selected Reprints：

[1] QCD correction to e+e- → J/ψ+g+g at B Factories; Yan-Qing Ma, Yu-Jie Zhang, Kuang-Ta Chao，Phys.Rev.Lett.102， 162002（2009）.

[2] QCD radiative correction to color-octet J/ψ inclusive production at B Factories; Yu-Jie Zhang, Yan-Qing Ma, Kai Wang, Kuang-Ta Chao, Phys.Rev.

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[3] Relativistic correction to e+e- → J/ψ+g+g at B factories and constraint on color-octet matrix elements; Zhi-Guo He, Ying Fan, Kuang-Ta Chao, Phys.Rev.D81，054036（2010）.

[4] Predictions of Light Hadronic Decays of Heavy Quarkonium 1D2 States in NRQCD; Ying Fan, Zhi-Guo He, Yan-Qing Ma, Kuang-Ta Chao, Phys.Rev. D80，014001(2009).

二、模型独立味改变中性流诱导顶夸克衰变的次领头阶 QCD 修正

长期以来，人们在实验中发现，所有基本粒子（夸克）在所参与的交换不带电粒子的相互作用前后，其固有的属性不发生变化，即味不改变。因而，人们一直认为，基本粒子在相互作用中保持中性流味守恒是粒子物理学的基本规律之一。在粒子物理的标准模型中，这个规律的确可以很自然地得以体现。但人们猜测，当在较高的能区存在某种偏离标准模型的相互作用规律时，夸克中性流味守恒的规律有可能被破坏，虽然其几率很小，但仍有可能被高精度的实验所发现。因此，全世界的高能物理学家在不同的高能物理实验中（从日本和美国的 B 工厂到 美国的 Tevatron 和 欧洲的 LHC 等）一直在致力于寻找这种味改变中性流存在的实验证据。本项目深入研究了这个问题，取得如下成果：

系统研究了顶夸克的中性流味守恒破坏 （反常耦合）问题。有关的 4 篇论文，特别是发表于《物理评论快报》（Phys. Rev. Lett. 102,072001（2009）的论文 帮助了美国费米国家实验室的实验物理学家们直接测量顶夸克的 QCD 反常耦合系数，使得实验家们可以检验到目前为止在基本粒子物理学中所发现的最重的基本粒子—顶夸克的相互作用性质，从而实质性地影响了国际高能物理学界对顶夸克的理解。美国费米国家实验室 Tevatron D0 实验组和 CDF 实验组在 2007 年、2009 年及 2010 年发表的实验结果论文（Phys.Rev.Lett.99：191802, 2007；Phys.Rev.Lett.102:151801, 2009；Physics Letters B 693：81，2010）中，都采用了李重生等人的上述理论结果，从而得到了顶夸克 QCD 反常耦合系数的最新实验上限以及相应的衰变分支比上限，CDF 实验组还在论文中向李重生致谢：

“The authors express their gratitude to Chong Sheng Li of Peking University for very useful communication and for providing a new calculation of FCNC top-quark branching ratios in a very timely fashion.”

参考文献：

[1] Jian Jun Liu, Chong Sheng Li, Li Lin Yang, Li Gang Jin，Next-to-leading order QCD corrections to the direct top quark production via model-independent FCNC couplings at hadron colliders，Physical Review D，72，2005，074018-1--074018-7.

[2] Li Lin Yang, Chong Sheng Li, Yang Gao, Jian Jun Liu，Threshold resummation effects in direct top quark production at hadron colliders，Physical Review D，73，2006，074017-1--074018-6.

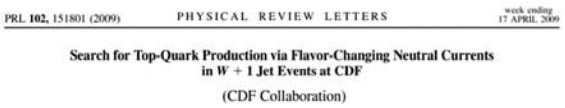
[3] Jun Gao, Chong Sheng Li, Jia Jun Zhang, and Hua Xing Zhu，Next-to-leading order QCD corrections to the single top quark production via model-independent t-q-g flavor-changing neutral-current couplings at hadron colliders，Physical Review D，80，2009，114017-1--114017-12.

[4] Jia Jun Zhang, Chong Sheng Li, Jun Gao, Hao Zhang, Zhao Li, C.-P. Yuan, Tzu Chiang Yuan，Next-to-leading order QCD corrections to the top quark decay via model-independent FCNC couplings，Physical Review Letters，102，2009，072001-1--074018-4.

二、The NLO QCD corrections to the top quark decay induced by the model-independent flavor-changing neutral-current

It has been found for a long time in the experimental studies that all the quarks appearing in the neutral current interactions do not change their flavors. Thus, it is a basic understanding that flavor conservation in the neutral current interactions is one of the basic laws of particle physics. This appears naturally in the standard model (SM) of particle physics, but people conjecture that if there is some kind of new physics beyond the SM at a high energy scale, the flavor conservation may be violated. Thus, the experimentalists all over the world (B factory in Japan and US, Tevatron and LHC) have dedicated to find the evidence of such a flavor-changing neutral-current interaction. In our program we have studied these projects thoroughly, and the achievements are as following:

We systematically studied the flavor violations in the top quark anomalous neutral current interactions, which resulted in 4 published papers. The experimentalists at the Tevatron have used them to measured the top quark anomalous QCD couplings with high precision. Thus our works，especially the paper published in Phys. Rev. Lett. 102,072001（2009）, play an important role in the understanding of the top quark properties. Both the D0 and CDF collaborations at the Tevatron have used our results in their studies to obtain the upper limits for the top quark anomalous QCD couplings and the top quark rare decay branching ratios (Phys.Rev.Lett.99：191802, 2007; Phys.Rev.Lett.102:151801, 2009；Physics Letters B 693：81，2010). Moreover, the CDF collaborations have expressed their acknowledgements to Prof. Chong Sheng Li in their paper:


PRL 102, 151801 (2009) PHYSICAL REVIEW LETTERS week ending 17 APRIL 2009

Search for Top-Quark Production via Flavor-Changing Neutral Currents in $W + 1$ Jet Events at CDF

(CDF Collaboration)

"The authors express their gratitude to Chong Sheng Li of Peking University for very useful communication and for providing a new calculation of FCNC top-quark branching ratios in a very timely fashion.

References：

[1] Jian Jun Liu, Chong Sheng Li, Li Lin Yang, Li Gang Jin，Next-to-leading order QCD corrections to the direct top quark production via model-independent FCNC couplings at hadron colliders，Physical Review D，72，2005，074018-1--074018-7.

[2] Li Lin Yang, Chong Sheng Li, Yang Gao, Jian Jun Liu，Threshold resummation effects in direct top quark production at hadron colliders，Physical Review D，73，2006，074017-1--074018-6.

[3] Jun Gao, Chong Sheng Li, Jia Jun Zhang, and Hua Xing Zhu，Next-to-leading order QCD corrections to the single top quark production via model-independent t-q-g flavor-changing neutral-current couplings at hadron colliders，Physical Review D，80，2009，114017-1--114017-12.

[4] Jia Jun Zhang, Chong Sheng Li, Jun Gao, Hao Zhang, Zhao Li, C.-P. Yuan, Tzu Chiang Yuan，Next-to-leading order QCD corrections to the top quark decay via model-independent FCNC couplings，Physical Review Letters，102，2009，072001-1--074018-4.

三、高温超导涡旋态理论

1986 年高温超导体的发现开创了至今还非常活跃的几个领域的研究。其一是高温超导体的超导微观机制，其二是它在特定外界条件下（比如一定温度和外场）的物理特性（这和实际应用密切

相关）。虽然经过 20 多年的努力，高温超导的微观机理还没有确定和完全了解，但它物理特性的研究和实际的应用却得到很大进展。即使高温超导的微观机理还不确定，根据 Landau 的相变理论，高温超导体的宏观物理特性的研究，和低温超导体一样，可以用 Ginzburg-Landau 超导理论来研究。但不同于低温超导，高温超导的研究要考虑热涨落的影响。

超导体的应用是和研究其在电磁场作用下的物理特性密切相关。高温超导体是二类超导体，不同于一类超导体，磁场可以穿透二类超导体 (混合态) 而不失去超导特性。磁场穿透二类超导体形成一些量子化的磁通线，或者称为涡旋线，或者涡旋子。

磁通线在不同磁场、温度、无序 (掺杂) 条件下，可以形成各种物态，如涡旋晶格、玻璃态、液态等等。不同的涡旋态有不同的超导电性，如玻璃态是超导态，液态不是超导态。 研究涡旋子的物态和其物理特性不仅对实际应用非常重要，它也有非常重要的基础研究意义 。通过控制磁场、温度、无序，实验很容易得到不同的涡旋物态及其之间的相变转换。实验也可详细地研究涡旋物态及相变。这些研究对相变理论，和一般的物态理论的研究有非常重要的意义。如涡旋玻璃态的研究对一般玻璃态理论研究有非常大的帮助。由此可见，高温超导涡旋态的研究不仅有巨大的实用价值，也有非常重要的基础理论研究价值。

李定平教授和台湾交通大学儒森斯坦教授从 Ginzburg-Landau 模型出发，过去十余年中，对二类超导体，特别是高温超导体的涡旋态进行了系统的理论研究。世界上首次定量描述涡旋相变，比如熔化和玻璃态相变，理论和实验非常的吻合。

他们的理论不仅解释了一些实验曲线，理论一些预言相继得到实验的证实。现在列举一些相关的实验如下：

1) 晶格态亚稳终结线 (Spinodal) 理论预言被此实验，相关实验是美国 Rutgers 大学超导实验室完成， Physical Review Letters 92, 227004 (2004)。

2) 证实溶化曲线和他们的理论公式结果预言一致，相关实验文章荷兰 Kamerlingh Onnes 超导实验室和日本筑波超导大学实验完成，Physical Review Letters 95, 177005 (2005); Phys. Rev. B 75, 184512 (2007)。

3) 以色列威兹曼研究所超导实验室 BSCCO 的涡旋相图的实验也证实他们的理论预言，相关实验是 Physical Review Letters 98, 167004 (2007)。

李定平教授和儒森斯坦教授最近在 REVIEWS OF MODERN PHYSICS 发表综述文章总结他们十多年的部分工作成果，“Ginzburg-Landau theory of type II superconductors in magnetic field”，VOLUME 82, Page 109, JANUARY–MARCH 2010.

相关文献：

[1] Baruch Rosenstein and Dingping Li，Rev. Mod. Phys. 82, 109 (2010)

[2] Dingping Li and Baruch Rosenstein，Phys. Rev. B 70, 144521 (2004)

[3] Dingping Li and Baruch Rosenstein，Phys. Rev. Lett. 90, 167004 (2003)

[4] Dingping Li and Baruch Rosenstein，Phys. Rev. B 65, 220504 (2002)

[5] Dingping Li and Baruch Rosenstein，Phys. Rev. Lett. 86, 3618 (2001)

三、Theory of the vortex matter in high Tc superconductors

The discovery of the high Tc superconductors at 1986 has created several very active research fields up to now. One of the active fields is the investigation of the microscopic mechanism of the high Tc superconductivity, another one is the macroscopic quantum characteristics of the superconducting

materials under certain external conditions, like temperature and external magnetic and electric fields which is closely related to the applications of the superconductivity. Though more than twenty years passed, the microscopic mechanism of the high Tc superconductivity has not been settled, but the understanding of the macroscopic quantum characteristics of the superconducting materials and the application of high Tc superconductivity have been greatly advanced. Even the microscopic mechanism has not been understood completely, the macroscopic quantum characteristics can be investigated using phenomenological theory, the Ginzburg-Landau theory as it was done in low Tc superconductivity. But different from low Tc superconductivity, one needs to include the thermal fluctuation effect in high Tc superconductivity.

The application of the superconductivity is closely related to the studying its physical behavior of the materials under external electric and magnetic field. High Tc superconductors are so called type II superconductors, which are different from type I, the magnetic field can penetrate the bulk of the materials without losing the superconductivity. The magnetic field penetrating the type II superconductors forms flux lines, which are called vortices.

Vortices in type II superconductors can form different phases in different temperature, external magnetic field and disorder, for example, vortex lattice, vortex glass and vortex liquid. Different phases have different conductivity behavior, for example, vortex glass is superconducting, but vortex liquid is not. The studying of the phase of the vortex matter and their physical properties is not only important in the technology applications of high Tc superconductors, but also is important to the fundamental research to the theory of the phases of the matter appeared in nature. By tuning the temperature, external magnetic field, and disorders, one can easily transform one phase of the vortex matter to another phase. Experimentally one can study the vortex matter phases and their phase transitions in great details. Thus the vortex matter of high Tc superconductors is one of best materials for studying phases and phase transitions, and is fundamentally important to the theories of phases and phase transitions for other matters due to the universal properties of phases and phase transitions. For example, it is very hard to study the glass transition in other materials, but it is quite easy to study the phase and the phase transition of the vortex glass in high Tc superconductors. In summary, the studying of the vortex phase in high Tc superconductors is not only important due to the practical application, but also important to the fundamental research.

Prof. Dingping Li has collaborated with Prof. B.Rosenstein from National Chiao Tung University more than ten years in the studying of the vortex matter. Starting from Ginzburg-Landau theory of superconductivity, they have systematically studied the type II superconductors, especially the vortex matter of the high Tc superconductors. They quantitatively obtained the phase transition lines, for example melting line and glass transition line in agreement with experiments.

During passed ten years, they not only explained some existing experiment data, but some theoretical predictions were confirmed experimentally appeared latter than our theoretical calculations.

1)The existence and the location of the Spinodal line were experimentally conformed by the superconductor laboratory of the Rutgers University of USA, Physical Review Letters 92, 227004 (2004).

2)The formula of the melting line was experimentally verified by the Kamerlingh Onnes laboratory of Netherland and University of Tsukuba of Japan, Physical Review Letters 95, 177005 (2005); Phys. Rev. B 75, 184512 (2007).

3)The prediction of four different phases of the vortex matter was experimentally confirmed by the superconductor laboratory of Weizmann institute of Israel, Physical Review Letters 98, 167004 (2007).

Prof. Dingping Li and B. Rosenstein published a review paper summarizing parts of our research results from last ten years, “Ginzburg-Landau theory of type II superconductors in magnetic field”, REVIEWS OF MODERN PHYSICS, VOLUME 82, Page 109, JANUARY–MARCH 2010.

Relevant references:

[1] Baruch Rosenstein and Dingping Li，Rev. Mod. Phys. 82, 109 (2010)

[2] Dingping Li and Baruch Rosenstein，Phys. Rev. B 70, 144521 (2004)

[3] Dingping Li and Baruch Rosenstein，Phys. Rev. Lett. 90, 167004 (2003)

[4] Dingping Li and Baruch Rosenstein，Phys. Rev. B 65, 220504 (2002)

[5] Dingping Li and Baruch Rosenstein，Phys. Rev. Lett. 86, 3618 (2001)

02 凝聚态物理与材料物理研究所 Institute of Condensed matter and Material Physics

凝聚态物理与材料物理研究所现有教职工 58 人，其中教授 18 名，副教授 15 名，讲师 4 名，工程技术人员 18 名，百人研究员 3 名。研究领域包括宽禁带半导体物理和器件，凝聚态理论，纳米半导体与半导体光子学，表面物理与扫描探针显微学，高温超导体及其相关材料、物理与器件，纳米结构和低维物理，软凝聚态物理，以及磁性物理和新型磁性材料。

There are 58 faculty members in the institute, consisting of 18 professors, 15 associate professors, 4 lecturers, 18 engineering technicians, and 3 Bairen research professors. The research fields covering a wide range include Devices and Physics of Wide-gap semiconductors, Condensed Matter Physics, Nanosized Semiconductors and Optoelectronic Physics, Surface physics and Scanning tunneling microscopy, Physics and Devices of High Temperature Superconductors, Low-dimension Nanostructure and Physics, Soft Condensed Matter Physics, and Physics of Magnetism and Advanced Magnetic Materials.

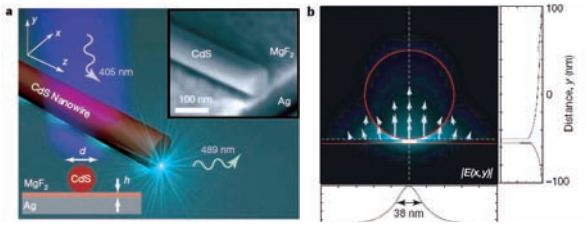
一、纳米半导体与光电子物理研究

- 纳米半导体材料和物理
- 纳电子 / 纳光子器件和物理
- 有机半导体光子学
- 硅基混合激光器
- 硅光子学

1. 在深亚波长尺度的等离激元激光

激光科学在提供高功率、较快、较小的相干光源方面取得了成功。最近，可以达到衍射极限的微型激光器已经问世。 然而这种激光器在光学模式尺寸和物理器件维度上依然受到要大于光场半波长的限制。因此，要实现能够在远小于衍射极限的纳米尺度直接产生相干光场的超微型激光器依然存在挑战。一种途径是利用表面等离激元，它能够使光紧密地局域化。但是迄今为止，在光学频率上的欧姆损耗抑制了基于该方法的真正的纳米尺度激光器的实现。最近有理论工作预言：在一个混合等离激元波导中维持超小模式时，这样的损耗能够被大大降低。加州大学伯克利分校华裔教授张翔率领的研究团队和北京大学戴伦教授及其博士生马仁敏采用包含一根高增益 CdS 半

导体纳米线、5nm 厚的 MgF2 绝缘介质层和银表面的混合等离激元波导，从实验上演示了纳米尺度的等离激元激光。其产生的光学模式比衍射极限小 100 倍。光发射寿命的直接测量结果显示纳米线的激子自发发射速率增强了高达 6 倍。其原因来自强的模式限制和明显的无阈值激射特征。等离激元激光提供了探索光和物质相互作用的可能性，在有源光子电路、 生物传感器和量子信息等领域开辟了新的道路。该工作于八月三十日在《自然》杂志上刊登 (Rupert F. Oulton, Volker J. Sorger, Thomas Zentgraf, Ren-Min Ma, Christopher Gladden, Lun Dai, Guy Bartal & Xiang Zhang, “Plasmon lasers at deep subwavelength scale”, Nature 461, 629 (2009).) 该工作一经发表立刻被报道：中新社旧金山八月三十一日电 (记者 刘丹): 美、中科学家联合研制出世界最小的半导体激光器。这项被称为“表面等离子体激光技术”的研究在激光物理学界堪称里程碑，于八月三十日在《自然》杂志上刊登，由加州大学伯克利分校华裔教授张翔率领的研究团队、北京大学戴伦教授及其博士生马仁敏共同完成。



(a) CdS 半导体纳米线、5nm 厚的 MgF2 绝缘介质层和银表面的混合等离激元波导示意图。插图是实物的 SEM 照片。(b) 纳米尺度的等离激元激光示意图。

a, The plasmonic laser consists of a CdS semiconductor nanowire on top of a silver substrate, separated by a nanometre-scale MgF2 layer of thickness h. This structure supports a new type of plasmonic mode. The mode size of which can be a hundred times smaller than a diffraction-limited spot. The inset shows a scanning electron microscope image of a typical plasmonic laser, which has been sliced perpendicular to the nanowire’s axis to show the underlying layers. b, The stimulated electric field distribution and direction |E(x, y) | of a hybrid plasmonic mode at a wavelength of l5489 nm, corresponding to the CdS I2 exciton line. The cross-sectional field plots (along the broken lines in the field map) illustrate the strong overall confinement in the gap region between the nanowire and metal surface with sufficient modal overlap in the semiconductor to facilitate gain.

2. 纳米线环形光学微腔研究成果

环形光学微腔具有品质因子高、体积小等优点。将微环腔与波导耦合，可以实现集成光子器件中的很多重要功能元件，如全光开关与调制器、电光调制器、滤波器、探测器、光互联网络等。另外该类光学微腔可以应用于低阈值激光器、高灵敏生物微传感器、量子光学、非线性光学和量子信息处理等前沿交叉学科的研究。我们首次制备并研究了 CdS 纳米线微环腔 (图 1（a）) 及耦合的纳米线微环一法 - 珀腔。深入研究了这些微腔的光学共振模式和影响其品质因子 (Q) 的关键因素。此外，实验发现在这种耦合的纳米线微环一法 - 珀腔中，直的纳米线不但可以作为波导将环形微腔中的共振光引出，而且对环型微腔中的共振模式有调制作用（图 2 （a-d））。该工作发表在 Nano Letters 杂志上 (R. M. Ma, X. L. Wei, L. Dai, S. F. Liu, T. Chen, S. Yue, Z. Li, Q. Chen, and G. G. Qin, “Light Coupling and Modulation in Coupled Nanowire Ring-Fabry-Pe´rot Cavity”, Nano Letters 9, 2697 (2009)).)。

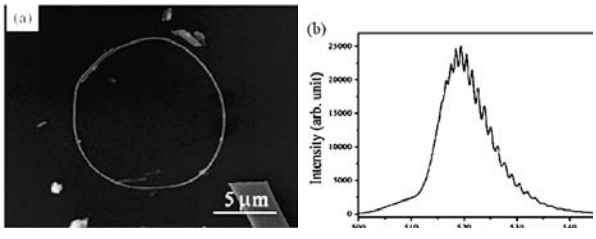


图 1(a) CdS 纳米线微环的 SEM 照片；（b）CdS 纳米线微环的空间分辨光荧光谱

Figure 1 (a) NW ring with side-by-side overlap coupling geometrie with the overlap length to be about 3.75 μ m. (b) Spatially resolved PL spectra of the NW ring depicted in (a).

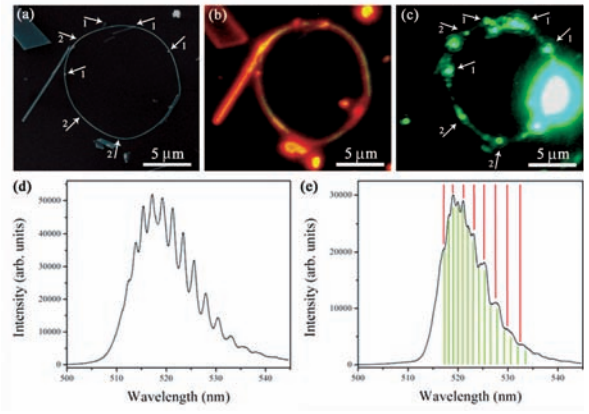


图 2. 耦合的 CdS 纳米线微环－法 - 珀腔的 SEM 照片 (a)、光学显微镜照片（b）、荧光图象（c）。直的 CdS 纳米线（d）和耦合的 CdS 纳米线微环－法 - 珀腔（e）的空间分辨光荧光谱。

Figure 2. SEM (a), dark field (b), and PL image (c) of a NW ring coupled to a straight NW. Light spots marked by arrows 1 are due to adhered particles, those marked by arrows 2 are due to defects on the NW. The corresponding positions are also marked in the SEM image in (a). (d) Spatially resolved PL spectrum of the straight NW prior to being contacted to the NW ring. (e) PL spectrum collected at the output end of the straight NW with the exciting point on the NW ring. Red and green lines mark the respective mode positions of the F-P cavity and the ring cavity.

3. 硅混合激光器

作为延续摩尔定律的方案之一，硅基光互连被广泛研究。其中硅光源是关键。人们几十年来探索了诸多方案。但最实用的是 INTEL 和 UCSB 联合提出的 InP-Si 直接键合激光。而我们采用选区金属键合实现了可实用的室温连续的硅基激光。且工艺简单，成本低，对超净要求低。该工作与半导体所王圩院士组合作完成。发表在 IEEE PHOTONICS TECHN LETT 并申请了美国专利 [Tao Hong, Guang-Zhao Ran, Ting Chen, Jiao-Qing Pan, Wei-Xi Chen, Yang Wang, Yuan-Bing Cheng, Song Liang, Ling-Juan Zhao, Lu-Qiao Yin, Jian-Hua Zhang, Wei Wang, and Guo-Gang Qin, IEEE PHOTONICS TECHN LETT, 22, 1141 （2010）]。

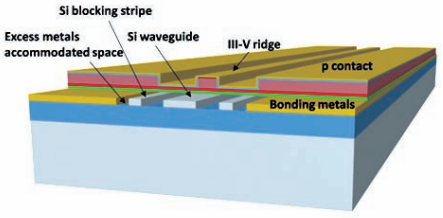


图 1 选区金属键合硅混合激光结构示意图。

Figure 1. The schematic diagram of a hybrid InGaAsP–Si laser by selective area metal bonding.

图 2 器件端面 SEM 照片。

Figure 2 SEM image of the cross section

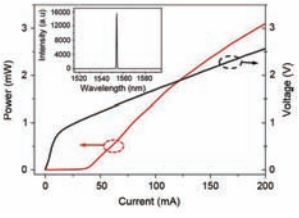


图 3 电流 - 电压 - 光功率特性及光谱（插图）。

Figure 3 I-V-optical power curves.

一、 Nano semi-conductor and electro-optics

1.Plasmon lasers at deep subwavelength scale

Laser science has been successful in producing increasingly highpowered, faster and smaller coherent light sources. Examples of recent advances are microscopic lasers that can reach the diffraction limit, based on photonic crystals, metal-clad cavities and

nanowires. However, such lasers are restricted, both in optical mode size and physical device dimension, to being larger than half the wavelength of the optical field, and it remains a key fundamental challenge to realize ultracompact lasers that can directly generate coherent optical fields at the nanometre scale, far beyond the diffraction limit. A way of addressing this issue is to make use of surface plasmons, which are capable of tightly localizing light, but so far ohmic losses at optical frequencies have inhibited the realization of truly nanometre-scale lasers based on such approaches. A recent theoretical work predicted that such losses could be significantly reduced while maintaining ultrasmall modes in a hybrid plasmonic waveguide. Here we report the experimental demonstration of nanometre-scale plasmonic lasers, generating optical modes a hundred times smaller than the diffraction limit. We realize such lasers using a hybrid plasmonic waveguide consisting of a high-gain cadmium sulphide semiconductor nanowire, separated from a silver surface by a 5-nmthick insulating gap. Direct measurements of the emission lifetime reveal a broad-band enhancement of the nanowire’s exciton spontaneous emission rate by up to six times owing to the strong mode confinement and the signature of apparently threshold-less lasing. Because plasmonic modes have no cutoff, we are able to demonstrate downscaling of the lateral dimensions of both the device and the optical mode. Plasmonic lasers thus offer the possibility of exploring extreme interactions between light and matter, opening up new avenues in the fields of active photonic circuits18, bio-sensing and quantum information technology. (Rupert F. Oulton, Volker J. Sorger, Thomas Zentgraf, Ren-Min Ma, Christopher Gladden, Lun Dai, Guy Bartal & Xiang Zhang, “Plasmon lasers at deep subwavelength scale”, Nature 461, 629 (2009).)

2.Light Coupling and Modulation in Coupled Nanowire Ring-Fabry-Pe´rot Cavity

Microdisk and microring cavities, which operate on whispering gallery modes (WGMs), are another important type of microcavity that has key merits of high quality factor (Q) and compact size. Besides the application in high Q lasers, the strong confinement of electromagnetic energy in a small microring cavity can result in very functional microphotonic integrated circuits. All optical switches and modulators, electro-optic modulators, channel add-drop filters, and optical cross-connect networks have been achieved by coupling microring cavities to straight waveguides in various material systems.We reported the fabrication and study of CdS NW ring cavities for the first time. We also constructed a coupled ring-F-P (R-F-P) cavity by placing a cleaved straight NW by the side of a NW ring cavity with a nanoprobe system installed in a scanning electron microscope (SEM). We also investigated the optical resonant modes insides these cavities, and the critical factors that influence the Q value of them. Moreover, we found that the straight NW served not only as a waveguide to couple the light out from the NW ring but also as a modulator to modulate the WGMs of the NW ring cavity. (R. M. Ma, X. L. Wei, L. Dai, S. F. Liu, T. Chen, S. Yue, Z. Li, Q. Chen, and G. G. Qin, “Light Coupling and Modulation in Coupled Nanowire Ring-Fabry-Pe´rot Cavity”, Nano Letters 9, 2697 (2009)).

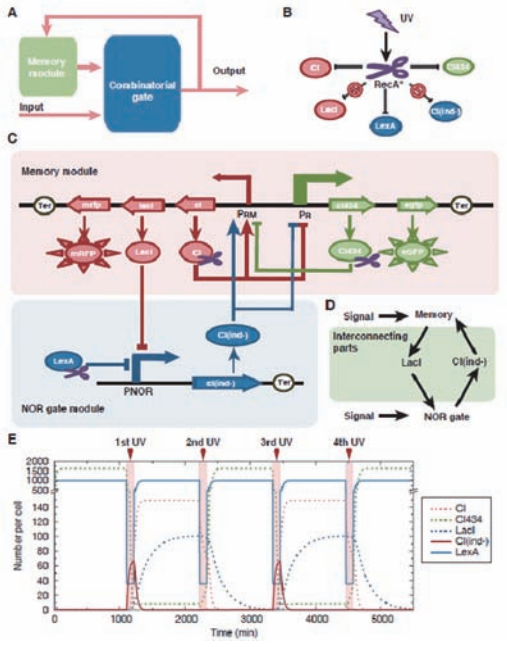
3. A Selective-Area Metal Bonding InGaAsP–Si Laser

To expand the Moore’s Law, optical interconnect on Si chip is intensively studied worldwide. The silicon light source is a key. Although numerous approaches have been investigated for it, the most practical one is the InP-Si hybrid laser, which was first demonstrated by Intel and UCSB. In our Lab, a 1.55- m hybrid InGaAsP–Si laser has been fabricated by the selective-area metal bonding method. The laser operates with a

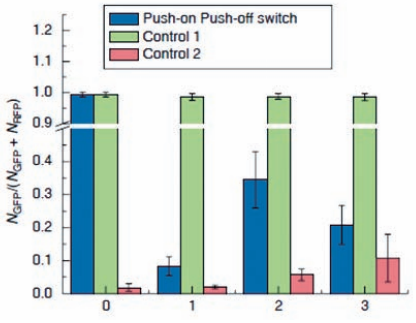
maximum output power of 0.45 mW is realized [Tao Hong, et al， PHOTONICS TECHN LETT，22，1141 （ 2010）]. This is a joint research with Wang Wei group in Institute of Semiconductor, CAS

二、非线性科学在合成生物学中的应用——软凝聚态研究

北京大学物理学院凝聚态与材料物理研究所软凝聚态研究组在合成生物学研究中与的了重要进展。应用电子工程中普遍采用的逆向工程方法，结合非线性动力学理论，开创了从理性设计角度开展合成生物学的理论与实验研究。



基于这个研究方法，设计了一个的生物器件：可执行触点式开关的大肠杆菌。该器件由一个记忆模块和一个或非门构成，在同一外界信号下可以来回执行两种不同的功能。右图 A 是应用逆向工程远离设计的控制网络的逻辑图；图 E 是对应的非线性动力学分析。图 C 是实现此逻辑的生物网络控制图。



我们是试验结果表明此研究思路是可行的。左图展示了实验结果。此生物器件已经完成并发表在英国《自然》杂志社新创刊的科学刊物《分子系统生物学》上。文章发表后当月成为该刊物下载量第一的论文。

二、The Soft Condensed Matter Physics

The Soft Condensed Matter group in the Institute of condensed matter and applied physics at Peking University has achieved important progress in synthetic biology research. We applied the concept of reverse engineering in electronic engineering, combined with the nonlinear dynamics theory, create a method of synthesize biological circuit through rational design.

Based on this method, we rationally designed a biological control circuit than can perform push-on-push-off switch in E. Coli. bacteria. This circuit can conduct different functions with the same input signal in a manner of back and forth. In the Fig. on the right, A is the logic circuit that designed through reverse engineering; E is the result of nonlinear analysis of the circuit dynamics; C is the biological realization of the circuit.

Our experimental result proofs that the method is valid. The Fig. on the left shows the experimental result. This work has been published in the journal Molecular Systems Biology, a newly created journal in Nature Publish Group. It became number 1 downloaded paper of the month.

三．近场光学研究

1. 表面等离激元的平面聚焦

通过纳米微加工技术制备银纳米岛阵列和平面内菲涅尔波带片，在这一结构内分别实现了对表面等离激元（SPP）的激发、传播、聚焦以及和背景激发光分离。利用聚焦 SPP 激发 CdS 纳米带，实现介质承载 SPP 波导。利用有限时域差分计算方法模拟了 SPP 通过菲涅尔波带片聚焦的现象。（ACS Nano; 4(2010) 75-82）

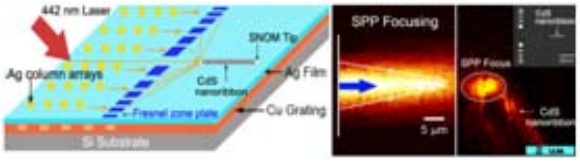


图 1：表面等离激元平面内聚焦以及和 CdS 纳米带的耦合

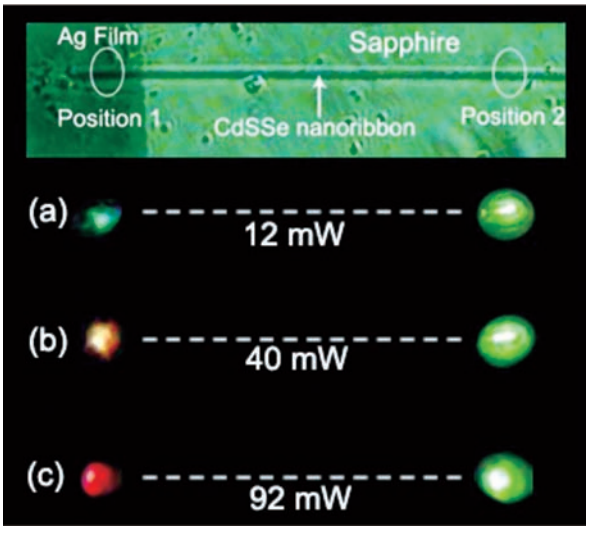
Figure 1: Planar surface plasmon polariton focusing and coupling with CdS nanoribbon.

2. 近场光学研究半导体纳米带表面等离激元的波导红移调控

利用近场光学扫描显微术 (SNOM) 研究半搭在银膜表面的 Se 掺杂 CdS 纳米带（CdS0.65Se0.35,CdSSe）的近场原位出射光谱。发现在银膜表面的 CdSSe 纳米带的原位光谱随激发光功率的增强有着明显的能量红移。SPP 共振增强效应和 Franz-Keldysh 效应被用于解释出射荧光的红移现象。（Phys. Rev. B; 82 (2010) 085403）

图 2：部分覆盖在银膜表面的 CdSSe 纳米带光学透射像（上），以及在不同激发光功率下位置 1 和位置 2 的原位光致荧光（下）。

Figure 2: Optical transmission image of the CdSSe nanoribbon partly placed on the Ag film. (a-c) The sequence of dark-field PL spots corresponding to positions 1 and 2, respectively.



3. 对称性破缺金属纳米围栏实现表面等离激元单点聚焦

利用 SNOM 研究了纳米金属围栏分别在径向偏振光和线性偏振光激发下的 SPP 干涉现象。通过对围栏引入对称性破缺的概念，实现在线性偏振光激发下围栏中心的亚波长尺度单点聚焦。利用数值模拟和解析计算相结合，建立 SPP 在围栏内部的波动模型，解释 SPP 聚焦形成机制。改变对称性破缺的程度，即改变左右两个半圆围栏的大小，可以实现其中心点干涉相消或相长的调制。(Nano Lett.; 11,893-897) 此工作作为特色亮点论文被自然亚洲材料推介。（NPG Asia Materials, 2011）利用领结型纳米光学天线实现银纳米线表面等离激元耦合及出射效率的增强。（Nano Lett.; 11, doi: 10.1021/nl200179y）

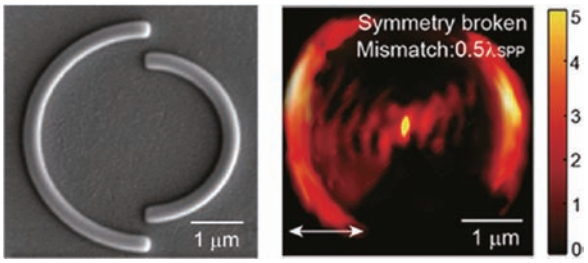


图 3：对称性破缺金属围栏的扫描电镜图和在线性偏振光激发下的近场光学像

Figure 3: SEM image for the symmetry broken nanocorral and its near-field optical distribution under the linearly polarized incident light.

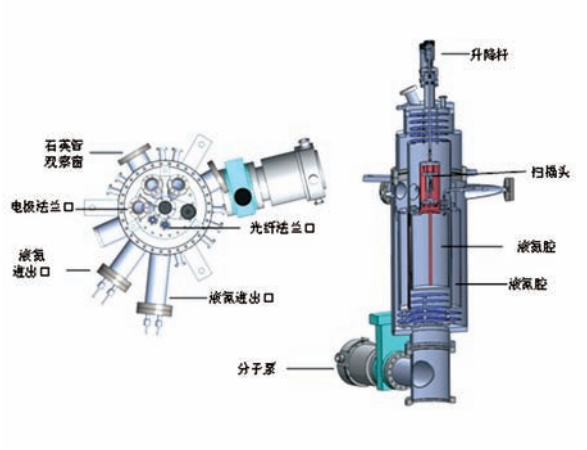
4. 自主研发低温扫描近场光学显微镜

在半导体纳米结构、有机荧光分子等材料中许多复合发光的现象在低温下一些非辐射复合过程发生的机率降低，载流子热运动的平均能量降低，因此发光效率比室温下大为提高，光谱宽度减小，信噪比提高，而且诸如激子复合等现象一般也只能在低温下才能出现，载流子的寿命，迁移率等等其它性质也往往与温度密切相关。利用近场光学的高空间分辨率，结合低温的手段，可以对这些发光现象进行深入的研究。我们目前研制工作温度在 10K 左右的扫描近场光学显微镜取得重要进展，并对一些典型的样品如量子点、量子线的低温发光性质开展研究。

1) 自行设计了真空腔体和低温杜瓦的结构，并完成制图工作。设计真空度达到 2×10-10Torr, 样品台温度低于 10K。低温杜瓦部分为双层杜瓦制冷系统。

2) 自行研制的粗逼近步进马达采用压电陶瓷的惯性运动实现 . 针尖探测是基于石英音叉剪切力工作模式 . 低温下，xy 扫描台的扫描范围可达 30 × 30 m2，形貌分辨率优于 1 nm.

3) 低温扫描近场光学显微镜的光学系统设计工作于反射式针尖收集模式下。照明光由光纤经过法兰导入真空腔体 , 经两个透镜欠聚焦于针尖下方的样品表面。针尖与音叉固定于中心开孔的透镜上，光纤由孔中穿出从镜筒侧面引出。



已正式发表的代表性论文：

[1] Planar Plasmonic Focusing and Optical Transport Using CdS Nanoribbon; Z. Y. Fang, C. F. Lin, R. M. Ma, S. Huang, and X. Zhu; ACS Nano; 4 (2010) 75-82.

[2] Color-changeable Properties of Plasmonic Waveguide Based on Se-doped CdS Nanoribbons; Z. Y. Fang, S. Huang, Y. W. Lu, A. L. Pan, F. Lin, and X. Zhu; Phys. Rev. B; 82 (2010) 085403.

[3] Plasmonic Focusing in Symmetry Broken Nanocorrals; Z. Y. Fang, Q. Peng, W. T. Song, F. H. Hao, J. Wang, P. Nordlander, and X. Zhu; Nano Lett.;11 (2011), 893-897.

[4] Photonics: Rounding up the light; http://www.natureasia.com/asia-materials/highlight.php?id=858 NPG Asia Materials (2011).

[5] Plasmonic Coupling of Bow tie Antennas with Ag Nanowire; Z. Y. Fang, L. R. Fan, C. F. Lin, D. Zhang, A. J. Meixner, X. Zhu; Nano Lett.; 11 (2011), Doi: 10.1021/nl200179y

三．The near-field optics

1. Surface plasmon polariton (SPP) focusing by using in-plane Fresnel zone plate

Using nanofabrication technology, Ag nano-column arrays and an in-plane Fresnel zone plate (FZP) were fabricated to realize the SPP excitation, propagation, focusing and the separation from the background optical signal. Dielectric-loaded SPP waveguide can be generated by coupling the focused SPP wave into the CdS nanoribbon. Finite-difference time-domain method was used to simulate the phenomenon of SPP focusing.（ACS Nano; 4(2010) 75-82）

2. Color-tunable properties of plasmonic waveguide based on Se-doped CdS nanoribbons

The near-field in-situ spectrum of Se-doped CdS nanoribbon half placed on the Ag film was investigated by using scanning near-field optical microscopy (SNOM). The wavelength of the SPP emission experienced spectroscopic red-shift with the increasing of the incident laser power. SPP field enhancement effect and the Franz-Keldysh effect were used to explain the red-shift phenomenon of CdSSe in-situ photoluminescence (PL).（Phys. Rev. B; 82 (2010) 085403）

3. Plasmonic focusing in symmetry broken nanocorrals

The interference pattern within the plasmonic corral was investigated under radially and linearly polarized incident light by using SNOM. A subwavelength SPP focus can be generated in the center by introducing the idea of symmetry breaking to the nanocorral structure. FDTD simulations and analytical calculations were used to explore this SPP interference behavior. (Nano Lett.; 11, 893-897) This work was featured highlighted by NPG Asia naterials (2011). The enhancement of the SPP coupling and emission of the Ag nanowire was realized by fabricating the Bowtie antenna pairs at the incident and output ends of the Ag nanowire （Nano Lett.; 11, doi: 10.1021/nl200179y）

4. Home-made low-temperature scanning near field optical microscope

The light-emitting phenomena of semiconducting nanostructures, organic fluorescent molecules, and so on have a tight relationship with temperature. At low temperatures the occurrence probability of nonradiative recombination processes and the average energy of thermal carriers are reduced, so the luminous efficiency is much higher than room temperature, the spectrum width decreases, and the signal to noise ratio becomes higher. Especially, the exciton recombination can generally occur at low temperatures. The lifetime, mobility of carriers, and other properties are often closely related with the temperature. Combining the high spatial resolution of scanning near-field optical microscope and the low-temperature means, these phenomena can be well studied. For the low-temperature scanning near-field optical microscope, it is difficult to set up a light path at low-temperatures in the vacuum system which is well integrated with scanning probe technologies. This is a challenging task. At present, no other research groups have built a low-temperature scanning near-field optical microscope in China. Our goal is to develop a scanning near-field scanning optical microscope working at the temperature of about 10 K, with which, some luminescent nanomaterials, such as quantum dots, and nanowires, can be explored at low-temperatures.

The set-up progress of the low-temperature scanning near-field optical microscope:

1)Designed a cryostat vacuum chamber. Vacuum chamber contains the upper and lower parts, which are the sample stage and the double-layer Dewar refrigeration system, respectively. The vacuum is better than 2 × 10-10 Torr, the lowest temperature on the sample stage is below 10 K.

2)The rough approaching of optic fiber probe was completed by the inertial stick-slip movement of a piezoelectric ceramic motor. The working principle of the optic fiber probe is based on the quartz tuning fork shear force mode. At low temperatures, the range of xy scanning is up to 30 ×30 m2, with the topographical accuracy better than 1 nm.

3)Optical part of the instrument has been completed. The low-temperature scanning near-field optical microscope works on the reflective tip collection mode. The excitation light propagating within a multimode fiber is introduced into the UHV chamber through a fiber flange, and then by two lenses defocused on the sample stage. The fiber tip sticking on the tuning fork was fixed on a lens with a center hole that guides the fiber to the outside of the optical tube, and finally passes through the vacuum chamber to a spectroscopy.

Selected Publications：

[1] Planar Plasmonic Focusing and Optical Transport Using CdS Nanoribbon; Z. Y. Fang, C. F. Lin, R. M. Ma, S. Huang, and X. Zhu; ACS Nano; 4 (2010) 75-82.

[2] Color-changeable Properties of Plasmonic Waveguide Based on Se-doped CdS Nanoribbons; Z. Y. Fang, S. Huang, Y. W. Lu, A. L. Pan, F. Lin, and X. Zhu; Phys. Rev. B; 82 (2010) 085403.

[3] Plasmonic Focusing in Symmetry Broken Nanocorrals; Z. Y. Fang, Q. Peng, W. T. Song, F. H. Hao, J. Wang, P. Nordlander, and X. Zhu; Nano Lett.;11 (2011), 893-897.

[4] Photonics: Rounding up the light; http://www.natureasia.com/asia-materials/highlight.php?id=858 NPG Asia Materials (2011).

[5] Plasmonic Coupling of Bow tie Antennas with Ag Nanowire; Z. Y. Fang, L. R. Fan, C. F. Lin, D. Zhang, A. J. Meixner, X. Zhu; Nano Lett.; 11 (2011), Doi: 10.1021/nl200179y.

四、纳米结构与低维物理研究

- 功能准一维纳米结构与物理
- 二维石墨烯 : 规模制备与量子输运
- 基于固体纳米孔的 DNA 单分子探测

1. 功能准一维纳米结构与物理研究

本实验室是国际上最早从事纳米线研究的小组之一，迄今已经发表与纳米线相关的论文 170 余篇，被引用 6000 余次。目前关注的重点集中在以下几个方面：

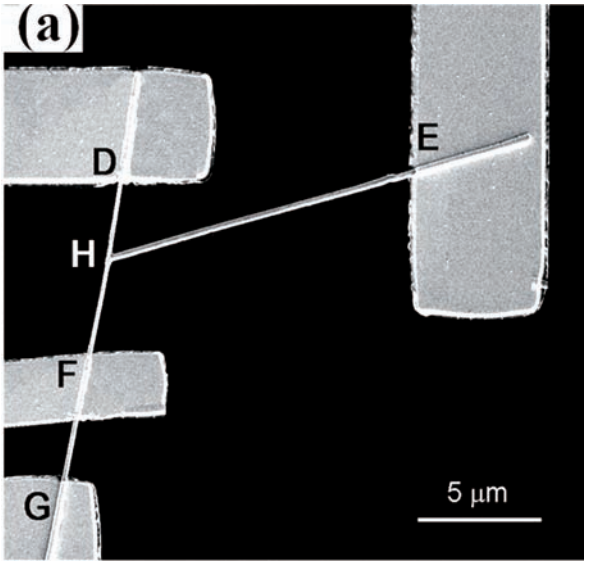
1) 功能纳米线的可控生长与掺杂

a) 对生长机理的深入了解是实现纳米材料可控制备的必由之路。利用环境扫描电镜进行纳米线生长机理的原位研究，以期掌握纳米线生长动力学的基本规律。

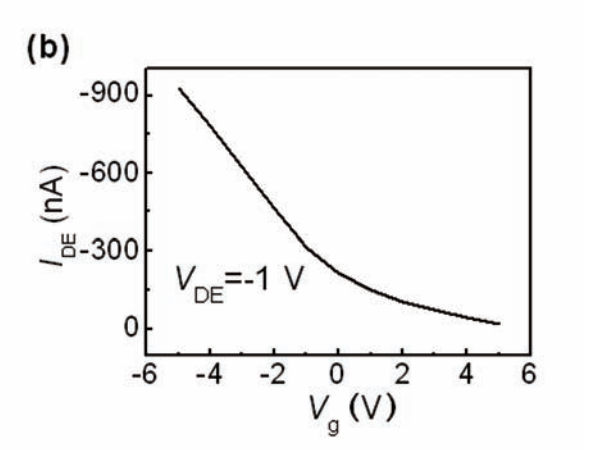
b) 掺杂是调制材料性质的重要途径，在 禁带半导体纳米线材料中掺入磁性元素可以获得稀磁半导体纳米线，而纳米线 p-n 结超晶格结构则是实现纳米激光器的基础。

c) 通过氧化磷原位掺杂探索了 ZnO 纳米线

的 p- 型掺杂机理，发现当磷浓度较高时，受主的浓度可以完全补偿施主缺陷，这时 ZnO 纳米线显现出 p 型输运特性；当磷元素浓度较低时，受主的浓度只能补偿一部分施主缺陷，这时纳米线显示为 n 型输运特性；制备了一种氧化锌纳米线 p-n 同质结，展现出高电流开关比特性 (Nano Letters, 2009)：



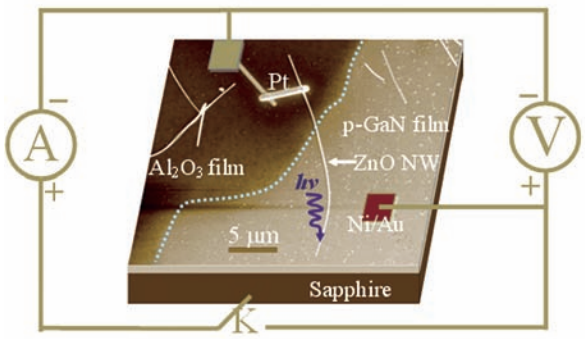
SEM image of T-shaped junction



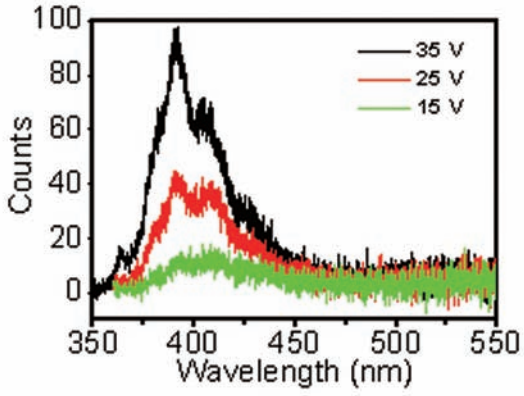
The p-type transfer characteristics of the p-n junction

2) 基于纳米线异质结的自驱动纳米器件

基于对半导体纳米线光电导的系统研究和理解，设计了一种基于单根 n-ZnO 纳米线 /p-GaN 薄膜异质结的太阳能纳米光伏器件：在 p-GaN 薄膜上沉积一层 A2O3 绝缘层，在横跨 p-GaN 薄膜 / Al2O3 绝缘层之间放置一根 n-ZnO 纳米线，形成了一个纳米 p-n 异质结结构。该 p-n 异质结构成一个紫外电致发光二极管， 同时也是一个性能优异的纳米光伏器件，其开路电压高达 2.7 V, 最大输出功率约 80 nW《Advanced Materials，2010》。



SEM image of n-ZnO nanowire/p-type GaN film heterojunction

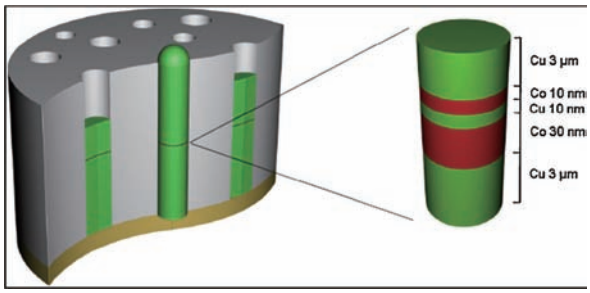


Electroluminescence of n-ZnO/p-GaN heterojunction at different forward bias from 15 V to 35 V

3) 纳米线中的电荷与自旋输运

派遣研究生积极开展国际合作研究，与瑞士洛桑理工大学（EPFL）的 Ansermet 教授组合作，利用电化学沉积方法制备了一种单根纳米线金属超晶格 Co/Cu/Co 自旋阀，通过激光加热该纳米

线自旋阀结构研究了纳米线自旋阀的热输运，获得了很高的热电流，发现热流和电流一样会产生热自旋转移矩，可调控纳米线自旋阀的开关磁场《Physical Review Letters，2010》。



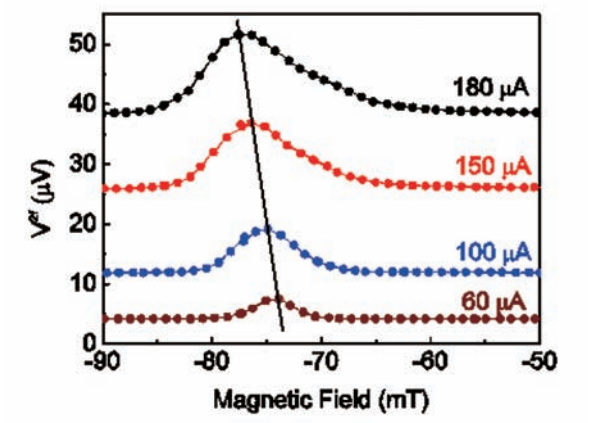
Schematic presentation of a sample of one spin valve inside a Cu nanowire

2. 二维石墨烯：规模制备与量子输运

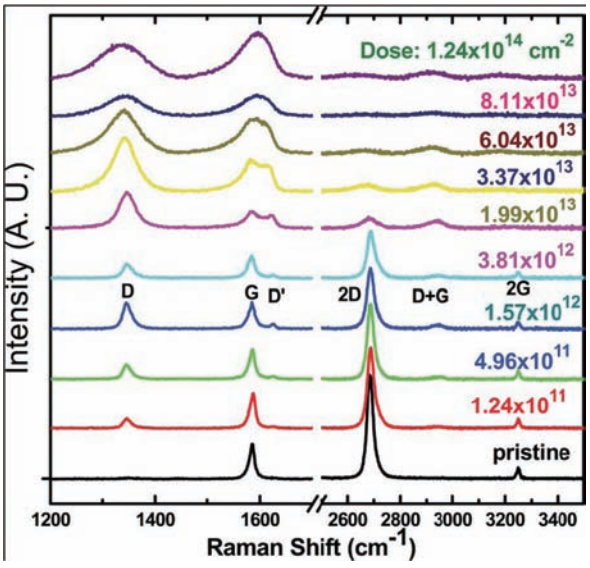
1) 石墨烯性质随离子辐照的演化

a) 利用聚焦离子束 30 kV 的 Ga 离子辐照，人工缺陷被逐渐引入到石墨烯中。2D 峰与 G 峰的拉曼信号强度比随离子辐照剂量的增加而减少。

b) 随缺陷的引入，载流子迁移率和最小电导逐步下降，狄拉克点逐渐向正门电压方向移动。在高度无序的石墨烯样品中，电导随温度的依赖关系满足莫特二维变程跳跃电导模型。



V2f measurements on a nanowire spin valve at different ac current values indicated in A.



The evolution of Raman spectrum of a monolayer graphene with the ion irradiation using different dosages as denoted.

3. 基于固体纳米孔的 DNA 单分子探测

1) 通过在溶液中电泳驱动分子穿过一个纳米尺度的孔可以实现基于纳米孔器件的单分子探测和分析能力。在纳米孔的有限空间里可以通过各种手段对大量分子进行快速的分析，当高聚物分子穿过纳米孔时，高聚物分子的结构信息和探测的信号特征有一一对应关系。

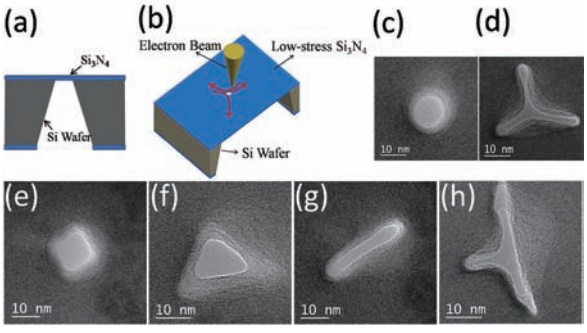
2) 利用该特性可以直接对数千碱基对长度的单链 DNA 分子进行表征，避免了扩增或标记实验准备环节，使得快速低成本 DNA 测序技术成为可能。基于纳米孔器件的 DNA 测序技术是最有可能实现第三代测序技术的实时测序方法之一（在 24 小时内花费 1000 美元以下实现单个人的基因组测序），成为目前研究和应用探索的热点。

3) 利用纳米介孔对 DNA 进行探测，纳米介孔的实现是第一步。目前国际上经常采用的为 SiN 支撑悬空膜。我们在 SiN 纳米介孔的制备过程中发现，利用透射电子显微镜中的会聚电子束，可以实现对纳米介孔的精细可控加工操作，实验精度可达 1 nm, 详见图。通过移动会聚电子束在纳

米介孔的不同位置，在几十秒的时间内可实现 100 nm 厚的 SiN 膜从圆形到几乎任意几何构型的精细纳米加工。

4) 在此项技术基础上，我们实现了宽 2 nm，长 90 nm 的纳米光栅的精细加工，如图 2 所示。这项技术非常简单快捷，并且不同于以往纳米级光栅的加工手段。这里的会聚电子束更像是一把刀子，在移动过程中，实现快速准确的对材料基底的切割，实现所需的光栅长度。所实现的纳米光栅对于研究原子波，量子光学，纳米流体，分子间相互作用方面都有着非常重要的潜在应用。

5) 此项工作最近已发表在 Nanotechnology 22 (2011) 115302 上，并被 nanotechweb.org 网站作为 highlight 进行了报道。



Figure：SiN nanopores reshaped to different geometries by convergent electron beam in TEM.

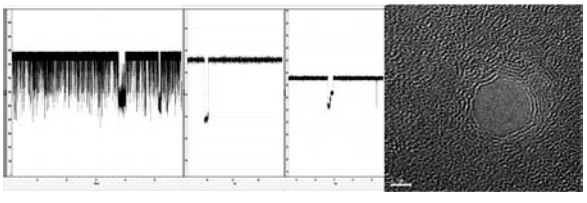


Figure Left: DNA translocation through SiN nanopores. Ion current vs time curve, each current blockage corresponds to a DNA translocation event. Middle: Different current blockage shape corresponds to different DNA configuration when going through nanopores. Right：Graphene nanopores with diameter 4~5 nm.

6) 在 DNA 生物分子探测方面，本实验室已经在国际上研究较为成熟的 SiN 膜上开展了一些初步尝试性实验，得到直径在 10 nm 以下，厚度为几十 nm SiN 纳米介孔在 KCl 离子溶液的离子电导和 DNA 穿孔的电流信号，如图所示。将单独的穿孔事件放大，会发现 DNA 穿孔时的构型不尽相同，得到的阻滞电流和阻滞时间也不尽相同。这充分展示了利用纳米介孔器件对生物分子进行单分子探测的可行性。

7) 石墨烯由于其原子级厚度，独特的力学和电学性能，有望大大提高利用纳米介孔进行 DNA 测序的空间分辨率。在石墨烯纳米介孔器件制作方面，我们开始了一些初步尝试。目前，在制作 Si/SiO2/SiN 支撑膜结构和转移石墨烯方面，积累了一些初步经验。图 4 为利用透射电子显微镜在转移好的石墨烯表面打孔的 TEM 照片。纳米介孔尺寸在 4-5 nm 之间。

4. 表面等离激元共振模式形成机理研究

1) 利用自主发展的模板剥离新方法制备了出表面超级光滑、具有极限特征尺寸的全金属纳米结构及阵列。利用扫描电镜中阴极荧光谱具有的高空间、高能量分辨能力，系统研究了金属纳米腔中阴极荧光谱的面分布，揭示出清晰的表面等离激元的共振模式分布，理论结合实验证明这些模式强度对应于表面等离激元的垂直分量《Physical Review Letters，2010》。通过金属纳米腔与量子点、纳米线材料的耦合，可望实现表面等离激元纳米激光器等光学器件。

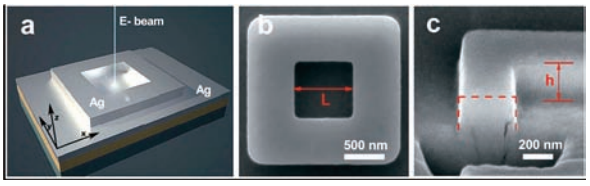


Figure. (a): Schematic of the nanocavity and electron beam irradiation. (b):Top-view SEM image of a cavity with a cavity length of 720 nm. (c) 52。-tilted SEM image of focused ion beam milled, cross-sectional profile of a cavity.

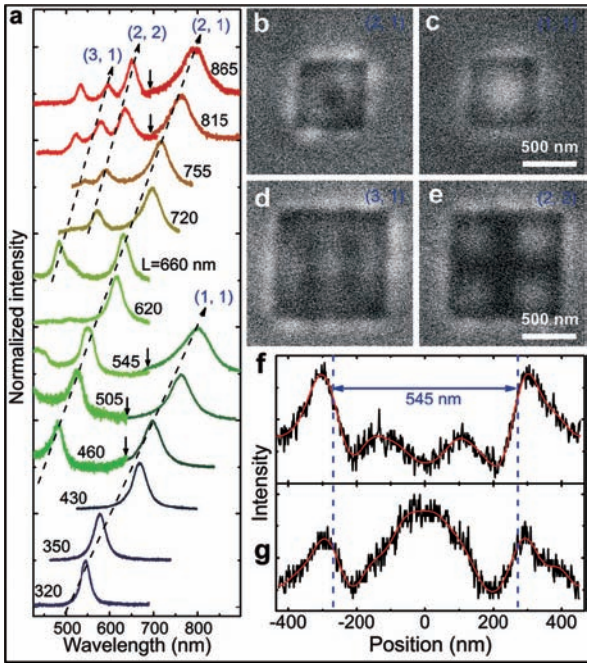


Figure. (a) CL spectra of 12 nanocavities with cavity length increasing from 320 (bottom) to 865 nm (top). The black arrows indicate the breaks of two measurements. (b),(c) Typical monochromatic CL images for plasmonic modes (2; 1) and (1; 1), respectively. (d),(e) Typical monochromatic CL images for plasmonic modes (3; 1) and (2; 2), respectively. (f),(g) Line profiles of modes (2; 1) and (1; 1) along the center of the cavity from the CL images (b) and (c), respectively.

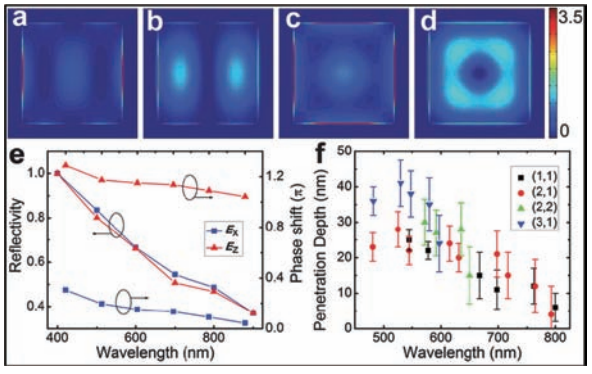


Figure. Calculated mode patterns of the out-of-plane (a),(c) and in-plane components (b),(d) of SPPs at 550 nm wavelength for the 545-nm-long cavity, respectively. (e) Reflectivities and reflection phase shifts of the in-plane component Ex and the out-of-plane component Ez of SPPs. (f) The penetration of SPPs into the cavity reflectors, calculated by comparing the measured resonant wavelength and physical cavity length based on Eq. (1). Error bars originate from the difference between the two orthogonal physical cavity side lengths. Because of its three-dimensional confined characteristics and omnidirectional reflectors, the nanocavity exhibits a small modal volume, small total volume, rich resonant modes, and flexibility in mode control《Physical Review Letters，2010》.

代表性论文抽印本：

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四、Nanostructures and Low Dimensional Physics

- 1-D Nanostructures and Mesoscopic Physics
- 2- D Graphene: Fabrication and Quantum Transport
- DNA Detection based on Nanopore Microscope

1.Dimensional Nanostructures and Mesoscopic Physics

Our group is among the leading positions in synthesis and characterization of nanowires, and more than 170 papers have been published up date and cited >6000 times by colleagues world-wide. Our interests are focused below：

1)Fabrication, Controllable growth and Doping Mechanism

a)Investigation of the unidirectional growth mechanism of the nanowires is crucial to controllable and scaling-up fabrication of nanowires and their applications. Environmental SEM is used to have an in-situ study of the nanowire growth dynamics.

b)Doping is important to modify the properties of the semiconductor nanowires. Magnetic element doping

can confer upon the semiconductor nanowire with spin characters besides their charge properties to fabricate diluted semiconductor nanowires, while p-type doping in semiconductor nanowires is necessary to synthesize p-n junctional superlattice nanowires which is the key to fabricate nanowire nanolasers.

c)P-type doping mechanism was investigated via in situ doping of P2O5 during ZnO nanowires growth, and found that P content is crucial to stable p-type ZnO nanowires. A peculiar p-n junction was obtained in "T" shaped ZnO nanowires and their transport properties were studied:

Figure SEM image of T-shaped junction

Figure The p-type transfer characteristics of the p-n junction

2)Self-powered Nanodevices based on Single Nanowire

Heterojunctions consisting of single n-type ZnO nanowires and p-type GaN film have been fabricated. Photovoltaic (PV) effects in these p-n junctions have been systematically investigated with the illumination of an UV laser or 1-sun source at different temperatures and various incident light power. The PV devices exhibited short-circuit currents of ~103 mA/cm2, open-circuit voltages 2 ~2.7 V and a maximum output power ~80 nW《Advanced Materials，2010.

Figure SEM image of n-ZnO nanowire/p-type GaN film heterojunction

Figure Electroluminescence of n-ZnO/p-GaN heterojunction at different forward bias from 15 V to 35 V

3)Charge and Spin Transport in Nanowires

Via international collaboration with Prof. Ansermet's group in EPFL in Lausanne, Co/Cu/Co metal nanowire spin valve was fabricated using electrochemical deposition. Large heat currents are obtained in Co/Cu/Co spin valves while heated using laser beam. Two effects of the heat current produced in this way: a change in switching field as a function of the applied ac current, and a change as a function of the dc current of the amplitude of the peak in the second harmonic response, which are evidence for a thermal spin transfer torque acting on the magnetization《Physical Review Letters，2010.

Figure Schematic presentation of a sample of one spin valve inside a Cu nanowire

Figure V2f measurements on a nanowire spin valve at different ac current values indicated in A.

2.2- Graphene: Fabrication and Quantum Transport

1) Tune the graphene properties via ion irradiation

2) The artificial disorders in graphene were induced by 30 keV Ga+ ion irradiation using a focused ion beam system.

3) The Raman intensity ratio of the 2D band to G band decreases with increasing the irradiation dosage.

4) When further enhancing the ion irradiation, the Dirac point was continuously shifted toward positive gate voltage, and Defects always decrease the mobility and minimum conductance of the sample

Figure The evolution of Raman spectrum of a monolayer graphene with the ion irradiation using different dosages as denoted

Figure (a) The characteristics of gate-voltage dependent conductivity of the graphene irradiated using different ion dosages. (b) The shifts of Dirac point versus the ion dosage《Journal of Chemical Physics，2010》

3. DNA Detection based on Nanopore Microscope

1) The controllable deformation of nanopores was

realized by moving a convergent electron beam in a high-resolution transmission electron microscope. Nanostructures with the desired geometries were successfully fabricated from the original nanopores in 100 nm-thick and 260 nm-thick Si3N4 membranes. The formation dynamics is a competition process between the knock-on effect of the high-energy electron beam and surface tension driven shrinkage.

2) This approach can be used to finely tune critical dimensions and deform nanopores to particular desired geometries with single-nanometer precision, which offers substantial opportunities in flexibly fabricating nanostructures for various applications such as nanoelectronics and nanofluidics.

3) We used convergent electron beam (CEB) in TEM to reshape the nanopores. Circular nanopores were drilled in a few minutes when a high-energy electron beam was converged to a bright spot on free-standing Si3N4 membranes. By moving the CEB to an area near one corner of the nanopore, deformation with the desired geometry could be realized directly.

4) To achieve the anticipated pattern or structure, the irradiation spot of the electron beam can be moved at will, using it as a "paintbrush", starting from an initial nanopore and stopping when the desired geometry is obtained. Different geometries can be fabricated with the same nanopore sequentially.

5) Nanoslits with a 2 or 3 nm width and 100 nm length were realized by this approach (see image above), which can find applications as supporting membranes and masks. The geometry of nanostructures can be modified under irradiation of the electron beam to a lower surface free energy in the fluid state, with the help of the knock-on effect from the CEB 《Nanotechnology，2011》.

Figure SiN nanopores reshaped to different geometries by convergent electron beam in TEM

Figure Left: DNA translocation through SiN nanopores. Ion current vs time curve, each current blockage corresponds to a DNA translocation event. Middle: Different current blockage shape corresponds to different DNA configuration when going through nanopores. Right：Graphene nanopores with diameter 4~5 nm.

6) DNA translocation event through SiN nanopores with diameter under 10 nm has been studied in ionic KCl solution. Current blockage vs time curve gives different types of translocation event. The different dwell time and current blockage corresponds to different DNA translocation configurations (shown in middle).

7) Graphene is a true 2-D molecule whose layer thickness is smaller than that of a single base in DNA molecule, which makes it possible to improve the spatial resolution of DNA translocation through nanopores. Graphene has been transferred to Si/SiO2/SiN free-standing membrane and nanopores were drilled at graphene surface under electron beam irradiation in TEM. The diameter is around 4-5 nm, as shown in the figure above (right).

4. Resonant Modes Confined in Metal Nanocavity

1) The confined modes of surface plasmon polaritons in boxing ring-shaped nanocavities have been investigated and imaged by using cathodoluminescence spectroscopy. The mode of the out-of-plane field components of surface plasmon polaritons dominates the experimental mode patterns, indicating that the electron beam locally excites the out-of-plane field component of surface plasmon polaritons.

2) A comparison between the experimental results and the theoretical simulations proved that the electron

beam locally excites the out-of-plane field component of SPPs, while the observed plasmonic modes correspond to the modes of the out-of plane field component.

Figure. (a): Schematic of the nanocavity and electron beam irradiation. (b):Top-view SEM image of a cavity with a cavity length of 720 nm. (c) 52。-tilted SEM image of focused ion beam milled, cross-sectional profile of a cavity.

Figure. (a) CL spectra of 12 nanocavities with cavity length increasing from 320 (bottom) to 865 nm (top). The black arrows indicate the breaks of two measurements. (b),(c) Typical monochromatic CL images for plasmonic modes (2; 1) and (1; 1), respectively. (d),(e) Typical monochromatic CL images for plasmonic modes (3; 1) and (2; 2), respectively. (f),(g) Line profiles of modes (2; 1) and (1; 1) along the center of the cavity from the CL images (b) and (c), respectively.

Figure. Calculated mode patterns of the out-of-plane (a),(c) and in-plane components (b),(d) of SPPs at 550 nm wavelength for the 545-nm-long cavity, respectively. (e) Reflectivities and reflection phase shifts of the in-plane component Ex and the out-of-plane component Ez of SPPs. (f) The penetration of SPPs into the cavity reflectors, calculated by comparing the measured resonant wavelength and physical cavity length based on Eq. (1). Error bars originate from the difference between the two orthogonal physical cavity side lengths. Because of its three-dimensional confined characteristics and omnidirectional reflectors, the nanocavity exhibits a small modal volume, small total volume, rich resonant modes, and flexibility in mode control《Physical Review Letters，2010》.

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五、III 族氮化物半导体光电功能材料与器件

2009-2010 年，围绕国家重大需求，在自支撑 GaN 衬底材料、高质量 InN 外延材料、AlGaN 基 3-5 μm 子带间跃迁红外探测材料、GaN 基垂直结构大功率 LED 器件等方面取得了重要进展，在 GaN 基低维结构的本征自旋性质和掺杂磁性等物理研究上也取得了系列进展，建成分子束外延 (MBE) 和氢化物气相外延 (HVPE) 氮化物半导体材料生长系统，极大地提高了团队研究实力和承接国家重大研究项目的能力。

1. 自支撑 GaN 衬底材料研究

GaN 同质外延衬底是目前国际上 III 族氮化物半导体研究的热点和难点。我们自主发展了缓变调制配合周期调制的外延生长方法获得了 300 μm 厚、无裂纹的 GaN 厚膜（图 1a），结合激光剥离技术成功获得了 2 英寸自支撑 GaN 衬底材料（图 1b），GaN 衬底材料的 x 射线衍射 (002), (102) 和 (100) 衍射峰的半高宽分别达到 110, 72 和 83 arcsec。

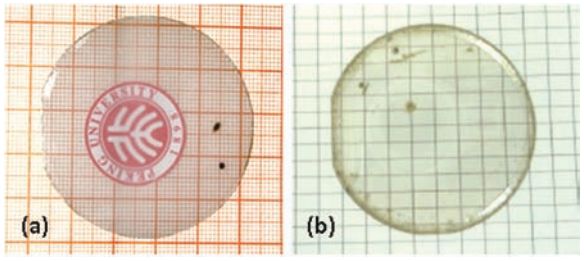


图 1 Figure 1

2. InN 材料的 MBE 生长研究

开展了 InN、高 In 组分 InGaN 及其相关器件结构的 MBE 生长研究。InN 外延薄膜的 n 型载流子室温迁移率为国际报道最高值，实现了 InN 的 p 型掺杂（图 2），成为国际上少数几个实现了 p 型 InN 的课题组之一。

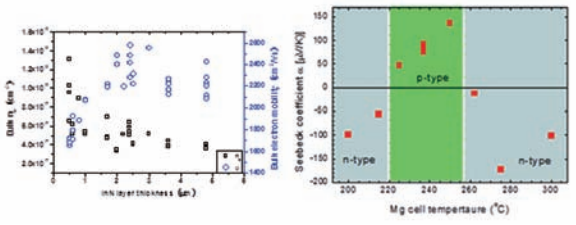


图 2 Figure 2

3. AlGaN 基子带间跃迁 (ISBT) 红外探测材料与器件研究

采用金属有机化学气相沉积 (MOCVD) 方法制备了高 Al 组分、高掺杂的 AlGaN/GaN 多量子阱结构，观察到了波长 3-5 μm 的中红外波段的光吸收（图 3），并结合理论计算确认了红外吸收来自量子阱中载流子从基态到第一激发态的子带跃迁。该工作填补了国内空白，为下一步 AlGaN 基 3-5 μm 大气窗口红外波段光电探测器件的实现和红外、紫外双色探测的单片集成奠定了材料基础。

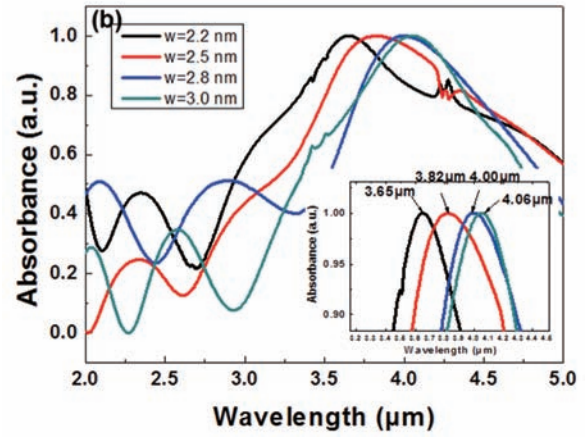


图 3 Figure 3

4. 利用微纳结构提高 GaN 基 LED 出光效率研究

提出了基于介观光学概念的 GaN 基发光器件的新构想，即把具有高效反馈、耦合输出或传输的微纳结构运用于 GaN 基 LED。发展了一套完整的转移微纳结构到 GaN 电注入器件的制备技术，使 GaN 基 LED 的出光效率得到了显著提高（图 4）。

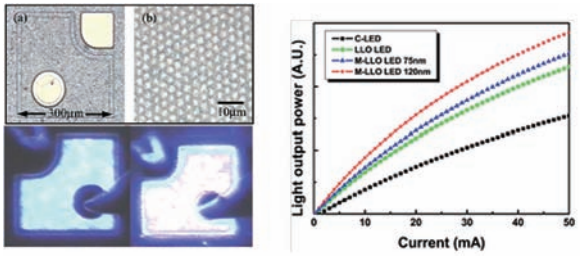


图 4 Figure 4

5. MBE 和 HVPE 氮化物半导体外延生长平台建设

在北京大学“985”学科建设工程和相关合作企业的强力支持下，我们顺利完成了 MBE 和 HVPE 两套大型氮化物半导体外延生长设备的规划、建设和调试工作（图 5），并已制备出高质量的氮化物半导体材料。这两套大型生长设备极大地提高了团队研究实力和承接国家重大项目的能力，在国家“十二五”开局的“863”计划、“973”计划、军口等重大项目申请中发挥了关键作用。

图 5(a) 从美国 SVT 公司引进的 MBE 装置，用于 III 族氮化物半导体及其低维量子结构的外延生长。Figure 5(a) MBE equipment, made by SVT Co. in USA, for the growth of III-nitride films and quantum structures

图 5(b) 从美国 Osemi 公司引进的 HVPE 装置，用于 GaN 厚膜的外延生长，是制备自支撑 GaN 同质衬底材料的关键设备。

Figure 5(b) HVPE equipment, made

by Osemi Co. in USA, for the high-speed epitaxial growth of thick GaN films on sapphire, which is the key equipment for fabricating free-standing GaN substrates.

五、III-nitride semiconductor materials and devices

During 2009-2010, the group of wide bandgap semiconductors focused on the researches of free-standing GaN substrates, high quality InN epitaxial materials, AlGaN/GaN quantum well materials for 3-5 μm infrared light detecting, and GaN-based vertical structure high power LEDs. Meanwhile, the MBE and HVPE systems for the epitaxial growth of III-nitride semiconductors have been set up in our group.

1. The free-standing GaN substrate is highly desired for high performance GaN-based opto-electronic devices. We have successfully developed the new HVPE growth technique and obtained the crack-free 300- m-thick GaN epitaxial films on sapphire substrates. Furthermore, we obtained the 2" free-standing GaN substrates based on the laser lift-off technique. The crystal quality of the free-standing GaN substrates is of high quality，the XRD FWHMs of (002), (102) and (100) refractions are 110, 72 and 83 arcsec, respectively. (See Figure 1)

2. The epitaxy of InN, high In content InGaN and the related devices structures have been investigated by using MBE system. The InN epilayer with the record electron mobility has been achieved. We also succeeded in p-type doping of InN films, and thus became one of few groups who could realize p-type InN films in the world. These achievements are very helpful for realizing high efficiency solar cells based on III-nitrides semiconductors. (See Figure 2)

3. High Al content, high n-type doping AlGaN/GaN multiple quantum wells (MQWs) for intersubband transitions (ISBTs) have been prepared on GaN/sapphire templates by means of MOCVD technique. The intersubband absorptions between 3.6~4.1 μm in wavelength was observed clearly. (See Figure 3)

4. The electrons, photons and exitons limited in mesoscopic optical microsturctures induce a series of particular phenomenon, and give out new basis for the progress of novel optical devices. In our study, the micro- and nano- structures with high feedback and couple-out or transport have benn introduced in GaN-based LEDs. The out efficiency of LEDs with micro- and nano- structures demenstrated high performance. (See Figure 4)

5. The MBE and HVPE systems for the epitaxial growth of III-nitride semiconductors were set up in our group in the past 2 years. (See Figure 5)

03 现代光学研究所 Institute of Modern Optics

北京大学现代光学研究所是在北京大学原物理系光学专业的基础上于 2000 年 5 月组建物理学院时成立的，第一任所长由长江特聘教授龚旗煌教授担任。北大现代光学研究于 1933 年由饶毓泰先生开创，有着悠久的历史和良好的研究基础。目前北京大学光学学科是“211 工程”和“985 工程”重点建设内容，是国家重点学科和“人工微结构和介观物理国家重点实验室”的主要支撑学科之一。以现代光学所为基地，北京大学还与中科院联合成立了“中科院—北京大学超快光科学和激光物理联合中心”。

光学所以队伍建设为核心，通过培养和引进一批优秀青年学者，使现代光学所得以迅速发展。现代光学所现有教授 6 人，北京大学“百人计划”研究员 2 人，副教授 9 人。现有 2 人担任国家 973 和国家重大科学研究计划项目首席科学家，分别是龚旗煌教授任“介观光学与新一代纳 / 微光子学器件”项目首席科学家，李焱教授任“新型分子和受限小量子体系的制备、光电磁功能及其调控的研究”项目首席科学家。现代光学所张家森教授，李焱教授，蒋红兵教授，刘运全研究员共四人入选教育部新世纪优秀人才支持计划。2005 年龚旗煌教授带领的“介观光学与飞秒光物理”团队获得国家自然科学基金委创新研究群体资助并于 2009 获得滚动支持。经过近十年的发展，光学所成员在各自领域均已取得非常显著的成绩并得到国内外同行的肯定，部分光学所成员担任 Optics Letters、Chemical Physics Letters 等国内外重要杂志编委、副主编和 Nonlinear Optical Phenomena and Applications (SPIE)，Asian Conference on Ultrafast Phenomena 等学术会议主席。

早年北京大学光学以光谱学研究著称，随着激光技术和现代光学理论和应用研究的深入，光学已被赋予崭新的内容并在科技进步和人类生活中发挥着重要的作用，北京大学光学紧随国际前沿发展，开拓新的光学研究领域，目前已形成飞秒超快光物理，介观光学与光电子学，原子分子光物理等三个主要研究方向。现代光学所成员已在 Nature Photonics, Phys. Rev. Lett., Adv. Mater. 等刊物上发表重要学术论文。经过十年的发展，北京大学现代光学所已经形成了具有国际竞争力的光学科研和教学重要基地，在国内外的影响力日益增加。

Institute of Modern Optics at Peking University grew out of the former optics major of the physics department in PKU, and was established in May, 2000 when Physics School of physics came into existence. The first head is Professor Qihuang Gong, who is a Cheung Kong scholar professor. Far since 1933, Professor Yutai Rao started his study in modern optics in PKU. Presently, optics in PKU is the key component of the 211 program and the 985 program. PKU’s optics is also a national key discipline, and it is one of the main support disciplines in state key lab for artificial microstructure and mesoscopic physics. Under the cooperation of Peking University and the Chinese Academy of Sciences, the “CAS-PKU ultrafast optics and laser physics center” was established.

There are six professors, two 100 Talents Program professors and nine associate professors in Institute of Modern Optics. Especially, Prof. Qihuang Gong is the chief scientist of the “mesoscopic optics and new nano/micro optical instruments” program and Prof. Yan Li is the chief scientist of the “study of the fabrication, photo-electromagnetic function and the modulation of novel molecules and limited small quantum systems” program. Among our faculties, Prof. Jiasen Zhang, Prof. Yan Li, Prof. Hongbing Jiang and Prof. Yunquan Liu are supported by Program for New Century Excellent Talents in University. In 2005, leading by Prof. Qihuang Gong, the “mesoscopic optics and femtosecond optical physics” group won the support by the Foundation for Innovative Research Groups of the National Natural Science Foundation of China. More over, this support was scrolled in 2009. After about 10 years’ development, our faculties did outstanding research work in their areas and were known by researchers all over the world. Part of our faculties are now editorial members, topical editors of chief journals such as Optics Letters、Chemical Physics Letters, and chairmen for academic conferences such as Nonlinear Optical Phenomena and Applications (SPIE), Asian Conference on Ultrafast Phenomena.

In the early years, the optics in PKU was known for spectroscopy. With the development of laser technology

and in depth research on both the theory and application of modern optics, optics is endowed new contents and plays an important role in the advancement of science and technology and in our daily life. Presently, the optics in PKU mainly contains three research directions: femtosecond ultrafast optical physics, mesoscopic optics and optoelectronics, atomic/molecule optical physics. Our faculties have published important research papers such as in Nature Photonics, Phys. Rev. Lett., Adv. Material. After ten years' development, the Institute of Modern Optics in PKU is now an important base for optical research and teaching, and it wins more and more impact both in and out of China.

一、微纳光子学研究

介观尺度下光与物质相互作用的规律及其在光的产生、传输、调控、探测和传感等方面的应用是当前微纳光子学的前沿和热点。回音壁模式光学微腔和光子晶体是两种典型且重要的微纳光子学研究对象。

回音壁模式光学微腔具有极高的品质因子和较小的模式体积被广泛应用于诸多重要的纳微光子学物理和器件研究。最近，我们系统研究了金属覆盖的微芯圆环体系 (如图 1a), 不但发现了传统光学回音壁模式和内表面等离激元回音壁模式 (如图 1b 和 1c)，还首次理论证明了一种外部回音壁模式 (如图 1d)。借助表面等离激元的特异性质，该外部模式既具有与内部回音壁模式相比拟的高品质因子，又具有高度的光场局域性，几乎 90% 以上的能量可以分布在腔体之外。该外部回音壁模式的生物传感器灵敏度达 500 nm/RIU，较传统回音壁模式生物传感器高一个数量级。中国科技大学邹长铃博士等人参与研究。该研究成果发表在 Physical Review Letters 105, 153902 (2010)）上。部分科技网站和媒体报道了该项成果。例如，科学网以“科学家首次发现优良回音壁模式”报道了该项成果。

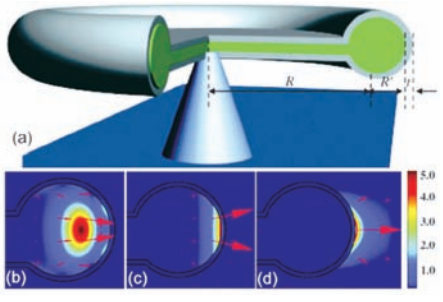


图 1 (a) 金属覆盖的微芯圆环示意图；(b)-(d): 该体系支持的传统回音壁模式、内表面等离激元。

Figure 1 (a) Schematic illustration of a metal-coated silica toroidal microcavity supported by a silicon pillar. (b)-(d) False-color representations of the squared transverse electric fields for conventional optical, interior and exterior plasmonic whispering gallery modes, respectively.

光子晶体全光开关是构造集成光子回路、光互联网络以及光计算等的核心部件之一。超快时间响应和低功耗是全光开关的重要指标。我们提出了一种实现新型非线性光学复合材料的新原理: 利用金属纳米颗粒表面等离激元共振增强非线性光学效应来获得大的非线性光学系数，通过激发态能量转移同时实现材料的超快速时间响应。利用 Nano-Ag:MEH-PPV 复合材料二维光子晶体，通过光子能隙的迁移实现了超快、低阈值全光开关效应。泵浦光强降低到 230kW/cm2，开关时间达到 35ps，开关效率高达 60%；如图 2 所示。相关工作发表在 Appl. Phys. Lett. 94, 2009: 031103 上。

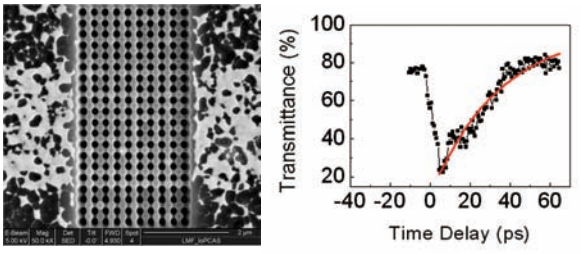


图 2：（左栏）纳米复合材料二维光子晶体的扫描电镜照片；（右栏）Nano-Ag:MEH-PPV 纳米

复合材料光子晶体全光开关效应。

Figure 2: (Left) SEM image of two-dimensional nanocomposite photonic crystal; (Right) Nano-Ag:MEH-PPV composite photonic crystal all-optical switching effect.

相关工作发表以后获得了同行的好评。例如，美国科技新闻网 PhysOrg.com 以“纳米复合材料支持光子开关（Nanocomposite material provides photonic switching）”为题，评价这项工作“未来技术的集成光子器件的研究，现在正在中国的北京大学开展，… …。在理解了这些纳米复合材料的工作原理之后，制备出能够为更小的、更有效的器件的基础材料是可能的。”

系列研究工作得到了国家自然科学基金委的“创新研究群体”项目和国家 973 项目等的资助。

一、Progress in Micro/nano-photonics

Nowadays, the rules of interactions of light and matter in the micro/nanoscale, and their applications in the fields of light generation, propagation, modulation, detection, and sensor are the research frontier and hot topic of micro/nano-photonics. The whispering gallery microresonator and photonic crystal are two typical and important research objects of micro/nanoscale photonics.

Optical whispering-gallery microresonators provide a powerful platform for various photonic applications ranging from low-threshold lasing to highly sensitive bio/chemical sensing. They are also used for fundamental studies including cavity opto-mechanics, cavity quantum electrodynamics and quantum information science in the past few years. Despite the great success of the whispering gallery mode, the characteristic that the mode energy is confined mainly to the cavity body limits its application in certain important fields. Recently, we have studied a metal-coated microtoroid system in detail (Fig. 1(a)). It is found that this hybrid system supports not only conventional optical (Fig. 1(b)) and interior plasmonic whispering gallery modes (Fig. 1(c)), but also a novel kind of high-Q exterior plasmonic whispering gallery modes (Fig. 1(d)). More than 90% energies of the new mode are concentrated in the exterior surface, showing a high field locality. One of applications of this type of exterior modes is highly sensitive biosensing. In this work, we have demonstrated a biosensing with the sensitivity as high as 500 nm/RIU. Moreover, we have found that the exterior whispering gallery modes can be efficiently excited by a tapered fiber. The coupling between interior and exterior modes is also investigated. Interestingly, this coupling not only produces a strong anti-crossing, but also forms a long-lived anti-symmetric mode. These exterior modes are compatible with micro-fluidics and thus hold great potential for various applications, e.g., highly sensitive biosensors.

Photonic crystal all-optical switching is one of the essential units constructing the integrated photonic circuits, optical interconnection networks, and optical computing. Ultrafast response time and low power are key characteristics of photonic crystal all-optical switching. We proposed a new mechanism for realizing nonlinear optical composite materials: adopting surface plasmon resonance (SPR) resonantly enhancing nonlinearity to obtain large nonlinear optical coefficients, and using the excited states energy transfer process to ensure ultrafast response time. Ultrafast and low threshold power all-optical switching was realized based on the photonic bandgap

shift in two-dimensional nano-Ag:MEH-PPV composite photonic crystal. The pump intensity was reduced to 230 kW/cm2. The switching time achieved 35 ps. The switching efficiency was as high as 60%, as shown in Fig. 2.

This work gained the excellent comments of the international researchers in this field. For example, the scientific news web of America PhysOrg.com reported this work by the title "Nanocomposite material provides photonic switching": "The development of integrated photonic devices in tomorrow's technology is taking place today at Peking University in Beijing, China, where a group of scientists has manufactured and tested a nanocomposite material that could be used in integrated photonic devices".

This series of work was supported by the Creative Research Group project of the National Natural Science Foundation of China, and the National Basic Research Program of China.

二、强激光场原子分子物理

- 多光子电离和隧道电离
- 强激光场双（多）电离
- 强激光场中分子动力学
- 强激光场的相干控制

离子电子动量成像谱仪具有符合测量功能，是研究强场原子分子相互作用物理本质的重要工具。北京大学现代光学所经过多年的努力，在人工微结构和介观物理国家重点实验室资助下，成功地建设国内首台用于强激光场原子分子物理研究的离子电子动量成像谱仪，谱仪的离子和电子的动量分辨率达到国际同类装置的先进水平。该装置与先期建设的周期量级相位锁定飞秒激光器联合使用，极大地提升北大在原子分子光物理方向的实验研究能力。通过测量周期量级飞秒激光脉冲作用下，氮气和氧气等分子非序列双电离产生的离子碎片的角分布，获得了分子电离与分子取向角的关系，再现了分子最高占有轨道。

2010 年，与北京应用物理与计算数学研究所和德国马克斯一普朗克核物理研究所等研究组密切合作，采用高功率飞秒激光振荡器和离子电子动量谱仪装置，实验上首次研究了激光强度处于原子双电离阈值附近的电子关联问题，发现原子结构对非序列双电离的电子 。

图 1：周其凤校长视察实验室

Figure 1: PKU President Qifeng Zhou views Labs.

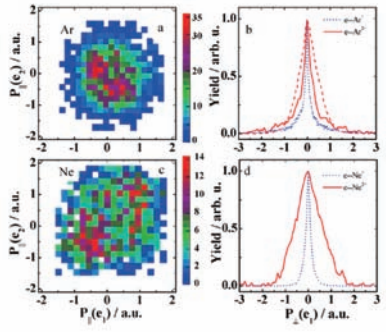


图 2：（左栏）激光偏振面氩原子和氖原子的电子关联动量谱；（右栏）双电离电子的横向动量。

Figure 2 (left) Electron momentum correlation spectra of Ar and Ne atoms in the laser polarization plane. (right) The electron transverse momentum distributions of double ionization.

关联行为具有重要影响：氖原子的双电离电子出射是在激光偏振面内肩并肩出射 (所谓关联)，氩原子的双电离产生电子是在激光偏振面内背靠背出射 (所谓反关联)。理论上，考虑到电子在激光场中的多次碰撞，以及电子再碰撞激发后隧道电离过程，很好地解释了氩原子的反关联现象。这是科学家首次研究激光强度处于双电离阈值附近的非序列电离问题，将能帮助人们从本质上认识强激光场中原子分子电子的关联行为和强场量子多体行为。该研究成果发表在 Physical Review Letters (104, 173002 (2010)) 上。

二、Atoms and molecules in strong laser fields

- Multiphoton ionization and tunneling ionization
- Strong-field double (and multiple) ionization
- Molecular dynamics in strong laser fields
- Coherent control with strong laser fields

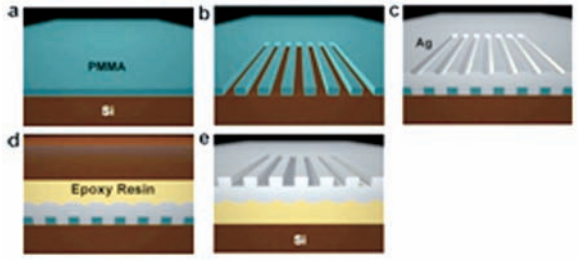
Coltrims(Cold-target recoil ion momentum spectroscopy) is a very powerful research tool for the interaction of atoms and molecules with strong laser fields. After several years' effort, we have successfully built a Coltrims setup at Peking University under the support of the State Key Laboratory for Mesoscopic Physics, as shown in Fig. 1. The momentum resolutions of the setup have reached the best Coltrims setup around the world. Combined the Coltrims with few-cycle phase-stabilized femtosecond amplified system, the research capacity in the atomic, molecular and optical physics (AMO) has been improved significantly. We have obtained the ionization possibility with the molecular orientation and molecular high-occupied molecular orbitals through the measurements of ionic fragments after nonsequential double ionization of molecules, i.e., N2 and O2, using few-cycle laser pulses.

In 2010, we collaborated with the Institute of Applied Physics and Computational Mathematics and Max-Planck Institute for nuclear physics, using a high power femtosecond oscillator and a Ctrims, we have experimentally investigated the electron correlation dynamics of non-sequential double ionization of atoms at the threshold. We have found that the atomic structures play an important role for the electron correlation. For example, the electron emissional direction of double ionization for Ne is the side-by-side in the laser polarization plane, but it is back-to-back for Ar, as shown in Fig. 2. Theoretically, considering electron multiple rescattering and electron-recollosion induced tunneling effects, we have successfully explained the electron anticorrelation behavior. This is the first work on the non-sequential double ionization at the threshold and this work can help understand the electron correlation of atoms and molecules and few-body danamics in strong laser fields. This work is published on Physical Review Letters (104, 173002 (2010)).

三、纳米光子学

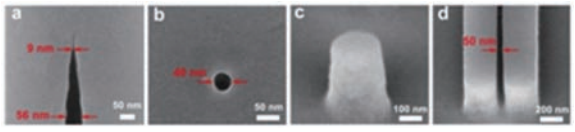
- 纳米光学
- 表面等离激元光学
- 纳米系统中的光电子学
- 纳米结构中的超快现象

我们提出了表面超平滑纳米金属结构的制备方法，获得了 0.55 ~ 0.88 nm 的表面粗糙度。利用这种方法可以方便地制备出陡直高深宽比、特征尺度 9nm 的金属纳米结构。



制备过程：(a) 在硅片上旋涂 PMMA；(b) 利用电子束曝光在 PMMA 上制备图案；(c) 在 PMMA 上镀金属；(d) 将金属层粘到另一硅片上；(e) 将原来的硅片剥离并用丙酮清洗残余的 PMMA。

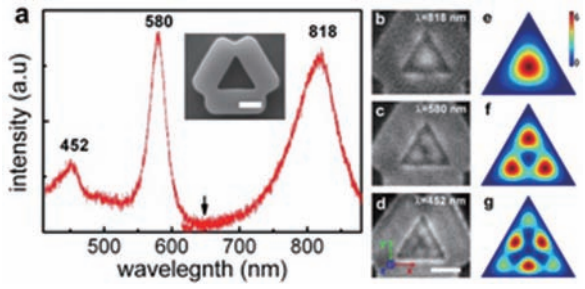
Fabrication process: (a) A silicon wafer is spin-coated by PMMA. (b) PMMA is patterned by standard EBL. (c) A metal layer is deposited on patterned PMMA. (d) The metal layer is glued to another substrate. (e) The sample is turned upside down after the first substrate is stripped off and residual PMMA is rinsed with acetone.



制备的典型结构的扫描电镜照片。高度均为 300nm。

Typical SEM images of fabricated nanostructures. The height of the patterns is 300 nm.

利用阴极荧光显微镜研究了三角形表面等离激元纳米腔中的模式，实验结果和数值计算比较表明阴极荧光显微镜获得的是表面等离激元垂直于表面分量的强度分布。



(a) 935nm 边长腔的阴极荧光谱；(b-d) 单色阴极荧光图案；(e-g) 电场垂直分量的数值模拟模式。标尺为 500 nm。

(a) CL spectrum of a cavity with a 935 nm side length. (b-d) Monochromatic CL images. (e-g) Simulated mode patterns of the out-of-plane electric field components of the surface plasmon polaritons. Scale bars are 500 nm.

代表性论文：

[1] Plasmonic Vertical Resonant Nanocavities, X. L. Zhu, J. S. Zhang, J. Xu, and D. P. Yu, Nano Lett., in press.

[2] Ultrafine and Smooth Full Metal Nanostructures for Plasmonics; X. L. Zhu, Y. Zhang, J. S. Zhang, J. Xu, Y. Ma, Z. Y. Li and D. P. Yu, Adv. Mater. 22, 4345-4349 (2010).

[3] Confined Three-Dimensional Plasmon Modes inside a Ring-Shaped Nanocavity on a Silver Film Imaged by Cathodoluminescence Microscopy, X. L. Zhu, Y. Ma, J. S. Zhang, J. Xu, X. F. Wu, Y. Zhang, X. B. Han, Q. Fu, Z. M. Liao, L. Chen, and D. P. Yu, Phys. Rev. Lett. 105, 127402 (2010).

[4] Plasmonic Demultiplexer and Guiding, C. L. Zhao and J. S. Zhang, ACS Nano 4, 6433-6438 (2010).

三、Nanophotonics

- Nanooptics
- Plasmonics
- Optoelectronics of nanoscale systems
- Ultrafast phenomena in nanostructures

We proposed PMMA template stripping method to fabricate high quality metal nanostructures with the RMS roughness of 0.55 ~ 0.88 nm, a high aspect ratio, and a feature size of 9 nm.

Plasmonic modes in equilateral-triangle nanocavities were studied using cathodoluminescence (CL) spectroscopy. The comparison between the experimental result and the simulation shows that the monochromatic CL images were dominated by the intensity patterns of the out-of-plane electric field components of the surface plasmon polaritons.

Selected publications:

[1] Plasmonic Vertical Resonant Nanocavities, X. L. Zhu, J. S. Zhang, J. Xu, and D. P. Yu, Nano Lett., in press.

[2] Ultrafine and Smooth Full Metal Nanostructures for Plasmonics; X. L. Zhu, Y. Zhang, J. S. Zhang, J. Xu, Y. Ma, Z. Y. Li and D. P. Yu, Adv. Mater. 22, 4345-4349 (2010).

[3] Confined Three-Dimensional Plasmon Modes inside a Ring-Shaped Nanocavity on a Silver Film Imaged by Cathodoluminescence Microscopy, X. L. Zhu, Y. Ma, J. S. Zhang, J. Xu, X. F. Wu, Y. Zhang, X. B. Han, Q. Fu, Z. M. Liao, L. Chen, and D. P. Yu, Phys. Rev. Lett. 105, 127402 (2010).

[4] Plasmonic Demultiplexer and Guiding, C. L. Zhao and J. S. Zhang, ACS Nano 4, 6433-6438 (2010).

四、有机电致磷光材料与器件的研究

自从 20 年前开发出来的薄膜有机电致发光二极管（Organic Light Emitting Diodes, OLED）以来，在这方面已经取得了惊人的进步。但是通常采用的荧光材料（单线态发光）的内量子效率理论上只有 25%，如果采用磷光材料（三线态发光），理论上可以得到 100% 的内量子效率发光。但是因为蓝色属于宽带发光，其导电能力将大大降低，故蓝色电致磷光很难实现高效发光。

对于蓝色磷光器件，按照通常的理论需要开发具有高电子传输性能及高三线态能级的宽带材料。但是高三线态能级的宽带材料与高电子传输性能通常是两难命题。我们与日本城户淳二教授合作通过设计一种高三线态能级的宽带材料（能隙达到 4.0eV, 宽于一般的半导体材料），其电子传输性能低于现有的材料，但是由于其能够很好地阻挡空穴传输，故使得器件中的电荷传输能够很好达到平衡，结果出人意料地达到了将近 100% 的内量子效率，由此给高效蓝色磷光器件的设计提供了新的思路 1，随后被 NPG Asia Materials 的“Research Highlights” 以“Organic LEDs: Blue Perfection（有机发光：完美的蓝色）”为题进行了报道 2，并被评为 2009 年中国光学重要成果。我们应邀在 Advanced Materials 上就有机磷光发光材料及其器件发表了综述性文章 3，论文系统总结了近期红、绿、蓝及白色有机磷光材料及器件方面的最新研究成果，并重点阐述了蓝色磷光材料及其器件的最新进展。

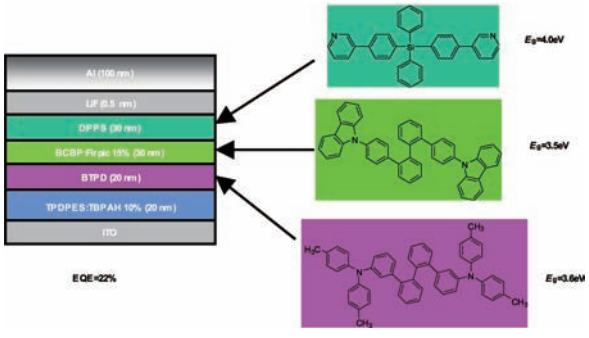


图 1. 高效蓝色磷光器件的结构

Figure1. The device structure

参考文献：

[1] Lixin Xiao et al., Adv. Mater. 2009, 21, 1271–1274

[2] Research Highlights in NPG Asia Materials, 28, Apr., 2009 http://www.natureasia.com/asia-materials/highlight.php?id=420

[3] Lixin Xiao et al., Adv. Mater. 2010, xx, 1–27 doi/10.1002/adma.201003128/pdf

四、Recent Progresses on Materials for PhOLEDs

Although OLED has been commercialized as flat panel display since 1997, only singlet excitons were emitted. To full use of singlet and triplet excitons, electrophosphorescent device (PhOLED) has attracted increasing attentions. However, compared with red and green PhOLEDs, highly efficient blue PhOLEDs are hard to be obtained due to the large energy gaps of blue phosphorescent dyes which lead to insufficient carrier injection and exciton confinement.

Generally, electron transporting (ET) capability is the factor of limiting the quantum efficiency of OLEDs. While, the author[1] synthesized an ET silane DPPS with wide Eg and weak ET ability. Out of expectation, nearly 100% IQE was obtained with it as the combined ET and HB layer, which suggesting an alternative way of designing ET materials for blue PhOLEDs. The device structure is shown in Figure 1. The results have been highlighted by NPG Asia Materials with a title of “Organic LEDs: Blue Perfection”. Based on these results, we are invited to publish a review paper on the materials for PhOLEDs, in which recent progresses in red, green, blue, and white phosphorescent materials for OLEDs are reviewed.

References：

[1] Lixin Xiao et al., Adv. Mater. 2009, 21, 1271–1274

[2] Research Highlights in NPG Asia Materials, 28, Apr., 2009 http://www.natureasia.com/asia-materials/highlight.php?id=420

[3] Lixin Xiao et al., Adv. Mater. 2010, xx, 1–27 doi/10.1002/adma.201003128/pdf

04 重离子物理研究所 Institutes of Heavy Ion Physics

现有教职工 43 人，其中教授 9 人，副教授 16 人（含高级工程师），讲师 6 人，工程师 12 人。研究领域包括加速器物理与技术、基于加速器的核技术及应用、核能相关技术和医学物理等。拥有 4.5MV 单级静电加速器、2×6 串列静电加速器、14C 测量加速器质谱计、2k 液氦循环系统和加速器中子照相系统等大型仪器设备。

There are 43 faculty members in the institute, consisting of 9 professors, 16 associate professors, 6 assistant professors and 12 engineers. The research fields include Accelerator Physics and Technology, Accelerator Physics and Technology，Nuclear Technology and applications Based on Accelerators, nuclear energy and Medical Physics. The big research facilities in the institute are 4.5MV Van de Graaff accelerator, 2×6MV tandem accelerator, 14C compact AMS, 2K cryogenic system and accelerator-based neutron radiography system.

一、稳相加速产生自组织 GeV 纳库质子束团

常规 TNSA 加速方法中离子的有效长度很短，实验中离子能量增益仅仅在几十 MeV 左右。研究中发现超短超强激光与超薄固体靶相互作用时存在一种稳相加速机制，可以产生高品质的高能单色离子。由于激光光强横向分布一般为高斯分布，加速过程中固体靶将逐渐弯曲，往往导致薄膜靶被中心击穿。之后激光对离子的加速作用提前结束，从而限制了离子的能量增益，也影响了束流的品质。研究发现利用等离子体横向不稳定性可以实现对离子的中心聚束，借此可以产生自聚焦的纳库级 GeV 质子束，从理论上解决了中心击穿的问题。这一进展对离子癌症治疗、激光核聚变快点火和新概念加速器等研究将产生重要影响。

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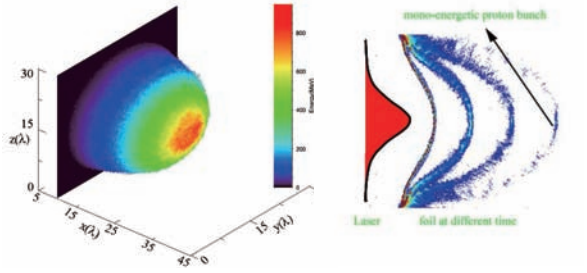
[1] Self-organizing GeV nano-Coulomb collimated proton beam from laser foil interaction at 7 × 10^{21} W/cm^2,X.Q. Yan, H.C. Wu, Z.M. Sheng, J.E. Chen, J. Meyer-ter-Vehn, Phys. Rev. Lett. 103, 135001 (2009)



一、Self-organizing nano-coulomb GeV proton beam in Phase-Stable regime

Target normal sheath acceleration (TNSA) is the predominant mechanism leading to the emission of multi-MeV, high-quality ion beams. Radiation Pressure Acceleration is more efficient, especially in Phase Stable regime. It is found that self-organizing, quasi-stable regime of laser proton acceleration, producing 1 GeV nano-Coulomb proton bunches from laser foil interaction at an intensity of 7 × 1021 W/cm2. While foil plasma driven in the wings of the driving pulse is dispersed, a stable central clump with 1 - 2 diameter is forming on the axis. The stabilisation is related to laser light having passed the transparent parts of the foil in the wing region and enfolding the central clump that is still opaque. These ion beams are attracting much attention in many potential applications covering radiograph transient processes, ion beam tumor therapy, and fast ignition of fusion cores.

References：

[1] Self-organizing GeV nano-Coulomb collimated proton beam from laser foil interaction at 7 × 10^{21} W/cm^2,X.Q. Yan, H.C. Wu, Z.M. Sheng, J.E. Chen, J. Meyer-ter-Vehn, Phys. Rev. Lett. 103, 135001 (2009)

二、高梯度射频超导加速腔研发

射频超导加速器广泛应用于 X 射线自由电子激光、散裂中子源等大科学装置，未来的国际直线对撞机（ILC）也将采用射频超导技术。高梯度射频超导加速腔是高能超导加速器最为关键的部件，受到国际加速器界的普遍重视。物理学院重离子物理研究所射频超导研究组通过对超导腔设计、冲压成形，高真空电子束焊接、表面处理、微波测量与加速电场平整度调节等进行深入研究，在高梯度超导腔研制方面取得重要进展，所研制的国产超导腔性能优良并得到美国 JLAB 实验室

验证。自主设计并研制成功 DC-SC 光阴极注入器的核心部件——具有低 β 半腔结构的 3.5-cell 超导加速腔，加速梯度达到 23.4MV/m，超过了国际上同类型超导腔的最高水平。研制的 TESLA 型 9-cell 射频超导加速腔 (PKU-3) 的加速梯度为 28.6MeV/m, 达到了国际直线对撞机 28MV/m 的可使用标准。2010 年 9 月 9 日的 ILC NewsLine 对此研究成果行进了报道（http://www.linearcollider.org/newsline/），ILC 全球设计（GDE）项目经理、日本 KEK 国家实验室的 Akira Yamamoto 博士认为“这只超导腔的成就不仅是中国射频超导技术发展，也是全球 ILC 合作的一个重要里程碑，这是一个令人兴奋的消息”。

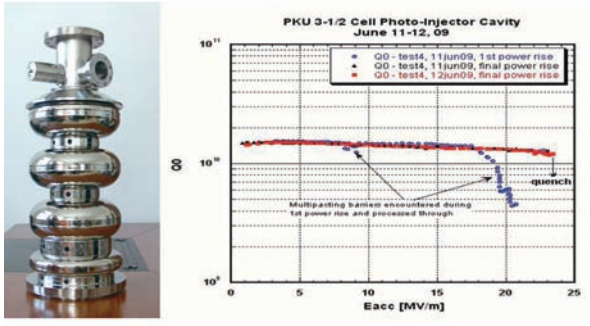


Fig. 1 3.5 -cell cavity and acceleration gradient measured at Jlab

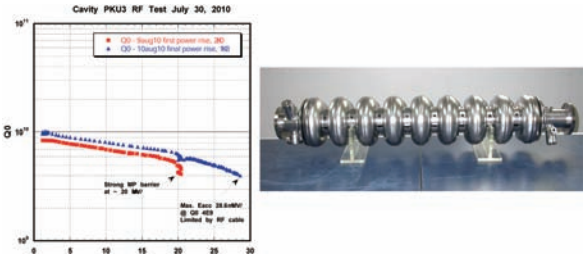
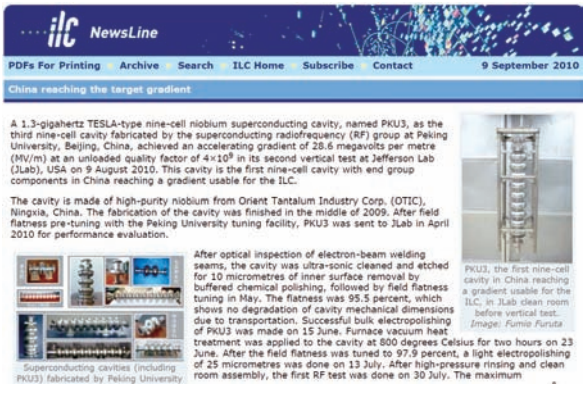


Fig. 2 9-cell cavity and acceleration gradient measured at JLab

二、R&D of superconducting cavity with high acceleration gradient

Superconducting accelerators are widely used for large scientific facilities such as X ray Free Electron Laser and Spallation Neutron Source. International Linear Collider will also choose superconducting acceleration technology. Superconducting cavity with high acceleration gradient is the most important component of high energy accelerators and many laboratories worldwide are developing the technique of cavity fabrication. Recently, SRF group of the Institute of Heavy Ion Physics, School of Physics have made important progress on R&D of superconducting cavity based on the study of Nb material with high RRR value, physical design of cavity, deep drawing, electron beam welding, surface treatment and RF field flatness tuning. We design and fabricate a 3.5cell cavity for DC-SC superconducting photo-cathode injector. The acceleration gradient of this cavity reached 23.4MV/m, which is the highest record of the cavities with low half cell. A TESLA-type nine-cell niobium superconducting cavity made by our group achieved an accelerating gradient of 28.6 MV/m, meet the usable requirement of ILC. In the ILC NewsLine of Sept. 9, 2010, Dr. Akira Yamamoto, said on behalf of the ILC Global Design Effort Project Managers , “The achievement of PKU3 is very exciting and it is a very important milestone to both of Chinese superconducting technology development and the global cooperation for ILC activities. We are very much impressed to hear of this exciting news and would send our sincere congratulation for the PKU team and the global cooperation”.

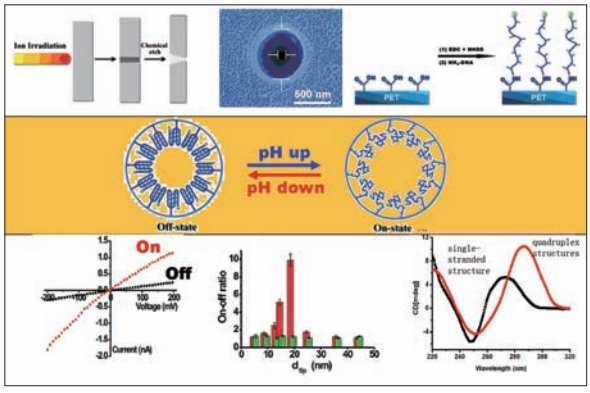
Figure 1, 2



三、载能离子技术辅助制备功能性纳米孔及仿生离子通道

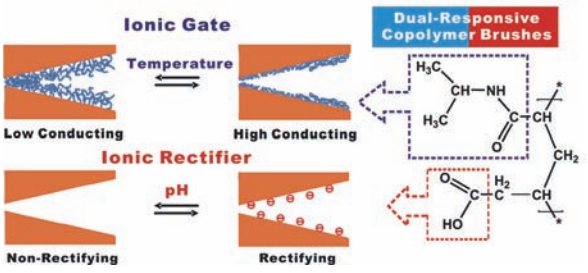
载能离子技术由于其可以精准、可控地在物质中沉积能量，造成结构损伤或分子链断裂，近年来在生命科学，化学，材料科学等领域的应用中显示出其独特的优势。王宇钢教授课题组结合核科学与技术，化学，生物学，以及材料科学等多学科的研究对象和研究手段，构筑了基于单纳米核孔的、离子输运性质可调控的仿生智能离子通道。

1. 利用纳米核孔内表面富含的羧酸根集团，将响应性 DNA 分子马达接枝在单纳米核孔内，构筑了环境 pH 调制的、通过 DNA 构象变化实现对离子电导实施开关的人工离子通道体系。相关工作 2008 年及 2009 年在 JACS 上发表后，相继被《Nature》及《NPG Asia Materials》评为研究亮点，同年入选中国科学院发布的《2009 科学发展报告》。

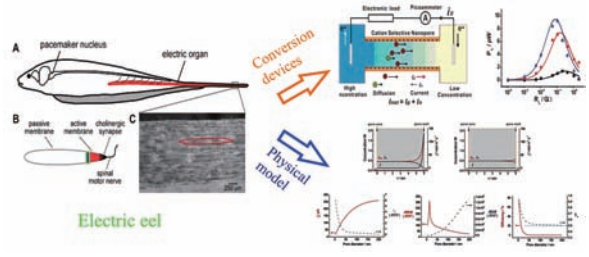


2. 通过将纳米核孔内表面金属化，将具有温度响应特性的聚合物分子刷与单纳米核孔相结合，制备出具有温度响应整流效应的纳流二极管体系。这种具有温度可调整流功能的纳流器件可以用来构建具有原位调控流体通讯功能的复合型纳米器件。相关工作被 2010 年第四期的《ChemPhysChem》杂志选为封面文章发表。

3. 我们在一个圆锥形的纳米孔道上接枝具有温度和 pH 双重响应特性的共聚物分子刷，将离子门控功能与离子整流功能集成到同一个纳米核孔内表面上，制成具有温度和 pH 双重响应特性的单纳米孔道器件。相关研究工作发表在 2010 年的《Advanced Functional Materials》上。



4. 基于单纳米核孔内表面电荷密度高及离子选择性强的独特性质，我们制备了基于离子浓度驱动的纳米孔道能源转换器件。这种孔道器件所转化的化学能来自于简单无机盐溶液，适合用于构建自驱动的复合型纳米机器。相关研究工作发表在 2010 年的《Advanced Functional Materials》上。



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One Solid-State Nanopore via Modification with Dual-Responsive Copolymer Brushes，Wei Guo , Hongwei Xia , Liuxuan Cao , Fan Xia , Shutao Wang , Guangzhao Zhang ,Yanlin Song , Yugang Wang* ,Lei Jiang ,* and Daoben Zhu, Adv. Funct. Mater. 2010, 20, 3561–3567

[4] A Biomimetic Potassium Responsive Nanochannel: G-Quadruplex DNA Conformational Switching in a Synthetic Nanopore, XuHou, Wei Guo, Fan Xia, Fu-QiangNie, Hua Dong, Ye Tian, Liping Wen, Lin Wang, Liuxuan Cao, Yang Yang, JianmingXue, Yanlin Song, Yugang Wang*,Dongsheng Liu*, and Lei Jiang*, JACS, 131, 7800-7805, 2009 (Highlighted by NatureChina)

[5] Gating of single synthetic nanopores by proton-driven DNA molecular motors, Xia, Fan; Guo, Wei; Mao, Youdong; Xue, Jianming; Hou, Xu; Liu, Huajie; Liu, Dongsheng; Song, Yanlin; Ji, Hang; Ouyang, Qi; Wang, Yugang*; Jiang, Lei, JACS, 130, 8345-8350, 2008 (Highlighted by Nature and NatureAsia Materials.

三、**Functional and bio-inspired nanochannels fabricated by ion-track technology**

When solid-state materials were irradiated by a swift heavy ion, energy deposition causes damage on the atomic structure of the substrate. Because it is precisely and controllable depositing energy onto the substrate materials, the ion-track technology shows promising potential in the field of nuclear, life, chemical and material sciences. Professor Yugang Wang and his colleagues have accomplished a series of bio-inspired synthetic nanochannel based on the ion-track-etched single nanopores.

1. pH-responsive DNA molecules can be immobilized into the nanopore through chemical reactions with the carboxyl groups on the inner pore wall. High- (on-state) and low- (off-state) conductance states were found within this nanopore-DNA system corresponding to the single-stranded and i-motif structures of the attached DNA motors.

2. By electrolessly plating gold onto the nanopore wall and grafting temperature-responsive polymer brushes, an abiotic smart single-nanopore device that rectifies ionic current in response to the temperature was constructed. This work paves a new way for controlling the preferential direction of the ion transport in nanofluidics by modulating the temperature.

3. A dual-functional nanofluidic device that integrates the ionic gate and the ionic rectifier within one solid-state nanopore was fabricated. The chemical modification strategy could be applied to incorporate other stimuli-responsive materials for designing smart multi-functional nanofluidic systems resembling the “live” creatures in nature.

4. Inspired by biological systems, a fully abiotic single-pore nanofluidic energy-harvesting system that converts Gibbs free energy in the form of a salinity gradient into electricity is demonstrated. Therefore, it could be seen as the artificial and simplified version of the natural electrocyte, which harvest electric power from physiological environment to power the implantable biomedical devices in the same way as the living system.

Representative publications:

[1] Current Rectification in Temperature-Responsive Single Nanopores, Wei Guo, HongweiXia,Fan Xia, XuHou, Liuxuan Cao, Lin Wang, JianmingXue,

GuangzhaoZhang,Yanlin Song, Daoben Zhu, Yugang Wang*,and Lei Jiang*, ChemPhysChem(cover story), 2010, 11, 859 – 864

[2] Energy Harvesting with Single-Ion-Selective Nanopores: A Concentration-Gradient-Driven Nanofluidic Power Source，Wei Guo, Liuxuan Cao, Junchao Xia, Fu-QiangNie, Wen Ma, JianmingXue, Yanlin Song, Daoben Zhu, Yugang Wang*, and Lei Jiang*, Adv. Funct. Mater. 2010, 20, 1339–1344

[3] Integrating Ionic Gate and Rectifier Within One Solid-State Nanopore via Modification with Dual-Responsive Copolymer Brushes，Wei Guo , Hongwei Xia , Liuxuan Cao , Fan Xia , Shutao Wang , Guangzhao Zhang ,Yanlin Song , Yugang Wang* ,Lei Jiang ,* and Daoben Zhu, Adv. Funct. Mater. 2010, 20, 3561–3567

[4] A Biomimetic Potassium Responsive Nanochannel: G-Quadruplex DNA Conformational Switching in a Synthetic Nanopore, XuHou, Wei Guo, Fan Xia, Fu-QiangNie, Hua Dong, Ye Tian, Liping Wen, Lin Wang, Liuxuan Cao, Yang Yang, JianmingXue, Yanlin Song, Yugang Wang*,Dongsheng Liu*, and Lei Jiang*, JACS, 131, 7800-7805, 2009 (Highlighted by NatureChina)

[5] Gating of single synthetic nanopores by proton-driven DNA molecular motors, Xia, Fan; Guo, Wei; Mao, Youdong; Xue, Jianming; Hou, Xu; Liu, Huajie; Liu, Dongsheng; Song, Yanlin; Ji, Hang; Ouyang, Qi; Wang, Yugang*; Jiang, Lei, JACS, 130, 8345-8350, 2008 (Highlighted by Nature and NatureAsia Materials.

05 等离子体物理与聚变研究所
Institute of Plasma Physics & Fusion Studies

等离子体物理与聚变研究所现有教职工 6 人，其中教授 3 人（包括一名兼职院士和一名长江学者讲座教授）、百人研究员 1 人、副教授 1 人、办公人员 1 人。研究领域包括聚变等离子体物理、空间与天体等离子体物理、高能量密度物理、大规模数值模拟等，涉及等离子体物理学的各主要领域。

The faculty of plasma physics has 5 members of 3 full professors, a Bairen research professor and an associate professor, as well as an office assistant. The research areas of the institute covers major fields in plasma physics and fusion studies, from fusion plasma physics, astrophysical and space plasma physics, and high energy density physics, to large scale simulations.

等离子体物理

- 托卡马克物理与磁约束聚变研究
- 空间与天体等离子体物理
- 等离子体大规模数值模拟

1. 托卡马克等离子体中的磁流体模式

中国环流器二号托卡马克等离子体放电过程中看到了典型的锯齿模诱发模数为 2/1 的新经典撕裂模；

基于我们自己发展的驱动磁重联理论模型，将模数为 1/1 的锯齿模因为环耦合效应产生的 2/1 分量作为边界条件，并利用环流器二号等离子体

参数，计算了锯齿模驱动 2/1 新经典撕裂模的过程，与实验结果吻合很好。

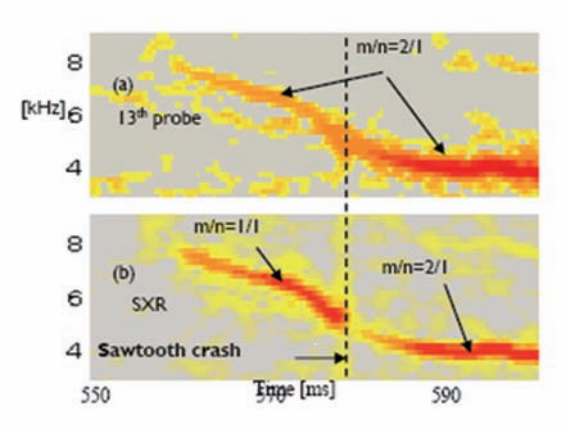


图 1：HL-2A 上观测到的锯齿模（m/n=1/1）和新经典撕裂模（m/n=2/1）的软 X 射线信号。

Fig. 1 SXR signals of the sawtooth (m/n=1/1) and neoclassical tearing mode (m/n=2/1) in HL-2A tokamak plasmas.

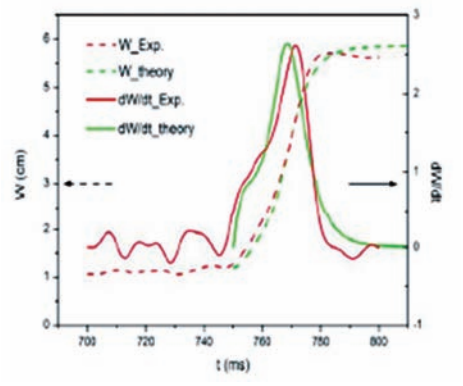


图 2：实验结果（红线）与理论模型结果（绿线）的比较。

Fig. 2 Comparison of experimental (red curves) and modeling (green curves) results.

安全因子非单调分布剖面是未来国际热核聚变实验反应堆（ITER）改善约束运行模式之一；但是这种分布可能导致等离子体双撕裂模不稳定性、甚至离轴锯齿崩塌；剪切流的存在可以改善甚至完全抑制这种不稳定性，我们的研究表明 1）主要的致稳效应是“非局域剪切”即有理面的相对运动；2）双磁岛之间的相互作用会引起“互锁模”现象，导致“离轴锯齿模”；3）超过一定剪切强度的亚声速流就有可能使得双撕裂磁岛饱和，避免“离轴”锯齿崩塌。

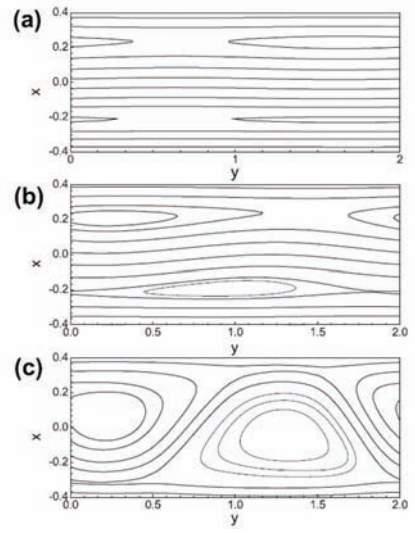


图 3：一个典型的“互锁模”过程。

Fig. 3 A typical island “interlocking” process.

2. 日冕等离子体物理研究

日冕等离子体加热是太阳物理的重要挑战之一，主要的日冕加热模型有电流片（欧姆）加热和波加热两种；

我们研究了日冕等离子体中的阿尔芬共振现象，发现：1）阿尔芬共振过程中会同时产生波的模式转换和奇异电流片；2）在电流片的区域会同时有波加热和欧姆加热现象；3）二者对冕环能量平衡的贡献在同一数量级。

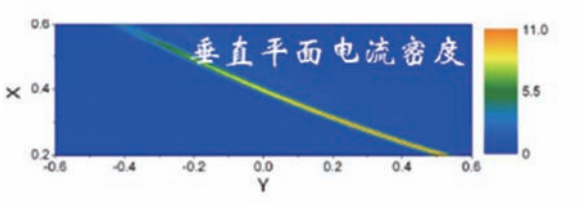


图 4：阿尔芬共振层上奇异电流片的形成。

Fig. 4 Formation of a singular current sheet on Alfvén resonance.

日耀斑现象也是日冕等离子体物理的重要研究对象；我们与国家天文台、中科院物理所的实验室天体物理研究团队合作模拟了磁重联导致日耀斑环顶 X 射线源的物理过程：

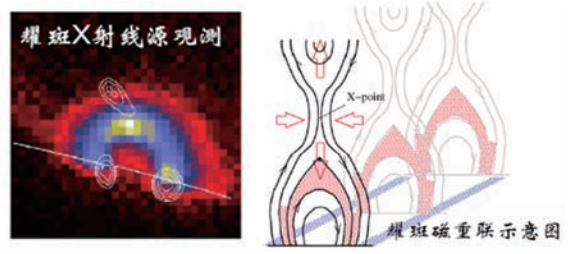


图 5：日耀斑环顶 X 射线源的观测结果与模型解释。

Fig. 5 Loop-top X ray source, the observation and model.

强激光打靶产生高温、高密度、强磁场条件下的等离子体的强驱动快磁重联产生类似日耀斑环顶的等离子体分布；

磁重联出流与“环顶”等离子体的相互作用产生强 X 射线；

提出了理论模型并进行了数值模拟，得到与实验数据吻合很好的结果。

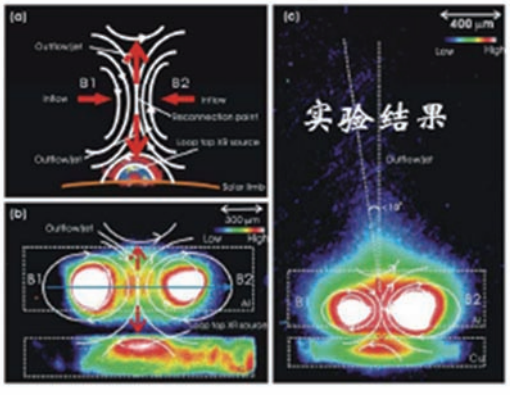


图 6：(a) 实验室模拟设计与 (b, c) 实验结果的照片。

Fig. 6 (a) The experiment set-up and (b, c) results.

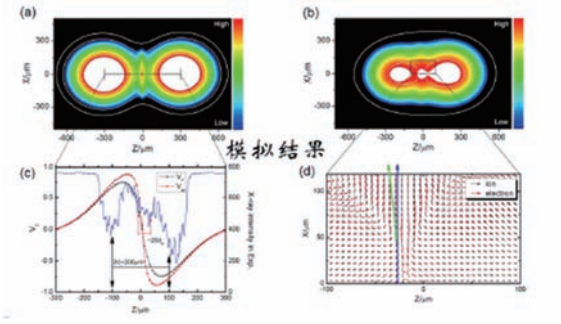


图 7：相应的数值模拟结果。

Fig. 7 Corresponding numerical simulation results.

3. 太阳风湍流谱的卫星观测

太阳风湍流谱的研究是空间与天体物理学研究的前沿问题；

以往的卫星观测研究依据单颗卫星沿轨道在不同时间的测量数据得到的频谱，在平稳湍流和 Taylor 假设下推算 k 空间的湍流谱，而实际的 k 空间湍流谱需要空间多点的同时测量；

利用 Cluster 卫星提供的空间多点的同时测量的数据，我们测量了太阳风湍流的 k 空间功率谱，得到了与 GS95 模型（ ）相近的幂律分布。

图 8：Cluster 卫星观测到的太阳风湍流谱。

Fig. 8 Spectra of solarwind turbulence observed by Cluster.

利用 Cluster 卫星数据，我们还得到了太阳风中波的演化和模式转换的功率谱及色散关系。

代表性论文：

[1] Synthetic solar coronal heating on current sheets; Wang XG, Ren LW, Wang JQ, Xiao CJ, Astrophysical Journal 694 (2009) 1595-1601

[2] Modelling looptop X-ray source and reconnection outflows in solar flares with intense

lasers; Zhong JY, Li YT, Wang XG, Wang JQ, Dong QL, Xiao CJ, et al, Nature Physics 6 (2010) 984–987

[3] Interlocking and nonlinear saturation of double tearing modes in differentially rotating plasmas; Wang XQ, Wang XG, Xu WB, Wang ZX, Physics of Plasmas 18 (2011) 012102

Plasma Physics

- Tokamak physics and magnetic fusion
- Astro and space plasma physics
- Large scale plasma simulations

1. MHD modes in tokamak plasmas

Characteristic processes of a 2/1 neoclassical tearing mode (NTM) induced by a sawtooth collapse were observed in HL-2A tokamak discharges.

Based the forced reconnection model developed by ourselves, with the 2/1 component of the 1/1 sawtooth mode due to the toroidal coupling as the boundary condition for the NTM, as well as using the HL-2A parameters, we calculated the evolution of the 2/1 NTM; and the result was in good agreements with the soft X-ray (SXR) data observed.

Reversed-shear discharge with non-monotonous q-profiles is one of the advanced operation modes for future ITER; nevertheless, the profile may be unstable for double tearing modes (DTMs), and even trigger off-axis sawtooth collapses.

Shear flows however may suppress the instability, we found that, 1) particularly by the “non-local” flow shear, i.e., the relative motion between the dual rational surfaces, was crucially important; 2) the interaction between the dual islands may on the other hand “interlock” them to lead to the off-axis sawtooth mode; 3) the stronger flow shear in the sub-sonic regime can saturate the island to avoid the crashes.

Figure 1, 2, 3

2. Studies for solar coronal plasmas

As a longstanding challenge to solar physicists, coronal heating is studied by two major models: current sheet (Ohmic) heating and wave heating.

We studied Alfvén resonances in solar coronal plasmas and found that: 1) mode conversion and singular current formation occurred together in the Alfvén resonance process; 2) the wave-heating and current-sheet-heating then also induced together; 3) their contributions to coronal energy balance were on the same order of magnitude.

Solar flares are also studied extensively in coronal plasma physics; we worked with the joint lab-simulated astrophysics team of NAOC and IoP, CAS to simulate the loop-top X ray source formation process due to coronal magnetic reconnection.

In the process:

* The loop-top-like plasma was created by fast reconnection strongly driven by high temperature, high density, and robustly magnetized plasmas produced by laser beams;

* The outflow of magnetic reconnection interacted with the loop-top like-plasma to emit the X ray;

* A theoretical reconnection model was proposed to simulate the process numerically, and then the result was in good agreement with experiment data.

Figure 4, 5, 6, 7

3. Observations of solar wind turbulence spectra

Solar wind turbulence spectra studies are on the frontier of space and astrophysics.

Previous measured spectra were mostly from the single satellite observation data at various moments along the orbit, with certain assumptions, while real k-space spectra needed multiple point data at the same moment.

Making use of Cluster data of 4-satellites, we measured the k-space turbulence spectra of solar wind and obtained the power-low spectra close to the GS95

$$E(k_{\perp}) \sim k_{\perp}^{-(12)}, \quad E(k_{\parallel}) \sim k_{\parallel}^{-(15/3)}.$$

model of We also obtained the dispersion relation and mode conversion of waves in solar wind, from Cluster data.

Figure 8

Selected Reprints：

[1] Synthetic solar coronal heating on current sheets; Wang XG, Ren LW, Wang JQ, Xiao CJ, Astrophysical Journal 694 (2009) 1595-1601

[2] Modelling looptop X-ray source and reconnection outflows in solar flares with intense lasers; Zhong JY, Li YT, Wang XG, Wang JQ, Dong QL, Xiao CJ, et al, Nature Physics 6 (2010) 984–987

[3] Interlocking and nonlinear saturation of double tearing modes in differentially rotating plasmas; Wang XQ, Wang XG, Xu WB, Wang ZX, Physics of Plasmas 18 (2011) 012102

06 技术物理系 Department of Technical Physics

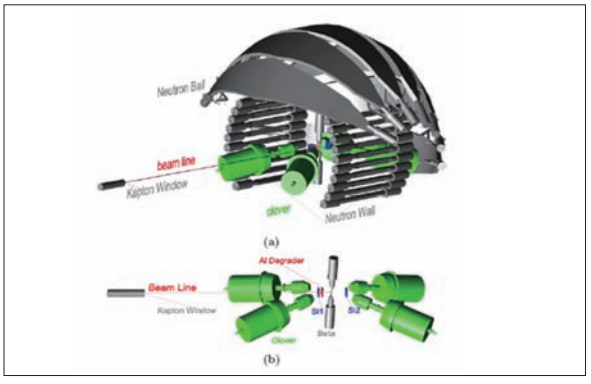
技术物理系现有教职员工 23 人，其中：教授 6 人，副教授 9 人，“北大百人计划”研究员 1 人，高级工程师 2 人，讲师 1 人，工程师 4 人。研究方向包括：实验核反应、实验核结构与核衰变、理论核结构与核衰变、理论核天体、实验高能物理、实验粒子物理、中高能理论、应用核物理、辐射防护、探测器研发、核电子学。拥有一台 2×1.7 MV 加速器，主要用于应用核物理研究（离子束技术与应用）。技术物理系是“核物理与核技术国家重点实验室”的重要组成部分，拥有全国唯一的核物理理科基地和核物理国防紧缺专业。

There are 23 faculty members in the department, consisting of 6 professors, 9 associate professors, 1 “BaiRen” research professor, 2 senior engineers, 1 lecturer and 4 engineers. The research fields include experimental nuclear reaction, experimental nuclear structure and decay, theoretical nuclear structure and decay, theoretical astrophysics, experimental high-energy physics, experimental elementary particles, theoretical medium-high energy physics, applied nuclear physics, radiation protection, detector technique, nuclear electronics. The department is an important part of State Key Laboratory of Nuclear Physics and Technology, with a facility of 2×1.7 MV accelerator for applied nuclear physics. It is also the only department in China, which is supported by the national project for fostering talents of nuclear science and by the national project of defense in nuclear physics.

一、β 延迟中子衰变研究

对滴线附近的丰中子原子核，其 β 衰变 Q 值一般很大，可经 β 衰变布居到子核的束缚和非束缚激发态，从而伴随发射 γ、n、α 等。测量衰变半衰期和这些延迟发射的粒子，能够得到母核、子核的丰富的结构信息。因此 β 延迟粒子测量成为研究滴线区原子核性质的一种特殊手段。

我们自 2002 年开始自主建设和升级了一套中子球装置（如下图），是目前国际上最好的三台同类装置之一，也是我国高校在核物理大科学装置上成功建设的第一个实验终端 [1,2]。



利用该装置在兰州重离子加速器国家实验室开展了丰中子氮同位素结构的系统研究 [3,4]，特别是首次测量了 21N 的 延迟中子和 γ 衰变谱 (见后面图)，得到 13 组中子和 5 条 γ 线，从而初步建立了母核 21N 和子核 21O 的衰变纲图，得到十分重要的结构信息，刺激了相关的理论研究。

代表性论文：

[1] Hu QY; Ye YL; Li ZH et al., IEEE Trans. on Nucl. Sci., 52 (2005)473

[2] Jianling Lou, Zhihuan Li , Yanlin Ye , Hui Hua et al., Nucl. Instr. Meth.A606 (2009) 645

[3] J.L.Lou, Z.H.Li, Y.L.Ye, H.Hua et al., Phys. Rev. C 75(2007)057302

[4] Z.H.Li, J.L.Lou, Y.L.Ye，H.Hua et al., Phys. Rev. C 80（2009）054315

一、Study of β-delayed Neutron Emission

For neutron rich nucleus close to the drip-line, the β decay energy (Q value) is usually very large and many bound and unbound excited states of the daughter nucleus may be populated through the decay process, and then emit particles such as γ rays, neutrons, α particles and so on. Detection of the β-decay and the accompanied delay particles provides very rich structure information of the mother and daughter nuclei. Therefore measurement of β-delayed particle emission has becoming an effective and special tool to explore the structure of exotic nuclei close to the drip-line.

A neutron sphere detection system was built and upgraded since 2002 [1,2], which is one of the three best facilities of this kind in the world, and is also the first experimental terminal successfully built and installed by the Chinese universities at the big nuclear physics facility.

Systematic investigations of the structure of neutron rich Nitrogen isotopes were carried out at Heavy Ion Research Facility in Lanzhou (HIRFL) by using this neutron sphere system [3,4]. Especially the first observation of the β-delayed particle spectroscopy was reported, including 13 groups of neutrons and 5 gamma-ray lines, based on them the decay scheme of the mother nucleus 21N and the daughter nucleus 21O were obtained. This has provided very important structure information for further theoretical studies.

Selected Publications：

[1] Hu QY; Ye YL; Li ZH et al., IEEE Trans. on Nucl. Sci., 52 (2005)473

[2] Jianling Lou, Zhihuan Li , Yanlin Ye , Hui Hua et al., Nucl. Instr. Meth.A606 (2009) 645

[3] J.L.Lou, Z.H.Li, Y.L.Ye, H.Hua et al., Phys. Rev. C 75(2007)057302

[4] Z.H.Li, J.L.Lou, Y.L.Ye，H.Hua et al., Phys. Rev. C 80（2009）054315

二、原子核的分子态结构与衰变

通常，原子核被看成内部核子在平均场中近似独立运动的多体体系，但在某些情况下，核内核子可以结团形成所谓的核子集团。早在 60 年代已经预言：N=Z 附近原子核可能存在多 α 集团结构，特别令人感兴趣的是原子核的分子态结构。在分子态结构中，原子核由 2 个或更多个质量接近的核子集团组织，集团之间还可以存在共价中子或质子。已经普遍认为：Be、C、Mg 等原子核在靠近衰变域值的激发态中可能存在分子态结构。

我们基于平均场模型，提出了一个核子集团与核心之间的微观相互作用势 [1]，并已成功地用于各种集团衰变计算 [1-4]。我们模型的最大优点是：建立了核结构与核衰变之间的直接联系，这样可以通过衰变研究原子核的结构。作为一个典型例子，我们详细研究了 24Mg 高激发共振态的 8Be+16O and 12C+12C 分子态结构与相应的衰变特性，计算很好给出了实验已经观测到衰变宽度，更有意义的是：我们的模型计算能确定这些分子态的自旋，这对相关实验非常有意义 [3]。进一步地，我们从 R 矩阵理论出发，得到了一个描述原子核各种集团衰变的普适规律，给出了原子核集团结构与衰变的微观机制 [5,6]。

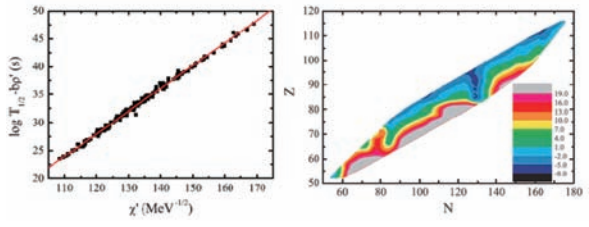


Fig.1: Universal cluster-decay law. [C. Qi, F.R. Xu et al., PRL 103, 072501 (2009).]

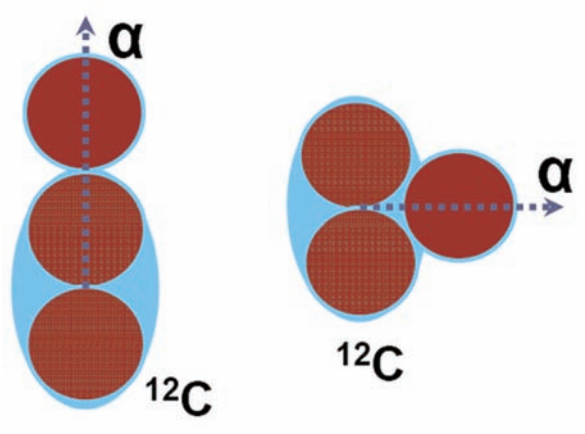


Fig.2: Linear and triangular molecular structures of excited states in 12C. [J. C. Pei, F. R. Xu, PLB 650, 224 (2007)].

代表性论文：

[1] F.R. Xu, J.C. Pei, Phys. Lett. B 642, 322 (2006).

[2] J. C. Pei, F. R. Xu, Phys. Lett. B 650, 224 (2007).

[3] Chen Xu et al., Phys. Rev. C 81, 054319 (2010).

[4] J. C. Pei, F. R. Xu, Z. J. Lin, and E. G. Zhao, Phys. Rev. C 76, 044326 (2007).

[5] C. Qi, F.R. Xu, R.J. Liotta, R. Wyss, Phys. Rev. Lett. 103, 072501 (2009).

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二、Molecular Structures and Decays in Atomic Nuclei

Usually a nucleus is considered as a many-body system in which nucleons are assumed moving independently in a mean field. But in some cases, the nucleons can group to form so-called cluster. As early as in 1960s, it was predicted that nuclei near N=Z can have multi-alpha cluster structures. Of particular interest is the molecular structure in which a nucleus appears with two or more nucleon-groups that have similar masses even with covalent neutrons or protons. The molecular structure has been suggested, e.g., in beryllium, carbon and magnesium isotopes, mostly in their excited states with excitation energies in the vicinities of the corresponding decay thresholds.

Based on mean field, we proposed a microscopic potential for the interaction between the cluster and core [1], which has been successfully applied to the calculations of various cluster decays in the frame of the quantum tunneling [1-4]. One of the advantages of our model is to establish a link between the structure and decay of a nucleus, which provides a way to investigate structure through decay. As an interesting example, we have intensely studied the molecular structure of highly-excited resonant states in 24Mg. In the excitation energies of ≈ 20 - 33 MeV, the excited states have the molecular structures of 8Be+16O and 12C+12C [3]. With our calculations, observed decay widths have been explained well with reasonable spin assignments which have been difficult to be determined experimentally. On the other hand, starting from the R-matrix theory, we obtain a universal decay law to predict various cluster decays, giving a microscopic mechanism to understand cluster decays [5,6].

Selected publications:

[1] F.R. Xu, J.C. Pei, Phys. Lett. B 642, 322 (2006).

[2] J. C. Pei, F. R. Xu, Phys. Lett. B 650, 224 (2007).

[3] Chen Xu et al., Phys. Rev. C 81, 054319 (2010).

[4] J. C. Pei, F. R. Xu, Z. J. Lin, and E. G. Zhao, Phys. Rev. C 76, 044326 (2007).

[5] C. Qi, F.R. Xu, R.J. Liotta, R. Wyss, Phys. Rev. Lett. 103, 072501 (2009).

[6] C. Qi, F.R. Xu et al. Phys. Rev. C 80, 044326 (2009).

三、原子核结构与核天体物理

原子核晕现象、手征性、电磁矩与电磁转动、形状相变、谱学性质、巨共振与矮共振、核天体物理等。

1. 形变晕的微观自洽描述

采用相对论 Hartree-Bogoliubov 理论研究了形变原子核的中子晕，在 44Mg 中发现了晕轨道与核芯之间的形状退耦现象（见图 1）。

2. 原子核质量与宇宙年龄

基于经典快过程模型，研究了贫金属星 CS 31082-001 中的快过程元素丰度分布。确定了该贫金属星年龄为 135±29 亿年，该年龄可以作为宇宙年龄的下限（见图 2）。该工作被美国物理学会 Physics 网站加以报道。

3. 原子核超允许 β 跃迁与 CKM 矩阵幺正性

采用自洽的相对论无规相位近似研究了超允许 β 跃迁的同位旋修正，并检验了 CKM 矩阵的幺正性（见图 3）。该工作引起了 Particle Data Group 最新一期《Review of Particle Physics》的关注，并在 2010 年国际核物理大会 W. Marciano 教授的大会报告中被重点评述。

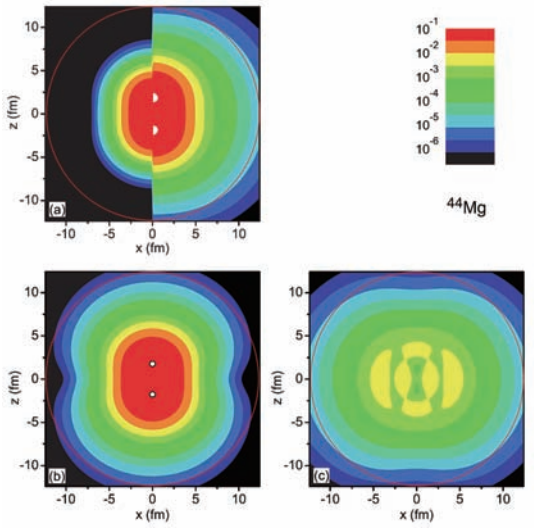


Fig. 1: Density distributions of 44Mg. [Phys. Rev. C 81, 011301(R) (2010)]

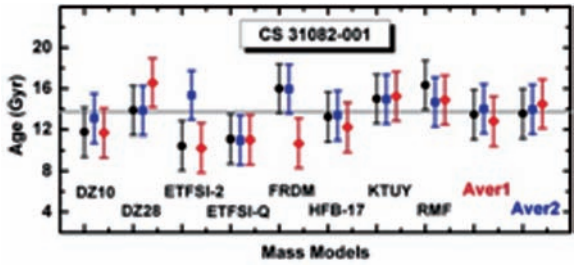


Fig. 2: Ages of the metal-poor stars CS 31082-001. [Phys. Rev. C 80, 065806 (2009)]

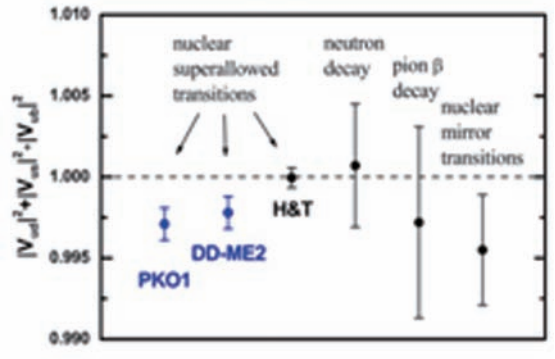


Fig. 3: The sum of squared top row elements of the CKM matrix. [J. Phys. Conf. Ser. 205, 012028 (2010)]

代表性文献：

[1] N. Paar, Y.F. Niu, D. Vretenar, and J. Meng, Phys. Rev. Lett. 103, 032502 (2009).

[2] B. Y. Sun, H. Toki, and J. Meng, Phys. Lett. B 683, 134-139 (2010).

[3] Y.F. Niu, N. Paar, D. Vretenar, and J. Meng, Phys. Lett. B 681, 315-319 (2009).

[4] B. Qi, S.Q. Zhang, J. Meng, S.Y. Wang, and S. Frauendorf, Phys. Lett. B 675, 175-180 (2009).

[5] P.W. Zhao, Z.P. Li, J M. Yao, and J. Meng, Phys. Rev. C 82, 054319 (2010).

[6] J.M. Yao, J. Meng, P. Ring, and D. Vretenar, Phys. Rev. C 81, 044311 (2010).

[7] W.H. Long, P. Ring, J. Meng, N. Van Giai, and C.A. Bertulani, Phys. Rev. C 81, 031302(R) (2010).

[8] S.G. Zhou, J. Meng, P. Ring, and E.G. Zhao, Phys. Rev. C 81, 011301(R) (2010).

[9] Z.M. Niu, B.H. Sun, and J. Meng, Phys. Rev. C 80, 065806 (2009).

[10] Z.P. Li, T. Nikši , D. Vretenar, and J. Meng, Phys. Rev. C 80, 0613019 (2009).

[11] H.Z. Liang, N. Van Giai, and J. Meng, Phys. Rev. C 79, 064316 (2009).

[12] J. Meng and S.Q. Zhang, J. Phys. G: Nucl. Part. Phys. 37, 064025 (2010).

三、Nuclear Structure and Astrophysics

Nuclear halo phenomena, chirality, electromagnetic moments and electric/magnetic rotations, shape phase transitions, spectroscopic properties, giant and pygmy resonances, nuclear astrophysics, etc.

1. Self-consistent microscopic descriptions of deformed halo: Neutron halo in deformed nuclei has been investigated within the relativistic Hartree-Bogoliubov model. A decoupling of the halo orbitals from the deformation of the core was found in 44Mg (see Fig. 1).

2. Nuclear masses and age of Universe: The r-process abundance pattern in the metal-poor halo star CS 31082-001 has been investigated based on the classical r-process approach. The age of this metal-poor star is determined as 13.5±2.9 billion years, which can serve as the lower limit of cosmic age (see Fig. 2). This work was highlighted on the website Physics of American Physical Society.

3. Nuclear super allowed β transitions and the unitarity of CKM matrix: Self-consistent relativistic RPA approaches have been applied to calculate the isospin corrections for the superallowed β transitions, and the unitarity of the CKM matrix has been examined (see Fig. 3). This work was cited in Review of Particle Physics by Particle Data Group 2010, and highlighted by Professor W. Marciano in his plenary talk at International Nuclear Physics Conference 2010.

Selected publications：

[1] N. Paar, Y.F. Niu, D. Vretenar, and J. Meng, Phys. Rev. Lett. 103, 032502 (2009).

[2] B. Y. Sun, H. Toki, and J. Meng, Phys. Lett. B 683, 134-139 (2010).

[3] Y.F. Niu, N. Paar, D. Vretenar, and J. Meng, Phys. Lett. B 681, 315-319 (2009).

[4] B. Qi, S.Q. Zhang, J. Meng, S.Y. Wang, and S. Frauendorf, Phys. Lett. B 675, 175-180 (2009).

[5] P.W. Zhao, Z.P. Li, J M. Yao, and J. Meng, Phys. Rev. C 82, 054319 (2010).

[6] J.M. Yao, J. Meng, P. Ring, and D. Vretenar, Phys. Rev. C 81, 044311 (2010).

[7] W.H. Long, P. Ring, J. Meng, N. Van Giai, and C.A. Bertulani, Phys. Rev. C 81, 031302(R) (2010).

[8] S.G. Zhou, J. Meng, P. Ring, and E.G. Zhao, Phys. Rev. C 81, 011301(R) (2010).

[9] Z.M. Niu, B.H. Sun, and J. Meng, Phys. Rev. C 80, 065806 (2009).

[10] Z.P. Li, T. Nikši , D. Vretenar, and J. Meng, Phys. Rev. C 80, 0613019 (2009).

[11] H.Z. Liang, N. Van Giai, and J. Meng, Phys. Rev. C 79, 064316 (2009).

[12] J. Meng and S.Q. Zhang, J. Phys. G: Nucl. Part. Phys. 37, 064025 (2010).

07 天文学系 Department of Astronomy

天文学系现有教职工 12 人，其中教授 7 名，副教授 2 名，百人研究员 2 名，办公行政 1 名。研究领域包括宇宙学与星系形成、高能天体物理、星际介质物理 - 恒星与行星系统、粒子天体物理等，涉及各天文尺度及极端天体环境。

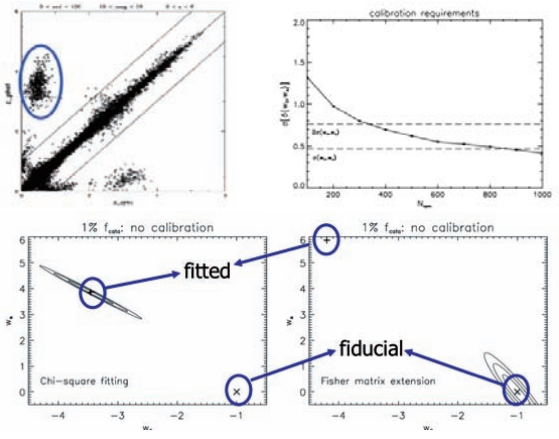
There are 12 members in the department, consisting of 7 professors, 2 associate professors, 2 Bairen research professors, and 1 secretary for administration. The research fields include Cosmology and Galaxy Formation, High Energy Astrophysics, Interstellar Medium Physics-Stellar and Planet System, and Astroparticle Physics, covering a wide range of astronomical scales and astrophysical conditions.

一、宇宙学与结构形成

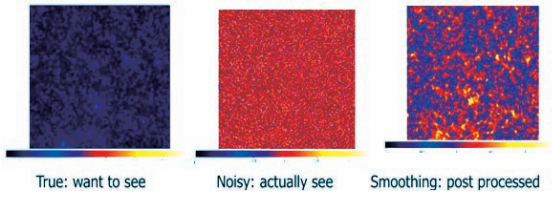
1. 系统误差对弱引力透镜宇宙学研究的影响

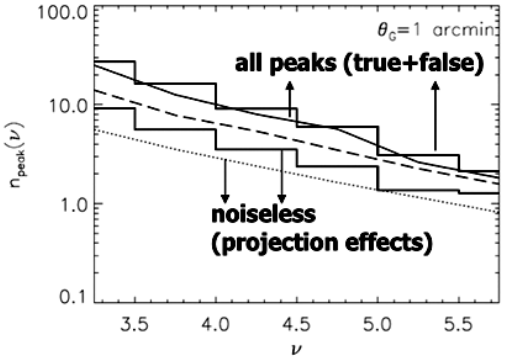
弱引力透镜效应直接与宇宙大尺度结构相关，并依赖于宇宙膨胀历史，因此成为暗物质和暗能量研究的重要手段之一。另一方面，各种系统误差的影响将成为利用未来大型弱引力透镜观测进行宇宙学研究的主要制约因素，而对其透彻理解已成为该领域前沿研究的重要方面。我们的工作主要包括：

• 深入分析星系测光红移灾难性误差对宇宙学研究的影响，特别是对限制暗能量状态方程所带来的系统偏差。结果表明，我们必须将灾难性误差控制在小于 ~0.1% 的范围内，才可使其带来的系统偏差小于统计误差。我们进一步分析了相应的光谱红移测量定标的要求。对于未来～ 10000deg2 的巡天观测，我们需要对测光红移在［3，4］之间的星系，进行 >10000 个红移测量，才能有效地控制灾难性误差至 < 0.1%。



• 详细分析了星系内禀椭率所带来的噪声对星系团弱引力透镜研究的影响。 研究表明，噪声会改变星系团弱引力透镜峰值位置和高度，这一影响敏感地依赖于星系团本身的物质分布。另一方面，星系团的存在造成其周围噪声峰的出现几率大大提高。我们进一步建立了理论模型，使得我们可以计算弱引力透镜观测所得到的峰值统计，从而有效而准确地进行宇宙学研究。

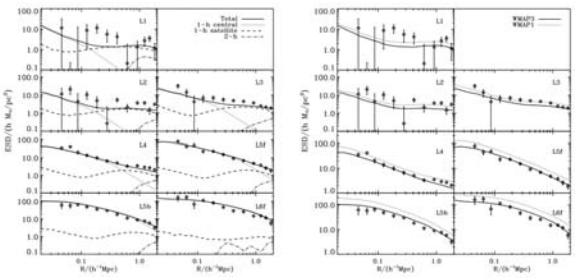




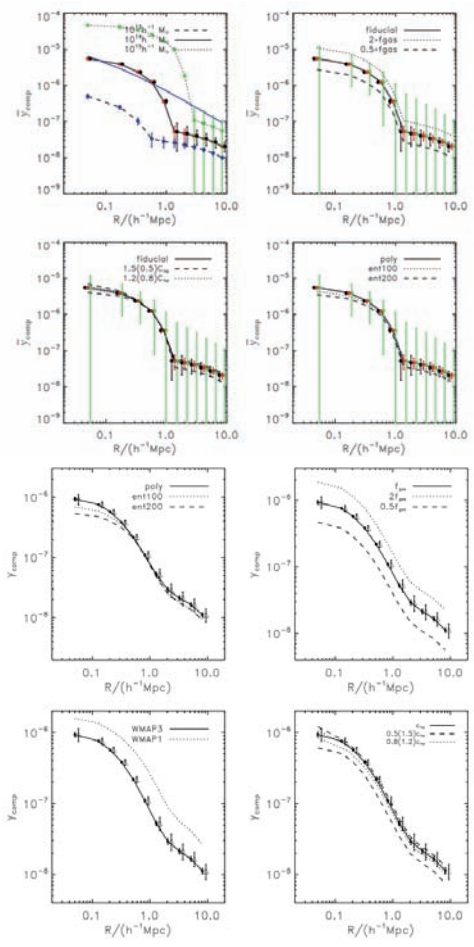
2. 星系群物质分布和气体性质的研究

星系，星系群，和星系团的物质分布及气体分布，与其形成与演化过程密切相关，而如何利用观测有效地提取相应的信息，是宇宙学研究的重要方面之一。我们的工作主要包括：

• 利用 SDSS 星系群样本和 SDSS 星系－星系弱引力透镜效应观测，我们深入分析了与不同星系（中心星系，卫星星系，不同亮度，不同形态的星系 等）相关的暗晕物质分布结构。结果表明，$_8 = 0.75$ 的 CDM 模型可 以很好地与观测相符合，而对于 $_8 = 0.9$，理论预言明显高于观测信号。



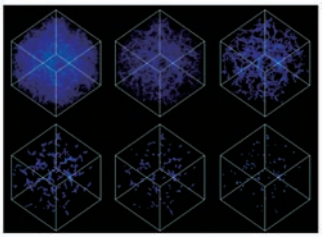
• 结合星系红移巡天观测和 SZ 观测，我们深入分析了利用 stacking 方法和星系－ SZ 互相关的方法研究星系群内热气体分布的可行性。结果表明，对于高灵敏度的 SZ 观测，如 SPT 等，利用我们的方法，可以有效地研究质量低至～ 1013 h-1 Msun 的星系群内的气体性质。

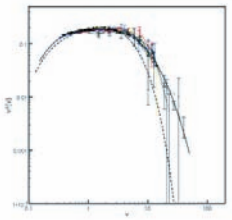


3. 超星系团结构统计分析

随着观测，数值模拟和理论研究的发展，我们对星系，星系团等结构的形成与演化有了深入的理解。进一步研究大尺度结构环境对其性质的影响，亦成为宇宙学结构形成研究的主要方面之一。我们的主要工作为：

• 利用数值模拟，深入分析了超星系团结构的统计性质。我们发现，其质量函数亦具有普适性。我们进一步给出了拓展的 Jenkins 质量函数形式，其可同时适用于与星系，星系团等相关的维里化暗晕，和超星系团结构。这为未来利用超星系团结构进行宇宙学研究提供了重要的理论基础。





代表性论文

[1] Catastrophic Phot-z errors and the dark energy parameter estimates with cosmic shear; L. Sun, Z.H. Fan, C. Tao, J.-P. Kneib, S. Jouvel and A. Tilquin; ApJ, 699, 958 (2009)

[2] Noisy weak-lensing convergence peak statistics near clusters of galaxies and beyond; Z.H. Fan, H.Y. Shan and J.Y. Liu; ApJ, 719, 1408 (2010)

[3] Modeling galaxy-galaxy weak lensing with Sloan Digital Sky Survey groups; R. Li, H.J. Mo. Z.H. Fan, M. Cacciato, F.C. van den Bosch, X.H. Yang and S. More; MNRAS, 394, 1016 (2009)

[4] Probing hot gas in galaxy groups through the Sunyaev-Zeldovich Effect; R. Li, H.J. Mo, Z.H. Fan, F.C. van den Bosch and X. H. Yang; MNRAS, in press (2011)

[5] Statistical properties of supercluster-like filaments from cosmological simulations; H.L. Yan and Z.H. Fan; ApJ, in press (2011)

一、Cosmology and Structure Formation

1.Impacts of systematic errors on weak-lensing cosmological studies

The weak-lensing effect depends both on large-scale structures in the universe and on the cosmic expansion history. Therefore it has become one of the most important means in probing the nature of dark matter and dark energy. On the other hand, for future large weak-lensing observations, their cosmological applications will be mainly limited by different systematic effects. To thoroughly understand their influences has been an important aspect of forefront research in the field. Our studies mainly include:

• Detailed analyses for the impacts of catastrophic photo-z errors on weak-lensing cosmological applications, particularly on the induced biasing effects for the determination of the equation of state of dark energy. It is shown that in order to limit the bias to be within the statistical error range, the fraction of galaxies with catastrophic errors must be controlled to be less than 0.1%. We further investigate the corresponding requirement for the spectral-z calibration. For future surveys of area ~10000 deg2, more than 10000 spectral-z measurements for galaxies with their photo-z in the range of [3,4] are necessary.

• Detailed analyses for the impacts of noise arising from intrinsic ellipticities of source galaxies on clusters' weak-lensing effects. It is shown that depending sensitively on the density profile of a cluster, the existence of noise affects both the location and the height of its peak signal. On the other hand, the mass distribution of the cluster can enhance the occurrence probability of noise peaks significantly. We set up a theoretical model to calculate the statistical abundance of weak-lensing peaks, which allows us to perform cosmological studies with peak statistics accurately and efficiently.

2. Studies of the mass distribution and gas properties in groups of galaxies

The mass distribution and gas properties associated with galaxies, groups and clusters of galaxies are closely related to their formation and evolutionary history. To accurately extract such information from observations has been one of the important goals in cosmological studies. Our research includes mainly:

• With group catalogs constructed from SDSS and the galaxy-galaxy weak-lensing measurements, we analyze in detail the mass distribution of dark matter halos associated with different galaxies (central, satellite, different luminosities, and different morphologies). It is shown that the Λ_{CDM} model with σ_8=0.75 can give rise to results that are consistent with observations very well. On the other hand, models with higher σ_8, such as σ_8=0.9, predict significantly stronger g-g lensing signals than those measured from observations.

• We investigate in detail the feasibility of the stacking method and the galaxy-SZ cross correlation method in probing gas properties down to group scales with SZ measurements in conjunctions with galaxies redshift surveys. It is demonstrated that with high sensitivity SZ measurements, such as SPT, our methods can be used successfully to study gas properties for groups with mass as low as ~1013 h-1 Msun .

3.Statistical analyses of supercluster-like structures

With the developments of observations, numerical

simulations and theoretical studies, our understandings regarding the formation and evolution of galaxies and clusters of galaxies have been improved considerably. Meanwhile, it has become feasible and one of the major efforts in the field to study the large-scale environmental effects on properties of galaxies and clusters of galaxies. In this aspect, our studies focus on:

• With numerical simulations, we explore in detail the statistical properties of supercluster-like structures. It is shown that their mass function follows a universal behavior, similar to that of virialized dark matter halos. We further present a generalized Jenkins functional form that can describe well the mass function of both virialized halos and supercluster-like structures. This provides an important theoretical framework for cosmological studies with supercluster-like structures.

Selected publications

[1] Catastrophic Phot-z errors and the dark energy parameter estimates with cosmic shear; L. Sun, Z.H. Fan, C. Tao, J.-P. Kneib, S. Jouvel and A. Tilquin; ApJ, 699, 958 (2009)

[2] Noisy weak-lensing convergence peak statistics near clusters of galaxies and beyond; Z.H. Fan, H.Y. Shan and J.Y. Liu; ApJ, 719, 1408 (2010)

[3] Modeling galaxy-galaxy weak lensing with Sloan Digital Sky Survey groups; R. Li, H.J. Mo. Z.H. Fan, M. Cacciato, F.C. van den Bosch, X.H. Yang and S. More; MNRAS, 394, 1016 (2009)

[4] Probing hot gas in galaxy groups through the Sunyaev-Zeldovich Effect; R. Li, H.J. Mo, Z.H. Fan, F.C. van den Bosch and X. H. Yang; MNRAS, in press (2011)

[5] Statistical properties of supercluster-like filaments from cosmological simulations; H.L. Yan and Z.H. Fan; ApJ, in press (2011)

二、星系核中超大质量双黑洞和恒星的相互作用及其可观测特性

天文观测表明大多数星系的核心都存在着比太阳重百万倍以上的超大质量黑洞。根据目前流行的冷暗物质宇宙学，星系之间进行着频繁的并合，而星系的并合必将在星系核中产生超大质量双黑洞（以下简称“双黑洞”）。我们组主要从事双黑洞周围物质在红外、光学以及 X- 射线等波段的电磁波辐射特性研究，尤其致力于发现一个区别于超大质量单黑洞的电磁波辐射特征。这对于认证星系核中的双黑洞、检验冷暗物质宇宙学模型，探测引力波辐射、研究广义相对论效应以及引力波天体物理等都具有至关重要的意义。

1. 双黑洞潮汐撕裂恒星的速率：

过去几年人们成功探测到了超大质量黑洞潮汐撕裂恒星所产生的光学、紫外、X- 射线辐射（“潮汐闪耀”）。我们用数值散射实验模拟了恒星在双黑洞引力场中的运动，并且计算了在星系并合形成双黑洞的过程中恒星进入“潮汐半径”从而被黑洞潮汐撕裂的速率。我们的研究结果表明：

1) 双黑洞与恒星的三体相互作用可以将远离黑洞潮汐半径的束缚恒星散射入黑洞的潮汐半径（图 1），从而大大提高双黑洞潮汐撕裂恒星的概率。

2) 大量束缚恒星将在几十万年的时间内被双

黑洞潮汐撕裂，速率可高达每十年一颗，比单黑洞系统中的速率高四个量级左右。

3) 这种双黑洞形成造成的暴发式的潮汐闪耀现象，可以通过正在建设中的宇宙暂变源巡天在不久的将来进行统计检验。

2. 双黑洞潮汐撕裂恒星的光变特性：

利用三体系统稳定性的理论分析结合数值模拟散射实验 (图 2)，我们研究了撕裂后恒星等离子体碎片被双黑洞吸积的过程。我们发现：

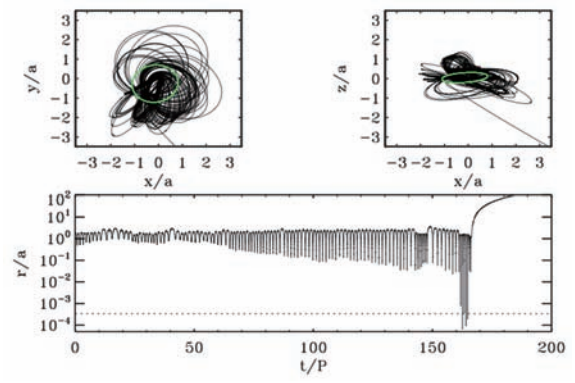


图 1：数值三体模拟中双黑洞（绿色）和恒星（黑色）的轨道在 x-y 平面（左上）和 x-z 平面（右上）内的投影，以及恒星与主黑洞间距随时间的演化（下）。在时间为 160 倍双黑洞轨道周期时，恒星被散射入主黑洞的潮汐撕裂半径（点线）。

Figure 1： Orbits of binary black hole (green) and star (black) from numerical three-body simulation, projected in the x-y (top left) and x-z (top right) planes, and evolution of the separation (bottom panel) between star and primary black hole. After about 160 orbital periods of the binary black hole, the star is scattered into the tidal radius (dotted line) of the primary black hole. (Chen, X.; Madau, P.; Sesana, A.; Liu, F. K., 2009, ApJL, 697, L149).

1) 双黑洞对撕裂恒星碎片的吸积初始时与单黑洞对潮汐撕裂恒星的吸积相同，即吸积率随时间幂律衰减。

2) 当时间大约等于双黑洞轨道周期的四分之一时，黑洞对物质的吸积因次黑洞（双黑洞中质量较小的黑洞，质量较大的为“主黑洞”）的影响而中断，然后在时间大约等于双黑洞轨道周期时，双黑洞对恒星残片的吸积又可能会零星地重新开始。

3) 因此这种双黑洞造成的潮汐闪耀中断效应可以在未来暂变源巡天中通过对暂变天体的长期监测来观测研究。通过这样的光变观测可对普通星系中心处于休眠状态的、产生引力波辐射的超大质量双黑洞进行探测研究。

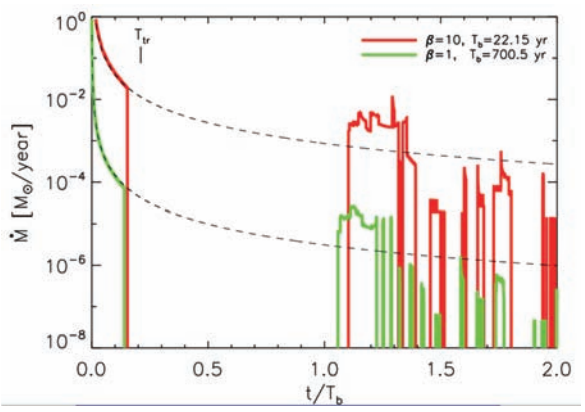


图 2：数值散射实验得到的双黑洞对恒星残留等离子体的吸积率随时间的演化（实线，不同曲线代表不同的恒星初始角动量）。虚线是单黑洞情况下中心黑洞的吸积率。

Figure 2： The accretion rate of stellar debris by binary black hole as a function of time, derived from numerical scattering experiments (solid lines, different lines refer to different initial angular momenta of star). The dashed lines are the accretion rates in the cases of single black holes. (Liu, F. K.; Li, S.; Chen, X., 2009, ApJL, 706, L133).

代表性文章：

[1] Chen, X.; Madau, P.; Sesana, A.; Liu, F. K.

2009, ApJL, 697, L149

[2] Liu, F. K.; Li, S.; Chen, X. 2009, ApJL, 706, L133

二、Interactions Between Supermassive Black Hole Binaries and Stars in Galactic Nuclei and their Observational Signatures

Observations discovered that most galaxies harbor supmermassive black holes (SMBHs) heavier than million solar masses in their nuclei. In the popular cold dark matter cosmology, galaxies merge frequently, inevitably leading to the formation of supermassive black hole binaries (SMBHBs) in galactic nuclei. Our group have been investigating the electromagnetic radiations in infrared, optical, to X-ray bands produced by the matters around SMBHBs, and especially trying to find a unique electromagnetic signature different from those in single SMBH systems, which is of key importance to the identification of SMBHBs, testing cosmological models, detecting gravitational wave radiation, studying general relativistic effects and gravitational wave astrophysics.

1. Rates of tidal stellar disruption by SMBHBs: During the past few years, people have successfully detected the optical, ultraviolet, and X-ray radiations ("tidal flares") due to the tidal disruption of stars by single SMBHs. Using numerical scattering experiments, we simulated the stellar orbits in the gravitational filed of SMBHBs and calculated the rate of stars entering the spheres of "tidal radii" of black holes where the stars are tidally disrupted. Our results showed that

1) The three-body interactions between SMBHBs and stars could scatter bound stars initially far from the black holes into the tidal radii (Figure 1), tremendously increasing the probability of stellar disruption.

2) A large amount bound stars would be disrupted by a SMBHB in a time span of 100,000 years, and the stellar-disruption rate could be as high as one event per ten years, about four orders of magnitude higher than the rates in single SMBH systems.

3) The burst of tidal flares triggered by SMBHB formation can be statistically tested in the future survey of cosmic transient sources.

2. The variability of stellar disruption flares by SMBHBs: Using both the stability theory of three-body systems and numerical scattering experiments, we further studied the accretion of the plasma debris of disrupted stars by SMBHBs.

1) Initially the accretion of stellar debris by SMBHB is similar to that in a single black hole system, i.e. the accretion rate decays as a power law.

2) At about one quarter of the binary orbital period, the accretion of stellar debris is interrupted by the perturbing secondary (less massive) black hole, and at about one orbital period of SMBHB, the accretion of stellar debris may resume.

3) By searching the galaxy nuclear sources in the future transient object survey for interrupted tidal flares, dormant SMBHBs emitting gravitational wave radiation can be identified.

Selected publications：

[1] Chen, X.; Madau, P.; Sesana, A.; Liu, F. K. 2009, ApJL, 697, L149

[2] Liu, F. K.; Li, S.; Chen, X. 2009, ApJL, 706, L133

08 大气与海洋科学系
The Department of Atmospheric and Oceanic Sciences

大气与海洋科学系拥有一支优秀的教师队伍。现有教职员工近30人，其中中科院院士4人（兼职3人），国家千人计划讲座教授1人，教授11人（兼 职1人，国家杰出青年1人），北京大学百人计划研究员3人，副教授和高级工程师9人，讲师2人。近年来，不断有国外优秀人才加盟大气与海洋科学系，使教师 队伍充满了活力和生机。近几年来，每年科研经费达1000万元，每年发表SCI论文近40篇。目前，我系教师的主要研究领域有：大气辐射与遥感、云物理与 大气化学、大气边界层与环境、数值天气预报与模拟、大气动力学和非线性动力学、气候动力学与模拟、物理海洋、海 - 气相互作用与气候变化等。

The Department of Atmospheric and Oceanic Sciences has a strong faculty team. There are currently approximately 30 staff members, including 4 Academicians of the Chinese Academy of Sciences (3 of whom are Adjunct Faculty of the Department), 1 National “Qianren” Chair Professor, 11 Professors (including 1 Adunct Professor and 1 National Outstanding Young Scientist), 4 Peking University “Bairen” Research Scientist, 9 Associate Professors and Senior Engineers, and 2 Lecturers. More outstanding and internationally-trained scientists are joining the Department, invigorating our team of faculty members. For the past few years, we have received approximately 10 million RMB per annum in research funding and have published approximately 40 SCI journal papers each year. Main research areas of our faculty currently includes: atmospheric radiation and remote sensing; cloud physics and atmospheric chemistry; atmospheric boundary layer and environment; numerical weather prediction and simulation; atmospheric dynamics and non-linear dynamics; climate dynamics and modeling; physical oceanography, air-sea interaction and climate change, etc.

一、云物理与大气化学研究

北京大学物理学院大气与海洋科学系“云物理与大气化学” 赵春生教授研究组致力于研究气溶胶 - 云 - 辐射相互作用和对流层臭氧化学。2009-2010年主要研究工作如下：

1. 利用地面观测数据分析了上海市区臭氧及其前体物的基本特征，并结合模式模拟讨论了臭氧光化学过程的影响因素，为制定臭氧控制政策提供了科学依据。

2. 利用飞机观测气体及气溶胶污染物资料，首次在北京地区发现了存在于行星边界层之上的高空污染层。提出了污染物借助“山的烟囱效应”（Mountain Chimney Effect，MCE）突破边界层顶并输送到高空的物理机制，揭示了局地环流对城市污染分布和输送的重要影响。

3. 通过分析上百架次飞机探测气溶胶数据，对北京地区气溶胶垂直分布特征进行了统计和分类；进而计算了气溶胶光学特征并与卫星遥感结果进行了比对。结果揭示了气溶胶垂直分布对气溶胶光学厚度的影响。

4. 利用北京地区75架次机载云滴谱数据，统计分析了5种不同类型暖云的云滴数浓度、液态水含量、有效半径等云微物理参量。为改善模

式中对云的描述，我们对云滴有效半径提出了新的参数化公式。

5. 与国内外多家单位合作开展了一系列气溶胶、大气化学外场观测研究。

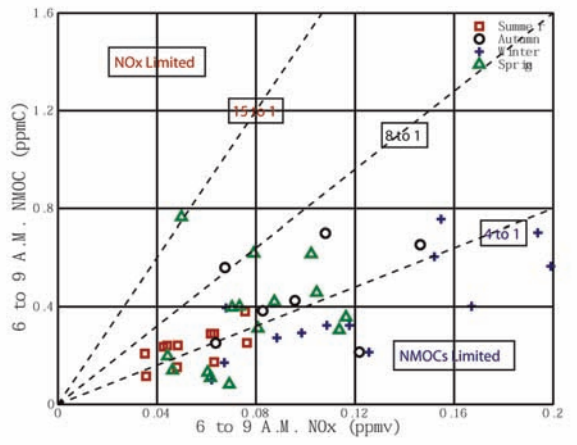


图 1：上海市区臭氧典型日变化日非甲烷有机物和氮氧化物比例，代表臭氧光化学产生对前体物的敏感度。

Figure 1: NMOC/NOx ratios on TODC days in downtown Shanghai, which represent the chemical region for ozone production. (Ran et al., JGR, 2009)

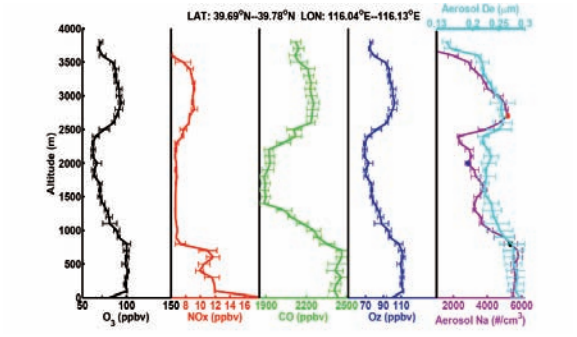


图 2：通过飞机探测在北京地区发现的存在于边界层之上的高空污染层。(Chen et al., JGR, 2009)

Figure 2: Aircraft detected elevated pollution layer above the PBL over Beijing area. (Chen et al., JGR, 2009)

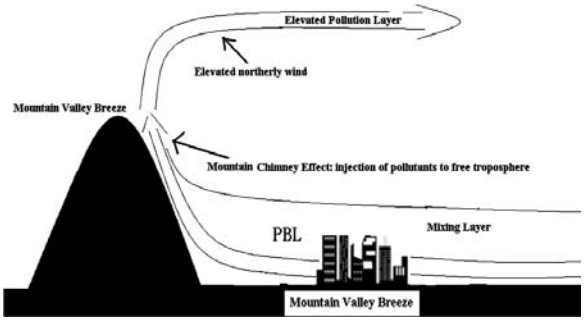


图 3：山的烟囱效应示意图

Figure 3: Schematic of Mountain Chimney Effect

代表性论文：

[1] Ran, L., et al., Ozone photochemical production in urban Shanghai, China: Analysis based on ground level observations. Journal of Geophysical Research-Atmospheres, 2009. 114.

[2] Liu, P. F., et al., Aircraft study of aerosol vertical distributions over Beijing and their optical properties. Tellus Series B-Chemical and Physical Meteorology, 2009. 61(5): p. 756-767.

[3] Deng, Z. Z., et al., Statistical analysis of microphysical properties and the parameterization of effective radius of warm clouds in Beijing area. Atmospheric Research, 2009. 93(4): p. 888-896.

[4] Chen, Y., et al., Aircraft study of Mountain Chimney Effect of Beijing, China. Journal of Geophysical Research-Atmospheres, 2009. 114.

一、The Cloud Physics and Atmospheric Chemistry (CPAC)

The Cloud Physics and Atmospheric Chemistry (CPAC) group at Peking University emphasizes research and graduate-level teaching in aerosols, clouds, aerosol-cloud interactions, remote sensing and tropospheric chemistry. The highlights of 2009-2010 research are as following:

1. Ground level ozone and its precursors measured in an urban site of Shanghai were analyzed to characterize ozone photochemical production in this region. Model simulations were further conducted to help improve understandings of ozone issues and develop effective ozone abatement strategies.

2. For the first time, a remarkable elevated pollution layer above the planetary boundary layer (PBL) was observed by aircraft measurements in Beijing area. The Mountain Chimney Effect (MCE) was proposed to interpret the mechanism of pollutants injected from the PBL into free troposphere. Our study emphasizes the important influences of local circulation on the distribution and transport of urban pollutants.

3. We classified and analyzed more than 100 flights of airborne in-situ measurements to characterize the aerosol vertical distribution over Beijing area. Aerosol optical properties were calculated and compared with satellite retrieval, of which the result shows significant influences of aerosol vertical distribution on the aerosol optical depth.

4. Using 75 flights of airborne in-situ data, cloud microphysical parameters including number concentration, liquid water content and effective radius were summarized for 5 different types of warm clouds. A new parameterization of cloud effective radius was proposed to improve the representation of radiative properties of clouds in models.

5. Conducted several field campaigns under international cooperation, focused on aerosols and atmospheric chemistry.

Figure 1, 2, 3

Selected articles:

[1] Ran, L., et al., Ozone photochemical production in urban Shanghai, China: Analysis based on ground level observations. Journal of Geophysical Research-Atmospheres, 2009. 114.

[2] Liu, P. F., et al., Aircraft study of aerosol vertical distributions over Beijing and their optical properties. Tellus Series B-Chemical and Physical Meteorology, 2009. 61(5): p. 756-767.

[3] Deng, Z. Z., et al., Statistical analysis of microphysical properties and the parameterization of effective radius of warm clouds in Beijing area. Atmospheric Research, 2009. 93(4): p. 888-896.

[4] Chen, Y., et al., Aircraft study of Mountain Chimney Effect of Beijing, China. Journal of Geophysical Research-Atmospheres, 2009. 114.

二、南极平流层变暖和臭氧洞恢复

大气平流层温度主要是由臭氧含量决定的，因为臭氧吸收太阳紫外辐射加热大气平流层。人

们通常认为平流层在过去 30 年是变冷的，原因是臭氧层严重损耗。可是，我院胡永云教授与其合作者美国华盛顿大学的付强教授使用微波遥感第 4 通道的温度资料给出的证据表明，南半球高纬度和南极平流层在过去 30 年冬春季存在强的变暖，9-10 月份最大变暖达 7-8 K（见附图）。他们的进一步研究表明，该变暖是由波动驱动的绝热增温造成的，而且与海面温度升高有关。气候模式模拟试验表明，观测的海面温度强迫确实可以产生大气波动增强和平流层南极变暖。这些结果意味着，随着人类排放的温室气体的增加，海面温度将继续升高，平流层波动和极地温度也将升高，这将有利于南极臭氧洞的恢复。研究结果发表在 2009 年“大气化学和物理”，第 9 卷，4329-4340 页。

附图：1979-2006 年平流层低层温度趋向。该温度趋向是从微波遥感第 4 通道计算的。图中的等值线表示 t- 检验值。对于 28 年的时段，t- 检验值 1.7 和 2.5 分别对应 90% 和 98% 可信度。

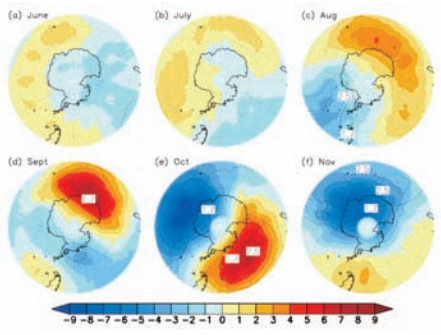


Figure: Temperature trends in the lower stratosphere for the period of 1979–2006, derived from satellite Microwave Sounding Unit channel 4 observations. The trends are shown from June to November. Color interval is 1 K per 28 years. Contours denote t-test values. For 28 years, student’s t-test values 1.7 and 2.5 correspond to 90% and 98% confidence levels, respectively.

二、Antarctic Stratospheric Warming and the Recovery of the Ozone Hole

Stratospheric temperature is mainly determined by ozone which absorbs solar ultraviolet radiation and warms the stratosphere. It was generally thought stratospheric temperature has been decreased in the past 30 years due to severe ozone depletion. However, using satellite Microwave Sounding Unit channel 4 temperature data, Prof. Yongyun Hu and his collaborator, Prof. Qiang Fu at University of Washington, show evidence of significant stratospheric warming over Southern Hemisphere high latitudes and large portions of the Antarctic polar region in winter and spring seasons for the period of 1979-2006, with a maximum warming is 7–8 K in September and October (see Figure). They further show that the warming is caused by enhanced wave-driven adiabatic heating, and that the warming has close correlations with sea surface temperature (SST) increases. Using general circulation model simulations forced with observed time-varying SSTs, they reproduced similar warming patterns in the Antarctic stratosphere and increasing wave activity. As SST warming continues as a consequence of greenhouse gas increases due to anthropogenic activity, the stratospheric warming would also continue, which benefits the recovery of the Antarctic ozone hole. The results were published on Atmospheric Chemistry and Physics, volume 9, page 4329-4340, 2009. (See Figure)

三、定量评估海洋在全球气候变化中的角色

- 全球气候变化及全球变暖
- 太平洋年代际振荡
- 热带海洋—大气相互作用

从事海气相互作用及气候变化方面的基础性研究。过去两年的研究集中在定量评估海洋在气候变化中的作用，如全球变暖背景下热带 ENSO 如何变化，海洋在 ENSO 变化中的具体作用如何等等。全球变暖以及热带的厄尔尼诺现象对中国的降水分布及强度都有很大的影响。我们的研究表明在全球变暖的不同阶段，ENSO 的振幅会出现显著的状态漂移。具体来说，目前我们处于全球变暖的瞬变阶段，未来 10-30 年内发生较强 ENSO 事件的可能性比较大。在全球变暖的平衡阶段，未来 30 年以后 ENSO 的强度将会减弱。我们的研究表明 ENSO 强度最重要的制约因素是热带温跃层的强度，而后者因温跃层温度的缓慢变化可以随时间逆转。这个研究对 ENSO 的预测具有指示作用。

三、**Quantifying the Ocean Role in Global Climate Change**

- Global Climate Change and Global Warming
- Pacific Decadal Oscillation
- Tropical Ocean-Atmosphere Interaction

During the past two years we focus on quantifying the ocean role on the global climate change, such as the tropical El Nino-Southern Oscillation (ENSO) variability under the global warming, the ocean role in ENSO long term change etc.. Global warming and the ENSO variability can significantly affect the pattern and intensity of the precipitation over China mainland. Our studies disclose that the ENSO amplitude will experience a significant regime shift during different stages of the global warming. Specifically, currently the climate is in the transient stage of the global warming, which means it is more likely to have stronger ENSO in the future 10-30 years. During the equilibrium stage of the global warming, it is more likely to have weaker ENSO thereafter. The key factor to control the ENSO intensity is the status of the tropical thermocline, while the intensity of the latter can be reversed with time due to the slow evolution of the tropical subsurface temperature. Our studies provide a crucial guidance to the future ENSO prediction.

Selected publications：

[1] Yang, H., and L. Wang, 2011: Tropical Oceanic Response to Extratropical Thermal Forcing in a Coupled Climate Model: A Comparison between the Pacific and the Atlantic. J. Climate, in press.

[2] Yang, H., and F. Wang, 2009: Revisiting the Thermocline Depth in the Equatorial Pacific. J. Climate, 22, 3856-3863.

[3] Yang, H., F. Wang, and A. Sun, 2009: Understanding the Ocean Temperature Change in Global warming: the Tropical Pacific. Tellus, 61A(3), 371-380.

[4] Yang, H., and L. Wang, 2008: Estimating the nonlinear response of tropical ocean to extratropical forcing in a coupled climate model. Geophys. Res. Lett., 35, L15705, doi:10.1029/2008GL034256.

[5] Yang, H., and Q. Zhang, 2008: Anatomizing the Ocean Role in ENSO Changes under Global Warming. J. Climate, 22, 6539-6555.

09 普通物理教学中心
Teaching Center of General Physics

北京大学物理学院普通物理教学中心是北京大学物理学院下属的一个三级机构，其前身为北京大学物理系普通物理教研室，负责普通物理各类课程的长期建设、教学研讨活动和对外教学交流活动的组织以及教学日常组织管理工作。中心下设一个演示实验室和 10 个主干基础课课程组，每个课程组设课程主持人和主讲人，中心的主要任务是承担全校普通物理 01 — 05 共五个系列平台课程的教学任务，授课对象为理科将近 2000 学生，年授课工作量约 222000 人学时。

普通物理教学中心努力传承北大普物教学的优良传统，初步形成了一支专任和兼任相结合，科研与教学相结合，老、中、青教师相结合的与北大地位相称的普物教学团队，团队的职称结构和年龄结构合理，专业分布广泛，团队规模适度，结构优化，学术水平高，教学质量好。

Teaching Center of General Physics, is a third-level institution, Peking University former known as Peking University Department of General Physics Teaching and research, responsible for the long-term construction of various types courses of general physics, teaching seminars, foreign exchange activities of teaching, and the daily organization and management of teaching. Teaching Center consists of Laboratory demonstration center and 10 course groups that are set moderators and lecturers. The center's main task is to undertake teaching tasks of Physics 01-05 series courses, teaching nearly 2,000 students for the science, about 222,000 people teaching hours each year.

Teaching Center of General Physics inherit the fine tradition of general physics teaching of Peking University, has formed a teaching team, featured as combination of a full-time and part-time, research and teaching, the old, middle-aged and young teachers. The teaching team of general physics has the reasonable structure of job title and age, widely study area, an appropriate team scale, structural optimization, high academic standards and teaching quality.

一、《求新求实，持续建设光学课程三十年》获 2009 年度国家级教学成果二等奖

历经几代人的努力，特别是新时期三十年来在钟锡华教授的带领下，课程组成员持续改革与建设，该课程建设取得如下重要成果：

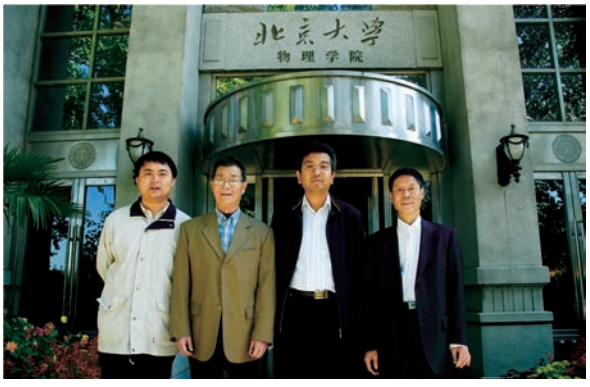
1. 该课程以教材建设为核心，出版了《光学》和《现代光学基础》两套优秀教材。两套教材的特点是概念准确，内容新颖，图像清晰，推演简洁和语言生动。教材建设达到了很高的水平。同时带动了课程其它教学环节的全面建设。先后出版了三本与主教材配套的题解指导书。

2. 注重培养和锻炼青年教师，形成了一支学术水平高、年龄结构合理、教学与科研相结合的师资队伍。

3. 从 1980 年代开始经不懈努力建成了一套丰富多彩的光学演示系列实验（含 35 个），深受学生的欢迎。实验室获得了北京大学先进实验室称号，在高校同行中有很高声誉和广泛影响，是演示促进教学的一个成功范例。

4. 注重教学研究，在教学研究和学术研究方面取得了一系列显著成果。在刊物上发表了与光学内容密切相关的论文 30 余篇，其中绝大部分均已反映在课堂讲授和教材中。教学激励研究、以研究充实教学，使该课程充满活力和现代气息，是该课程建设的又一个显著特色。

5. 光学课程于 2005 年评为国家级精品课，已经成为一门有着现代光学面貌和脉络的基础课，具有内容丰富、视野开阔、格调多样和充满活力的特色，且保持着概念清晰、理论系统和图像丰富的特点。这是一门使学生感到亲切而激动的课程。而且，三十年来一直致力于推动全国高校光学教学与学术研究，为提高全国高校光学师资的学术水平和教学水平作出了显著的贡献，在全国光学教学届享有很高声望。



一、One result of General Physics Teaching Center: "Innovation and Truth Seeking, thirty years of continuous construction of the optical Course" won 2009 National Teaching Achievement Second Award

Through the efforts of several generations, especially in the new period in three decades under the leadership of Professor ZHONG Xi-hua, course team members continued to reform and made the following important achievements:

1. They focused on textbook construction, and had the two excellent textbooks, "Optics" and "Fundamentals of modern optics" to be published. The characteristics of these two textbooks are accurate concept, innovative content, clear impression, concise derivation and language alive. The textbook construction reached a high level and also led to the overall construction of the optical Course. The three books of problem solution have been published to support the main textbooks.

2. After training and exercise of young teachers, a teaching team with high academic standards, a reasonable age structure, the combination of teaching and research has been formed.

3. By the tireless efforts since the 1980s, the optical

demo series of variety experiments (with 35) were greatly enjoyed by students. The laboratory won the title of advanced laboratories of Peking University, and had high reputation and wide influence among the university counterparts, and was a typical example that demo experiments had promoted teaching.

4. Focus on teaching research, a series of remarkable achievements in teaching and academic research has been made. More than 30 papers published in the journal were closely related to the optical content, most of which were reflected in classroom lectures and textbooks. Promotion of teaching and research each other was a significant feature of our course construction.

5. Their optical course as the national excellent course in 2005, has become a basic course that had a face and the context of modern optics with a rich, broad vision, style diverse and dynamic characteristics, and maintained a clear concept and theory of systems and image-rich features. This was a course that had enabled students to feel warm and exciting. Moreover, they committed to promoting the optical research and teaching of national universities in three decades, made a significant contribution to the academic and teaching standards of optical teachers of national university, and enjoyed a high reputation among the optical teaching session in the country.

二、普物教学中心主任王稼军教授荣获 2010 年度宝钢优秀教师特等奖

宝钢教育基金会在全国 100 余所高等院校和中国科学院 18 所直属研究所设立“宝钢教育奖”，旨在奖励优秀人才，力行尊师重教，推动产学合作，支持教育发展。经 2010 年宝钢教育奖评审工作委员会通讯评审和 2010 年宝钢教育奖评审委员会最终评选决定，最后从优秀教师奖推荐人中选出优秀教师奖特等奖 10 名。物理学院普物教学中心主任王稼军教授荣获该年度宝钢优秀教师特等奖。

王稼军教授从事物理教育、科研、人才培养工作，三十四年如一日，把自己的精力投入到教学、学生培养、课程和教材建设等工作。她在教学中不断探索提高教学质量的途径。她的课在学生中有极好的口碑，对教学所倾注的心血得到了学生的赞誉。她在教学中以教书育人为己任，学生都亲切的称她为“王姐姐”，并且被学生评为北京大学十佳教师。她先后担任物理系副主任、普物教学中心主任等教学组织、协调、管理工作，为我校物理基础课教学质量的提高，为教学交流、新教师的培养做了大量工作。长期负责物理学院物理基地建设的具体实施和管理。长期担任我国高等学校教学指导委员会、中国物理教学委员会、北京市物理学会的组织领导工作，为提高全国的物理教学水平，发挥北京大学物理学院在全国物理教学中的引领、辐射作用做出了极为突出的贡献。

二、Prof. Jiajun Wang, director of Teaching Center for General Physics, won the 2010 BaoSteel Grand Prize for Outstanding Teachers

BaoSteel Prize for Outstanding Teachers is a BaoSteel Education Award, which was set up by Baosteel Education Foundation at more than 100 Chinese universities and 18 academic institutes directly under the Chinese Academy. The aim of the award is to reward talent, exercise respect for teachers, promote industry-university cooperration, and support education. The 2010 BaoSteel Grand Prizes were given to Prof. Jiajun Wang, director of Teaching Center for General Physics at Peking university's school of physics, and the other 9 candidates, after communicational reviews and a final selection by the BaoSteel Education Award Committee.

Prof Jiajun Wang has spent 34 years in physical education, scientific research, personnel training, and made special contribution to general physics teaching materials, student training, and exploration in improving teaching quality. For her efforts devoted to teaching, she has got an excellent reputation in students. She has long been called Sister Wang, and won the Prize for Top Ten Teachers of Peking University selected by all the students in the university.

She has served as deputy director of Physics Department, director of Teaching Center for General Physics, and has made great effort in improving teaching quality, teaching research, and trainning new teachers. She has long been responsible for construction and management of Physics Education Base at school of physics. She is also member of Chinese Steering Committee of Higher Education, Physical Education Committee of China, Physical Society of Beijing and has made great effort in improving the level of the national physical education, and making Peking University's physics teaching a leading role in the country.

10 基础物理实验教学中心
The Teaching Center for Experimental Physics

北京大学基础物理实验教学中心是“国家级实验教学示范中心”，承担国家级精品课：“普通物理实验”和“近代物理实验”的基础课教学，并开设研究型的“综合物理实验”选修课。目前在岗专职教师 8 名（教授 2 名，副教授 4 名，讲师 2 名），实验技术人员 7 名（高级工程师 1 名，工程师 2 名，助理工程师 4 名）。

The Teaching Center for Experimental Physics at Peking University is a national demonstration center of experiment teaching. It is mainly engaged in teaching of “General Physics Experiment” and “Modern Physics Experiment”, which are of high-quality nationwide and belong to “National Outstanding Courses”. Besides, the center gives a research course called “Comprehensive Physics Experiment” to students who are willing to investigate some experimental problems. Now there are 15 faculty members in the center, in which are 2 professors, 4 associate professors, 2 lecturers, 1senior engineer, 2 engineers, and 4 assistant engineers.

基础物理实验教学与研究

- 基础物理实验仪器和教学
- 前沿物理实验技术和教学
- 教学研一体化的实验教学模式

1. 维弦球链系统振动模研究平台

图 1, Figure 1

周期系统中的波一直是物理学研究的重要内容。但是，要在教学中让学生直接测量和观察晶体中的电子波函数是几乎不可能的。实际上，布洛赫波和带状频（能）谱并非晶体中电子所特有，而是所有周期系统中波的共同特征。研究一个简单系统通常会比研究一个复杂系统更能揭示物理本质。在所有周期系统中，由一段周期性地穿有小球的弦构成的一维弦球链可能是最简单的。因此，我们建立了一套弦球链振动模研究实验装置（见图 1）。借助对弦球链系统振动模的研究，低年级学生不仅也能很好地理解布洛赫波、能带结构、表面态等概念，而且，由于弦球链系统满足的振动方程和一维狄拉克梳势中电子所满足的定态薛定谔方程在数学形式上极为相似，他们甚至还可以测出电子的波函数。借助此装置还可以研究杂质态、无序态、界面态和超晶格等。由于弦球链系统可以完全按实验者的意愿构建，同学们还得到了一些在实际晶体中不可能得到的新结果。

2．非线性对流斑图实验的教学研究

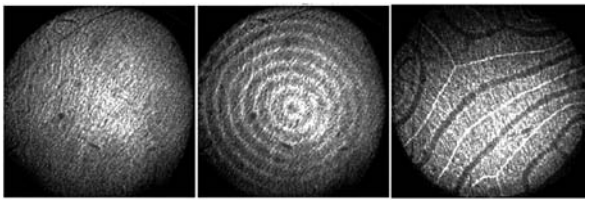


图 2, Figure 2

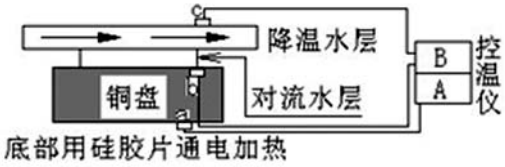


图 3, Figure 3

斑图动力学是研究远离平衡态情况下系统出现的时空结构。瑞利贝纳对流系统是其中常用的非线性系统之一，直到目前此系统也仍然受到许多学者的关注。此系统是一层薄的流体，上下表面控制恒定的温度差，当温差达到某一临界温度前流体无流动，之后流体自发地形成有序结构的流动，采用阴影照相的光学显示方法可观察到对流水层随温差变化时从无序到有序的转变过程。

我们利用本科生物理实验综合指导课指导本科生成功搭建了此系统的装置。此实验装置用在 2010 年秋季学期的近代物理实验课上，选择了这个实验的学生们全部都表现出很高的兴趣。此实验涉及流体力学、光学和非线性动力学等多方面的基础知识，综合性很强，据了解，此类实验或装置在国内大学的本科生实验教学内容中还未见过介绍或报道过。

3. 奥赛集训队和国家队实验培训

2007 年 11 月至 2010 年 12 月，基础物理实验教学中心受物理学院的委托，承担了四届集训队的实验培训和选拔任务。在集训期间，实验中心的老师们继承和发扬北大实验教学的优良传统，在坚持基础实验的规范训练、注意打好基本功的

基础上进行应试培训。使原来实验基础好的学生更加扎实，给原来实验训练不够的同学提供了提高的机会和条件，经过学生本人努力，在竞赛中也取得较好成绩。这些学生对物理实验和实验研究都产生了浓厚的兴趣，积极参与实验教学和科学研究工作，并初步取得了成绩，通过培训和选拔，参赛选手的实验成绩有所提高，在 2008 年—2010 年三届参赛（亚赛和奥赛共 5 次）中，中国队选手连续获得了个人总分（理论和实验两项相加）第一的好成绩。特别值得一提的是，在 09 年的国际奥赛中史寒朵同学获得了个人总分第一和实验第一的好成绩，这在国际奥林匹克竞赛史上还是第一次有女生获得了总分第一的殊荣，在颁奖仪式上赢得了经久不息的掌声，为中国队争取了极大荣誉。

Teaching and research of physics experimentation

- Instruments of basic physics experiments and related teaching
- Experimental skills of frontier physics and related teaching
- Research-oriented teaching and study of physics experiments

1. The Laboratory for Study on the Vibration Modes of wire-bead Chain

One of the important parts of physics is to study the waves in various periodical systems. However, it is almost impossible for students to do what like observing the wave function of an electron in crystalline. In fact, the characters like Bloch waves and band frequency (energy) spectra are related to not only the electrons in crystalline but also the waves in all periodical systems. Usually, to study a simple system can reveal more physics than to study a complex one. Among all the periodical systems, the wire-bead chain, which can be made by threading a wire through a number of beads and distributing the beads periodically, looks like the simplest one. So, a setup had been developed to study the vibration modes of the wire-bead chain(to see the figure 1). wire-bead After studying on the vibration modes of the wire-bead chain, the juniors or even sophomores can understand the concepts such as Bloch wave, energy band and surface state quite well. Furthermore, for the vibration equation of a wire-bead chain is almost the same as the Schrödinger equation of an electron in Dirac comb, the students can even acquire the wave function of an electron from a wire-bead chain. Based on the setup, the students can also study the problems, such as impurity state, disordered state, interface state and superlattice, etc. Since the parameters of wire-bead chain can be easily changed according to the investigator`s intend, the students could acquire some things that could not be acquired in a real crystalline.

Figure 1

2.Experiment of nonlinear convective pattern

Pattern dynamics is to study the spatiotemporal structures of nonlinear system far away from

equilibrium. Rayleigh-Benard convection is one of the nonlinear systems, until now it still attracts many researchers' eyes. The top and bottom surfaces of a fluid layer is under different temperatures, when the difference is beyond the critical point, the fluid layer is convective and forms regular structures, which can be observed by shadowgraph images.

We have successfully developed such experimental system with the involvement of undergraduates taking Innovative Physics Laboratory Course. This experimental system has been used in the Modern Physics Laboratory Course for senior undergraduates in Fall semester of 2010. Students have shown strong interests in exploring this original comprehensive experiment, as it requires cross-disciplinary fundamental knowledge in fluid dynamics, optics, and nonlinear dynamics. To our knowledge, no such experiment or system has ever been introduced or reported in undergraduate physics labs in China.

Figure 2, 3

3. Training for International Physics Olympiad

Since November of 2007, the Teaching Center of Experimental Physics has undertaken the task of the School of Physics to train physics-talented high-school students in experiment for participating in International Physics Olympiad. The training was performed on the basis of the present physics labs and the traditional teaching on experimental physics at Peking University. It has focused on the fundamental aspects required for the students to make physics experiments, such as experimental ideas, methods and skills. There was widespread relief that such training improved their practical ability in the competitions. All the contestants, chosen from the trained students, have obtained gold medals in all the International and Asian Physics Olympiad for 3 years of the training, and every times of the competitions, the absolute winner, who has obtained the first place with sum of the theoretical and experimental scores, has been one of our students. It is particularly worth to mention that Handuo Shi, was the absolute winner and obtained the best score of experimental part of the International Physics Olympiad in 2009, and as a female participant, Shi's success is unprecedented in the history of the international Physics Olympiad and has caused a sensation in the international community of physics competition.

11 电子显微镜专业实验室
Peking University Electron Microscopy Laboratory

北京大学电子显微镜实验室始创于 1964 年。1992 年，被确认为电子光学与电子显微镜国家重点学科专业实验室。在国家创建“世界一流大学”的方针指导下，北京大学领导正确把握时机，利用“985”计划投巨资为实验室装备了国际上最先进的 Tecnai F30 场发射透射电镜、DB-235 离子 - 电子双束纳米工作站。目前，实验室现拥有场发射透射电镜、聚焦离子束系统、场发射环境扫描电镜等大型设备 8 台，及完善的电镜制样设备，总价值超过 500 万美元。实验室现有包括中科院院士、国家“杰出青年”在内的教职工 10 名，7 人具有高级职称，4 人具有博士学位。在读博士、硕士研究生 30 余名。

建设方针和奋斗目标：努力将实验室建成我国电子显微学的基础研究和专业人才培养基地；高水平

显微结构测试、分析和纳米科技研究中心。经过15年的努力，建设成为“国际一流”的电子显微镜实验室。

主要研究方向：电子显微学基础：衍射、衬度理论，电子能带结构；分析电子显微学。纳米科技：纳米结构材料、纳米电子器件、光子晶体研究。显微结构分析在物理、化学、材料、电子、地质等学科研究中的应用。材料计算和材料设计。

Electron Microscopy Laboratory, PKU was first established in 1964 and authorized as State Special Laboratoryby the ministry of education, P.R.C. in 1990.Under the support of the “985” project, a Tecnai F30 transmission electron microscopy and an ion-electron dual-beam nano-technique workstation, the most advanced instrument in the world, have been constructed in the laboratory. Now the laboratory is equipped with 6 sets of TEM & SEMs and consummate sample-preparing facilities.

Now there are 12 staffs and over 20 graduate students in the laboratory including an academician of CAS and a national preeminence youth. Guideline & Object:Make great efforts to constructed the laboratory to be national base for the research on electron microscopy, professional training and one of the nano-technique research centers. And eventually become a world wide famous laboratory on electron microscopy.

Tecnai G20 透射电镜

Tecnai F30 透射电镜

Tecnai F20 透射电镜

离子－电子双束系统（FIB）

场发射环境扫描电镜（ESEM）

一、纳米表征分析方法在凝聚态物理研究中的应用

北京大学物理学院电子显微镜实验室在材料显微结构及其与物理性质相互关系研究方面取得了重要进展，特别是利用现代电子显微学表征手段研究纳米材料的显微结构与物理性质方面取得重要突破：由于电子束极高的空间和能量分辨能力，可以在精确地在纳米尺度对纳米材料的特定区域进行高分辨的定量研究。我们利用安装在扫描电镜中的阴极荧光光谱分析方法研究了 ZnO 等半导体纳米线材料在弯曲应变作用下发光及电子结构随应变的演化规律，研究了弯曲半导体纳米线中电子结构对应变梯度的依赖关系，揭示了张应变使纳米线的能隙变窄，发光峰红移、压应变使能隙变宽，发光峰蓝移的奇特规律。

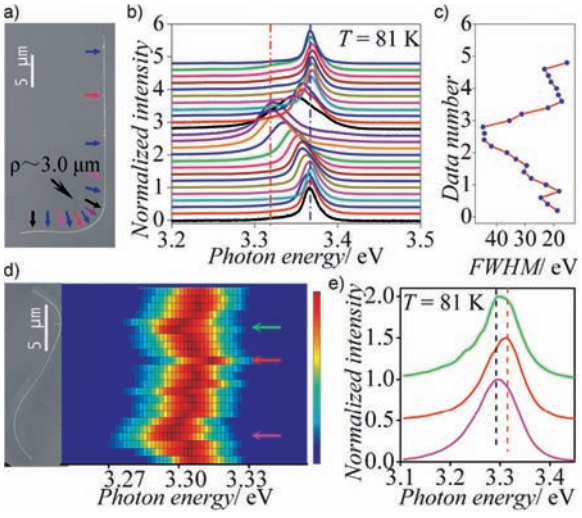


Fig.1：CL measurements from a ZnO NW bent into an L-shape (a–c; diameter ~150 nm) at81 K and an S-shape (d,e; diameter ~140 nm) at room temperature.

论文发表在《Xiaobing Han, Liangzhi Kou, Xiaoli Lang, Jianbai Xia, Ning Wang, Rui Qin, Jing Lu, Jun Xu, Zhimin Liao, Xinzheng Zhang, Xudong Shan, Xuefeng Song, Jingyun Gao, Wanlin Guo, and Dapeng Yu, Advanced Materials 21, 4937-4941,2009》上。

我们还利用原位透射电镜研究了弯曲 ZnO 纳米线中张应变与压应变的发布情况，并结合理论分析揭示了外加应变对半导体纳米材料电子结构与发光的调制的物理机理。

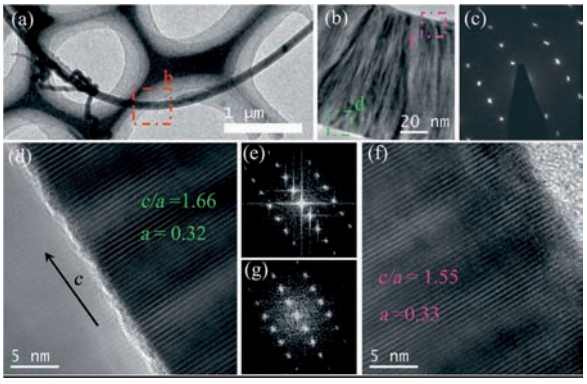


Fig.2:TEM analysis of a bent ZnO NW (diameter~100 nm).

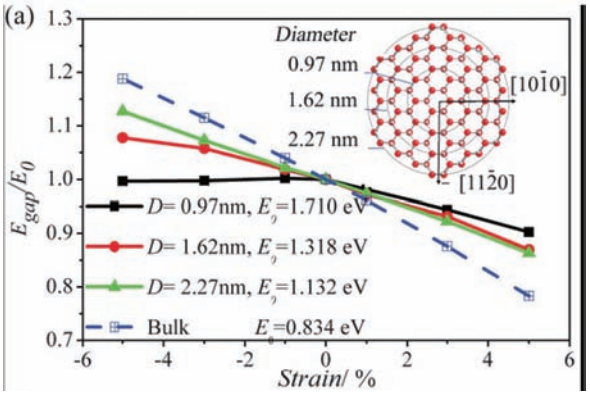


Fig.3: The variation of band structure with deformation.

一、Systematic CL spectra analyses in Condensed Matter Physics

Systematic CL spectra analyses combined with high-resolution TEM characterization of ZnO NWs bent into different shapes with bending strain range of a few percent show significant deformation-induced

reduction in band gap (red shift) and broadening of the near edge emission in the CL spectra. Theoretical calculations based on both first-principles DFT and an effective-mass envelope function theory reveal identically that tensile strain makes the main contribution to the band gap reduction. This work should provide an atomic mechanism for the electronic and mechanical coupling behavior of deformed ZnO nanostructures, and bending engineering can be used to design possible novel nanodevices.

12 高能物理研究中心 Center for High Energy Physics

北京大学高能物理中心由李政道先生担任主任。目前有 8 位海外资深学者，8 位国内特聘兼职研究员，6 位青年学者，4 位博士后研究人员。研究的领域包括：宇宙学、量子场论、粒子物理唯象学、强子物理等。

With Prof. T. D. Lee as the director, the Center for High Energy Physics at Peking University now has 8 senior fellows from abroad, 8 research associates, 6 junior fellows and 4 postdocs. The research interests include: cosmology, quantum field theory, particle physics phenomenology and hadronic physics.

超弦与宇宙学

1. Kerr- 类型黑洞的全息描述

我们研究了 Kerr-Newman 以及 Kerr-Newman-AdS-dS 黑洞的全息描述，发现它们可以通过有限温度的二维共形场论（CFT）来描述。黑洞的宏观熵可以由 CFT 的微观熵来得到；我们应用并推广了通常 AdS/CFT 中的方法来计算 Kerr 黑洞、Kerr-Newman 黑洞以及 Kerr-Newman-AdS-dS 黑洞中各种实时关联函数并与对偶的 CFT 中的关联函数进行比较，得到了令人满意的结果；我们发现 Kerr-Newman-AdS-dS 黑洞存在着两种不同的全息描述，分别基于角动量和电磁场量子数。

2. 卷曲 AdS/CFT 对应关系研究

讨论了三维拓扑有质量引力理论中的卷曲 AdS/CFT 对应：计算了类空拉伸黑洞和类光卷曲黑洞背景中的标量、矢量和旋量扰动的赝正则模。发现必须考虑合适的量子数对应，这样赝正则模的频率与对偶 CFT 的预言一致。进一步地，我们发展了卷曲的黑洞背景中的实时关联函数的计算方法，得到了与对偶 CFT 预言一致的结果；发现了三维拓扑有质量引力理论中一类新的自对偶黑洞解，分析了其热力学性质，研究了这种几何的渐进对称性群，计算了对应的中心荷，讨论了它可能的 CFT 对应。

3. 黑洞中的潜藏共形对称性及其应用

讨论了潜藏共形对称性在建立黑洞的全息描述时的作用；发现了对于极端黑洞适用的共形坐标，并讨论了其物理意义；利用潜藏共形对称性讨论了存在全息描述的三维黑洞的各种赝正则模，发现它们可以通过代数方法简洁地构造，而他们的频率都有统一的形式。

4. AdS/CFT 对应关系中的非局域算子和可积性

构造了 ABJM 理论中 1/6-BPS Wilson- 圈算子，计算了其到双圈的真空期待值，讨论了其 AdS 对偶；研究了 LLM 几何以及 Maldacena-Nunez 背景下的 5-brane 的位形，包括可能的 BPS 位形以及非 BPS 位形，并讨论了在 AdS/CFT 对应中可能

的场论对应算子；系统研究了 AdS 背景下超对称 Sigma 模型在费米 T- 对偶下的对称性。发现对于 SU 超群的超陪集空间，其定义的模型总是有费米 T- 对偶对称性，而对于 OSp 超群的超陪集空间，其定义的模型不具有费米 T- 对偶对称性 .

5. Horava-Lifshitz 引力及其相关物理研究

研究了 Horava-Lifshitz(HL) 引力中可能存在的引力标量模及其在宇宙学中的可能应用，提出我们不必额外引进暴胀子来实现暴胀；讨论了理论的自洽性，指出理论自洽必须要求加可投影条件但此时的静态球对称解只有 Schwarzschild(-dS) 解从而说明 HL 引力此时没有对太阳系试验有新的修正；讨论了在 Lifshitz 点附近的标量和规范场论并提出这类场论可以自然地解释宇宙中 Gamma 射线的时间延迟问题。

代表性论文抽印本：

[1] Real-time Correlators and Hidden Conformal Symmetry in Kerr/CFT Cor-

respondence;Bin Chen and Jiang Long; JHEP 1006:018,2010;

[2] Self-DualWarped AdS3 Black Holes; Bin Chen and Bo Ning; Phys. Rev. D82,124027

(2010);

[3] Supersymmetric Wilson Loops in N=6 Super Chern-Simons-matter theory;

Bin Chen and Junbao Wu; Nucl.Phys.B825:38-51,2010;

[4] Scale Invariant Power Spectrum in Horava-Lifshitz Cosmology without Mat-

ter; Bin Chen, Shi Pi and Jin-Zhang Tang; JCAP 0908:007,2009.

String and Cosmology

1. Holographic descriptions of Kerr-type black holes

We studied the holographic descriptions of Kerr-Newman and Kerr-Newman-AdS-dS black

holes, and found that they could be holographically described by two-dimensional CFT at finite temperatures. The macroscopic entropy of the black holes could be reproduced from the CFT entropy via the Cardy formula.

We generalized the usual prescriptions in AdS/CFT correspondence to compute various realtime correlators in Kerr, Kerr-Newman and Kerr-Newman-AdS-dS black holes. We found

perfect agreements with the dual CFT predictions.

We found there existed two different holographic descriptions of Kerr-Newman-AdS-dS black holes, in view of the angular momentum and the charge.

2. Warped AdS/CFT corre-spondence

We discussed the warped AdS/CFT correspondence in the context of three-dimensional topological massive gravity theory: we calculated the scalar, vector and spinor quasi-normal modes of spacelike stretched and null warped black holes. We found that only taking into account of the proper identifications of quantum numbers, the frequencies of quasi-normal modes are in agreement with CFT prediction. Furthermore we computed the real-time correlators in the warped backgrounds and found agreement with CFT prediction as well.

We found a new class of self-dual black hole solutions

in three-dimensional topological massive gravity theory, analyzed its thermodynamics, investigated its asymptotic symmetry group, calculated the corresponding central charge, and set up the possible warped Ad-S/CFT correspondence.

3. Hidden conformal symmetry in black holes

We discussed the implications of hidden conformal symmetry on setting up the holographic descriptions of black holes.

We discovered the conformal coordinates for extreme black holes, and discussed their physical Implications.

We studied the quasi-normal modes of three-dimensional black holes, which have holographic descriptions, with the help of hidden conformal symmetry. We constructed various quasinormal modes algebraically and elegantly.

4. Non-local operators in AdS/CFT correspondence

We constructed 1/6-BPS Wilson loop operator in ABJM theory, computed its expectation

value up to 2-loop level, and discussed its possible AdS dual.

We investigated the M5-brane configurations in LLM geometry and Maldacena-Nunez geometry, including the BPS and non-BPS ones, discussed their possible correspondents in dual field theory.

We systematically studied the fermionic T-duality in supersymmetric modes in AdS backgrounds.

We found that for the super-coset spaces based on SU supergroups, the models are invariant under duality, while for the supercoset spaces based on OSp supergroups, the models are not invariant.

5. Aspects in Horava-Lifshitz gravity

We studied the extra scalar mode in the Horava-Lifshitz gravity, and pointed out it might

lead to scale-invariant primordial power spectrum, which suggest that it may play the role of inflaton.

We argued that the self-consistency of HL gravity required the projectability condition, under which the only static spherical solution is Schwarzschild(-dS). Our study suggest that

there is no correction to solar system test in HL gravity.

We constructed the renormalizable actions for the scalar and abelian vector field at a Lifshitz

point characterized by the dynamic critical exponent z. We suggested that the time delay

in gamma-ray bursts could be naturally explained in our framework.

Selected Reprints：

[1] Real-time Correlators and Hidden Conformal Symmetry in Kerr/CFT Cor-

respondence;Bin Chen and Jiang Long; JHEP 1006:018,2010;

[2] Self-DualWarped AdS3 Black Holes; Bin Chen and Bo Ning; Phys. Rev. D82,124027

(2010);

[3] Supersymmetric Wilson Loops in N=6 Super Chern-Simons-matter theory;

Bin Chen and Junbao Wu; Nucl.Phys.B825:38-51,2010;

[4] Scale Invariant Power Spectrum in Horava-Lifshitz Cosmology without Mat-

ter; Bin Chen, Shi Pi and Jin-Zhang Tang; JCAP 0908:007,2009.

13 量子材料科学中心
International Center for Quantum Materials

量子材料科学中心是北京大学于 2010 年 1 月成立的一个新型教学与科研机构 . 中心现有科研人员 14 人，其中讲座教授 4 人，教授 2 人，副教授 7 人，助理教授 1 人，均担任博士生导师。成员中 1 人入选中科院院士，3 人入选中组部“千人计划”，3 人入选中科院“百人计划”，3 人获得国家杰出青年科学基金。

中心的主要研究领域是凝聚态物理和量子材料科学。目前具体研究方向及内容包括：量子输运、关联电子现象、低维电子气的量子行为、凝聚态物理中的拓扑效应、介观超导体系、量子材料和器件的制备和物性研究、自旋电子学、表面量子行为、先进扫描探针显微学、超冷原子气、介观量子效应、 量子材料物性的第一性原理计算、 超快光谱学、软物质中的相变及临界现象、玻璃材料的性能和形成机理、单分子尺度上的物理化学、多尺度物性研究等。

International Center for Quantum Materials (ICQM) is a newly-founded research and education center at Peking University. Its current academic staff comprises 4 Chair Professors, 2 tenured Professors, 7 tenure-tracked Associate Professors and 1 tenure-tracked Assistant Professor.

ICQM research is dedicated to a wide range of subjects in the general area of condensed matter physics and quantum materials science. Topics and systems of current interest include quantum transportation, strong-correlated electron systems, low-dimensional electron systems, topological effects in condensed matter physics, mesoscopic superconducting systems, spintronics, advanced scanning tunneling microscopy, ultra-cold atoms, computational simulations for quantum materials, ultra-fast spectroscopy， phase transitions in soft matters, physical chemistry at the single molecule level, and etc..

一、电场驱动的氧化铈相变过程及其机理

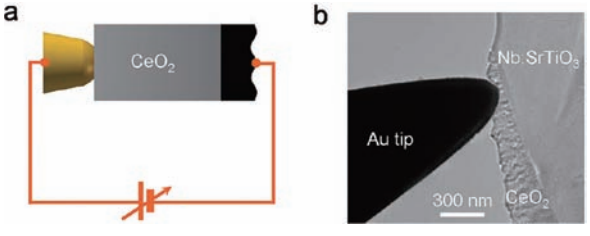
通过在透射电镜中对样品引入外电场，原位研究了调控偏压后氧化铈薄膜的动力学相变过程。首次在常温下观测到电场引起的从二氧化铈到三氧化二铈的还原过程；以及当撤掉电场后，三氧化二铈又被氧化生成二氧化铈的可逆循环反应。

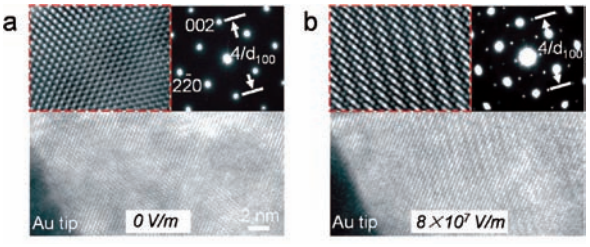
系统研究了电场对氧化铈中氧空位势垒改变以及扩散通道的影响。

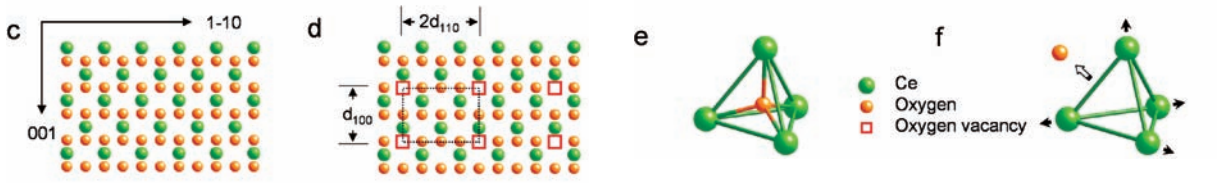
提出电场诱导相变的新机制，为解决室温下有效处理汽车尾气污染等相关问题提供了一种新思路。

代表文论：

Peng Gao, Zhenchuan Kang, Wangyang Fu, Wenlong Wang, Xuedong Bai,* and Enge Wang*, “Electrically driven redox process in cerium oxides”, J. Am. Chem. Soc.132, 4197-4201(2010)。







一、Electrically Driven Redox Process in Cerium Oxides

The dynamic changes taking place during the electrically driven redox reaction have been imaged by in situ high-resolution transmission electron microscopy, where reversible phase transformations induced by oxygen vacancies have been reproducibly achieved.

The formation and migration mechanism of oxygen vacancy under the applied electrical field has been studied systematically.

A novel electrically driven redox process of cerium oxides has been proposed at low temperature, which will be useful to improve the performance of the catalysts and reduce car pollution under the cold-start condition.

Representative Article：

Peng Gao, Zhenchuan Kang, Wangyang Fu, Wenlong Wang, Xuedong Bai,* and Enge Wang*, “Electrically driven redox process in cerium oxides”, J. Am. Chem. Soc.132, 4197-4201(2010).

二、玻色 - 爱因斯坦凝聚物中的隐涡旋

我们在数值上研究了旋转双阱势中玻色 - 爱因斯坦凝聚物 (BEC) 里的涡旋形成 [1]。图 1 是我们得到的一个典型结果。从图 1(a) 中可以清晰地看到，由于双势阱的存在，BEC 被分为两块，每块中有同等数量的涡旋，并且涡旋大致按熟知的三角晶格分布。我们同时在图 1(b) 中画出了该 BEC 的相位分布。对比图 1(a) 可以看到，在中间势垒处和 BEC 的边缘有很多相位奇点在图 1(a) 中没有涡旋对应。原因很简单，这些部位的 BEC 浓度太低，涡旋显示不出来。这个现象早就被其它研究者注意到，并被称为“鬼涡旋”[2]。这些研究者进一步发现鬼涡旋不带角动量。

但我们发现中间势垒处的相位奇点和边缘处的相位奇点是不一样的，它们带有角动量。因而称其为隐涡旋。关于超流体中的涡旋个数有个著名的费曼规则 [3]。具体说，这个规则要求 lz = Nt/2，其中 lz 是每个原子的角动量，Nt 是涡旋的总数。对于图 1 中的例子，我们的数值结果给出 lz _ 16，而图 1(a) 中的涡旋数是 18。只有把中间势垒处的相位奇点个数算上，费曼规则才正好被满足。这就表明中间势垒处的相位奇点带角动量，不同于边缘处的鬼涡旋。我们进一步的研究表明，隐涡旋的存在具有普遍性，它可以出现许多其它阱势中，例如旋转的环形势阱中。这样，涡旋可以分为三种基本的类型：普通的涡旋（或许可以叫“显涡旋”), 鬼涡旋 , 和隐涡旋。

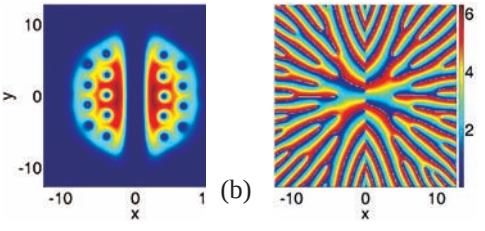
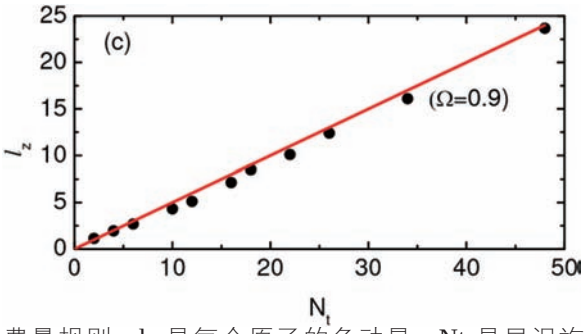


图 1：当系统达到稳态时，旋转双阱中玻色 - 爱因斯坦凝聚物的 (a) 密度分布 (b) 相位分布。(c)



费曼规则。lz 是每个原子的角动量，Nt 是显涡旋和隐涡旋的总数。根据费曼规则应有 lz = Nt/2(红线)；数值结果是圆点。

Figure 1: (a) Density distribution and (b) phase distribution of a Bose-Einstein condensate in a rotating double-well potential when the system has reached a steady state. (c) Feynman’s rule. lz is the angular momentum per atom and Nt is the total number of visible vortices and hidden vortices. The solid line is for Feynman’s rule, lz = Nt/2. The circles are for numerical results.

参考文献：

[1] L. Wen, H. W. Xiong, and B. Wu, Physical Review A 82, 053627 (2010).

[2] M. Tsubota, K. Kasamatsu, and M. Ueda, Phys. Rev. A 65, 023603 (2002); K. Kasamatsu, M. Tsubota, and M. Ueda, Phys. Rev. A 67, 033610 (2003).

[3] R. P. Feynman, Application of Quantum Mechanics to Liquid Helium (Progress in Low Temperature Physics vol I) ed C. J. Gorter (North-Holland, Amsterdam, 1955).

二、Hidden vortices in a Bose-Einstein condensates

We have studied numerically vortex formation in a Bose-Einstein condensate in a rotating double-well potential[1]. Shown in Fig. 1 is one of our typical results. In Fig.1(a), it is clear that a BEC is divided into two equal parts, and each part is filled with a symmetric vortex array of the well-known triangular structure. We have also plotted the phase distribution of the same BEC in Fig. 1(b). Comparing with Fig.1(a), we see that there are many phase singularities in the region of the central barrier and the outskirts of the BEC, which have no corresponding vortices in Fig. 1(a). The reason is simple: the cloud density is too low in these regions to manifest these phase singularities. This is known in the literature and, in fact, these phase singularities are called “ghost vortices” [2]. The research shows that these ghost vortices do not carry angular momentum.

However, our further analysis shows that the phase singularities in the central region are different from the ones at the outskirts: they carry angular momentum. For the vortex number in a superfluid, there is a well-know Feynman’s rule[3]. The rule says lz = Nt/2, where lz is the angular momentum per atom and Nt is the total number of vortices. For the case in Fig.1, our numerical result shows that lz _ 16 while the number of vortices inFig.1(a) is 18. The Feynman’s rule is satisfied only after including the number of phase singularities in the central region. This indicates that these phase singularities carry angular momentum and they are not ghost vortices. Wecall them hidden vortices. We have also found that hidden vortex is a general phenomenon, which can happen in

many other situations, for example, rotating anisotropic rings. As a result, we can say that there are three typical vortices: the usual vortex (maybe call visible vortex), ghost vortex, and hidden vortex. (See Figure 1)

References:

[1] L. Wen, H. W. Xiong, and B. Wu, Physical Review A 82, 053627 (2010).

[2] M. Tsubota, K. Kasamatsu, and M. Ueda, Phys. Rev. A 65, 023603 (2002); K. Kasamatsu, M. Tsubota, and M. Ueda, Phys. Rev. A 67, 033610 (2003).

[3] R. P. Feynman, Application of Quantum Mechanics to Liquid Helium (Progress in Low Temperature Physics vol I) ed C. J. Gorter (North-Holland, Amsterdam, 1955).

三、高分辨率电子能量损失谱仪探测电 - 声耦合矩阵元

确定电子与体系内各种原激发的耦合的具体形式对于理解关联系统中各类物理现象具有关键作用。例如，对于高温超导体系，如果能够确定电 - 声耦合的具体形式，就可以判断其与高温超导电性机理的相关性。我们此前发展了利用角分辨光电子谱获取电子 - 玻色子耦合谱函数的最大熵方法，通过探测电子的色散在低能下的扭折（kink），获取描述电子 - 玻色子耦合的 Eliashberg 函数 [1]。该技术已应用于一系列高温超导材料 [2]。但是，当这一技术应用于高温超导材料和其他复杂的强关联体系时，仍有一定的局限性。一方面，由于高温超导材料的电子结构具有很强的各向异性，用上述方法无法获得电 - 玻色耦合各向异性的完整信息；另一方面，由于高温超导材料具有 d 波超导配对对称性，而电子色散的重整化只与电 - 玻色耦合中的 s- 波分量相关，所以即使配对是由探测到的电 - 玻色耦合引起，也无法通过测量电子色散获取相关的耦合分量。

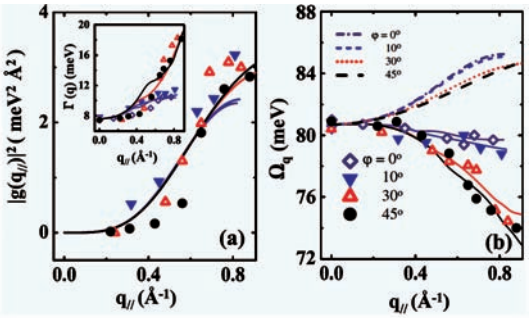


FIG. 4 (color online). (a) $|g_q|^2$ determined by Eqs. (1)–(3) and the fitting (solid lines) to Eq. (4) with $a = 0.47$ meV Å and $b = 0.29$ meV Å. The inset shows the measured $\Gamma(q)$ as well as the data calculated with $|g_q|^2$ for different φ. (b) Measured $\Omega(q)$ with data calculated with Eq. (5). Here we assume a bare phonon dispersion $\Omega^{\text{bare}} = 83.5 - 1.16[\cos(q_x a_0) + \cos(q_y a_0)] - 1.11\cos(q_x a_0)\cos(q_y a_0) + 0.32[\cos(2q_x a_0) + \cos(2q_y a_0)]$(meV), as plotted in broken lines.

针对这些问题，我们与中科院物理所的郭建东实验小组合作，发展了直接确定关联系统中电声子耦合矩阵元的新方法。这个方法利用高分辨率电子能量损失谱技术测量电 - 声耦合对声子的影响，即声子模式的色散重整化和寿命，通过对它们的分析，并综合角分辨光电子发射谱确定的电子结构，反演出不同电子初态与末态动量之间的电 - 声耦合矩阵元。这种方法原理上可以获得电声子耦合各向异性的完整形式。目前，利用这一方法，我们已完成了对 Bi2Sr2CaCu2O8+δ 体系中一只光学支声子电声耦合的测定。文章发表在 Physical Review Letters 上 [3]。

参考文献：

[1] Junren Shi et al., Phys. Rev. Lett. 92 , 186401 (2004).

[2] X. J. Zhou, Junren Shi, et al., Phys. Rev. Lett. 95 , 117001 (2005); W. Meevasana et la., Phys. Rev. Lett. 96, 157003 (2006).

[3] Huajun Qin, Junren Shi, Yanwei Cao, Kehui Wu, Jiandi Zhang, E. W. Plummer, J. Wen, Z. J. Xu, G. D. Gu, Jiandong Guo, Phys. Rev. Lett. 105, 256402 (2010) .

三、Direct Extraction of the Electron-Phonon Coupling Matrix Elements from the High Resolution Electron Energy Loss Spectroscopy

The interaction between electrons and various collective excitations (bosons) is the central gradient for understanding many of the novel physical properties in condensed-matter systems. For instance, a thorough understanding of the electron-phonon coupling (EPC) in high-Tc compounds will help to determine its relevance to the superconductivity in these systems. A few years ago, we developed a maximal-entropy method to directly extract the spectral function of EPC from the kink of the quasi-particle dispersion measured by the angle-resolved photoelectron spectroscope (ARPES) [1]. The technique had been applied to the investigations of a number of high-Tc compounds [2]. However, the method suffers a couple of shortcomings when applied to the high-Tc compounds and other complex systems. First, the electronic structures of these systems have strong anisotropy, and the method cannot determine the full structure of the anisotropic EPC. Second, the d-wave superconductivity pairing in these compounds is only possibly relevant to the EPC components that cannot be detected by the ARPES measurements.

In collaboration with Jiandong Guo’s group in Institute of Physics, Chinese Academy of Sciences, we have developed a new method for determining the full structure of the EPC matrix-elements, and to overcome the shortcomings of the existing method. We utilize the data from the high-resolution electron energy loss spectroscopy (HREELS), which measures the impact of the EPC to the phonons, such as the renormalization to the phonon dispersion and lifetime. With the help of the detailed electronic structure obtained from the ARPES measurement, we could determine EPC matrix elements between all the initial and final electron states. Using this method, we have determined the EPC matrix elements for an optical phonon branch in Bi2Sr2CaCu2O8+ δ compound. The paper was published in Physical Review Letters [3].

References：

[1] Junren Shi et al., Phys. Rev. Lett. 92 , 186401 (2004).

[2] X. J. Zhou, Junren Shi, et al., Phys. Rev. Lett. 95 , 117001 (2005); W. Meevasana et la., Phys. Rev. Lett. 96, 157003 (2006).

[3] Huajun Qin, Junren Shi, Yanwei Cao, Kehui Wu, Jiandi Zhang, E. W. Plummer, J. Wen, Z. J. Xu, G. D. Gu, Jiandong Guo, Phys. Rev. Lett. 105, 256402 (2010).

14 北京大学科维理天文与天体物理研究所 The Kavli Institute for Astronomy and Astrophysics (KIAA)

科维理天文与天体物理研究所（Kavli Institute for Astronomy and Astrophysics，KIAA — PKU）是北京大学和美国科维理基金会合作于 2006 年 6 月成立并于 2008 年开始运行，首任所长是美国艺术与科学院院士、著名理论天体物理学家林潮（Douglas N. C. Lin）教授。研究所致力于成为中国和亚太地区一个国际一流的天文与天体物理研究中心和人才培养基地，以国际最高水准推动基础科学研究在中国的发展，主要从事以下几个领域的研究：1. 宇宙学和星系的形成；2. 引力物理和高能现象；3. 星际介质，恒星和行星。研究所实行与国际接轨的管理运行机制并在全球公开招聘研究人员和博士后，工作语言为英

语。研究所现有教授 5 人、百人计划研究员 3 人、博士后 7 人，以上人员中一半左右为外籍。

The Kavli Institute for Astronomy and Astrophysics (KIAA)is jointly supported by its host Peking University and an endowment made possible by a generous gift from the Kavli Foundation, USA. KIAA was established in June, 2006 and started operation in 2008. Professor Douglas N.C. Lin, a leading theoretical astrophysicist based at UC Santa Cruz and a member of the American Academy of Arts and Sciences, was appointed as the founding Director of KIAA. KIAA's mission is to establish an international center of excellence in astronomy and astrophysics which promotes the development of basic science in China. Its primary goal is to foster frontier research in a vibrant intellectual environment. The initial program of KIAA will be focused in the theoretical studies of three major areas of astrophysics: a) Particle cosmology, first light and galaxy assemblage; b) Gravitational physics and high-energy phenomena; and c) Star and planet formation. KIAA operates following an international management system and recruits faculty and post-doctors worldwide, using English as its working language. There are 5 professors, 3 “Bairen” research professors and 7 post-doctors in KIAA. About half of the above members are non-Chinese-nationality.

一、等级成团与银河系形成过程的研究

在过去的两年中，我承担了一些与银河系形成机制有关的研究。最近一些年来，等级成团理论已经成为星系形成与演化的重要机制之一。这个理论认为，较大的结构是由较小的结构并和形成的。星系在其形成与演化过程中必然要经历很多并和过程并留下痕迹。根据这个理论，我们试图寻找并分析能够反映银河系形成过程的痕迹。我和来自清华和北大的学生已经就这一问题做了相当的研究。我们主要使用 SDSS（Sloan Digital Sky Survey）等观测的大型数据库以及来自欧洲合作者的最新数值模拟数据，并采用更合理的数据分析方法研究这个问题。已经开始的研究项目有：

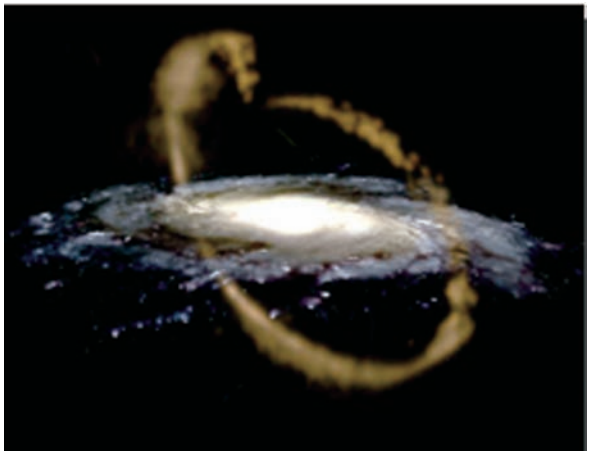


图 1：正在被银河系撕裂的人马座矮星系艺术想象图。围绕银河系两极的巨大的圆弧就是人马座碎片（包含恒星和气体）。取自 David Martinez-Delgado & Gabriel.

Figure 1: An artists impression of the disruption of the Sagittarius Dwarf satellite galaxy, which is currently in the process of being ‘devoured’ by the Milky Way. These large arcs encircling the Milky Way show Sagittarius debris (i.e. stars and gas), which is being torn away as it orbits the Milky Way. Credit: David Martinez-Delgado & Gabriel Perez.

1. 从 SDSS 观测数据证认与分析人马座碎片

SDSS 观测包含数以万计的恒星分光数据。我们证认并分析了人马座碎片，它是由于人马座矮星系（Sagittarius dwarf galaxy）受到银河系巨大的潮汐引力影响，被撕裂形成的。通过探测其性质，可以更好的限制对人马座碎片形成的模拟，从而更加准确的测定其前身星系的质量以及银河系的引力势。

2. 应用受到引力透镜影响的类星体探测银河系的结构

银河系的恒星或者恒星遗迹（黑洞、中子星或白矮星等）会对类星体产生引力透镜效应，由透镜效应可以反过来测定恒星的质量，从而能直接测定银河系的质量分布，而不是从光度分布得出质量分布。因此，若要更好的理解银河系的结构，这是一个重要的工具。考虑到将来要进行的大面积巡天观测，我们同时会研究这种方法在限制银河系质量分布上的效率。

3. 对银河系盘中的速度椭球倾角的分析

应用来自欧洲合作者的最新的星系盘形成模拟，我们研究数值模拟结果是否与观测相符。我们已经分析了这些模拟星系盘的运动学特征，并研究了不同的盘形成机制会对这些运动学特征产生什么样的影响。我们的结果显示在银河系的太阳半径处速度椭球总是指向星系中心，这与我们从 SDSS 和 RAVE 得到的观测结果相符。未来的观测，特别是中国的 LAMOST，将会给出更加精确的观测量，这有利于更加有效的限制模型参数。

到目前为止，我们就这些课题已发表论文一篇，并在一些国际会议上做了研究报告。这些研究项目除了具有国际上的重要性，同样能够有效的培养学生的科研能力。因此，当中国的巡天项目丰收之时，这些学生能够很快的投入到相关的科研中去。

一、The hierarchical growth scenario and the Galaxy

Over the course of the past two years we have undertaken a number of studies aimed at addressing how our galaxy, the Milky Way, formed. In recent years theories have converged on the hierarchical growth scenario, where structures are built up from the aggregation of smaller building blocks. By working with students both from Peking University and Tsinghua we have been carrying out the next crucial step, which is to identify and then analyse the signatures which remain today. We have addressed this issue through a number of complimentary approaches, utilising large public databases, such as the Sloan Digital Sky Survey (SDSS), and some of the latest numerical simulations from my collaborators in Europe. These projects range from analysing the structure of our Galaxy, to looking directly at the accretion events which are ongoing today. The main projects that I have been carrying out are:

1. A sample of Sagittarius debris from SDSS

The SDSS catalogue contains spectroscopic data for many tens of thousand stars. We have identified and analysed debris from one these building blocks, the Sagittarius dwarf galaxy, which is currently in the process of being ‘devoured’ by the Milky Way. Using this data we can place important constraints on simulations of the Sagittarius debris, which in turn can determine the mass of the progenitor and also the gravitational potential of the Milky Way.

2. Using lensed quasars to probe the structure of the Milky Way

In this project we investigated the gravitational lensing of quasars by stars and stellar remnants in the Milky Way, making predictions for future large-area sky surveys. This technique can be used to measure the masses of stars and also to probe the structure of the Galaxy - the most powerful aspect of this is that gravitational lensing probes the distribution of mass (which is unlike most other methods which probe the distribution of light). Therefore if we wish to understand the mass distribution of the Milky Way, which is crucial if we wish to understand its assembly, then this will be an important tool.

3. The orientation of the velocity ellipsoid in the Milky Way disc

Using state-of-the-art simulations of disc formation from my collaborators in Europe (Villalobos & Helmi 2008, 2010; Roškar et al. 2008, 2010), we are testing whether the predictions of these models match what we see around us. We have analysed the kinematic signatures of disc formation and investigated how these vary between these different simulations, which use different formation mechanisms. Our most important result is that the velocity ellipsoid is almost always orientated towards the Galactic centre, as has been observed by surveys such as SDSS and RAVE. Future surveys, in particular the Chinese LAMOST telescope, will be able to make more accurate measurements of this quantity and make firm tests of these simulations.

This has resulted in one publication and a number of presentations at international conferences, given both by me as well as my students. In additional to carrying out projects which are of international importance, these studies also help by training students. As a consequence, when Chinese surveys begin to bear fruit, these students will be ideally placed to carry out the scientific exploitation immediately.

学生活动 *Students*

在学院领导和老师们的高度重视和悉心培育下，同学们展现出骄人的成绩。以 2010 年为例，我院共有 192 名同学获得校级奖励，其中本科生 96 人，研究生 96 人，均占总人数的 15.89%。另外，共有 18 名同学获得院级奖学金，其中包括研究生和本科生各 9 人。

In the year 2010, a total of 192 undergraduate and graduate students in Peking University School of Physics earned their honors and awards on the university level, which account for 15.89% of total student number. Another 18 students won honors and awards on the school level.

2009 年物理学院迎新
New Arrival of Students in 2009

物理学院 2009 年毕业典礼
Graduation Ceremony in 2009

在院团委的指导下，物理学院学生会、研究生会举办了各类学术、文体活动，极大地丰富了物理学院学生的课余生活。其中包括：钟盛标学术论坛、萃英学术沙龙、新生辩论赛、“动量杯”系列体育比赛、飞跃交流会、定向越野大赛、春秋院衫订制、元旦晚会、中秋晚会等。

Seminars and activities of various kinds were held by the Student Union and the Graduate Association of the Physics School to enrich the students’ extracurricular life. These included the “Paul Shin-Piaw Choong Graduates’ Seminar,” Elite Academic Salon, Freshmen’s Debate Contest, “The Momentum Cup” Sports Contest, “Go abroad” Exchange Meetings, Directional Off-road Contest, School T-shirt Design Contest, the New Year’s Party, and the Mid-autumn Day’s Party, etc.

第八届北大物理“钟盛标物理教育基金”研究生学术论坛开幕
The Opening Ceremony of the Eighth “Paul Shin-Piaw Choong Educational Fund for Physics” Graduates’ Seminar at the School of Physics

第七届“北京大学钟盛标物理教育基金”暨第三届“北京大学钟陈玉　基金”颁奖典礼
The Award Ceremony of the Seventh “Paul Shin-Piaw Choong Educational Fund for Physics” and of the Third “Zhong & Chen Fund”

钱三强夫妇优秀科学家先进事迹报告会
Report on Qian Sanqiang’s Exemplary Stories

2009 年物理学院学生会合影
The School’s Student Union in 2009

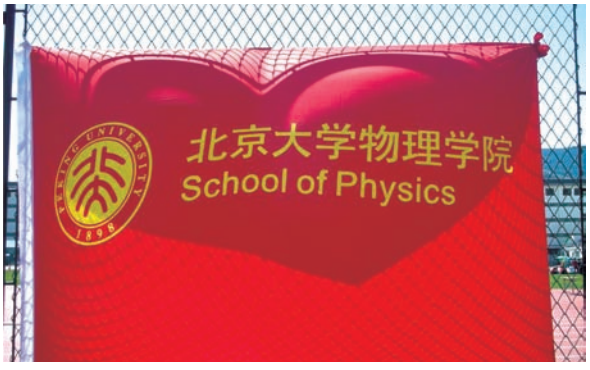
2010-2011 物理学院团校开学典礼
The Opening Ceremony of 2010-2011 Youth League School

院衫图案 2007-2008 款
The 2007-2008 School T-shirt Designs

此外，学生们还积极参与“挑战杯”五四青年科学奖竞赛，“江泽涵杯”数学建模与计算机应用竞赛”，“一二九”合唱比赛，“北大杯”各项体育赛事以及暑期社会实践活动，均取得不俗成绩，彰显了北大物院学生的卓越风采。

Physics students also took active part in university-held activities and contests, such as “The Challenge Cup” May 4th Youth Science Contest, “The Jiang Zehan Cup” Mathematics Modeling and Computer Application Contest, “The Dec 9th” Chorus Contest, “The PKU Cup” sports contest series and summer activities. The good results harvested in these activities and contests demonstrated the excellence and spirit of our students.

2009 年运动会力争上游
Students in 2009 Sports Games

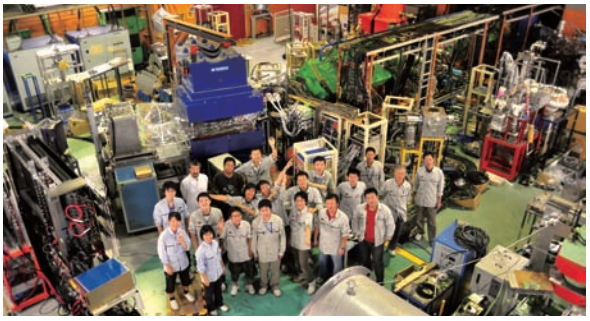


院旗 The School’s Flag

2010 年 12.9 合唱之一
Students at Chorus Performance 2010

2010 年 12.9 合唱之二
Students at Chorus Performance 2010

2009 级军训之艰苦训练
Students in Military Training 2009



2009 年 8 月，北京大学实验核物理组自主提出并在在日本理化所顺利完成了极端丰中子核 ^{8}He 的敲出反应实验。
In August 2009, the Peking University experimental nuclear physics group had proposed and successfully carried out a knockout reaction experiment for the extremely neutron rich nucleus ^{8}He.

面对新的机遇和挑战，北京大学物理学院在学科布局、队伍建设、人才培养等方面迈开新的步伐：着力引进和培养杰出的学科带头人和优秀的青年后备人才，新增多位“千人计划”、“长江学者”和“百人计划”研究员；继续探索和完善素质教育培养体系，建设“未名物理学子班”；进一步活跃学术研讨氛围，创办“百年物理讲坛”、“格致青年学术论坛”等高端学术活动；广泛建立与国内外一流大学和科研机构的合作关系，更大范围提升物理学院的国际影响力。

The School of Physics has made great efforts in improving subjects, attracting talents and cultivating students to cope with new challenges in the new century. We attracted and trained leading innovative talents and outstanding young men and students through “A Thousand Talents Project,” “The Yangtse River Scholar Project,” “A Hundred Researchers Project,” etc.; new ways such as “The Weiming Lake Physics Students’ Class” were created to enable students’ all-round development; a free and active research atmosphere was maintained by introducing the “Centennial Physics Lecture,” “The Physics Young Talents’ Seminar” and other high-end academic activities; we worked very hard to strengthen our external relationships with domestic and international leading universities and institutes to exert a greater impact upon the world.

校友与基金
Alumni and Funds

2009 年 6 月 6 日，北京大学物理学院召开第一届校友大会和校友会第一次理事会。

In June 2009, the Peking University School of Physics held its first alumni association meeting and the first session of board meeting.

2010 年 5 月召开了北京大学物理学院校友会第二次理事会议。物理学院院长王恩哥担任会长。6 月，参与组织由北京大学、中国物理学会和高等教育出版社联合主办的“物理教育研讨会暨赵凯华先生八十寿辰庆祝会”。10 月，为中国工程院院士、电磁与微波技术专家陈敬熊先生庆贺 90 岁寿辰。

In May 2010, the school held its second board meeting of alumni association. Dean Enge Wang assumed the role of the chairman. In June, the school participated in organizing “The Physics Education Seminar—Professor Kaihua Zhao’s Eightieth Birthday Celebration Party” jointly held by Peking University, China Physical Society and Higher Education Press. In October, the school celebrated the ninetieth birthday for the academician of the Chinese Academy for Engineering, the outstanding expert on electromagnetism and microwave technology, Professor Jingxiong Chen.

北京大学物理学院校友会第二次理事会议
The Second Session of Peking University School of Physics Alumni Association Board Meeting

陈敬熊先生庆贺 90 岁大寿庆祝活动
Professor Jingxiong Chen’s Ninetieth Birthday Celebration Activity

物理教育研讨会暨赵凯华先生八十寿辰庆祝会
The Physics Seminar and Professor Kaihua Zhao’s Eightieth Birthday Celebration Party

赵凯华老师
Professor Kaihua Zhao

结合学生就业需求，创办“周末职业发展”校友论坛，向同学们介绍不同行业特点，引导大家结合自身特点，制定成熟理性的职业发展规划。

In order to serve our students’ career development needs, the school alumni association has launched the “Weekend Career Development” alumni lecture series to render students a comprehensive view of different industries and positions and help them make rational decisions related to career development.

2001 级校友臧充之与同学们交流
The 2001’s Alumnus Chongzhi Zhang Talks with Students

2000 级校友赵志俊、张万成与同学们交流
The 2000’s Alumni Zhijun Zhao and Wancheng Zhang

80 级阚睿、数院 85 级白学政出席金融分享会
Alumni Representatives Rui Kan and Xuezheng Bai

举办 86 级校友毕业二十周年返校活动
The 1986’s Alumni Gathering after 20 years of Graduation

举办 00 级校友入学十周年交流会
The 2000’s Alumni Meeting with Students

2009 年校友新年聚会
Alumni New Year Party 2009

举办 2011 校友新年酒会
The 2011 Alumni New Year’s Party

本年度，学院共 8 项奖助金参与评审和颁奖活动。其中，77 物理班级基金奖励 5 人，使用金额￥25,000.00，账户余额￥61,654.51；80 物理兰怡女子助学金奖励 2 人，使用金额￥10,000.00，账户余额￥5,184.05；88 物理班级基金奖励 4 人，使用金额￥40,000.00，账户余额￥54,773.11；克诚奖学金奖励 4 人，使用金额￥20,000.00，账户余额￥00,000.00；陈互雄物理教育基金奖励 13 人，使用金额￥27,500.00，账户余额￥2,757,707.82；钟盛标物理教育基金奖励 97 人，使用金额￥97,000.00，账户余额￥547,151.16；胡宁奖学金奖励 1 人，使用金额￥5,000.00，账户余额￥80,000.00；帝光奖学金奖励 40 人，发放金额￥67,500.00。

In 2010, the school issued 8 items of student scholarships and aid funds. Specifically, the ’77 Physics Class Fund was awarded to 5 students with ￥5,000.00 per student; the ’80 Ellen Yi Lan Woman Physicist Scholarship was awarded to 2 students with ￥5,000.00 per student; the ’88 Physics Class Fund was awarded to 4 students with ￥10,000.00 per student; the Kecheng Scholarship as awarded to 4 students with ￥5,000.00 per student; the Chen Huxiong Educational Fund for Physics was awarded to 13 teachers and students with the total expense of ￥27,500.00; the Paul Shin-Piaw Choong Educational Fund for Physics was awarded to 97 teachers and students with the total expense of ￥97,000.00; the Hu Ning Scholarship was awarded to 1 student for ￥5,000.00; the Di Guang Scholarship was awarded to 40 teachers and students with the total expense of ￥67,500.00.

校友基金项目：
Alumni Funds:

校友捐赠基金 Alumni Funds	创立时间 Time of Establishment
叶企孙实验物理基金 Qisun Ye Experimental Physics Fund	1987
冯溪乔奖学金 Shechao Charles Feng Scholarship	1996
谢义炳基金 Xie Yibing Fund	1996
77 物理班级基金 ’77 Physics Class Fund	2002
钟盛标物理教育基金 Paul Shin-Piaw Choong Educational Fund for Physics	2002

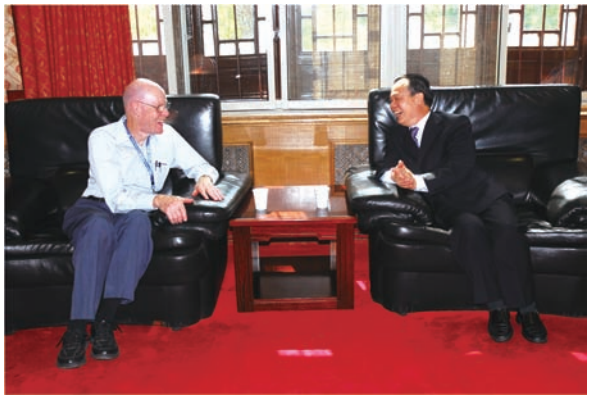
80 物理兰怡女子助学金 80 Ellen Yi Lan Woman Physicist Scholarship	2005
86 物理班级基金　86 Physics Class Fund	2005
88 物理班级基金　88 Physics Class Fund	2006
克诚奖学金　Kecheng Scholarship	2006
德康霓克奖学金 (校级项目)　Taconic Scholarship (University level)	2006
帝光奖学金　Di Guang Scholarship	2007
陈互雄物理教育基金　Huxiong Chen Educational Fund for Physics	2008
冯溪乔特别奖学金　Shechao Charles Feng Special Scholarship	2008
胡宁奖学金　Ning Hu Scholarship	2008
赵凯华基金　Kaihua Zhao Educational Fund for Physics	2010
求索奖学金　Truth-seeking Scholarship	2011
张文新教育基金　Wenxin Zhang Educational Fund for Physics	2011
海鸥奖学金　Ou Hai Scholarship	2011

合作与交流
Cooperation

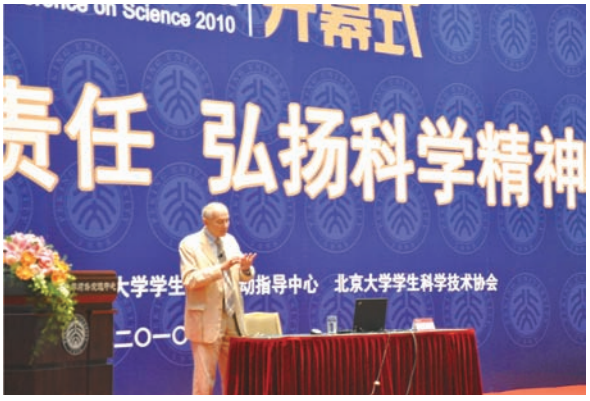
一、格物明理，接轨国际　The Centennial Physics Lecture

为进一步提升学院的国际影响力，为广大师生创造更多与国际学术大师直接交流的机会，学院广泛建立与国际一流大学和科研机构的合作关系，2010 年创办“北大百年物理讲坛”，并先后邀请了 Anthony J. Leggett（美国伊利诺伊大学）、Robert W. Wilson（美国贝尔电话实验室）、James W. Cronin（美国芝加哥大学）、Daniel C. Tsui（美国普利斯顿大学）Johannes Georg Bednorz（瑞士 IBM）五位诺贝尔物理学奖得主和多位国际顶尖的物理学家来到燕园进行学术访问。这一系列的学术盛宴，在校内外引起了良好的反响，也为即将到来的“北大物理百年”庆典拉开了序幕。

Anthony. J. Leggett（美国伊利诺伊大学）



Robert. W. Wilson（美国贝尔电话实验室）



James W. Cronin（美国芝加哥大学）

Daniel C. Tsui（美国普利斯顿大学）

Johannes. Georg. Bednorz（瑞士 IBM）

In order to further enhance the school’s international repute, we have launched the “Centennial Physics Lecture at Peking University” to create more opportunities for academic exchange and international corporation. In the year 2010, we invited five Nobel laureates and many other worldly-renowned physical scientists to give lectures and exchange ideas at the school, including Anthony J. Leggett, Robert W. Wilson, James W. Cronin, Daniel C. Tsui and Johannes Georg Bednorz. This series of academic exchanges serves as a prelude for the celebration of centennial physics at Peking University in 2013.

二、邀请报告与合作交流　Invited Talks and Exchange Meetings

2010 年度，学院按计划举办多项外事活动、接待顺访外宾及代表团，推动学术交流与合作进一步发展。具体工作如下：

In 2010, the school held many international talks and meetings to activate academic exchange and international coorpoation.

日本大阪大学两位副校长率领代表团，一行近 30 人，专程前来参加北京大学－大阪大学学术

交流日活动。阪大理学院院长 Kiyoshi Higashijima 教授和物理系主任 Yutaka Hosotani 教授就自己所从事的研究，做了十分精彩的报告。

In September, a group of 30 professors led by two vice presidents of Osaka University arrived at Peking University to participate in the "Peking University—Osaka University Exchange Day" activities. Kiyoshi Higashijima, head of the Science Academy at Osaka University and Yutaka Hosotani, dean of the Physics Department both gave brilliant lectures and exchanged with physics teachers and students.

《物理评论快报》（PRL）编辑主管 Daniel T. Kulp 博士，责任编辑 Ling Miao 博士和助理编辑 Sarma Kancharla 博士访问我院。学院王恩哥院长在北京大学国际量子材料中心会见了三位来访客人和陪同人员。会后，依次参观了物理学院光学实验室，半导体实验室和科维理天文与天体物理研究所。

In October, Physical Review Letters chief editor Dr. Daniel T. Kulp, executive editor Dr. Ling Miao and assistant editor Dr. Sarma Kancharla visited our school. After meeting with Dean Enge Wang at the International Center for Quantum Materials, the editor group visited the Institute of Modern Optics, the Laboratory for Semi-conductor, and the Kavli Institute for Astronomy and Astrophysics at Peking University.

朝鲜金日成综合大学数学力学部党委书记洪显表、教育科学研究中心所长李冠豪到物理学院参观访问，院党委副书记郑涛接待了到访的来宾。洪显表书记、李冠豪所长就学科设置、课程安排、招生就业、经费管理、科研情况等方面与郑涛老师展开热烈交流。

The Party Secretary Mr. Xianbiao Hong and the head of the Research Center of Education Science Mr. Guanhong Li of Kim Il-sung University North Korea visited our school. Our deputy Party Secretary Mr. Tao Zheng met with visitors and exchanged with them on subjects setting, courses planning, students admittance and employment, budget management, research development and so on.

2010 年 12 月 20 日，北京大学举办"北京大学台湾大学日"活动。下午，来访团与相关院系进行学术交流，并商讨合作意向。台大理学院院长罗清华提到，台大和北大在物理学领域的交流传统由来已久，目前合作的条件也较为成熟。他希望由物理学院牵头，充分加强双方系所中心和相关教授之间的联系，切实推进两院年轻教师互访和学生暑期学校项目，逐步落实两校共同发展大计。

In December 20th 2010, Peking University held

its “Taiwan University Day” activities. In the afternoon, visitors from the academy of science met with our teachers. Dean of the academy Prof. Qinghua Luo mentioned in their meeting that our two schools shared a long history of bilateral coorporation. He hoped that we can take our relationship to the next step by substantially strengthening the ties between professors and students on both sides.

物理学院 2010 年新生大会上，邀请到燕京大学物理系首任系主任 Paul A. Anderson 教授之子、哈佛大学教授 James G. Anderson 做了一个关于气候变化的特邀报告。此前，Anderson 教授还与物理学院大气与海洋科学系、环境学院的相关科研人员展开了富有意义的学术交流，并探讨了未来可能的合作方向。

Prof. James G. Anderson of Harvard University, son of the first dean of the Physics Department at Yenching University Paul A. Anderson, was invited to give a special report on climatic change at the 2010 freshmen’s meeting. Prof. Anderson also met with scholars at the Department of Atmospheric and Oceanic Sciences as well as at the School of Environment to discuss future collaborative opportunities.

三、国际访问学者 International Visitors

2010 年物理学院在国际学术交流方面十分活跃。先后约 100 多位国际知名学者来我院从事长期或短期的学术活动。

The international exchange is very active during the last year. More than 100 internationally renowned scholars have visited the school, for long or short-term academic programs.

四、学生的国际化培养　Student Cultivation

2010 年度，学院积极配合国际合作部完成各项学生联合培养计划的宣传和组织工作。北京大学学生海外学习项目（EAP）自 2007 年启动，向学生提供包括不同地区在内、涉及不同层次、不同时间周期的学生海外交流项目，让学生能够参与高水平的学术交流，开拓国际视野。本年度，学院参与的 EAP 项目包括 UCLA2011 本科生暑期科研项目、日本东京大学政府奖学金项目、美国加州大学交换项目、德国柏林自由大学交换项目、韩国浦项工业大学交换项目、欧盟伊拉斯谟对外窗口计划第二批申请等。

The Peking University Education Abroad Program, which was launched in 2007, provides students with high-end international exchange opportunities with different areas, levels and periods. In 2010, the school worked cooperatively with the Office of Foreign Affairs to promote students’ joint cultivation programs, including 2011 UCLA Undergraduate Summer Project, Tokyo University Government Scholarship Project, California University Exchange Program, Freie University of Berlin Exchange Program, South Korea Pohang University of Science and Technology Exchange Program, EMECW and so on.

奖励与荣誉
Awards & Honors

2009 年度：
In 2009

- 龚旗煌获杨芙清 - 王阳元院士奖教金特等奖
  Qihuang Gong was awarded Fuqing Yang-Yangyuan Wang Academician Education Foundation Special-class Award

- 龚旗煌荣获“全国归侨侨眷先进个人”
  Qihuang Gong was awarded the National Overseas Chinese Excellent Individual

- 胡永云荣获“2009 年度赵九章优秀中青年科学奖”
  Yongyun Hu was awarded the Jiuzhang Zhao’s Excellent Youth Science Award

- 孟杰荣膺 2009 年度华人物理学会“亚洲杰出成就奖”
  Jie Meng was awarded the Asian Excellence Award of the Chinese Physics Association

- 欧阳颀团队的“非线性科学在心颤机理及系统生物学中细胞周期控制上的应用研究”获 2009 年度国家自然科学二等奖
  Qi Ouyang’s Group was awarded the Second-class Award of National Natural Science Funds

- 许甫荣获中国物理学会吴有训物理奖
  Furong Xu was awarded the Youxun Wu Physics Award of the China Physical Association

- 杨金波、刘运全入选“教育部新世纪人才支持计划”
  Jinbo Yang and Yunquan Liu were included into the New Centennial Talents Project of the Ministry of Education

- 赵光达指导的理论物理专业张玉洁的博士论文获 2009 年全国优秀博士学位论文奖
  Yujie Zhang under guidance of Guangda Zhao was awarded the National Outstanding Dissertation Award

- 郑汉青荣获国家自然科学基金委杰出青年基金
  Hanqing Zheng was awarded the National Funds for Distinguished Young Scientists

- 钟锡华、王若鹏、陈志坚、张瑞明、周岳明的“光学课程建设”获国家教学成果二等奖
  Xihua Zhong, Ruopeng Wang, Zhijian Chen, Ruiming Zhang and Yueming Zhou were awarded the second prize of National Education Results

- 朱世琳荣获教育部“长江特聘教授”
  Shilin Zhu was awarded the “Yangtze River Scholar Award” of the Ministry of Education

2010 年度：
In 2010,

- 龚旗煌当选美国光学学会 (OSA) Fellow
  Qihuang Gong was awarded Fellow of Optical Society of America

- 胡小永获得北京大学王选青年学者奖
  Xiaoyong Hu was awarded Xuan Wang’s Young Scholar Award by Peking University

- 胡永云当选为中国气象学会副理事长
  Yongyun Hu was appointed the deputy director of board for China Meteorological Society

- 胡永云、颜学庆获国家自然科学基金委杰出青年基金
  Yongyun Hu and Xueqing Yan were awarded the National Funds for Distinguished Young Scientists

- 华辉获中国核物理学会胡济民教育科学奖
  Hui Hua was awarded the Jimin Hu Education Science Award of China Nuclear Physics Association

- 李重生的“顶夸克物理和 QCD 效应的研究”获 2010 年度高等学校自然科学一等奖
  Chongsheng Li was awarded the first prize for Higher University Natural Science

- 刘树华获北京市教学名师奖
  Shuhua Liu was awarded Beijing’s Teaching Excellence Award

- 刘运全研究员获得饶毓泰基础光学奖一等奖
  Yunquan Liu was awarded the first-class award of the Yutai Rao Fundamental Optics Award

- 孟杰获德国 GENCO 学会奖
  Jie Meng was awarded the German GENCO Award

- 彭良友副教授获得饶毓泰基础光学优秀奖
  Liangyou Peng was awarded the merit award of the Yutai Rao Fundamental Optics Award

- 王恩哥获本年度“何梁何利基金科学与技术进步奖”
  Enge Wang was awarded the Science and Technology Achievement Award by Ho Leung Ho Lee Foundation

- 王恩哥获“十佳全国优秀科技工作者”
  Enge Wang was awarded the National Top Ten Excellent Technology Scholars Award

- 王稼军获宝钢优秀教师特等奖
  Jiajun Wang was awarded the special award of Excellent Teacher by the Baosteel Group

- 朱世琳获第二十四届“北京市青年五四奖章”
  Shilin Zhu was awarded the 24th session of Beijing’s May 4th Youth Medal

- 核物理与核技术国家重点实验室正式通过验收
  State Key Laboratory for Nuclear Physics and Technology was approved after checking

- 人工微结构和介观物理国家重点实验室获评优秀类实验室
  State Key Laboratory of Artificial Microstructure and Mesoscopic Physics was awarded the Excellent Laboratory Award