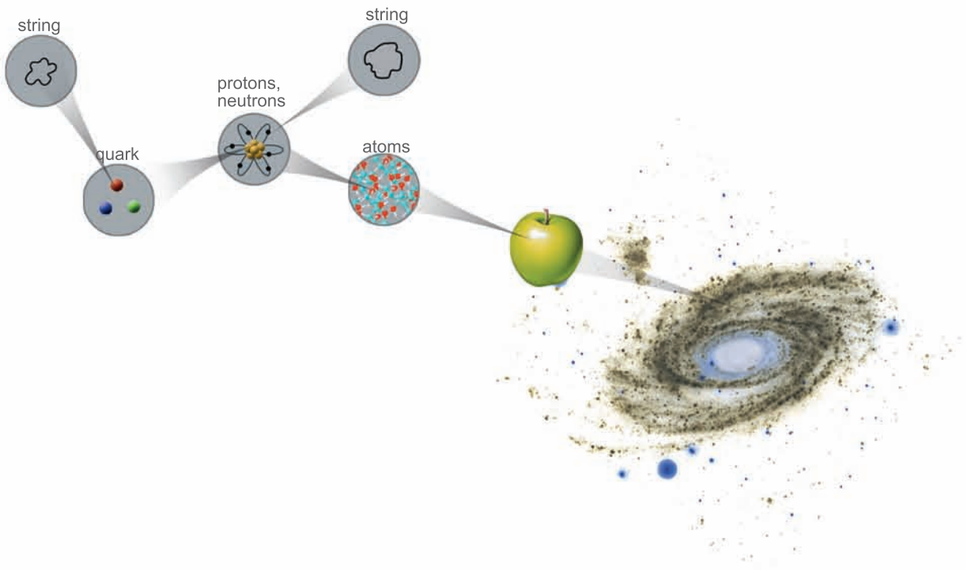

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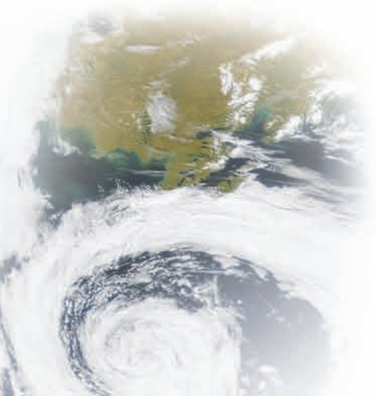

2011-2012 年报 Bi-annual Report

年报 2011-2012 Bi-annual Report

北京大学物理学院

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！

谢心澄
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.

Xincheng Xie
Dean of School of Physics, Peking University

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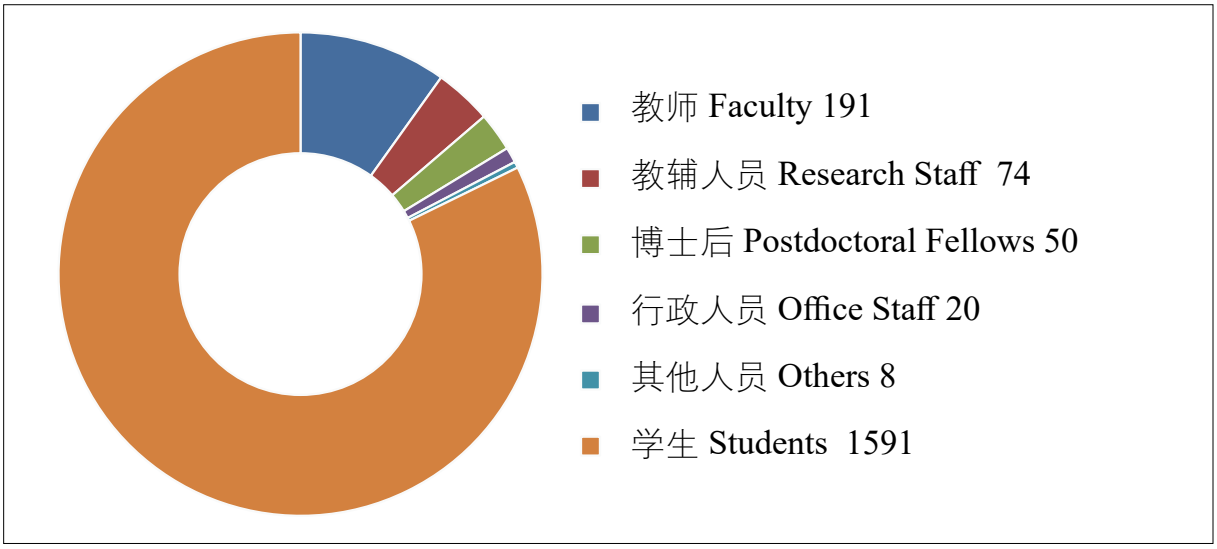

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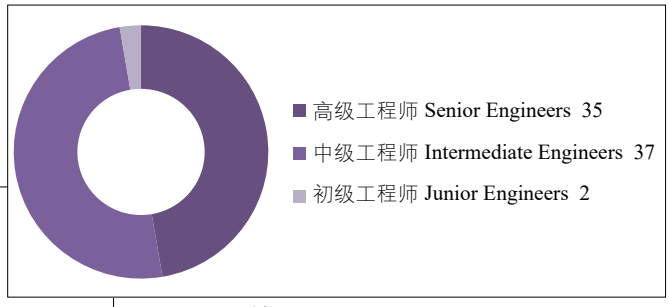

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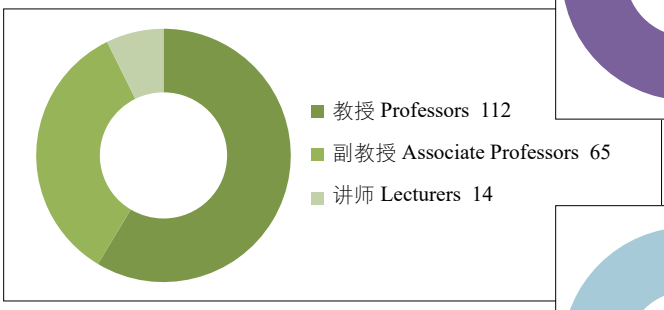

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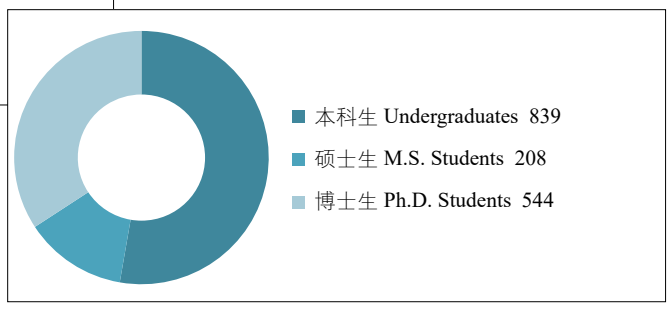

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下属机构
Divisions

- 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、粲偶素在强子对撞机上的产生和非相对论量子色动力学 (NRQCD) 的研究

重夸克偶素物理是研究量子色动力学的重要领域。如何理解粲偶素 J/ψ 粒子在强子对撞机上产生的截面和极化问题从上世纪九十年代以来一直是重夸克偶素物理中困扰人们的难题。传统的色单态模型包括领头阶（LO）与次领头阶（NLO）给出的大横动量（p_T）截面比费米实验室质子 - 反质子对撞机 Tevatron 的测量值小一个数量级以上。Braaten 等基于 NRQCD 提出色八重态机制，试图解释截面实验，但所预言的 J/ψ 为横极化，与 Tevatron 测量的 J/ψ 基本上无极化之间存在尖锐矛盾。2011 年赵光达教授和博士研究生马滟青、 王 凯 [Y.Q.Ma, K.Wang, K.T.Chao, Phys. Rev. Lett. 106, 042002 (2011)] 通过系统的研究发现，P 波色八重态的 NLO 贡献起决定性作用，通过改变 p_T 分布的幂次行为，从 LO 的 p_T^{-6} 改变为 NLO 的 p_T^{-4}，从而使截面的大横动量分布有数量级上的增强，通过选择包括所有 S 波和 P 波在内的 3 个色八重态矩阵元的 2 个独立线性组合，可以解释 Tevatron 上测量的截面，且所预言的欧洲大型强子对撞机 LHC 上大横动量截面与此后 CMS 及 ATLAS 的测量结果 (横动量达到 70 GeV) 一致。2012 年关于 J/ψ 极化的工作发现 [K.T. Chao, Y.Q. Ma, H.S. Shao, K. Wang, Y.J. Zhang, Phys. Rev. Lett. 108, 242004 (2012)]，P 波色八重态的贡献对极化也非常重要，其对横极化分量的贡献可以抵消来自自旋三重态 S 波色八重态对横极化的贡献，从而改变原有理论中以横极化为主的预言。采用与 2011 年工作中相同的 2 个矩阵元线性组合，可以得到基本上无极化的结果，与 Tevatron RunII 测量基本符合。 通过上述工作，可以同时对强子对撞机上大横动量 J/ψ 产生的截面和极化问题给出解释，并对实验给出进一步预言。

Tevatron 实验发现 P 波粲偶素 χ_{CJ}(J=1,2) 的产生截面比率 $R=\sigma(\chi_{C2})$: $\sigma(\chi_{C1})$ 约为 0.75，远小于领头阶 NRQCD 的预言值 5:3。对 NRQCD 次领头阶的研究表明 [Y.Q.Ma, K.Wang, K.T.Chao, Phys. Rev. D83, 114037 (Rapid Communication) (2011)]，由于 P 波产生截面的横动量分布行为发生改变，通过 P 波色单态与 S 波色八重态之间贡献的部分相消作用，可以对 P 波粲偶素 χ_{CJ}(J=1,2) 的产生截面比率的疑难给出一个自然的解释。由此进一步对 LHC 上 P 波粲偶素截面比所做出的预言，为 2012 年最新的实验结果所验证。

I. Charmonium production at hadron colliders and nonrelativistic QCD (NRQCD)

Heavy quarkonium physics is one of the important fields in the study of QCD. How to understand the production cross sections and polarizations of charmonium , e.g., J/ψ at hadron colliders has been one of the most challenging problems in quarkonium physics, since 1994 when the J/ψ surplus was observed at the Fermilab Tevatron. The calculated cross sections at leading-order (LO) and next-to-leading-order (NLO) in the conventional color-singlet model are smaller than data by at least one order of magnitude at large transverse momentum (p_T). The color-octet mechanism proposed by Braaten at al. was aimed at resolving the cross section problem but predicted J/ψ polarization to be transverse at large pT, whereas the observed J/ψ is almost unpolarized. Prof. K.T. Chao and his collaborators [Y.Q.Ma, K.Wang, K.T.Chao, Phys. Rev. Lett. 106, 042002 (2011)] find that with all color-singlet and color-octet S-wave and P-wave contributions considered the NLO color-octet P-wave contribution plays the crucial role to enhance the large p_T cross section by changing it from p_T^{-6} at LO to p_T^{-4} at NLO. By choosing 2 combinations of 3 long-distance matrix elements the Tevatron J/ψ cross section data can be well described, and, in particular, the predicted cross sections at the LHC are consistent with the most recent measurements at large p_T up to 70 GeV. The group further studied the polarization problem [K.T. Chao, Y.Q. Ma, H.S. Shao, K. Wang, Y.J. Zhang, Phys. Rev. Lett. 108, 242004 (2012)] and found that with the determined 2 combinations of matrix elements the transverse polarization component is almost cancelled out at large p_T between the color-octet S-wave and the color-octet P-wave contributions, which results in nearly unpolarized J/ψ. Thus the Tevatron polarization data can be understood and J/ψ polarization can be further predicted at the LHC. The above works may provide a way to resolve the long standing problems of J/ψ production cross section and polarization at hadron colliders.

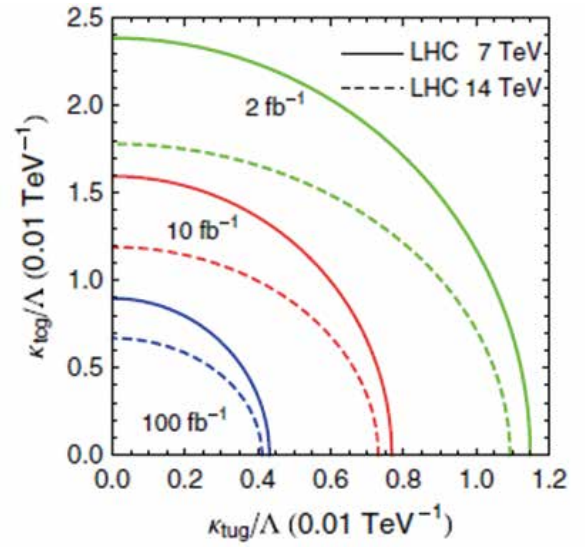
At the Tevatron another puzzling result was also observed that for the P-wave charmonium χ_{CJ} (J=1,2) the production cross section ratio $R=\sigma(\chi_{C2}):\sigma(\chi_{C2})\approx 0.75$, which is much smaller than 5:3 predicted at LO in NRQCD. The group studied the NLO contribution [Y.Q.Ma, K.Wang, K.T.Chao, Phys. Rev. D83, 114037 (Rapid Communication）(2011)] and found that the color octet S-wave is no longer the dominant contribution as at LO and the color-singlet P-wave contribution, which is enhanced at large p_T at NLO, becomes significant. A partial cancellation between the two may provide a natural explanation for the observed ratio R. The predicted values of R at the LHC have been confirmed by most recent experiments at the LHC in 2012.

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

1. 在早期 LHC 上寻找顶夸克的反常耦合产生

长期以来，人们在实验中发现，基本粒子相互作用时中性流味守恒是粒子物理学的基本规律之一。在标准模型中，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，但仍可能被高精度的实验发现。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 和欧洲核子研究中心的大型强子对撞机 LHC 等）一直在努力寻找这种味改变中性流存在的实验证据。李重生研究组（Phys. Rev. Lett.107, 092002, 2011）采用模型无关的方法详细研究了顶夸克中性流味守恒破坏 （反常耦合）的问题， 给出了用 LHC 上顶夸克从产生到衰变的各种观测量来系统确定顶夸克 QCD 反常耦合大小的精确理论预言。结果表明，在考虑了 Tevatron 的实验已给出的反常耦合大小的上限条件下，运行在 7TeV 质心系能量的 LHC 在积累较小的亮度之后就有可能在 5 σ 水平上发现顶夸克反常耦合的效应；此外，还首次指出，利用末态轻子电荷之比的信息可用来区分 tug 和 tcg 的耦合。LHC 的 ATLAS 和 CMS 实验组已在论文（Phys. Lett. B712，351，2012；CMS-PAS-TOP-11-022（arXiv:1209.3489）；ATLAS-CONF-2012-056, ATLAS-COM-CONF-2012-028）中采用了该文结果。李重生的博士生高俊为论文第一作者。



图一：LHC 在不同质心系能量和积分亮度下在 5 σ 水平上发现反常耦合的区域。

Figure 1: The 5 σ discovery limits of the anomalous couplings for the LHC with different c.m. energies and luminosities.

2. LHC 在 QCD 次领头阶水平上探索夸克复合结构

自上世纪六十年代夸克模型建立后，理论粒子物理学家们就开始探索各种可能的夸克复合结构模型。由于夸克的复合能标很高，以当时的实验水平很难被探测。随着 LHC 运行，人们看到了进一步探索夸克内部结构的希望。李重生研究组（Phys. Rev. Lett.106, 142001, 2011）给出了任何可能的复合夸克模型所诱导的 LHC 上的双喷注产生过程的精确理论预言，发现 ATLAS 实验组采用 QCD 双喷注产生的 K 因子的做法过大地估计了新物理的效应，精确结果将会降低 CMS 实验组给出的夸克复合标度的实验下限。这一结果对于实验家在 LHC 上寻找夸克的复合结构很有帮助，进而增进人们对深层次物质结构的认识。LHC 的 CMS 实验组在发表的论文（Phys.Rev.Lett.106,201804，2011；JHEP1205, 055, 2012）中重点引用了该文结果，从而给出了夸克下一层次结构的能量尺度严格下限。李重生的博士生高俊为论文第一作者。在 CMS 实验组的论文结尾，对李重生研究组与他们的有益讨论及所提供的有关数值程序专门做了致谢：

“We would like to thank J. Gao, C.-S. Li, J. Wang, C.-P. Yuan, and H.-X. Zhu for useful discussions and for providing the program to calculate the contact interaction predictions with NLO QCD corrections.”

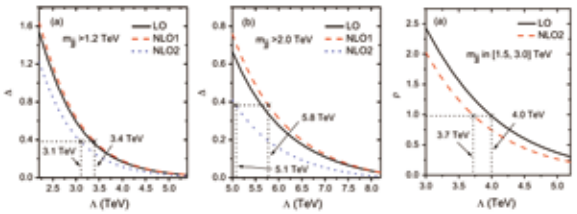


图 2：Δ 和 ρ 随夸克复合能标 Λ 的变化关系．其中 LO 和 NLO1 (2) 分别代表领头阶和近似（精确）次领头阶 QCD 的预言。

Figure2: as functions of the compositeness scale .

The LO and NLO1 (2) curves represent the leading and scaled (exact) NLO results.

II. Anomalous Top Quark Production and Quark Compositeness Research

1. Searching for Anomalous Top Quark Production at the Early LHC

We present a detailed study of the anomalous top quark production with subsequent decay at the LHC induced by model-independent flavor-changing neutral-current couplings, incorporating the complete next-to-leading order QCD effects. Our results show that, taking into account the current limits from the Tevatron, the LHC with TeV may discover the anomalous coupling at 5 level for a very low integrated luminosity of 61 pb-1. The discovery potentials for the anomalous couplings at the LHC are examined in detail. We also discuss the possibility of using the charge ratio to distinguish the tug and tcg couplings.

2. Next-to-Leading QCD Effect on the Quark Compositeness Search at the LHC

We present the exact next-to-leading order (NLO) QCD corrections to the dijet production induced by the quark contact interactions at the CERN Large Hadron Collider. We show that, as compared to the exact calculation, the scaled NLO QCD prediction adopted by the ATLAS Collaboration has overestimated the new physics effect on some direct observables by more than 30% and renders a higher limit on the quark compositeness scale. The destructive contribution from the exact NLO correction will also lower the compositeness scale limit set by the CMS Collaboration.

三、半导体和超导体异质结中电子的复径反射和空穴的镜向反射

Veselago 在 1968 年从理论上预言了存在负折射的可能性。负折射于 2001 年在光子晶体的实验中得以证实。电子是否有相似传输特征的研究对电子本征特性和量子输运有着特殊的意义。早在 1945 年，Mandel’shtam 曾指出负折射是具有负群速度波的普遍性质。自旋电子学是近年来的研究热点之一。在强自旋 - 轨道耦合的低密度半导体实验中人们发现电子可以都被限制在一个自旋螺旋态上。费米面呈现出特殊的拓扑特征。自旋 - 轨道耦合效应导致负取向态的出现，其特点是它的费米波矢与群速方向相反。这种负取向态的出现提供了电子体系电子传输与光学中负折射现象的联系。类似于光子晶体中的负折射，非均匀的自旋电子系统中也能够发生电子束的负折射。就反射来讲，至今人们普遍的观念是当电子斜着入射到平整的异质结表面时，在遭遇界面散射后，反射呈镜向反射，而不能重复原入射的路径反射。散射过程中电子的能量和动量守恒限制了这类称之为复径反射的沿原入射路径反射出现，以至于复径反射成为极其罕见的物理现象（除了垂直入射情形）。基于负取向态的存在，来自北京大学和澳大利亚伍龙岗大学研究人员组成的团队对电子发生复径反射的条件做了细致的分析和研究，在由不同强度自旋 - 轨道耦合半导体构成的异质体系中明确地显示了电子的复径反射。利用建立的“射线”方程，我们

分析和建立了复径反射和反射电子波矢与群速相对取向间的本征联系。负取向态和电子复径反射的存在标志着在半导体异质结的量子输运中找到了过去未曾发现的效应。这一在保持动量守恒规则前提下所呈现出电子复径反射的事实为反映经典力学和量子力学之间的不同提供了又一个概念简单而且自身出人意料的新事例。在考虑到电子和空穴态相反取向的特性，我们还发现利用电子和空穴等能面的拓扑特征不同，在低电子密度情形下也可以产生镜向安德烈夫反射。这一研究发现为在除石墨烯 / 超导界面能够出现镜向安德烈夫反射之外提供了又一证据。所不同的是镜向反射的空穴是在石墨烯价带而半导体情形是在导带。我们的研究还表明电子的复径反射和空穴的镜向反射在双层石墨烯中均可以出现，并且与能带谷的构形有着密切的联系。鉴于借助纵向外场可用来调制倒位对称性，这种依赖于能带谷的输运特征对电子学和光电子学有着巨大的应用潜力。研究指出采用多层异质结构，这种由负取向态导致的传输性质可用来聚焦发散的电子束或制备出谷选择 Veselago 电子反射镜和透镜。

相关文献：

[1] B. Lv, C. Zhang, Z.S. Ma, Specular Andreev reflection in the interface of a two-dimensional semiconductor with Rashba spin-orbit coupling and a d-wave superconductor, Physical Review Letters 108, 077002 (2012).

[2] Y.S. Ang, Z.S. Ma, C. Zhang, Retro reflection of electrons at the interface of bilayer graphene and superconductor, Scientfic Reprots 2, 1013 (2012).

[3] B. Lv, Z.S. Ma, Electronic equivalence of optical negative refraction and retroreflection in the two-dimensional systems with inhomogeneous spin-orbit couplings, Physical Review B 87, 045305 (2013).

III. Peculiar retroreflection of electrons and specular reflection of holes in heterostructures consisting of semiconductors and superconductors

It is of interest to investigate the electronic analogue of the electromagnetic phenomena of negative refractive materials, which was predicted by Veselago in 1968 and had been demonstrated in microwave scattering experiments in photonic crystals in 2001. As early as 1945, Mandel'shtam identified that the negative refraction is a general property of waves of any nature with a negative group velocity. Recent experiments in the low density semiconductors with a strong spin-orbit interaction (SOI) discovered that all electrons can be restricted in one of spin-helicity bands. As the topological distinction of Fermi surface, the SOI modifies propagating electron modes with the appearance of negative oriented states, whose Fermi wavevector and the group velocity emerge antiparallel to each other. The occurrence of negative oriented states provides the link with an electronic analogue of optical negative refraction. Similar to the negative refraction in photonic crystals, the negative refraction of electronic beam can, therefore, be occur in the inhomogeneous spintronic systems. So far, one firmly believes that the electron after being incident obliquely on the flat surfaces of heterostructures will not retrace its path so as to move retroreflectedly after suffering reflection from the surfaces. The retroreflection of electrons is a rare physical phenomenon in nature with the exception of normal incidence and is forbidden due to conservations of energy and momentum of electrons in the scattering. Based on the existing negative oriented states, our team of researchers from Peking University and University of Wollongong has revealed the first

obvious instance of realizing electronic retroreflection in the hybrid systems made of semiconductors with different SOI. Utilizing the ray equation analysis, we established an intrinsic connection between the retro-reflection and the relative orientation of the wavevector to the group velocity of a reflected electron. The existence of electron retroreflection with negative oriented states represents one last missing piece in the quantum transport phenomena of a semiconductor heterostructure. The result show that avoiding the violation of the momentum conservation rule represents a conceptually simple yet astonishing example highlighting one major difference between classical mechanics and quantum mechanics. With considerations of opposite oriented characteristics in electron and hole states, we also found that the specular Andreev reflection is entirely possible in the low density limit, where the equal energy surfaces of electrons and holes are topologically different. The finding provides another evidence of specular Andreev reflection besides that in a graphene/superconductor interface. The qualitative distinction is the specular reflected hole is in the valence band for graphene while remains in the conduction band in semiconductors. Because of its potential applications in future electronics and optoelectronics the bilayer graphene has attracted considerable attention. Our studies show that both retroreflection of electrons and specular reflection of holes can be allowed to occur. The potential of valley-dependent transport characteristics in application is tremendous due of the feasibility to tune its band gap with a vertical displacement field to break the inversion symmetry. The appearance of negative transport fluxes can be used to focus a divergent electronic beam in multilayer heterostructure or as a valley-selective Veselago electron-mirror.

Relevant references:

[1] B. Lv, C. Zhang, Z.S. Ma, Specular Andreev reflection in the interface of a two-dimensional semiconductor with Rashba spin-orbit coupling and a d-wave superconductor, Physical Review Letters 108, 077002 (2012).

[2] Y.S. Ang, Z.S. Ma, C. Zhang, Retro reflection of electrons at the interface of bilayer graphene and superconductor, Scientfic Reprots 2, 1013 (2012).

[3] B. Lv, Z.S. Ma, Electronic equivalence of optical negative refraction and retroreflection in the two-dimensional systems with inhomogeneous spin-orbit couplings, Physical Review B 87, 045305 (2013).

四、原子核理论研究

现代物理学和宇宙学研究表明，我们现在所处的宇宙中的明亮物质可能起源于高温条件下的轻子和无质量的夸克，这些无质量的夸克处于高度对称状态，例如电磁相互作用与弱相互作用统一、左手转动与右手转动对称，这种左右手转动对称称为手征对称性。当温度降到约 1015 K（上百 GeV）量级的时候，发生电弱对称性破缺，夸克获得质量（常称之为流质量），但对于构成质子、中子等低质量强子的最重要组分 — 轻夸克，这样获得的流质量很小，仅几 MeV，相应的手征对称性的破缺称为手征对称性明显破缺。但当温度降到约 1012 K（上百 MeV）量级的情况下，发生强子化、形成质子和中子等强子后，这些夸克的质量可能高达几百 MeV。相应的手征对称性破缺称为动力学破缺，被认为是量子色动力学（QCD）的非微扰效应。从相与相变的观点看，这样的演化过程是典型的相变，因此 QCD 相变（或者说强相互作用物质相变）成为

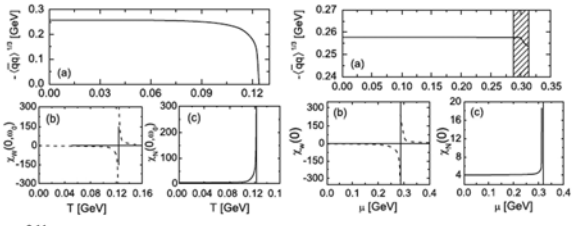
近年来原子核物理、粒子物理、统计物理及宇宙学等领域共同关注的重大课题。因此，近几年，物理学院理论物理研究所原子核理论组的研究工作主要集中在这个领域，并于 2011-2012 年间取得较大进展。

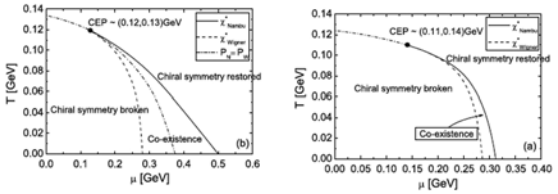
1. 有效胶子模型和包含横向效应的夸克 - 胶子相互作用顶角模型

相变是非微扰效应。为研究 QCD 相变，必须采用非微扰 QCD，即采用的理论框架必须同时具有手征对称性破缺和夸克禁闭及其改变两方面的性质。QCD 的 Dyson-Schwinger（DS）方程方法被认为是目前“几乎唯一的同时具有手征对称性破缺和色禁闭两方面性质的理论方法”。但 DS 方程是一组无穷嵌套但可数的耦合积分方程组，为具体应用，需要建立满足 QCD 的基本对称性的截断方案、并建立相应的有效胶子传播子模型和夸克 - 胶子相互作用顶角模型。该课题组的研究人员与合作者们提出一个不仅包含纵向效应（有 Ward-Takahashi 恒等式限制）还包含横向效应（非常重要，但目前尚不知道严格的约束条件）的夸克 - 胶子相互作用顶角模型，说明手征对称性动力学破缺使得（组分）夸克具有反常色磁矩和反常电磁矩，对核子反常磁矩的物理机制提出见解。相关结果发表在《物理学评论快报》（Phys. Rev. Lett. 106, 072001(2011)）上。该课题组还以博士研究生秦思学为主与合作者们一起提出一个红外定常的有效胶子传播子模型，该模型不仅可以统一此前的各种模型，还可以给出有效胶子的动力学跑动行为，并给出解决相应计算中的困难的方案。将 DS 方程与彩虹梯子近似下的 Bethe-Salpeter（BS）方程相结合，在四维协变情况下给出基态介子的质量和衰变常数等性质，还说明为描述激发态和奇异态介子的性质，必须超越彩虹梯子近似。相应结果分别以快报、正常论文形式发表在《物理学评论 C》（Phys. Rev. C 84, 042202(R) (2011); Phys. Rev. C 85, 035202 (2012)）上。这项工作得到了国家自然科学基金重点项目和科技部 973 项目的资助。

2. 表征相变并确定临界终点的判据及 QCD 相图

传统的研究相变的方法是分析系统的有效热力学势，但在非微扰情况下，人们很难甚至无法明显给出系统的有效热力学势，从而传统的相变判据失效。再者，在不同条件下，系统发生相变的级次可能不同，相边界曲线上由一级相变转向二级相变或连续过渡的状态称为相变的临界终点。QCD 相变中是否存在临界终点，如果存在，其位置在何处是相关研究中的核心问题之一。为在非微扰 QCD 框架下研究 QCD 相变及相应的临界终点，该课题组与合作者们提出手征磁化率判据，说明一相的手征磁化率由负无穷发散转向正无穷发散（实际即改变符号）表征该相由不稳定转变为稳定或亚稳；并且，对二级相变，不同相的手征磁化率在相边界曲线上的相同状态发散，对一级相变，不同相的手征磁化率在不同状态发散。于是，手征磁化率判据不仅可以确定二级（高级）相变或连续过渡的相边界曲线，还可以确定一级相变的相共存区，从而可以准确确定相变的临界终点。利用这一判据，不仅在 DS 方程方法下给出了 QCD 相变的相边界曲线，还确定了其临界终点，说明被称为“Quakyonic”相的手征对称但仍然禁闭的奇异相实际即一级相变的共存区的状态，还说明了此前不同方法给出相去甚远的临界终点位置的物理机制。相应成果发表在《物理学评论快报》（Phys. Rev. Lett. 106, 172301 (2011)）。此外，提出介子质量平方的符号作为相稳定性判据的方案，给出耦合强度与流夸克质量平面上的相图和一个动力学质量产生的直观图像（Phys. Rev. D 86, 114001 (2012)）。这项工作得到了国家自然科学基金重点项目和科技部 973 项目的资助。





图：左 — 二级相变时两相的手征磁化率在相同状态发散；中左 — 一级相变时手征磁化率在不同状态发散；中右 — 能够写出热力学势的模型下的 QCD 相图；右 — 不能写出热力学势的模型下的 QCD 相图。

IV. Study of nuclear theory

1. Models for the effective gulon propagator and for the quark-gluon interaction vertex which includes not only the longitudinal but also the transverse components

In order to investigate QCD phase transition sophisticatedly, one must take the nonperturbative QCD approach which demonstrates both the chiral symmetry breaking and confinement characteristics. The QCD Dyson-Schwinger equation (DSE) approach is now believed to be the "almost unique one" to hold these features simultaneously and naturally, since it provides relations between all the Green functions of QCD. However, the QCD DSEs are an infinite tower of coupled and nonlinear integral equations. To make use of the approach in practice, one must have appropriate truncation scheme and models for the effective gluon propagator and the quark-gluon interaction vertex. The researcher of this group, working together with collaborators, proposed a quark-gluon interaction vertex which includes not only the longitudinal part (constrained by the well known Ward-Takahashi identity) and the transverse part (very important but less known, since one still does not know the constraints explicitly). With such a vertex model, it shows that the constituent quark holds observable anomalous color/electric magnetic moment due to the chiral symmetry breaking (then, such a model is denoted as ACM model). It may have provided a mechanism for the anomalous magnetic moment of nucleon. This work has been published in Phys. Rev. Lett. 106, 072001 (2011). For the effective gluon propagator, Collaborating with some colleagues, the researchers in the group also proposed an explicit expression for the effective gluon propagator and the rainbow-ladder kernel for the Bethe-Salpeter (BS) equation, which can unify all the having existed models. In every respect tested, this model produces results for hadronic observables that are at least equal to the best otherwise obtained in comparable approaches (Combining it with the covariant BS equation, the ground-state, radially-excited and exotic scalar-, vector- and flavored- pseudoscalar-mesons are studied in rainbow-ladder truncation. The properties of the ground-states are produced excellently. The inability of this truncation to provide realistic predictions for the masses of excited- and exotic-states is confirmed and explained. Possible scheme to solve the problem is proposed). Moreover, it enables the natural extraction of a monotonic running-coupling and -gluon-mass. This work has been published in Phys. Rev. C 84, 042202(R) (2011) and Phys. Rev. C 85, 035202 (2012).

2. Criterion to identify the phase transition and to determine the critical endpoint, and the QCD phase

diagram

Conventionally, one studies phase transition by analyzing the effective thermal potential of the system. However, it is very difficult even impossible to have the effective thermal potential as the complete nonperturbative nature of the system is taken into account. Then the conventional approach gets impracticable. For phase transition itself, one has known that the phase transition may be in different orders under different conditions. The state separating the first order and the crossover or the second order is referred to as the critical endpoint (CEP). For the QCD phase transitions, besides the phase transition boundaries, the existence and its location of the CEP if it exists, are highly concerned and debated, and then become the main project of the current RHIC energy scan experiments and future FAIR experiments. To study the QCD phase transition with nonperturbative approach and shed light on the QCD phase diagram, the nuclear theory group establishes a criterion identifying phase transitions based on chiral susceptibilities. It shows evidently that the chiral susceptibilities of the two phases diverge at same state for second order phase transition and crossover, but at different states for the first order. Then the criterion of chiral susceptibility enables one to not only draw the phase boundary lines but also locate explicitly the CEP in the chemical-potential/temperature plane for strongly-interacting quark system whose interactions are described by any reasonable gap equation, even if the diagrammatic content of the quark-gluon vertex is unknown. As a consequence, the QCD phase diagram and the CEP are given in the DSE approach. Meanwhile, the so called quakyonic phase — an exotic phase where the chiral symmetry has been restored but the quarks are still in confinement, is just the coexistence states of the first order phase transition. Furthermore, with the model dependence of the phase diagram being analyzed quantitatively, it is shown that the physics mechanism for different theoretical methods having given distinct locations of the CEP in previous studies is that the models took different confinement length. This work has been published in Phys. Rev. Lett. 106, 172301 (2011). In addition, it is proposed that the sign of the mass square of mesons can also be a criterion to identify the stability of the phase. A QCD phase diagram on the plane in terms of the coupling strength and the current quark mass is given and an intuitive picture of the dynamical mass generation is proposed (Phys. Rev. D 86, 114001 (2012)).

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 63 人，其中教授 18 名，副教授 20 名，讲师 1 名，工程技术人员 18 名，百人研究员 6 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 63 faculty members in the institute, consisting of 18 professors, 20 associate professors, 1 lecturers, 18 engineering technicians, and 6 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、氮化物宽禁带半导体光电子与低维量子结构研究

GaN 基宽禁带半导体低维量子结构材料和器件在固态照明、全色显示、微波通讯、功率开关和光电探测等方面具有广阔的应用前景。近两年来，本中心在 GaN 基材料和器件方面开展了一系列研究工作，主持和承担了多项国家 973、863、基金以及国防项目，取得的成果既包含诸如量子输运、子带跃迁等基础性研究成果，也包括 GaN 基衬底材料，LED，LD，探测器等应用性研究成果，研制成功多种新型材料和器件，成功地实现了部分成果产业化，并对国家国防建设做出了多项贡献。发表各类学术论文 50 多篇，主要表现在：

（1）通过衬底预处理、模板表面预处理以及脉冲流量调制方法获得了 2 英寸 370 微米厚的自支撑 GaN 衬底，XRD 摇摆曲线结果是目前国内报道的最好值结果。

（2）使用 GaN 模板准同质外延 LED 结构，制备出高光效薄膜型 LED，是目前国内激光剥离、垂直结构LED芯片制备研究水平最高的单位之一。LED 的发光效率已经达到 110lm/W。LED 漏电和可靠性在国内处于领先水平。

（3）中心与加州大学洛杉矶分校合作，得到位错密度 7x105 cm-2，比蓝宝石上低 3-4 个数量级的 GaN 外延片，该结果在 APL 发表后即被国际著名期刊《compound semiconductor》以题为“Slashing Defects In GaN-On-Sapphire Films”进行报道。

（4）采用渐变组分 InGaN，AlN 插入层以及 GaN 解理腔成功实现了蓝光激光器的制备和电注入激射，激光器波长 434nm，是目前国内第一家实现蓝光激光器的高校。

（5）成功实现了图形化蓝宝石衬底，LED 激光加工设备的产业化，推动 LED 在文物照明、城市农业及医疗方面的应用，在其基础上成立了北京大学东莞光电研究院，加速北大光电科技成果在广东以及全国的产业化。

（6）发展了一种基于 AlN/GaN 超晶格插入层应力调控方法，通过预制裂纹释放应力， 同时控制裂纹的再填埋过程，得到原子级平整的 AlGaN/GaN 量子阱结构，在此基础上成功制备出中红外波段子带间跃迁（ISBT）量子阱探测器原型器件，在国际上率先在 2.5-3 微米波段观察到红外响应光电流信号。

（7）利用 MBE 边界温度控制技术生长出高质量 InN 晶体，电子室温迁移率达 3280 cm2/Vs，是国际上迄今报道的最高值。发现 InN 薄膜表面电子积累层对逆自旋霍尔效应（RSHE）引起涡旋电流有显著贡献，并且表面电子积累层的自旋轨道耦合系数与极性相关。

（8）用 MOCVD 方法获得高质量的晶格匹配 In0.18Al0.82N 外延层，在此基础上生长高质量的无应变 InxAl1-xN/GaN 异质结构，二维电子气 (2DEG) 浓度高达 1.95×1013cm-2，室温迁移率达到 1340 cm2/Vs。在低温磁输运实验中首次在该类异质结构中观察到 SdH 振荡和明显的 2DEG 双子带占据。从实验上确认 In0.18Al0.82N/GaN 异质结构中 In 在螺位错处的富集是其反偏漏电流的机制。

（9）在自行设计并搭建高场输运测量系统基础上，观察到 n 型 GaN 中耿氏不稳定性导致的电流控制型负微分电导效应，并确认 GaN 材料的击穿电压远不及理论预期的原因是电流控制型负微分电阻效应在器件沟道中产生的电流丝。

（10）观察到 AlxGa1-xN/GaN 异质结构中由逆自旋霍尔效应导致的反常自旋光电效应，估算出自旋横向力的大小为 ~10-19 牛顿，同时估算出光斑引起的涡旋霍尔电压为 ~10-6 伏特，该工作为在常温和宏观尺度研究逆自旋霍尔效应以及自旋流提供了新的实验方法。同时提出一种基于光致反常霍尔效应 (AHE) 和逆自旋霍尔效应测量自旋扩散系数的方法，成功测量了 AlxGa1-xN/GaN 异质结构中 2DEG 的自旋扩散系数。

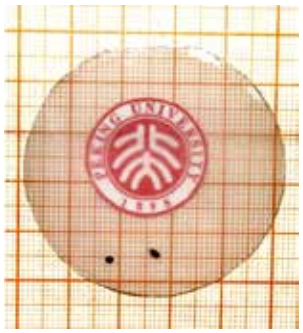


图 1：通过蓝宝石表面预处理 HVPE 生长的 2 英寸 GaN 自支撑衬底。

Figure 1: The photograph of 2 inch freestanding GaN substrate grown by HVPE after sapphire surface pretreatment.

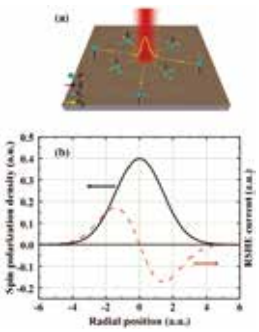


图 2：InN 薄膜的逆自旋霍尔效应：a) 示意图，b) 自旋极化密度及 RSHE 电流随径向位置的变化。

Figure 2: The reversal spinning Hall effect of InN film: a) schematic diagram, b) the dependences of spin polarization density and RSHE current on the radial position.

I. Study on nitride semiconductor optoelectronics and low dimension quantum structures

The materials and devices of GaN based wide bandgap low dimension quantum structures have much potential in the applications in solid state lighting, full-color display, microwave telecommunication, electric power switch and optoelectronic detection. In 2011-2012, the group carried out systemic work on the material growth and devices fabrication, which funded by national projects of 973, 863, Natural Science foundation and defense. They have achieved many important results, including not only the fundamental investigation as quantum transportation, infrared sub-band transition (ISBT), but also the applied results as GaN-based substrates, LED, LD, detector, and so on. They have published about 50 papers in famous journal, successfully industrialized some significant study results, and made many contributions to national defense. The achievements included: (1) 2 inch diameter and 370 um thick freestanding GaN substrate has been fabricated by pretreatment of sapphire, template and pulsed flux modification methods. X-ray diffraction results show the best results of GaN substrate in China. (2) The high efficiency thin film LED has been fabricated using quasi-homoepitaxial LED structures on thick GaN template. The luminous efficiency of white LED has been achieved as 110 lm/W. The low leakage, high reliability and repeatability for thin film LED was the highest level reported in China. (3) The group firmly collaborated with University of California, Los Angeles (UCLA) in GaN lateral growth on S-shape mask. The threading dislocation density is 7X105cm-2, which is 3-4 order lower than that on conventional sapphire substrate. After published in the journal of Applied Physics Letters, the famous journal of Compound Semiconductor commented it as “slashing defects in GaN on sapphire films”. (4) Blue laser was successfully fabricated and electrical injection stimulated emission was realized by graded In component InGaN, AlN interlayer and GaN cleavage cavity. Peking University is the first Chinese university with the ability to made blue laser. (5) The group have successfully industrialized the techniques of patterned sapphire substrate and laser processing in Guangdong Province. It impelled LED applications in cultural relic lighting, urban agriculture and medical treatment. The Dongguan optoelectronic Institution of Peking University has been built based the group. The institute accelerated the achievements of science and technology of Peking University industrialized in Guangdong province and other places in China. (6) They developed a strain control technique based on AlN/GaN superlattice interlayer. They prefabricated

cracks to relaxed strain. Then the cracks were buried to get atomic-level smoothness of AlGaN/GaN MQW structure. Finally, we successfully fabricated the prototype of ISBT MQW detector. They are the first group of the world who achieved photocurrent signal in the infrared range of 2.5-3 um. (7) The group have grown high quality InN crystal by MBE using boundary temperature controlled epitaxy method. The electron mobility was achieved as 3280 cm2/Vs, which is the best value up to now. They also found that the surface electron accumulated layer took an important role in reversal spin Hall effect (RSHE), and the spin-orbit coupling coefficient of the accumulated layer was correlated to the polarity. (8) The group have obtained high quality lattice-matched In0.18Al0.82N epilayer. Moreover, they grew high quality relaxed heterogeneous structure of InxAl1-xN/GaN, in which the concentration and mobility of 2DEG were achieved as 1.95x1013 cm-3 and 1340 cm2/Vs, respectively. The SDH oscillation and double sub-band occupation in this type heterogeneous structure were firstly reported in low temperature magnetic transportation. The enriched indium at the screw TD were observed and attributed to the reversal leakage current of the structures of InAlN/GaN. (9) The group built a high electric field transportation measurement system themselves. They observed the negative differential resistance (NDR) caused by the Gunn instability. They assured that the breakdown voltage of GaN material was much lower than that of the theoretical one because the current controlled NDR led to micro current in the device channel. (10) They have observed that the abnormal spin photoelectric effect was due to RSHE in the AlGaN/GaN heterogeneous structure. The lateral spinning force was estimated as 10-19 N, and the whirl Hall voltage by light spot was obtained as 10-6 V. This work provided a new method for study on the RSHE and spinning current in the situation at room temperature and macro scale. Meanwhile, they proposed a new measurement of spinning diffusion coefficient based on abnormal Hall effect (AHE) and spinning Hall effect. They have successfully measured the spinning diffusion coefficient of 2DEG in AlGaN/GaN heterogeneous structure.

二、表面等离激元纳米天线新型石墨烯碳单层光电探测器

原子尺度的碳单层 (graphene) 结构具有独特的光电转换性质。通过纳米加工制备的光学天线与碳单层构成的复合结构，可以有效地提高光电转换效率。近日，凝聚态所朱星教授团队的方哲宇百人计划研究员和美国 Rice 大学 P. Nordlander, N. Halas 教授合作，加工制备了两层碳单层之间的纳米尺度光学天线，这种三明治结构的光电探测器可以有效地用于可见光及近红外区域碳单层光电器件探测，光电流增强效应达 800%。探测得到的光电流主要来自于两部分的贡献：一是由表面等离激元在衰减过程中产生的热电子“hot electron”，以及由增强局域电场作用下碳单层自身激发的光电子，这种新型光电探测器在可见光和近红外区域获得了将近 20% 的内部量子效应。这项研究开创了基于表面等离激元光捕获效应和碳单层光电器件相结合新的研究领域。相关结果发表在《纳米快报》上 (Nano Letters 2012, 12, 3808-3813)。

该研究在线发表一周内就被 Nature Physics 的“News and Views”重点引用，并被推荐为未来研究热点。也被美国 Chemical & Engineering News 作为突破性研究进行了新闻报导。为此，方哲宇博士在今年八月份美国国际光学工程协会年会（SPIE）上应邀做大会特邀报告。此工作得到物理学院凝聚态所以及介观物理国家重点实验室的支持。

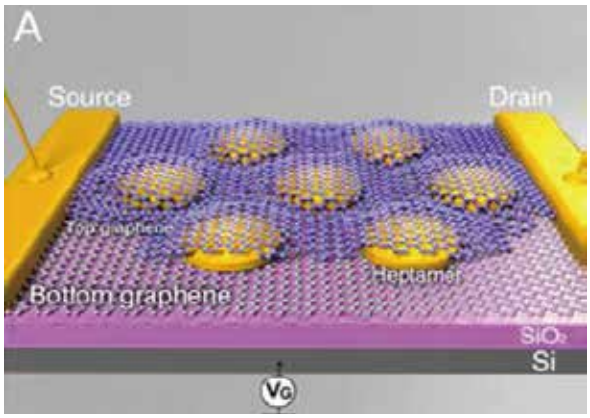


图 1：“碳单层 - 光学天线”三明治光电探测器示意图。

Figure 1: The scheme of grapheme-antenna sandwich photodetector.

II. Plasmonic Graphene-Antenna Sandwich Photodetector (Nano Lett. 12, 3808, 2012)

Nano Letters on line published plasmonic enhanced Graphene-Antenna Sandwich Photodetector investigation. (Nano Letters 2012, 12, 3808)

Nanoscale antennas sandwiched between two graphene monolayers yield a photodetector that efficiently converts visible and near-infrared photons intoelectrons with an 800% enhancement of the photocurrent relative to the antennalessgraphene device. The antenna contributes to the photocurrent in two ways: by thetransfer of hot electrons generated in the antenna structure upon plasmon decay, as wellas by direct plasmon-enhanced excitation of intrinsic graphene electrons due to theantenna near fi eld. This results in a graphene-based photodetector achieving up to 20% internal quantum efficiency in the visible and near-infrared regions of the spectrum.This device can serve as a model for merging the light-harvesting characteristics ofoptical frequency antennas with the highly attractive transport properties of graphene innew optoelectronic devices.

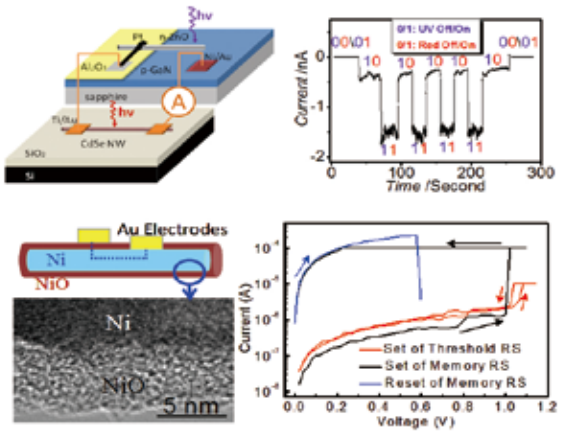
After published on line for one week, this paper was highlighted by Nature Physics and C&E news. This work was supported by State Key Lab for Mesoscopic Physics, and school of physics, Peking University.

三、“纳米结构与低维物理”研究

纳米结构与低维物理实验室 2012 年总结会议（2013 年 1 月 13~15 日）

Annual meeting of the Laboratory for Nanostructures and Low-Dimensional Physics held in the suburbs of Beijing, 13~15 January, 2013.

纳米线不仅是构筑复杂器件与系统的最小构造基元，也是物理学研究的理想对象。纳米结构与低维物理实验室在纳米线的自下而上可控制备、物理研究方面做出了开创性的贡献。经过十几年的发展，半导体纳米线不仅在量子比特 (Nature 442,667,2006、Nature 468, 1804，2010)、Majorana 费米子 (Science 336，1003，2012) 等新颖物理现象研究方面崭露头角，也在纳米发电机、图像显示技术新能源材料应用方面展现出美好的前景。尽管如此，如何充分发挥纳米线的尺寸效应、表面效应，开发高灵敏度、高效率的纳米器件仍然是全世界科学家的一大挑战。近两年来，北京大学“纳米结构与低维物理”实验室在半导体纳米线的光电、光伏效应、阻变开关效应研究方面取得新进展。



图： 单根纳米线器件效应研究。上：n-ZnO 纳米线 /p-GaN 自驱动纳米器件。下：Ni/NiO 纳米线电阻开关特性。

Figure: Single nanowire based nanodevices. Upper: The schematic picture of the integrated photodetectors: a CdSe nanowire device powered by an n-ZnO/p-GaN heterojunction photovoltaic unit（Advanced Materials 24,4707,2011）. Lower: Sketch of the device. The dotted line indicates the current path for the memory device. The I-V curves show the resistance switching behaviors of the Ni/NiO coreshell nanowire (Nano Letters 11, 4601 2011).

该实验室年轻教师廖志敏与研究生别亚青等通过微加工手段制备了单根 ZnO 纳米线与 GaN 的异质结结构，实现了自驱动纳米器件。该自驱动纳米器件具有快速的紫外光探测功能，光响应上升时间约为 20 微秒，下降端迟豫时间约为 219 微秒。利用光伏效应，该 p-n 结在紫外光激发下成功地驱动了 CdSe 纳米线红光探进行红光的高灵敏测器。联合器件在多波长光探测器、自驱动光探测器、以及光操纵逻辑门等方面有着潜在的应用。相关工作在 2011 年《先进材料》（Advanced Materials24,4707,2011）上。他们进一步研究了一种独特的 Ni/NiO 纳米电缆线结构的电阻开关特性，发现当限制电流比较小时，低电阻状态在低电压时不能存在；当限制电流比较大时，系统由高电阻态转变为低电阻态，实现了可多次重复的记忆电阻开关，从而实现了非易失性的存储功能。实验结果和理论分析表明通过电场来降低氧空位的迁移势垒是非常有限的，这不足以导致氧空位链的形成，而电流导致的焦耳热是NiO产生电阻开关的主要原因。相关工作发表于 Nano Letters, 11, 4601 (2011)。

该实验室年轻教师赵清与研究生王伟等利用生长在金属丝上排列有序的大面积高密度 ZnO 纳米线阵列，发明了一种新型双面透光，无需 ITO 玻璃，柔性染料敏化太阳能电池。该电池器件具有十分优异的弯折和双面透光性能，显著提高了太阳光的利用效率。该结构制作方法简单，易于推广，已在金、银、铜、钨等多种金属丝上制成器件。器件厚度超薄、质量轻，柔韧性好，用法灵活，应用前景十分广阔 (Advanced Functional Materials 22, 2775, 2012)。同时，仿照自然界中热带雨林结构，利用 p 型 Si 纳米线阵列 /CdS 纳米颗粒 /n 型 ZnO 纳米线阵列构建了多层扩展光吸收的纳米热带雨林太阳能电池结构，贯穿器件长度的 Si 纳米柱阵列提供了有效载流子传输通道，大幅扩展了对可见光的吸收利用，大幅降低了器件顶电极电阻，有望显著提高光电转化效率 (Nanoscale 4, 261,2012)。

III. Nanostructures and Low-dimensional Physics

Nanowires are not only the fundamental building blocks to build complex devices and systems, but also the ideal objects for physics research. After ten years of development, semiconductor nanowires demonstrate the novel physical phenomena including quantum bits, Majorana fermions, nano-generator, image display technology applications, which show a bright future. Nevertheless, how to give full play to the nanowire size effect, surface effect, open high-sensitivity, high-efficiency nanodevices is still a major challenge for scientists around the world. The Laboratory for Nanostructures and Low-Dimensional Physics （nanolab.pku.edu.cn）is the pioneer for catalytic-directed synthesis of 1-D semiconductor nanowires from the bottom, and made leading contribution to the field. The past two years, The NanoLab led by Prof. Yu has achieved research progress in terms of optoelectronics, photovoltaic effect and resistive switching effect of semiconductor nanowires.

p-n junction with short-circuit current density up to ~ 5×104 mA cm-2, open-circuit voltages ~ 2.7 V, and maximum output power ~ 1.1 μW. Furthermore, a multi-wavelength photodetector was fabricated by integrating the PV device with a CdSe nanowire red-light detector. The integrated nanocircuit functioned as an optical AND logic gate and operational multi-states output was also demonstrated.

Furthermore, the first controlled alternation between memory and threshold Resistance Switching (RS) in single Ni/NiO core-shell nanowires were demonstrated by setting the compliance current (ICC) at room temperature. The memory RS is triggered by a high ICC, while the threshold RS appears by setting a low ICC, and the Reset process is achieved without setting a ICC. In combination with first-principles calculations, the physical mechanisms for the memory and threshold RS are fully discussed and attributed to the formation of an oxygen vacancy (Vo) chain conductive filament and the electrical field induced breakdown without forming a conductive filament, respectively. Migration of oxygen vacancies can be activated by appropriate Joule heating and it is energetically favorable to form conductive chains rather than random distributions due to the Vo-Vo interaction, which results in the nonvolatile switching from the off- to the on-state. For the Reset process, large Joule heating reorders the oxygen vacancies by breaking the Vo-Vo interactions and thus rupturing the conductive filaments, which are responsible for the switching from on- to off-states. This deeper understanding of the driving mechanisms responsible for the threshold and memory RS provides guidelines for the scaling, reliability and reproducibility of NiO based nonvolatile memory devices.

Transparent, double-sided, flexible, ITO-free dye-sensitized solar cells (DSSCs) are fabricated using highly ordered, high-density ZnO nanowire arrays on stainless steel, Au, Ag, and Cu microwires as working electrodes. The devices show excellent flexibility and can increase sunlight use efficiency through two-sided illumination. The double-wire planar solar-cell configuration can be used as window stickers and readily realized for large-area roll-to-roll processing (Advanced Functional Materials 22, 2775 (2012)). Novel multilayer nanorainforest solar cells based

on p-Si nanopillar array/n-CdS nanoparticles/n-ZnO nanowire array heterostructures were achieved. Extended light absorption was achieved by choosing materials with good match of bandgaps. Si nanopillars provided efficient carrier transport paths. Introducing PMMA as supporting layer greatly decreased the top contact resistance, and significantly improved the conversion efficiency of the solar cell. Nanoscale 4, 261 (2012).

四、石墨烯的精确定位转移与物理性质研究

石墨烯具有无质量的狄拉克费米子（Dirac fermions）、半整数的量子霍尔效应、Klein 隧穿效应等奇特的物理性质，预示着石墨烯在下一代集成双极性场效应光电子器件、透明太阳能电池电极及其它全碳器件方面有着巨大的应用前景。传统的微机械剥离难以扩展为有效的大规模制备石墨烯的方法。该实验室青年教师廖志敏博士等发展出一种新方法，能将不同大小形状的石墨烯单片结构精确转移到任意衬底的指定位置而不损坏石墨烯本征性质，同时减少衬底环境对石墨烯性质的影响。拉曼光谱、场效应管特性及低温量子霍尔效应等研究方法证明了该转移方法的可靠性（Advanced Materials 23， 3938，2011）。

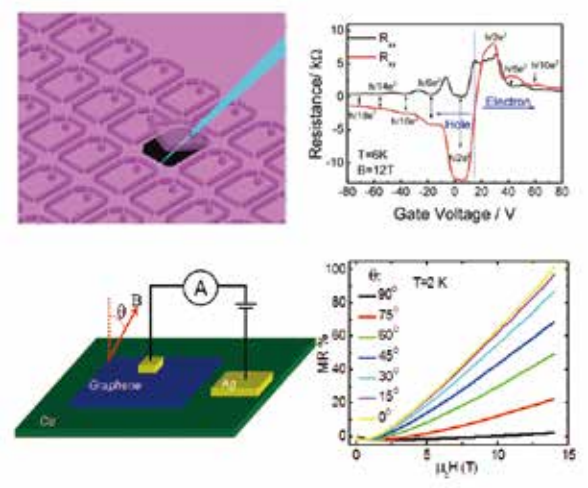


图 1: 上：石墨烯定点转移示意图及低温高磁场门压调制下的霍尔电阻。下：利用上述精确转移方法制备的石墨烯垂直器件结构的示意图及其磁阻对磁场的各向异性依赖。

Figure 1: Upper: Transfer scheme of Graphene microstamps; Longitudinal and Hall resistance versus gate voltage at low temperature and high magnetic field（Advanced Materials 23， 3938，2011）. Lower：Schematic of a graphene stack sandwiched by two electrodes constructed via above-mentioned precise transfer technique. The MR of a two-layer graphene stack measured at 2 K with different angles between the normal of the graphene plane and the magnetic field（Advanced Materials 24,1862，2012）.

虽然石墨烯二维面内量子输运特性已经取得了诸多的成果，但是垂直于石墨烯平面方向的输运特性却鲜有报道。最近，该实验室利用上述精确定位转移技术，制备了正常金属 / 多层石墨烯 / 正常金属垂直结构，研究了在电流垂直于石墨烯平面（current perpendicular to graphene plane）的情况下，温度、磁场对载流子输运的调制作用，发现当载流子在垂直方向输运通过两层石墨烯时，整个器件的仅电阻几十欧姆，且在 14T 的磁场下达到 100% 的磁阻效应。磁阻的大小对磁场方向非常敏感，并表现出强烈的各向异性。这种超薄的石墨烯器件单元可能在磁电子学方面有着潜在的应用（Advanced Materials 24,1862，2012）。

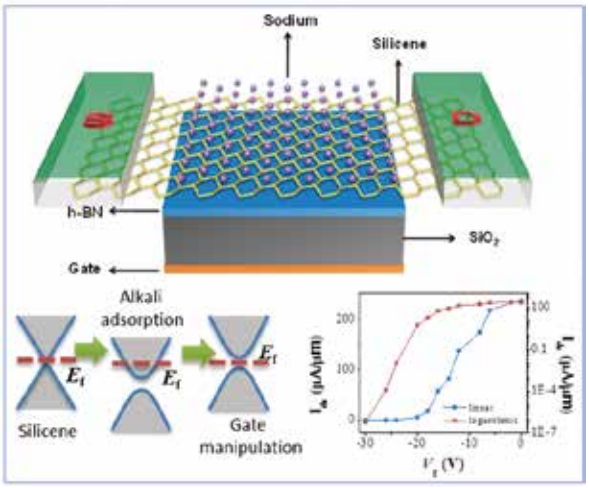


图 2: 基于 Na 吸附的硅烯结构的单门场效应管。

Figure 2: FET based on the Na-covered silicene. (Top) Schematic model; (Bottom left) The band gap opening by alkali adsorption and the Fermi level manipulation by the gate; (Bottom right) Transfer characteristic of the device.

石墨烯、硅烯都具有极高的载流子迁移率，但它们的能隙为零，不能直接去做高表现的场效应管。打开石墨烯和硅烯的能隙、保持高的载流子迁移率是它们走向电子器件应用的关键。该实验室的吕劲教授通过理论计算发现，施加垂直电场可打开硅烯能隙 (Nano Letters 12，113,2012）。他们基于密度泛函理论计算提出一种打开硅烯能隙的方案，即在硅烯上单面吸附金属原子，可以在保有硅烯高迁移率，同时有效地破坏硅烯的对称性，从而打开能隙。能隙的大小可以通过改变吸附浓度加以调节，最高可以达到 0.5 eV。通过对钠原子吸附的硅烯场效应管模型的量子输运模拟显示该器件的开关比可高达 108，满足高表现逻辑器件的需要。该理论为硅烯作为高表现的场效应管提供了一个新的实现途径（Scientific Reports 2, 853,2012)。

IV. Site-specific transfer-printing of individual micro-patterned Graphene and Interlayer interaction

Graphene, a perfect two-dimensional crystal of carbon atoms, has attracted intense interest in research due to its unique physical properties. Although mechanical exfoliation is an effective and successful sample preparation method for fundamental research, it is not a scalable process. Therefore, finding a cheap and efficient method to site-specific transfer-print individual, high-quality graphene microscale sheets to target substrates is highly desirable for the precise assembly of devices. We have developed a method of site-specific transfer of individual graphene microsheets to arbitrary substrates. Surface-enhanced Raman spectrum, gate voltage dependent conductance, half integer quantum Hall effect, and electrical interconnection are investigated to demonstrate advantages of the technique including precise positioning, avoiding extrinsic doping effect, maintaining the graphene quality, improving the efficiency of CVD grown graphene deployment, and convenient device repair.

Via transfer-printing of graphene, we also fabricated the vertical structure of metal/multi-layered graphene/metal, in which the carrier transport is perpendicular to the graphene plane. The transport studies showed that both temperature and magnetic field are capable of modulating the resistance (only tens of ohms), as current is perpendicular to graphene plane. At a magnetic field of 14T, magnetoresistance reaches 100%. Moreover, the magnitude of magnetoresistance is strongly dependent on magnetic field direction. The ultra-thin graphene devices may have potential applications in magnetic electronics.

Even though both graphene and silicene have ultra-high carrier mobility, their zero band gap nature make them cannot be directly used in high performance

field effect transistors (FET). Opening a band gap without degrading their high carrier mobility is vital for graphene and silicene to their application in nanoelectronics. Based on their previous works of building the BN/graphene/BN sandwich structure (NPG Asia Materials 4, e6(2012)) and applying external vertical electric field to silicene (Nano Letters 12, 113(2012)) to open a band gap, recently the Computational Materials Group led by Prof. Jing Lu at School of Physics, Peking University proposed a new scheme to open a band gap in silicene --- single side surface adsorption of metal atoms on silicene. Their density functional theory calculations predict that a band gap is opened in silicene by single-side adsorption of alkali atom as a result of sublattice or bond symmetry breaking. The band gap size is controllable by changing the adsorption coverage, with an impressive maximum band gap up to 0.50 eV. The ab initio quantum transport simulation of a bottom-gated FET based on a sodium-covered silicene reveals an on/off current ratio up to 108, meeting the requirement for the high performance logic devices. Therefore, a way is paved for silicene as the channel of a high-performance FET. This work was published in the new journal of Nature Publishing Group《Scientific Reports》 (Tunable and sizable band gap in silicene by surface adsorption, Scientific Reports 2, 853 (2012).

五、石墨烯图形化新方法及其在新型纳米太阳能电池和发光二级管（LED）方面的应用

纳米尺度太阳能电池和发光二级管在纳光电集成方面有重要的应用前景。 原则上，半导体单晶纳米线（带）可以生长在包括柔性衬底的任意衬底上，并可通过自下而上的方法构建器件，是制备新型纳米器件的理想候选材料。肖特基结相比 p-n 结具有材料普适性好、制作工艺简单等优点。然而，在传统的在肖特基结中，由于金属层会吸收大部分入射光，从而限制了该结构在光伏器件中的应用。具有高透过率、高电导率的石墨烯材料，为研制新型肖特基结太阳能电池带来了曙光。秦国刚、戴伦研究组在石墨烯图形制备方面取得了两项创新性成果：1）发展了一种石墨烯转移方法，该方法具有可精确定位、石墨烯材料利用率高、免刻蚀等优点；2）发明了一种大面积图形化石墨烯的方法，该方法具有图形精度高、对准精度高、 免刻蚀、 硅工艺兼容、可应用于制备器件阵列等优点（专利号 ZL 2010 1 0215355. 4）。在此基础上，研制成功高性能单根 CdS 纳米线 (带) 肖特基结太阳能电池 (光电转换效率 PCE~1.65%) (ACS applied materials & interfaces 2, 3406 (2010))。在该工作中，他们创新性地提出并制备了串联电阻小、光透过率高的金属薄膜 / 石墨烯复合肖特基电极。之后，利用 CdSe 和石墨烯功函数差较大，可以直接形成良好的肖特基接触的优点，他们研制成功单根 CdSe 纳米带 / 石墨烯肖特基结太阳能电池（转换效率 ~1.25% ）(Nanoscale 3,1477 (2011))。最近，他们受邀撰写石墨烯基肖特基结太阳能电池的 highlight 文章： “Graphene-Based Schottky Junction Solar Cells”, J. Mater. Chem. 22, 24224 (2012)。 此外，该研究组在国际上首次报道了半导体纳米线 / 石墨烯纳米带异质结 LEDs 的研究结果。在该工作中，他们创新性的设计并制备了一种面接触式器件结构，以增加有源区、减小串联电阻、提高电致发光效率。该工作为发展石墨烯基发光器件开辟了一条新途径 (J. Mater. Chem. 21, 11760 (2011))。

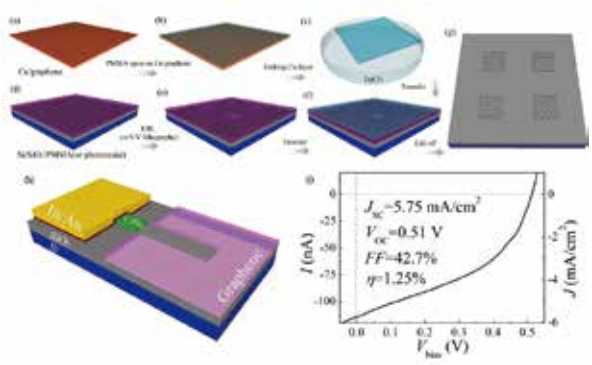


图 1：(a)-(g) 免刻蚀大面积图形化石墨烯方法：在 Cu/ 石墨烯上甩上 PMMA 胶后，采用 FeCl3 溶液腐蚀掉背面的 Cu 衬底，之后将石墨烯转移到带有 PMMA（或紫外光刻胶）图形的器件衬底上。 加热处理以增加石墨烯和图形窗口中器件衬底的粘附性。最后，在丙酮中浸泡去胶。该过程类似于传统微加工工艺中的剥离过程；(h) 单根 CdSe 纳米带 / 石墨烯肖特基结太阳能电池示意图；(i) 在标准 AM 1.5G 太阳光辐照下该太阳能电池的室温 I-V 特性。

Figure 1: A schematic illustration of the scalable graphene patterning process. (a) Synthesizing a large-scale graphene film on a Cu foil. (b) Spinning a layer of PMMA on the graphene. (c) Etching the underlying Cu foil using 1M FeCl3 solution. (d) Spinning a layer of PMMA (or photoresist) on a device substrate. (e) Pattering the PMMA (or photoresist) using electron-beam (or ultraviolet) lithography. (f) Manually collecting the graphene/PMMA film onto the device substrate. (g) Removing the PMMA (or photoresist) together with the graphene atop by a lift-off process in acetone. The patterned graphene is formed on the device substrate. (h) A schematic illustration of the CdSe NB/graphene Schottky junction solar cell. (i) Room-temperature I–V characteristic of the solar cell under the AM1.5G solar illumination with light intensity of 100 mW cm^{-2}.

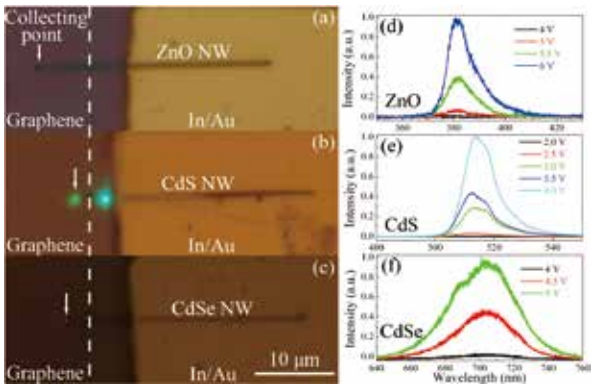


图 2：(a-c). 正向偏压为 5 V 时，石墨烯纳米带 /（ZnO, CdS, CdSe）纳米线异质结 LEDs 电致发光图象。(d-f). 这些器件在不同正向偏压下室温电致发光谱。

Figure 2: (a)–(c) The electroluminescence (EL) images of the GNR/SNW (ZnO, CdS, CdSe, respectively) heterojunction LEDs at a forward bias of 5 V. Dashed lines were used to demarcate the graphene from the substrate. White arrows: the light collecting points during the EL measurements. (d)–(f) Room-temperature EL spectra of the LEDs at various forward biases.

V. A simple and scalable graphene patterning method and its application in CdSe nanobelt/graphene Schottky junction solar cells

Nanoscale solar cells have important application prospect in nano-optoelectronic integration. Basically, semiconductor single crystalline nanowires (NWs) or nanobelts (NBs) can be grown on any substrates, including flexible substrates, and can be constructed into devices by the bottom-up method. Therefore, they are ideal candidates for constructing novel nanoscale devices. Compared to pn junction, Schottky junction has the advantage of material universality and fabrication simplicity. However, in traditional Schottky junction, the metal layer will absorb most of the incident light, which limits its application in photovoltaic devices. Graphene, with high light transparency and electrical conductivity sheds a new light on fabricating novel Schottky junction solar cells. Prof. Qin and Dai’s group has made two innovational achievements in fabricating graphene pattern: 1) developing a site-controllable patterned

graphene transfer method, which has the advantage of economizing graphene material and free from additional etching process; 2) inventing a scalable graphene patterning method, which has the merit of high pattern resolution and alignment accuracy, free from additional etching process, compatible to Si microprocess, applicable to fabricating device array etc. (patent number ZL 2010 1 0215355. 4). Based on these, they successfully fabricated high-performance single CdS NW Schottky junction solar cells (PCE ~1.65%) (ACS applied materials & interfaces 2, 3406 (2010)). In this work, they bring forward the concept of a combined Schottky electrode for the first time, which has the merit of low series resistance and high transparency. Later, by taking advantage of the bigger work-function difference between the CdSe and graphene, they successfully fabricate single CdSe NB/graphene Schottky junction solar cells (PCE ~ 1.25%) (Nanoscale 3,1477 (2011)). Recently, they are invited to write highlight paper: "Graphene-Based Schottky Junction Solar Cells", J. Mater. Chem. 22, 24224 (2012). Besides, they report novel graphene nanoribbon (GNR) /semiconductor nanowire (SNW) heterojunction LEDs for the first time. In this work, they design and fabricate a face-to-face contact device structure, which has the merit of larger active region, smaller series resistance, and higher electroluminescence efficiency. Their work opens a new route to developing graphene-based LEDs (J. Mater. Chem. 21, 11760 (2011)).

六、从分子到行为——时空变化环境下的细菌趋化性行为

感知外界环境变化并做出反应、趋利避害是生物生存的基本技能。细菌的化学趋向性行为是研究这一普适生存策略的最基本的素材。细菌的生存环境是不断变化的，对在这样复杂的环境下进化而来的趋化机制人们并没有深入的认识。北京大学物理学院欧阳颀教授课题组与美国 IBM T.J. 沃森研究所涂豫海教授合作，利用微流控技术，在百微米的空间尺度上实现了时空变化浓度梯度的精确控制，并用其观测了细菌的响应行为。发现了细菌在时空变化环境下趋化行为的新现象，并提出了基于个体分子机制的描述群体行为的平均场模型。首先在试验中发现结果依赖于外界浓度的变化频率：低频下，菌群的运动与浓度场的变化同步；而高频下，菌群的响应滞后于浓度信号的变化，甚至会聚集在低浓度区域（如图 1a-d 所示）。这一反常现象与经典的认识相悖。

这反常的实验现象本质上是由于细菌趋化性的分子机制决定的。从个体的分子机制到群体的行为，跨越多个时间和空间尺度，把这些知识联系起来，从系统的角度来理解本身是一个很大的挑战。该团队从细菌体内信号转导通路出发，建立了描述细菌群体行为的新模型，揭示了该现象的原因：细菌对环境的适应是通过对受体蛋白的甲基化修饰来实现的，当甲基化的速率跟不上环境的变化速度导致了菌群在高频下反常行为。新的模型架起了群体水平与分子水平上认识的桥梁，联系了不同尺度上的认识。该模型成功地解释了最大群体趋化速度与个体适应速率之间的标度率关系。还预言了新的反常规的现象：在行波环境中趋化速度方向会发生反转（如图 2 所示）。这种联系分子通路和细胞活动的多尺度建模方法可以用于其他生物系统的研究。

研究成果连续发表在最近两期的顶级物理杂志《物理评论快报》上 (Frequency-Dependent Escherichia coli Chemotaxis Behavior. Phys. Rev. Lett. 108, 128101 (2012). 与 Pathway-based mean-field model for Escherichia coli chemotaxis. Phys. Rev. Lett. 109, 048101 (2012))。两篇论文的第一

作者朱学珺和司光伟是北京大学前沿交叉学科研究院定量生物学中心招收的 08 级跨学科博士生，其背景分别为生物和物理。北京大学物理学院罗春雄副教授是实验中微流装置的主要设计者，合作指导了研究生的实验工作。该研究工作得到了国家自然科学基金，国家科技部等的支持。

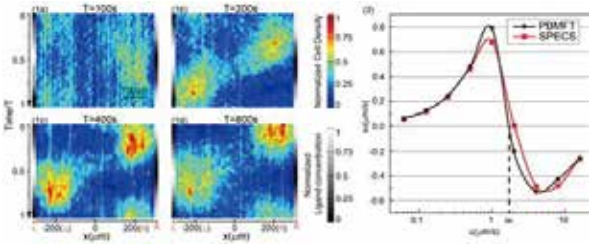


图 1：a-b：振荡浓度环境中不同周期下细菌密度的时空分布，细菌行为依赖于信号的频率（来源自 Phys. Rev. Lett. 108, 128101 (2012)）。图 2：基于分子机制的新模型预测在行波浓度环境下，细菌的群速度随波速变化而改变：当波速大于 uc 时，趋化速度将反向（来源自 Phys. Rev. Lett. 109, 048101 (2012)）。

Figure 1: a-b: Cell density distribution in oscillation attractant gradient environment. Bacterial behavior is frequency dependent. Figure 2: Cell population moving velocity reverses when the speed of driving travelling attractant concentration wave is larger than uc (simulation result based on the pathway based model).

VI. From molecule to behavior – Bacterial chemotaxis in spatial-temporal varying environment

Sensing the change of the surrounding environment and response to seek advantage or avoid disadvantages is the fundamental skills for living organisms. Among them, bacterial chemotaxis is a perfect model system to research this universal living strategy. While the environment bacteria live in varies both temporally and spatially, we still have little knowledge of how bacteria response to complex environment. The researchers in Prof. Qi Ouyang' lab, in collaboration with Prof. Yuhai Tu from IBM T.J. Watson research center realized a precise control of spatial-temporal varying chemical gradient in the scale of hundreds of micrometers, and measured the frequency dependent bacterial chemotaxis behaviors. They found frequency dependent bacterial chemotaxis behaviors and established a pathway based mean-field model to understand the unnatural behaviors in fast varying environment. In the experiment, they found that at low frequency, the bacterial population oscillates in synchrony with the attractant; in contrast, in fast-changing environments, the population response becomes smaller and out of phase with the attractant waveform. These observations are inconsistent with the classical chemotaxis model.

In theory, they found that this non-trivial phenomenon is determined by the intracellular molecular mechanism. It is a big challenge to understand the behavior of living organisms from the underlying interactions of bio-molecules as there are many scales (time and space) spanning from molecules to behaviors. The researchers develop a mean-field theory for E. coli chemotaxis based on the intercellular signaling pathway and explain the observations: a finite adaptation rate caused the non-trivial phenomenon in fast varying environment. This multi-scale model connects the cells' population level motility behavior with the molecular level pathway dynamics. It reveals a simple scaling dependence of the chemotaxis velocity on the adaptation rate in exponential gradients. Moreover, it predicts a surprising reversal of chemotaxis group velocity in traveling wave environments. This approach may be used to bridge molecular level pathway dynamics with

cellular behavior in other biological systems.

The results of the researches were published in the journal of Physical Review Letter (Phys. Rev. Lett. 108, 128101 (2012),and Phys. Rev. Lett. 109, 048101 (2012)).The first authors of these two articles are Xuejun Zhu and Guangwei Si, who are Ph.D. candidates from Center for Quantitative Biology which is a multidisciplinary research center. Prof. Chunxiogn Luo is the chief designer of the microfluidic device and co-directed the research work. This research work is partially supported by the NSF of China and the MOST of China.

03 现代光学研究所 Institute of Modern Optics

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 8 人，北京大学“百人计划”研究员 4 人，副教授 / 高工 6 人，讲师和工程师 3 人。其中，有 2 位 973 和国家重大科学研究计划项目首席科学家，3 位国家自然科学基金杰出青年基金获得者，1 位国家自然科学基金优秀青年基金获得者，7 位教育部新世纪优秀人才支持计划获得者，1 位北京市科技新星。2006 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 和 2012 年两次获得获得滚动支持。2012 年，团队还被授予中国侨界“创新团队奖”。经过十多年的发展，光学所成员在各自领域均取得非常显著的成绩并得到了国内外同行的肯定，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, International Conference on Nanophotonics, Femtochemistry IX, Asia Symposium for Intense Laser Sciences 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和拓展，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，北京大学光学站在国际前沿，开拓新的光学研究领域，目前已形成飞秒科学与强场光物理，介观光学与微纳光子学，光电功能材料与器件，量子光学与量子信息等四个主要研究方向。近年来，现代光学所成员已在 Nature Photonics, Nature Nanotechnology, Phys. Rev. Lett., Nano Lett., Adv. Mater.,Adv. Funct. Mater., ACS Nano 等刊物上发表许多篇重要学术论文。经过十多年的发展，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 （IMO）at Peking University (PKU) was established on the basis of the optics program of the Physics Department at PKU in May 2000, when the School of Physics was formed. The present head is Professor Qihuang Gong, who is a Cheung Kong Scholar Professor. Historically, Professor Yutai Rao initiated modern optics research at PKU in 1933 and developed it into a comprehensive optics program. At present, Optics Program carried by IMO is one of the key subjects of the 211 program and the 985 program at the University. It is also a National Key Discipline and one of the major research fields in the State Key Lab for Artificial Microstructure and Mesoscopic Physics. The Institute has also established several joint research centers

such as the CAS-PKU Ultrafast Optics and Laser Physics Center, and PKU Opto- Electronics Center.

Currently, the IMO faculty includes 8 full professors, 4 “PKU 100 Talents Program researchers”, 6 associate professors/senior engineers, 3 lectures/ engineers. In 2006, led 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. Due to its excellent research accomplishment, the project has been extended twice in 2009 and 2012 respectively. In 2012, it was awarded the Creative Group Prize by All-China Federation of Returned Overseas Chinese. After about 10 years' development, many faculties have carried outstanding research work in their research areas. Some of them serve as editorial members, topical editors of important journals such as Optics Letters, Chemical Physics Letters, and have acted as the chair of many important international conferences, e.g., Nonlinear Optical Phenomena and Applications (SPIE), Asian Conference on Ultrafast Phenomena, International Conference on Nanophotonics, Femtochemistry IX, Asia Symposium for Intense Laser Sciences.

In the early years, the optics in PKU was known for spectroscopy research. With the fast development of laser technologies, research at IMO has evolved into many important research branches and has been playing important roles in the advance of sciences and technologies. Currently, the optics research in the Institute mainly focuses on 4 important areas: femtosecond sciences and intense laser physics, mesoscopic optics and nanophotonics, opto-electronic materials & devices, and quantum optics & quantum information. The faculties have contributed much in these areas and have published many important research works in esteemed journals, such as Nature Photonics, Nature Nanotechnology, Phys. Rev. Lett., Nano Lett., Adv. Mater., Adv. Funct. Mater., ACS Nano, etc. After a decade development, with its growing reputation and impact, the Institute of Modern Optics at PKU is now an important center for research and education in optics.

一、强场原子分子物理研究

利用激光来探测原子分子的结构以及操控其内部的动力学一直是物理学的前沿课题之一，这些研究也极大地推动了相关科学和技术的进步。由于具有超短脉冲宽度和超强峰值功率，飞秒激光已经成为测量和操控原子分子超快行为的重要工具。强激光场作用下原子分子的动力学行为研究推动了阿秒科学、原子分子成像以及量子超快光场调控等新兴研究领域的快速发展。我们经过多年努力，建成了国际先进的原子分子光物理实验平台，并于 2011 年获得北京大学第六届实验技术成果奖一等奖。我们还在国内率先开发了精确求解双电子原子在激光脉冲作用下的全维含时薛定谔方程的大型并行程序，这种没有引入任何软化库伦势近似的 5 维空间 +1 维时间的双电子含时薛定谔方程，在国际上也仅有少数几个研究组能够精确求解。强场原子分子实验和理论研究平台的建立，极大提升了我国在强场原子分子物理领域的研究能力，2011-2012 取得了一系列进展。

2011 年我们首次实验发现：改变周期量级飞秒激光的载波相位，可以实现对一氧化碳分子二价电离态的非对称解离通道的控制，同时也实现分子三价离子的非对称解离通道的控制 [Y. Liu et al., Phys. Rev. Lett. 106, 073004(2011)]。该研究工作表明通过对超快光场进行控制，可以在分子电子态水平上实现对分子高阶电离和

解离通道过程的操控，并入选“2011 年度中国光学重要成果”。2012 年我们精确测量了强激光场下原子分子隧道电离区低能电子（<1eV）的精细能谱结构，揭示了隧穿电子与母体离子多次散射对电子能谱的重要影响 [(C. Wu et al., Phys. Rev. Lett. 109, 043001(2012)]。我们还发现隧道电离区的局域电离抑制现象，并指出强场隧道电离区的原子稳定化是局域电离抑制现象的主要机制 [H. Liu, et al., Phys. Rev. Lett. 109,093001(2012)]。上述研究进展深化了人们对强激光场下原子分子量子隧穿动力学的认识，对强场原子分子成像以及高通量阿秒脉冲产生具有重要意义，并入选“2012 年度中国高等学校十大科技进展”。

另外，我们提出了低能区阿秒条纹相机的概念，展示了电离的电子与其原子实相互作用时的波粒二象性，使得利用激光驱动的电子波包对原子分子势的全息成像成为可能 [M. Xu et al., Phys. Rev. Lett. 107, 183001(2011)]。

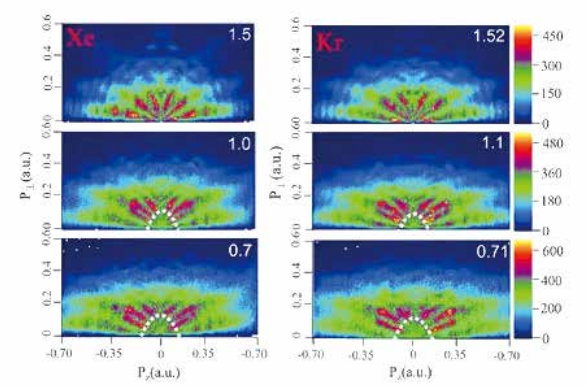


图 1：近红外强激光场中原子电离的光电子角分布。

Figure 1: Angular distributions of photoelectrons from Xe and Kr in near IR laser field.

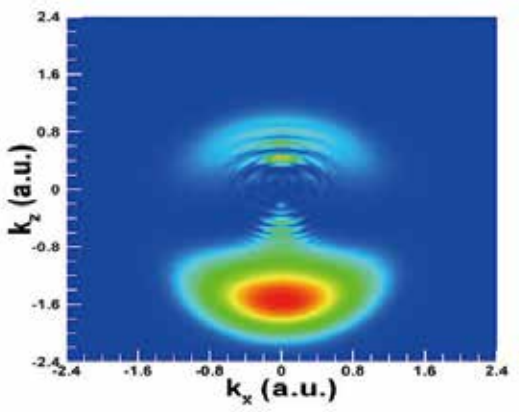


图 2：低能区的阿秒条纹相机谱。

Figure 2: Attosecond streaking spectra in the low energy region.

I. Physics study of strong field atoms and molecules

The probe of the atomic and molecular structures and control of their dynamics by lasers has been one of the research frontiers in recent decades. The progresses in these fields have greatly boosted relevant sciences and technologies. Femtosecond laser has become an important tool to measure and control the ultrafast dynamics of atoms and molecules due to its ultrashort pulse duration and ultrahigh intensity. At the same time, the study of strong field atomic and molecular dynamics has directly lead to the birth of attosecond sciences, atomic and molecular imaging, and coherent control with shaping laser pulses. We have established an experiment platform for strong field atomic and molecular physics in Peking University, which is internationally competitive and won the 1st rank award in the 6th Experiment and Technology Achievement Award at Peking University. We have developed an efficient parallel computer code to solve the time-dependent Schrödinger equation of two-electron atom in laser fields, among one of the very few groups which can attack such a computationally demanding problem. The establishment of the above experimental and theoretical platforms has greatly improved relevant researches in our country.

In 2011, we have demonstrated for the first time that the channel of symmetrical Coulomb explosion of double ionization of CO molecules can be controlled by tunneling the Carrier-envelope phase of strong few-cycle laser fields. The asymmetrical Coulomb explosion of triply ionization of CO molecules can also be manipulated [Y. Liu et al., Phys. Rev. Lett. 106, 073004(2011)].The work has been selected as one of the most important results of Chinese Optical Society in 2011. In 2012, we have measured the low-energy structure of photoelectrons in tunneling regime and have found that multiple rescattering has crucial roles on the photoelectron energy spectra [C. Wu et al., Phys. Rev. Lett. 109, 043001(2012)]. Subsequently, we further have found the phenomenon of local ionization suppression in tunneling ionization. With semi-classical simulation, they attributed the mechanism as the atomic stabilization in tunneling regime [H. Liu, et al., Phys. Rev. Lett. 109, 093001(2012)]. These experimental progresses will have serious influence on electron quantum tunneling, molecular imaging and high flux of high harmonic generation. The combined works were selected to be of the "Top 10 science and technology breakthroughs in 2012 in Chinese Universities".

Theoretically, we proposed the attosecond streaking in the low energy region, which showed the particle and wave duality of electron wavepackets and opened the possibility of holographic imaging of atomic and molecular structures and dynamics by electronic wavepackets [M. Xu et al., Phys. Rev. Lett. 107, 183001(2011)].

二、回音壁模式微腔光学研究

在北京天坛的回音壁，两个人贴着墙壁窃窃私语，即使相距很远也能够相互听得非常清楚。其原理是声波可以沿回音壁弯曲光滑的墙面不断反射而几乎不损耗能量，所以声音可以沿着墙壁传播到很远的距离。这种传播模式因此被称为回音壁模式，又称耳语回廊模式（Whispering gallery mode，WGM）。类似于声波，在介质微腔内部传播的光线可以发生连续的全内反射，从而实现光子的长时间和小空间尺度局域。光学微腔的时间局域性质通常由品质因子来描述，而空间局域性质可以由模式体积来描述。因为具有极高的品质因子和较小的模式体积，回音壁模式光学微腔可以极大的增强光和腔内外物质的相互作用，因而被广泛应用于各种微纳光子学物理和器件研究，例如，超低阈值微型激光器、超高灵敏度生物传感器、腔光力学、微型光梳和腔量子电动力学等。

对于微型激光器来说，其核心组成部分是光学谐振腔，且激光激射的阈值一般反比于光学谐振腔的品质因子。因而，具有极高品质因子的光学回音壁模式逐渐成为微型激光器研究的热点。然而，传统的回音壁模式激光器因具有旋转对称性，其激光出射是各向同性的，不利于实际应用。我们设计了一种特殊的非对称光学微腔，不但能够支持超高品质因子的回音壁模式，而且模式能量可以沿着特殊设计的方向出射。进而，在实验上，我们发展了一种全新的两步干法刻蚀技术，首次在硅芯片上成功的制备出了这种同时具备超高品质因子和高度定向性发射的非对称光学微腔。制备出的该类光学微腔的品质因子创纪录的超过 10^8。基于同样的技术手段可以制备出超低阈值、高度单向性的铒掺杂微型激光器，通过 1480 nm 波段自由空间光泵浦，该微型激光器表现出了极佳的 1550 nm 通讯波段单向性激光出射的性质，激光阈值小于 2 微瓦（如图 1a 所示），实验测量得到的远场发射角小于 10°

（如图 1b 所示）。这一研究结果发表在《先进材料》（Advanced Material）上，并被选为特刊《先进光材料》（Advanced Optical Materials）的封面文章（图 2）。这项研究工作不但对集成光子学芯片的微型光源具有重要意义，而且将来还可以被应用于某些重要的基础及应用物理研究，例如强耦合物理，腔光力学，超高灵敏度生物分子探测等。相关科技网站报道了该项成果。例如， Materials Views 网站以“利用超高 Q 值光学微腔实现高度定向性辐射”对该项成果进行了报道；德国《Optik & Photonik》杂志也以“Highly Unidirectional Emission from Ultrahigh-Q Microcavities”对该项成果进行了正面评价。

研究工作得到了国家自然科学基金，教育部新教师基金，北京大学和介观物理国家重点实验室的资助。

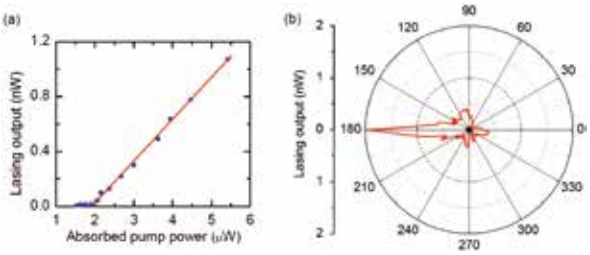


图 1: 自由空间光泵浦下铒掺杂非对称光学微腔的激光阈值 (a) 及远场出射分布 (b)。

Figure 1: (a) Lasing threshold behavior in an Er^{3+}-doped deformed microcavity under the free-space pumping and collection. (b) Far-field emission patterns, showing a highly unidirectional lasing emission along 180° direction.

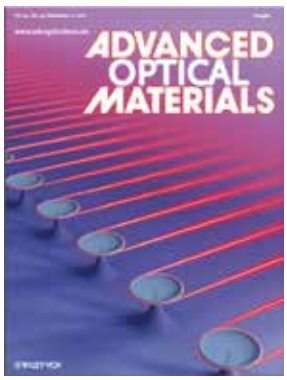


图 2：《先进材料》特刊《先进光材料》第 24 卷 35 期封面。

Figure 2: Cover picture of Advanced Optical Materials in Volume 24, Issue 35, a new section in Advanced Materials.

II. Progress in whispering gallery mode microcavity

Two people can hear each other whispering when they stand near the inner surface of the Echo Wall in Temple of Heaven, even if they are standing very far from each other. This is due to the continuous reflections of acoustic wave along the smooth inner surface of the Echo Wall, with very small propagation loss. Therefore, this kind of mode was named as whispering gallery mode (WGM). Analogy to acoustic wave, light can be trapped inside a dielectric microcavity, both spatially and temporally, through continuous total internal reflections along the inner surface of the microcavity. The temporal confinement is usually described by the quality factor (Q), while the spatial confinement by the mode volume. Due to the ultra-high quality factor and the small mode volume, the light-matter interaction is dramatically enhanced inside or outside the WGM microcavity, making WGM microcavity a promising platform for extensive applications, such as low-threshold microlaser, high-sensitivity biosensor, optical comb, and cavity quantum electrodynamics.

The key component of a mcirolaser is the microcavity. Generally, the lasing threshold in a microcavity is inversely proportional to the quality factor. Therefore, the high Q WGM microcavities have attracted growing interests in microlaser. Unfortunately, the emission of a traditional high-Q WGM microlaser is isotropic

due to the natural rotational symmetry, which hinders the practical applications. As a result, a microlaser with directional emission is strongly demanded for practical applications. Recently, we have theoretically designed a new type of microcavity which supported WGMs with both highly unidirectional emission and ultrahigh Q. The highly unidirectional emission results from the chaos-assisted tunneling, analogous to the dynamical tunneling, which is a pure quantum mechanical phenomenon. Furthermore, with a special pattern transfer technique and a reflow process, they fabricated such deformed silica microcavities. The resulting microcavities support nearly unidirectional emission and ultrahigh Q exceeding 100 million. This ultrahigh Q factor is four-order-of-magnitude higher than previous chip-based deformed microcavities. By doping erbium into the deformed microcavity, the lasing in 1,550 nm wavelength band was observed band with 1480 nm band optical pumping via free space. The resulting lasing has a ultra-low threshold of 2 microwatts (Fig. 1a), and unidirectional emission with a divergence angle about 10 degrees (Fig. 1b). A picture was selected as a cover picture in Advanced Optical Materials (Fig. 2), which is a new section in Advanced Materials. Researchers in University of Science and Technology of China and Washington University in St Louis also participated in this work.

In addition to the application in novel light source in integrated photonics, this microlaser also opens the door to some other fundamental physics studies, such as strong coupling physics, cavity optomechanics, and high-sensitivity biosensing. This work was also reported by some scientific websites and journals, such as Materials Views and Optik & Photonik in Germany.

This work was supported by the National Natural Science Foundation of China, the Research Fund for the Doctoral Program of Higher Education, and also supported by Peking University and State Key Laboratory for Mesoscopic Physics.

三、高效发光材料及其器件

薄膜有机电致发光二极管已经取得了惊人的进步并开始实用化，但是有些问题还有待进一步发展。一方面，从已有的 OLED 材料来看，p 型材料（传递空穴）传导速率远远高于 n 型材料（传递电子）传导速率，电子传输材料的不足是限制 OLED 效率的最重要因素之一，开发高电子传输速率的材料是重要的内容。另一方面，蓝色属于宽带发光，其导电能力将大大降低，蓝色发光材料及其器件也有待进一步发展。

基于 OLED 存在的以上问题，在电子传输材料方面，我们在高效有机发光方面的前期研究工作 1，采用超扭曲结构，降低分子的 π 共轭性，得到了宽带的电子传输材料 TemPPB，此材料不仅具有较高的能带（Eg=4.0eV），还具有较大的离化势（Ip=7.0eV），以及较高的玻璃化转变温度（Tg=97℃），其热稳定性得到较大改善，且三线态能级达到 3.2eV。这样有利于束缚高三线态能级的激子，因此适合用于作蓝色磷光发光器件的电子传输及空穴阻挡层材料。结果同样实现了近 24.5% 的外量子效率发光（接近理论极限），给高效蓝色磷光器件的设计提供了新的思路 2。

对于电子传输材料，除了希望其能够获得高的器件效率以外，其热稳定性也是一项很重要的性质，因为稳定性会影响其器件的使用寿命。我们合成了热学上非常稳定的二氮杂萘系列衍生物，它们不仅具有高效的电子传输能力，且具有较大的带宽 (2.94–3.33 eV)，相对于 Alq3 等传统电子传输材料，有更好的激子阻挡能力，从而得到了高效并稳定的绿色磷光 OLED。工作表明了

二氮杂萘系列衍生物是有良好应用前景的绿色磷光器件的电子传输材料。器件结构如图 1 所示意 [3]。

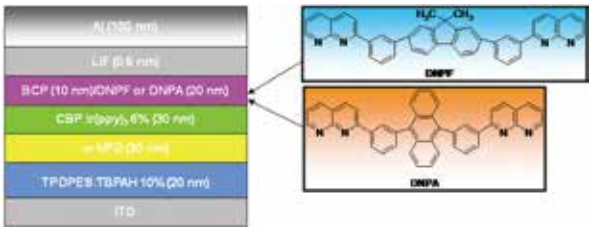


图 1：高效高稳定性电子传输材料及其器件结构示意图。

在蓝色发光材料方面，基于高热稳定性螺芴的扭曲立体结构来降低共轭性并保持高热稳定性，利用用高发光效率的基团菲，我们设计了深蓝色荧光材料 DPSF(图 2)，器件发光波长为 428nm 的深蓝光，色度坐标 CIE（0.15,0.08），与美国国家电视标准委员会标准蓝光（0.14,0.08）相当接近，同时达到 5.4% 的外量子效率发光（接近理论极限），在同类的蓝色荧光材料中处于领先行列 [4]。

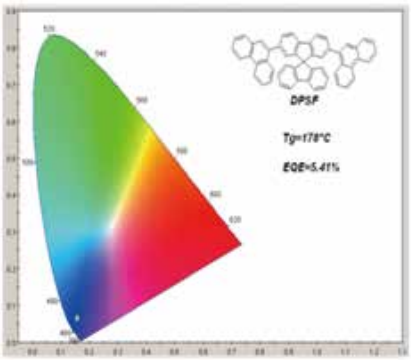


图 2：高效蓝色发光材料。

参考文献：

[1] Lixin Xiao et al., Adv. Mater. 2011, 23, 926-952.

[2] Lixin Xiao et al., J. Mater. Chem. 2011, 21, 19058.

[3] Lixin Xiao et al., Adv. Funct. Mater. 2012,DOI: 10.1002/adfm.201202194

[4] Xing Xing et al., J. Mater. Chem. 2012, 22, 15136.

III. Highly Efficient Materials for OLEDs

Organic light emitting diodes (OLED) has been commercialized as flat panel display since 1997, but some issues remain to be further developed. On the one hand, as the blue is a broadband light-emitting, its conductive capacity will be greatly reduced, so the blue light-emitting materials and their devices need to be further developed. The other hand, from the view point of the OLED materials developed, the mobility of p-type material (hole transport) is much higher than that of the n-type material (electron transport). The lack of efficient electron transporting material is the limit factor of OLED efficiency, therefore the development of an electron transport material is crucial to OLED.

Considering the above problems of OLED, in the side of electron transport material, based on our preliminary work on highly efficient OLEDs1, we employ a super twisted structure to reduce the π-conjugation of molecules, and obtain a wide gap electron transporting material TemPPB. This material not only has a higher energy band (Eg = 4.0 eV), but

also has a large ionization potential (IP = 7.0 eV), and a higher glass transition temperature (Tg = 97 ° C), and its thermal stability have been greatly improved, and triplet energy reached 3.2eV. Nearly 24.5% external quantum efficiency was achieved (close to the theoretical limit), which provides a new approach to design for highly efficient blue phosphorescent devices[2].

In addition to the hope that it can get high efficiency of the device for electron transport material, its thermal stability is a very important nature, because stability will affect the lifetime of the device. We have synthesized a series thermally stable naphthyridines derivatives, they are not only highly efficient electron transport ability, and having a larger bandwidth (2.94-3.33 eV), with respect to traditional electron transporting material such as Alq3, has a very good exciton blocking ability, to thereby obtain a highly efficient green phosphorescent OLED. This indicates that them possesses great potential application for the green phosphorescent device. The device structure is shown in Figure 1 schematically[3].

Based on high thermal stable spirofluorene and high luminous phenanthrene, we designed a deep blue OLED containing fluorescent DPSF with an emission at 428nm, CIE (0.15, 0.08) (Figure 2), quite close to the NTSC standard blue (0.14, 0.08), while 5.4% external quantum efficiency (close to the theoretical limit) was achieved, which is one of the best pure blue[4].

References：

[1] Lixin Xiao et al., Adv. Mater. 2011, 23, 926-952.

[2] Lixin Xiao et al., J. Mater. Chem. 2011, 21, 19058.

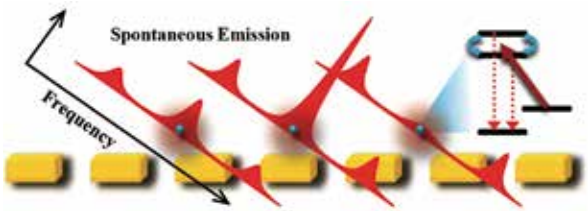
[3] Lixin Xiao et al., Adv. Funct. Mater. 2012,DOI: 10.1002/adfm.201202194

[4] Xing Xing et al., J. Mater. Chem. 2012, 22, 15136.

四、表面等离激元光学系列研究进展

基于纳米金属中自由电子集体振荡的表面等离激元光学，由于其巨大的近场增益、突破衍射极限以及超小的光学模体积等特点，使得在纳米尺度上光和物质的相互作用成为研究焦点，并可能用于解决目前信息科技中器件的小型化问题。

我们将纳米金属结构的表面等离激元诱导的各向异性的 Purcell 系数用于控制量子相干，提出了各向异性 Purcell 系数下四能级原子中自发辐射谱线线宽的控制机理，并在表面等离激元结构中证实此原理（图一）。这种纳米金属结构和量子的联合体系将会在有源、超紧凑的纳米器件中有一定的应用。该研究成果发表在 Nano letters，12，2488 （2012）上，工作一经发表，便被 Science 文章做为“用表面等离激元近场增益自发辐射”的先例而引用。

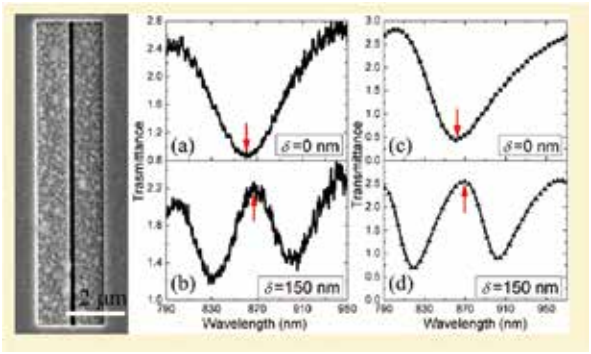


图一：表面等离激元周期性结构在纳米尺度上对原子自发辐射光谱线宽的周期性调制。

Figure 1: A nanoscale pulsing of line width of the spontaneous emission spectrum according to the periodical metallic nanostructure.

电磁感应透明（EIT）是一种量子干涉效应，具有窄谱的增强光透射，能极大的降低光速，因此在增强非线性、调制和传感等领域具有重要的应用前景。我们把电磁感应透明现象和表面等离激元结合起来，在实验上成功地观察到 SPP EIT-like 现象，理论和实验符合很好（图二）。研究

成果发表在 Nano letters，12，2494（2012）上。



图二：非对称 T 型狭缝结构单元中的表面等离激元类电磁感应透明现象。

Figure 2: Plasmon-induced transparency in a unit-cell structure of an asymmetric T–shape single slit.

还研究荧光相关光谱和单光子时间关联计数等方法系统地研究了孤立单个蝴蝶结形纳米孔内表面等离激元增强单分子荧光现象。蝴蝶结形纳米孔结构在单分子生化分析方面具有重要的应用前景。研究结果发表在 ACS Nano，6 (2)，1438–1448（2012）上。最后对基于表面等离激元的纳米颗粒电催化反应成像的研究进行了理论模拟，模拟结果为实验结论提供了强有力的支持。电催化反应发生引起颗粒附近的氢分子浓度增加，环境折射率减小，使其可以通过散射信号的变化进行监控。研究成果发表在 Nature Nanotechnology 7, 668 (2012) 上。

研究工作得到国家自然科学基金委“创新研究群体”项目、基金委重大研究计划“培育”项目、科技部 973 项目和介观物理国家重点实验室自主课题等的资助。

IV. Research progress on Plasmonics

Recent developments in nanotechnology and information technologies have made nanoscale light-matter interaction a tremendous research focus, which may be applied in the ultracompact nanodevices. Surface plasmon polaritons coming from collective oscillations of free electrons in metals, associated with strong local field enhancement, spatial resolution beyond the diffraction limit, and ultrasmall optical mode volume, have opened many possibilities of interfaces and applications for nanoscale waveguides, chem–bio sensing, solar cells, catalytic reactions, nonlinear optics, quantum optics, and so on.

By combining the anisotropic Purcell factor induced by surface plasmons in metallic nanostructures with the principle of quantum interference, we proposed the mechanism of using the anisotropic Purcell factor to control the line width of spontaneous emission spectrum. As proof of the mechanism and, in particular, as its application at subwavelength-confined anisotropic Purcell factor, several plasmonic structures were employed and interesting phenomena in the spontaneous emission spectrum appear (Fig. 1). The combined system of quantum emitters and plasmon nanostructure may open some perspectives for applications in ultracompact active quantum devices. This work was published in Nano Letters, 12, 2488 (2012) and cited as a precedent to “use surface plasmons to enhance the spontaneous emission” in Science soon after.

Electromagnetically induced transparency (EIT) is a quantum interference effect with a spectrally narrow optical enhanced transmission, which can lead to dramatically slowed down photons and has potential applications in enhanced nonlinearities, modulations, and sensors. Combining the EIT effect with nano-plasmonic structures, we experimentally demonstrated a surface-plasmon-polaritons-induced EIT-like (SPP EIT-like) optical response (Fig.2), which is greatly

favorable for the ultra–small functional devices and the increase of integrity of the photonic circuit. These pronounced features in the structure, such as the increased ultracompact size, quality factor, easy fabrication, and convenient experimental observation, have significant applications in ultra–compact plasmonic devices. This work was published in Nano Letters, 12, 2494 (2012).

We also reported experimental behaviors of polarization-dependent, plasmonic-enhanced molecular fluorescence within isolated bowtie nano-apertures (BNAs) milled in aluminum film studied by fluorescence correlation spectroscopy and lifetime measurements based on time-correlated single photon counting in an aqueous solution. The fluorescent behaviors are novel and clearly different from those within circular or rectangular nano-apertures. With an appropriate polarized excitation light, the fluorescence rate per molecule is significantly enhanced (～ 12-fold) within BNAs and the fluorescence lifetime and excitation volume are tunable by the excitation light polarization or the BNA size. The BNAs have potential applications, especially for single-molecule biological analysis. This work was published in ACS Nano, 6 (2), 1438-1448 (2012).

At last, we carried out theoretical simulations of the single-nanoparticle plasmonic images of the electrocatalytic activity and produced strong evidence in support of their conclusions. The scattering image contains contributions from both the nanoparticle and the hydrogen generated by the electrocatalytic reaction from protons in the solution reducing the surrounding refractive index, which could be monitored by P-ECi signals as a function of applied potential. Experimental images are in excellent agreement with our theoretical simulations by COMSOL multiphysics software. This work was published in Nature Nanotechnology, 7, 668 (2012).

This series of work is supported by the projects “the creative team” and “breeding” of great research program from the National Science Funding of China, 973 project from The Ministry of science and technology, and the funding from the State Key Laboratory for Mesoscopic Physics.

五、金属 / 介电微纳结构光调控研究取得重要进展

金属 / 介电微纳结构是纳米光子学领域研究各种微纳尺度下光传输、光子局域、光调控等新型物理效应和现象的重要平台。金属 / 介电微纳结构具有独特的近场光局域和光学非线性增强效应，因而是实现微纳全光开关等逻辑器件的重要基础。

我们提出了一种实现大非线性系数的金属 / 介电复合材料新原理：通过将周期性金属 / 介电结构 Bragg 共振增强非线性光学效应与强量子局域效应相结合，制备出在光通讯波段具有大三阶非线性光学系数和超快时间响应的 Au/ 多晶 LiNbO3 纳米复合材料，突破了光通讯波段微纳光子晶体器件研究在材料方面所受的限制；利用该纳米复合材料实现了低功率、超快速光子晶体全光开关器件原型：将阈值光功率降低了 3 个数量级，阈值光强从 GW/cm2 的量级降低到 9 MW/cm2, 接近实用化的要求；同时保持了 24.2 ps 的超快速时间响应和 80％的高开关效率，相关工作发表在权威期刊 Adv. Mater. 上（Advanced Materials 23, 4295 (2011)）。随后，我们通过将金属纳米颗粒表面等离激元共振增强非线性光学效应与光子晶体微腔的强光子局域效应相结合，制备出具有大三阶非线性光学系数的纳米复合材料光子晶体微腔，实现了低功率、高透过率

对比的全光二极管器件原型：将阈值光功率降低了 4 个数量级，阈值光强从几百 GW/cm2 的量级降低到 2.1 MW/cm2, 接近实用化的要求；将正反向透过率对比提高了 3 个数量级，达到了 11875。相关工作发表在重要刊物 Adv. Funct. Mater. 上（Advanced Functional Materials 21, 1083 (2011)）。

为了进一步在亚波长尺度上实现信号光传输的有效调控，我们设计并在金薄膜上制备出单个的非对称 T 型狭缝结构单元，在实验上成功地观察到 SPP EIT-like 现象。通过改变介质覆盖层的折射率，实现了可调谐电磁感应透明。研究论文发表在国际权威刊物 Nano Letters（Nano Letters 12, 2494 (2012))。在前面工作的基础之上，我们设计出一种同时具有长程传输和亚波长强光场局域特性的新型表面等离激元波导结构，在此基础之上，通过有效减小器件尺寸、微加工刻蚀精密控制位相差、连续激光激发单色表面等离激元模式的途径，克服了信号光线性相干方法的缺陷，将器件的特征尺度缩小了 4 倍（从几十 μm 减小到 5 μm），同时将“0”和“1”的强度对比提高了 4 倍，达到 24dB。而且，逻辑门功能的实现没有任何高功率阈值的要求。同时实现了超低功率、小型化、高逻辑状态对比的微纳全光逻辑门器件，相关工作发表在国际权威期刊 Nano Letters 上（Nano Letters 12, 5784 (2012)）。

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。

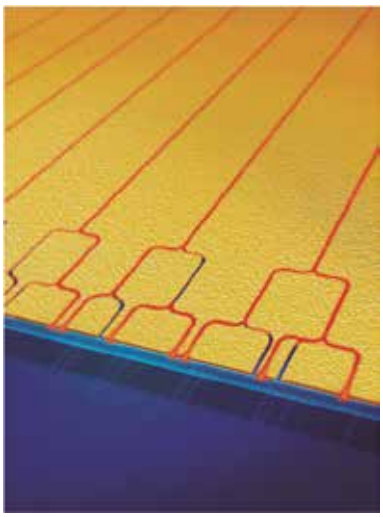


图 1：金属 / 介电复合材料微纳全光逻辑门结构示意图。

Figure 1: Schematic structure of the metal/dielectric composite all-optical logic.

V. Progress in Study of Optical Modulation in Metal/Dielectric Microstructures

Metal/dielectric microstructures are important platforms for the study of various phenomena and effects of light propagation, confinement, and modulation on the micro/nanometer scale in the field of nanophotonics. Metal/dielectric microstructures have unique near-field light confinement and nonlinearity enhancement effect, being the important basis of the nanoscale all-optical logic devices.

We proposed a new mechanism to construct metal/dielectric composite with large nonlinear susceptibility: Combining the Bragg resonance enhancing nonlinearity in periodic metal/dielectric microstructures and strong quantum confinement effect. Based on this method, they fabricated Au/polycrstal LiNbO3 composite with a large third-order nonlinear susceptibility. This overcomes the material limitation of nanoscale photonic crystal device study in the optical communication range. They realized low-power and ultrafast photonic crystal all-optical switching device prototype. The threshold power was reduced by three orders. The threshold intensity was reduced from GW/cm2 order to 9 MW/cm2, which nearly meets the requirement of practical applications. The ultrafast response time of 24.2 ps and a large

switching efficiency of 80% were also maintained. This work was published in Adv. Mater.（Advanced Materials 23, 4295 (2011)). Subsequently, we fabricated nanocomposite photonic crystal microcavity with a large third-order nonlinear susceptibility, realized by combining the surface plasmon resonance (SPR) of metal nanoparticles enhancing nonlinearity and strong photon confinement effect of photonic crystal microcavity. Based on the nanocomposite photonic crystal microcavity, we realized low-power and high-contrast all-optical diode device prototype. The threshold power was reduced by four orders. The threshold intensity was reduced from several hundred GW/cm2 order to 2.1 MW/cm2, which is nearly meets the requirement of practical applications. The transmission contrast reached 11875, which was enlarged by three orders. This work was published in Adv. Funct. Mater.（Advanced Functional Materials 21, 1083 (2011)).

In order to further realize the effective modulation of the signal light on the subwavelength scale, we designed and fabricated an asymmetrical T type slit structure in gold films, and successfully observed the SPP EIT-like phenomenon. The tunable SPP EIT-like effect was also realized by varying the refractive index of the dielectric cover layer. This work was published in Nano Letters（Nano Leters 12, 2494 (2012)). Based on the former works, we further designed a new SPP waveguide structure having long-range propagation and strong subwavelength confinement properties. Using the SPP waveguide, they overcame the defect of the method of signal light linear interference through effectively reducing the device size, precisely controlling the phase difference by microfabrication etching, and CW laser exciting quasi-monochromatic SPP waveguide modes. The feature device size was reduced by four folds (from several dozens μm to 5 μm). The intensity contrast between the logic states of “0” and “1” was enlarged by four folds, reaching 24 dB. Moreover, there is not any high-power requirement for the operation of the logic gates. Low-power, compact, and high logic contrast all-optical logic devices were realized. This work was published in Nano Letters（Nano Letters 12, 5784 (2012)）.

The 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.

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、^{14}C 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, ^{14}C compact AMS, 2K cryogenic system and accelerator-based neutron radiography system.

一、MeV 能区 ^{149}Sm(n, α)^{146}Nd 反应截面测量

^{149}Sm 是重要的裂变产物核之一，裂变产额较高。^{149}Sm(n, α)^{146}Nd 反应截面的确定，一方面对于核物理与核天体物理基础研究具有重要意义，同时对核能与核技术开发等有重要应用价值。该反应截面在 MeV 能区随中子能量快速变化，但由于余核是稳定的，不能用普通的活化法进行实验测量。实验测量的困难在于中子源强度低、反应截面小、本底干扰强、样品厚度的限制等。由于缺乏实验数据，核数据评价结果主要依靠核反应模型计算，导致不同的评价核数据库结果之间存在几十倍的差别。

采用高效率大立体角粒子探测器（双屏栅电离室）与大面积双样品相结合，在 MeV 能区 5 个中子能点，对上述核反应截面进行了系统的测量与分析。在 6.0 MeV 能点，采用薄、厚两种不同的样品进行重复测量，经过自吸收修正以后获得了一致的实验结果。准确测出了小到 50 μb 的核反应截面。结合理论分析，得到了从热能区到 MeV 能区可靠的激发函数。该工作填补了 MeV 能区该反应的实验数据空白，澄清了国际上不同评价数据库之间的巨大分歧。全部实验工作在北京大学物理学院重离子物理研究所 4.5 MV 静电加速器上完成。

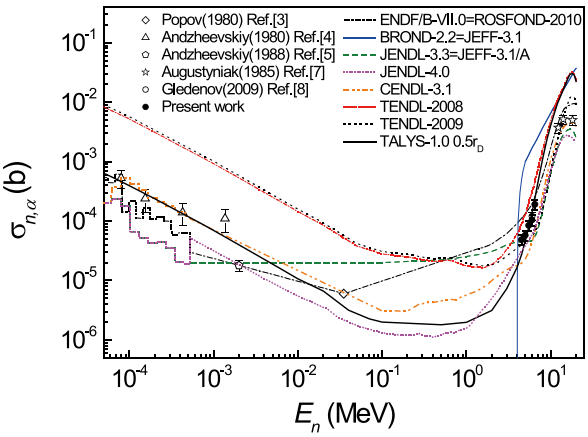


图 1： 测量的 ^{149}Sm(n, α)^{146}Nd 反应截面与评价库数据以及理论计算结果的比较。

Figure 1: Present cross sections of the ^{149}Sm(n, α)^{146}Nd reaction compared with nuclear data library evaluations and TALYS code calculations.

代表性论文：

[1] Guohui Zhang*, Yu. M. Gledenov, G. Khukhenkhuu, M. V. Sedysheva, P. J. Szalanski, P. E. Koehler, Yu. N. Voronov, Jiaming Liu, Xiang Liu and Jinxiang Chen, ^{149}Sm(n, α)^{146}Nd cross sections in the MeV energy region, Physical Review Letter, 107, 252502 (2011).

[2] Guohui Zhang*, Jiaming Liu, Zhiqi Gao, Hao Wu, Xiang Liu, Analysis and comparison of monoenergetic fast neutron fluence determination using ^{238}U samples at different positions with respect to the neutron source, Applied Radiation and Isotopes, 70 (2012) 888–892.

I. Measurement of ^{149}Sm(n, α)^{146}Nd Cross Sections in the MeV Region

^{149}Sm is one of the most important fission products, with relatively high fission yield. The ^{149}Sm(n, α)^{146}Nd cross section is of interest for nuclear physics, astrophysics as well as nuclear energy applications. However, in the MeV region where the cross section is changing fairly rapidly, there is no measurement datum. Measurements are difficult because activation techniques cannot be used, available neutron fluxes are relatively low, the cross section is fairly small, potential backgrounds can be large, and the sample thickness is limited by α-straggling. As a result, evaluated nuclear data libraries rely heavily on nuclear model calculations in this region, hence there are very large differences among different library of evaluations.

By using double-section gridded ionization chamber as high efficiency and large solid angle alpha detector and with large-area samples, ^{149}Sm(n, α)^{146}Nd cross sections are measured at five energy points in the MeV region. Measurement at 6.0 MeV is repeated with thick and thin samples, and the consistency is achieved after the correction of self absorption. Small cross section as 50 μb is obtained. Model calculations are also performed, and a good agreement is achieved between measurements and calculations from thermal to MeV energies. Our measurement is the first one performed in the MeV region, and large deviations among various evaluations are clarified. Experiments are performed at the 4.5 MV Van de Graaff accelerator of Peking University.

Selected Publications:

[1] Guohui Zhang*, Yu. M. Gledenov, G. Khuukhenkhuu, M. V. Sedysheva, P. J. Szalanski, P. E. Koehler, Yu. N. Voronov, Jiaming Liu, Xiang Liu and Jinxiang Chen, ^{149}Sm(n, α)^{146}Nd cross sections in the MeV energy region, Physical Review Letter, 107, 252502 (2011).

[2] Guohui Zhang*, Jiaming Liu, Zhiqi Gao, Hao Wu, Xiang Liu, Analysis and comparison of monoenergetic fast neutron fluence determination using ^{238}U samples at different positions with respect to the neutron source, Applied Radiation and Isotopes, 70 (2012) 888–892.

二、激光等离子体透镜与粒子加速

理论和加速实验研究表明，激光加速梯度可以达到 100GV/m 以上（比常规射频加速器高 3~6 个量级）。可以显著缩小加速器的尺寸和造价，是新一代加速器的重要候选。然而由于理论和技术的限制，激光加速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。重离子物理所颜学庆教授组在前期的研究中发现超短超强激光与固体靶相互作用时存在一种稳相加速机制 (PRL, 100, 135003 (2008); PRL. 102, 239502 (2009)); PRL 102, 239502 (2009)：即当激光归一化光强与膜片归一化厚度相当时，圆偏振激光可以如常规加速器一样对离子进行加速和纵向聚束，从而可以产生高品质的高能单色离子。通过国际合作，在多次实验中成功地证实了稳相加速机制的存在和优点（PRL 103, 245003 (2009); PRL 107, 115002 (2011)）。这些实验虽然证实了该方法可以大幅度提高离子束的能量、束流品质和束流强度。研究表明该方法加速质子到 100MeV 需要 1021W/cm2 以上的聚焦光强，薄膜靶对激光的信燥比也提出了极高的要求（>1010 @10ps），对高功率激光提出了苛刻的要求。

最近，北京大学物理学院颜学庆教授、陈佳洱院士、贺贤土院士和上海交通大学盛政明教授合作，提出在薄膜靶之前放置 “激光等离子体透镜”的新方法，可以对激光脉冲实现很强的横向聚焦，大幅度提高激光光强，缩短脉冲上升时间和改善脉冲的对比度。审稿人评论认为这是一个新的突破：The present work undoubtedly the present work undoubtedly breaks new ground and is of interest to many physicists。这有望提供新的技术途径来提高激光的对比度或者降低薄膜靶对激光对比度的要求，同时大大提高激光的聚焦光强。近期进一步的研究发现，高功率激光通过具有临界密度等离子体的等离子体透镜时，会产生高达百兆高斯的准静态磁场，在该磁场和激光电场的共同作用下，电子可以被磁场捕获并被激光电场直接加速，即逆自由电子激光机制。该机制可以产生高密度、高能量的电子束，对于 X 和伽马光源以及离子加速具有重要意义。等离子体透镜的工作以“Laser Shaping of a Relativistic Intense, Short Gaussian Pulse by a Plasma Lens”为题发表在物理评论快报（PRL 107, 265002 (2011)）上。

该系列研究得到科技部重大仪器专项项目、国家自然科学杰出青年基金、基金委重点项目、863 项目和某专项基地项目的资助。还得到了核物理与核技术国家重点实验室和北京大学应用物理与技术研究中心资助。

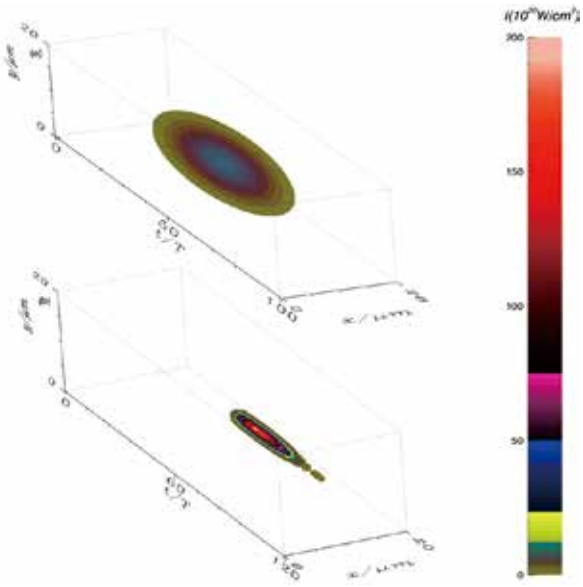


图 1：激光脉冲经过等离子体透镜前（上图）后（下图）能量分布图。

Figure 1: Energy distribution in 3D space（upper）and after shaping by the laser plasma lens (down).

II. Laser-driven plasma lens and particle acceleration

Ultrahigh-intensity lasers can produce accelerating fields of TV/m, surpassing those in conventional accelerators for ions by few orders of magnitude. Remarkable progress has been made in producing laser-driven ultra-bright MeV proton and ion beams in a very compact fashion compared to conventional RF accelerators. These beams have been produced up to several MeV per nucleon with outstanding properties in terms of transverse emittance and current, but typically suffer from exponential energy distributions. Phase Stable Acceleration (PSA) can generate the mono-energetic and collimated ion beam and is one of the most promising mechanisms for ion acceleration. Theoretical study shows that the required medical proton/carbon beams (200MeV for proton and 400MeV/u for Carbon) can be generated from hydrogen/carbon foil (sub micron) in a laser intensity of ~10^21/10^22W/cm2, while ultra high laser contrast (10^10) is required to avoid the pre-expanding of the thin foil.

Both ultra-high laser intensity and ultra-high laser contrast are challenging for state of art laser techology, recently Prof. Xueqing Yan, Prof.Jia-erh Chen and

Prof.Xiantu He from school of physics and college of engineering (Peking Univerisity) proposed laser driven plasma lens entitled “Laser Shaping of a Relativistic Intense, Short Gaussian Pulse by a Plasma Lens” on Physical Review Letters（PRL 107, 265002 (2011)）. In this letter the near-critical density plasma is firstly used as optical unit to focus, clean and steepen the laser pulse with relativisitc intensity. The plasma lens will be a key unit for the laser ion accelerator in the near future.

This work was supported by MOST key instrument project (2012YQ030142), National Natural Science Foundation of China (Grant Nos. 11025523, 10935002,10835003) and National Basic Research Program of China (Grant No. 2011CB808104). Finantial supports come also from Key Lab of High Energy Density Physics Simulation (CAPT).

三、基于强流射频四极场氘离子加速器的中子成像装置 (PKUNIFTY)

RFQ 加速器具有横向聚焦、纵向聚束与加速功能，是非常紧凑高效的低能离子加速结构，在加速器驱动洁净核能系统、散裂中子源、小型加速器中子源方面有非常重要的应用。而中子成像装置是 X 射线无损检测的重要补充，它对检测样品中的轻元素特别敏感，是航空航天火工品检测、复合材料无损检测不可缺少的重要研究设备。中子成像技术在西方欧美国家已经应用于航空航天产品的无损检测。北京大学 RFQ 课题组经过多年的研究攻关，于 2012 年 2 月研制完成基于强流射频四极场 D+ RFQ 加速器的中子成像装置（PKUNIFTY）（Figure 1），获得了一系列样品的中子成像照片 (Figure 2)，并于 2012 年 2 月通过专家组的测试，通过以王乃彦院士为组长的专家组的验收。该装置的建成填补了国内空白，并达到国际同类装置的先进水平。

PKUNIFTY 装置由电子回旋共振（ECR）离子源低能传输线（LEBT）、射频四极场（RFQ）加速器、高能束线、靶站极其中子慢化系统以及中子成像系统组成。RFQ 加速器工作在 201.5MHz，负载因子 1%-10% 可调，重复频率 100Hz, 可以加速 D+ 离子到 2MeV 能量，输出流强超过 15mA, 载束所需射频功率为 300kW. 10mA 4% 工作条件下，D+ 轰击铍靶可以产生 $2.4*10^{11}$n/s 中子，经过慢化后的热中子注量率为 $2*10^{4}$n/cm^2/s。

电子回旋共振离子源（ECR）工作在 2.45GHz，是一种产生强流、单电荷态离子束的离子源，用来产生强流的 H+，D+，He+ 等轻离子束，已被广泛用在 IPHI, IFMIF, SPIRAL II, FAIR, TASCO，DAE　ALUS 等项目中。表格 1 归纳了国际上 2.45GHz ECR 离子源的最好实验结果 [1,2,3]，彭士香老师研制的永磁 ECR 离子源（PMECRIS）结构紧凑，引出的三种束的束流密度都是世界上最高的。得到国际同行的高度评价，日本 REKIN 的 Nakagawa 博士、美国的 M. Stockli 博士、法国 CEA/Saclay 中心的 R.Gobin 先生等国际知名离子源专家分别在 ECRIS2010 会议总结、ICIS2011 会议总结、LINAC2012 邀请报告把北京大学的 PMECRIS 离子源列为该种类型离子源的典范加以肯定；中科院兰州近物所的赵红卫研究员认为：“北大的离子源是我们国内离子源领域的一大亮点。”

Table 1: Beam current produced by 2.45GHz ECR ion source around the world.

Labs	Los Alamos	CEA			CIAE	PKU		
Ion type	H+	H+	D+	He+	H+	H+	D+	He+
Facilities	LEDA	IPHI/ ESS/ FAIR	IFMIF/ Spiral II	Spiral II	CSNS	DWA	PKUNIF-TY	Coupled DFQ& SFRFQ
r(mm)	8.6	9	12	9	7	6	6	6
Energy (keV)	75	95	95	100	75	50	50	50
Current(mA)	130	157	175	104	150	120	83	65
Density(mA/cm2)	224	247	156	163	389	424	290	227

此外，北京大学离子源组还应实验室发展的需要成功地在 50kV 下获得了 70mA 的 Ar+ 束，50mA 的 O+ 束和 63mA 的 N+ 束 [3]。2012 年我们在 2.45GHz ECR 离子源上成功地在 40kV 下获得了 40mA 的纯 H_2^+，其比率占引出总束流的 54%[4]，远高于 INFN-Catania 的同类源的 20%/ 总流强 50mA 的水平 [5]；成功地获得了 4.4mA 的 He^{2+} 离子流 [6]，比之前的国际记录 15nA 高出了近 300 倍 [7]。在对现有离子源的磁场和放电室结构稍作修改后，我们成功地引出了 15mA 的 H- 离子束 [8]，远高于此类离子源保持的国际记录 5mA[9]。

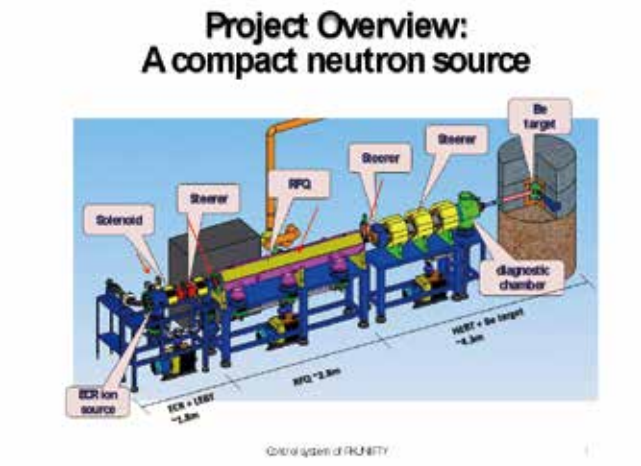


图 1：北京大学中子成像装置（PKUNIFTY）。

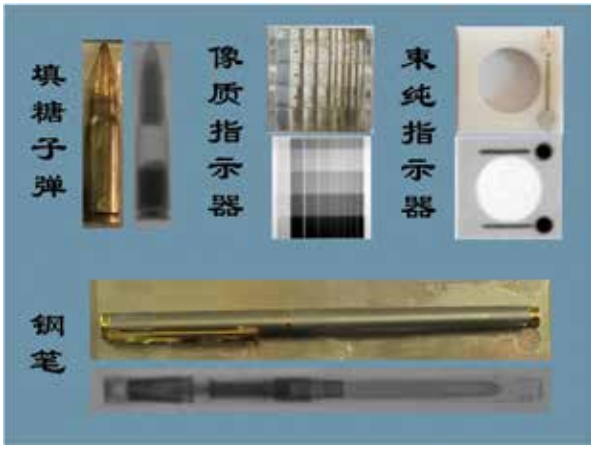


图 2：中子成像照片。

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专利：一种电子回旋共振离子源，专利号：201110026605.4

III. Peking University Neutron Imaging FaciliTY based on high intensity D+ radio frequency quadruple accelerator

Peking University neutron imaging facility (PKUNIFTY)(shown in Figure 1) is a radio frequency quadrupole (RFQ) accelerator based facility. The D-Be reaction was selected for neutron generation, and the energy of deuteron beam was set to 2 MeV. RFQ accelerator operates at 201.5MHz, the beam repetition frequency is 100Hz, duty cycle can be adjusted from 1% to 10%. The first beam commissioning was carried out at the end of 2011. The first neutron beam was obtained on Feb. 2, 2012. Since then, Neutron radiography experiments have been carried out. Figure 2 shows the preliminary NR results. The design of PKUNIFTY and its detailed results were published in the reference [1]-[6].

The 2.45 GHz ECR(Electron Cyclotron Resonance Ion Sources) is widely used to produce high current, single charged ions, mainly to generate H+, D+ or

He+ and some other light ions. This kind of source has been chosen to generate ions for many world level projects, such as LEDA in USA, IPHI & SPIRAL II in France, FAIR in Europe, TASCO and DAE ALUS in Italy, and IFMIF project. In PKU the Ion Source charged by Dr. Shixiang PENG keeps doing researches on 2.45GHz ECR ion source and ready produce H+, He+ and D+ for DWA, PKUNIFTY and Coupled RFQ&SFRFQ projects. Data listed in table 1 are the best results of this kind of source around the world. The highest beam intensities produced are kept by PKU PMECRIS[7]-[9]. The results obtained by PKU PMECRISs were highlighted by Dr. Nakaga from REKIN, JAPAN at the ECRIS2010 Summary, Dr. M. Stockli from SNS, USA at ICIS2011 Summary，Mr. R. Gobin from CEA/Saclay, France at his Invited talk during LINAC2012. Dr. H.W. Zhao from IMPCAS said "this is a big bright point of Chinese ion source domain."

We have produced 70mA Ar+,50mA O+ and 63mA N+ at 50kV with PKU PMECRISs for difference users in PKU. "It is pretty sure your source is probably the one with the best results in the world." (Comments from Mr. R. Gobin, CEA/Saclay).

During 2012, PKU PMECRISs delivered H2+ exceeding 40 mA[10],over 54% of the extracted beam in the H2+ fraction, with a total current of 76 mA, much higher than that INFN-Catania with H2+ fraction 20%/ for a 50 mA total beam[11].We have also got 4.4mA He2+, that is nearly 300 times of 15 nA reported in reference[12]. Through some modifications on magnet field configuration, discharge chamber structure and extraction system, we have got 15 mA H- ion beam at 40 keV by this prototype source[13],the world record is 5mA[14].

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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 8 人，其中教授 3 人（包括两名双聘院士和一名长江学者讲座教授）、“百人计划”研究员 2 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 7 members of 4 full professors, two Bairen research professors 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.

磁约束等离子体非线性波 - 粒子相互作用的物理过程研究

磁约束聚变等离子体中的非线性波 - 粒子相互作用，特别是兆瓦级大功率射频波注入对等离子体的加热与驱动以及这个过程中产生的快粒子（energetic particles）与等离子体本征模之间的相互作用，是实现磁约束聚变等离子体的高约束模式运行以及 ITER 和未来聚变堆燃烧等离子体物理研究的关键科学问题。在国家磁约束核聚变能研究专项支持下，北京大学聚变模拟中心与国内外同行合作，重点在快粒子与磁流体波本征模的非线性相互作用、低杂波与等离子体相互作用的数值模拟程序的发展方面开展研究，并取得了重要进展。

利用他领导发展的大规模回旋动理学模拟程序（GTC），林志宏教授指导张桦森博士模拟研究了等离子体比压（beta）分布诱导的 Alfvén 本征模（BAE）的非线性扫频过程。他们发现：快粒子的密度梯度会激发 BAE 波模幅度的指数增长，而 BAE 的增长反过来会影响快粒子的输运过程。在 BAE 的非线性发展阶段会形成快粒子相空间的相干结构。BAE 波对快粒子的捕获形成的相空间“岛”以及 BAE 波幅度调制引起的捕获粒子损失之间的竞争导致对 BAE 波频率的非线性调制。这一新的扫频机制为深入理解非线性波 - 粒子相互作用以及无碰撞等离子体中的输运过程提供了一个新的理论框架。这个工作的

第一作者张桦森博士（当时是北京大学等离子体物理与聚变研究所博士生）被邀请在 2012 年 Sherwood 国际聚变理论会议上做报告（是第一次由国内的研究人员在该会议上做邀请报告），主要结果发表在近期的《物理评论快报》上 [H. S. Zhang, Z. Lin, and I. Holod, Phys. Rev. Lett. 109, 025001, 2012]。部分基于这项工作，张桦森的博士论文得到了 2012 年蔡诗东等离子体物理奖。

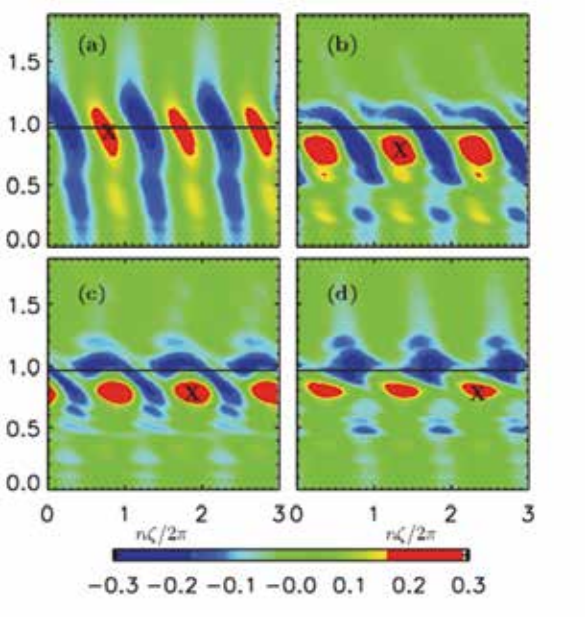

图 1：快粒子相空间（ζ - ω）非线性动力学过程（ζ - ω 对应图中 x-y 面）：快粒子扰动分布函数由颜色的变化显示（红色标志粒子相空间密度增加，蓝色标志粒子相空间密度减少）。从图中给出的四个时刻（a-d）的快粒子扰动分布可以看出相空间捕获粒子“岛”的演化。

Figure 1: Nonlinear dynamics in (ζ - ω) phase space with x-axis is ζ , y-axis is ω , described by of perturbed fast particle distribution function $\delta f_h/f_{h0}$. The phase space island evolution can be seen in time steps (a)–(d).

Nonlinear wave-particle interaction in magnetically confined plasmas

Nonlinear wave-particle interactions, particularly MW radio-frequency wave heating and current/flow driven, as well as eigenmodes interacting with energetic particles generated in the process, are fundamental issues in high performance (H-mode) operation scenarios and ITER (also future fusion reactors) burning plasma physics. Supported by ITER-China, PKU Fusion Simulation Center has focused on nonlinear interaction of energetic particles to eigenmodes of magnetohydrodynamics (MHD) waves, and development of plasma-LHW (lower hybrid wave) interaction code. Significant progresses have been made in last two years.

Making use of the gyro-kinetic toroidal massive simulation code (GTC), Prof. Lin Zhi-Hong and Dr. Zhang Hua-Sen studied nonlinear dynamics of beta-induced Alfvén eigenmode (BAE). It is found that a fast and repetitive frequency chirping is induced by the evolution of coherent structures in the phase space. The dynamics of the coherent structures is controlled by the competition between the phase-space island formation due to the nonlinear particle trapping and the island destruction due to the free streaming. This chirping dynamics provides a conceptual framework for understanding nonlinear wave-particle interactions underlying the transport process in collisionless plasmas.

The first author, Dr. Zhang (a PhD candidate then) presented this work as an invited talk on 2012 International Sherwood Fusion Theory Conference, Atlanta, Georgia, USA. He was the first researcher working in China to have this honor. The major

result is published in PRL [H. S. Zhang, Z. Lin, and I. Holod, Phys. Rev. Lett., 109, 025001, 2012] recently. His doctoral dissertation, partial based on this work, is awarded 2012 S. T. Tsai Plasma Physics Award.

06 技术物理系 Department of Technical Physics

技术物理系现有教职员工 25 人，其中：教授 6 人，教授级高级工程师 1 人，副教授 8 人，“北大百人计划”研究员 2 人，高级工程师 1 人，讲师 1 人，工程师 5 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、高能实验物理、中高能核理论、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），一个亚原子探测实验室，一个核物理教学实验室，北大 - 兰州联合核物理中心。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；承担 973 计划和基金重点项目；拥有非常广泛的国内外合作，包括高能物理重大国际合作和日本理化所 Nishina School 合作培养本科生科研能力。

There are 25 faculty members in the department, consisting of 6 full professors, 1 professorship engineer, 8 associate professors, 2 “BaiRen” research professors, 1 senior engineer, 1 lecturer and 5 engineers. The research fields include experimental nuclear reaction, experimental nuclear structure and decay, theoretical nuclear structure and decay, theoretical astrophysics, experimental high-energy physics, theoretical intermediate and high-energy physics, applied nuclear physics, radiation protection, detector technique and 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. The department holds a subatomic detector laboratory, an education laboratory for nuclear physics, and a PKU-Lanzhou joint center for nuclear physics. It is the only department in the universities of China , which is supported by the national project for fostering talents of nuclear science and by the national project of defense in nuclear physics. The researches are supported by many funds including project-973 and key project from national natural science foundation of China. The department has well established international and domestic collaborations including international high-energy experimental projects and undergraduate education program of Nishina School with RIKEN in Japan.

一、中子滴线核 ^{8}He 的敲出反应机制和基态结构

非稳定核物理（放射性核束物理）研究的对象，是尚未开发的广阔的未知核素领域。在离开 β 稳定线的区域，已经观察到原子核单粒子态壳层和有效相互作用的系统演变。而在同位旋极端不对称的滴线区，更是出现了晕和集团等新的结构自由度和新的有效相互作用。目前已经产生的质子滴线核达到 Z = 30 左右，而中子滴线核还只到 Z = 8 左右。由于极端弱束缚、低密度、连续态耦合以及核力的长程关联等原因，可以期待更重的滴线区还会出现大量新现象、新规律。

^{8}He 是 Z = 2 的滴线核，是中子 / 质子比最高的已知原子核，也是著名的双 Borromean 核，具

有丰富的集团结构和单粒子态结构。理论预言它有相当成分的 6He+2n 和 4He+2n+2n 的玻色子集团结构；而它的 4 个价中子所处的单粒子态，也分别有 (p3/2)4 和 (p3/2)2(p1/2)2 构型。实验研究这些状态的谱因子（概率），不仅对认识 8He 本身重要，而且对预言整个丰中子滴线区核的行为有指针性意义。

近年来北大组在日本理化所提出和实施了 ^{8}He 在质子靶上的敲出反应实验，所用能量为 82.3 MeV/u，流强达到 105 pps 量级，是目前世界上最强的 8He 束流。实验采用了自己特制的反冲质子探测器。此项实验首次在中能区实现了通过反冲质子标记的方法来区分不同的反应机制，特别是挑选出准自由敲出机制，这对直接观测基态结构是一个必要条件。在选择核芯敲出机制的基础上，获得了 6He 集团散射的微分截面，通过与理论截面比较提取了 8He 中 6He 集团结构的谱因子，发现其比壳模型预言的高出好几倍。另一方面，在选择价核子敲出机制的基础上，重建了 7He 共振态，结合准确的分辨率和接收度模拟，获得了到目前为止最准确的 7He 共振态宽度和谱因子，支持了从头计算理论（ab initio）给出的结果。

该结果在几个会议邀请报告中报道并发表在 Phys. Lett. B 707(2012)46-51（曹忠鑫博士为第一作者，叶沿林为通讯作者，江栋兴、郑涛、华辉、李志焕、李湘庆、葛愉成、楼建玲、李奇特等中日合作者 33 人参加），随即被若干理论工作重点引用，反冲质子标记方法也立即被国际上几项实验计划所采用，并邀请北大组参与实施。该工作得到 973 项目 2007CB815000 等的支持。

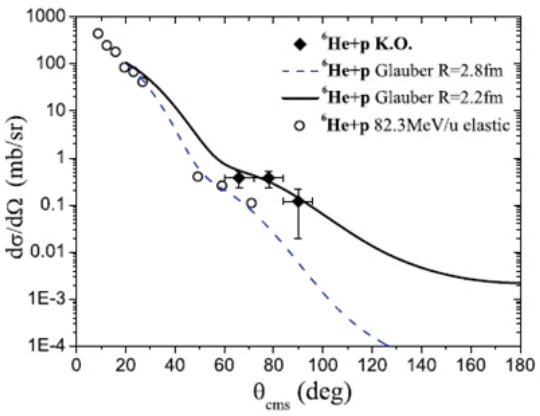

图 1：8He 中核芯集团 6He 的准自由敲出微分截面与 6He 弹性散射截面的比较。

Figure 1: Comparison of the differential cross section of the 6He core cluster knocked out from 8He, to that of the 6He elastic scattering.

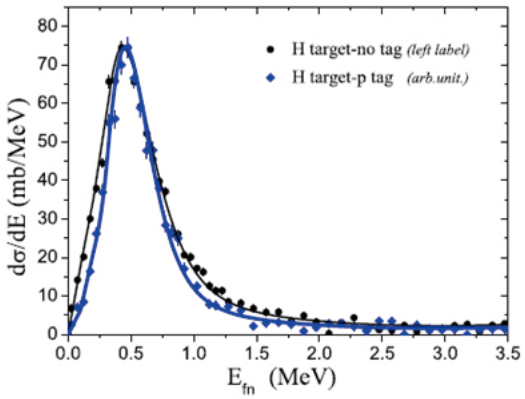

图 2：重建的 7He 基态共振峰。兰点表示采用了质子标记技术，黑点没采用。实线是拟合结果。

Figure 2: Reconstructed 7He resonance, with (blue) or without (black) recoil proton tagging. Lines fit the data.

I. Knockout reaction mechanism and the ground state structure of the neutron drip-line nucleus 8He

Unstable nuclear physics (RIB physics) is aimed at the unexplored large area on the nuclear chart. Away from the β-stability line, new phenomena, such as shell evolutions and changes of the effective interactions, have been observed. More exotically at the limit of the isospin asymmetry around the drip-line, new structure

degrees of freedom such as halo and cluster and new effective interactions have been emerged. So far the drip-line for protons has been reached up to Z=30, while that for neutrons can only be touched up to Z=8. Due to the extremely low binding energy, low density, strong coupling to the continuum and long range coupling of the nuclear force, it is expected that more exotic phenomena and new regulations will be found in the heavier drip-line area.

8He is a neutron drip-line nucleus at Z=2 with the highest neutron/proton ratio for any bound nucleus and the famous double-borromean structure. It is of very rich single-particle as well as cluster structure configurations. Experimental investigations of these exotic structures are important not only for describing 8He itself but also for understanding the behavior of nuclei in the whole drip-line area.

Recently the Peking University group has proposed and accomplished a knockout reaction experiment in RIKEN for 8He on a proton target. The 8He beam energy was 82.3 MeV/u and the intensity was about 105 pps, which is the most intense one in the world. In the experiment was applied the specially designed recoil proton detector. For the first time in the intermediate energy range the experiment realized the discrimination of various reaction mechanisms through the recoil proton tagging method. Especially the selection of the quasi-free knockout process is of primary importance in order to probe directly the ground state structure. Based on the core-fragment knockout mechanism, the differential cross sections for 6He cluster scattering was obtained and compared to theoretical predictions. The spectroscopic factor of this cluster configuration was extracted and found to be several times larger than the shell model predictions. On the other hand, 7He resonant state was reconstructed based on the selection of the valence nucleon knockout mechanism and the precise simulation of the detector resolutions and acceptance. The most precise results for the 7He resonance width and the related spectroscopic factor were obtained which support the theoretical predictions in the frame work of the ab initio calculation.

The results were reported in several conference invited talks and published in Phys. Lett. B 707(2012)46-51 with Zongxin Cao and Yanlin Ye the first and corresponding authors, respectively. The work was soon cited by several theoretical publications, and the recoil proton tagging method has been adopted by a few experiment proposals. Peking University group is invited to participate to these experiments and to take care of the recoil proton detection. This work is supported by the 973 project of China under grand number 2007CB815000.

二、原子核的奇特形状

核素版图上预言的 8000 多个原子核中，被认为 85% 以上的原子核具有长椭球现状。许甫荣教授和裴俊琛研究员课题组的理论研究指出：在特殊核区或特殊条件下，原子核可能具有奇特的现状，如超重核区的 β 6 形变、极高自旋下的大三轴形变。这些奇特的原子核形状造成了奇异的核性质和结构，相对应的有着复杂的转动谱，为研究量子多体问题提供了特有的物理载体。随着实验谱学技术的进展，超重原子核的高阶形变效应，超高自旋态的非轴对称形变等引起了广泛的关注。超重元素区相比于中重核区，其能级密度更大，原子核形变更硬，高阶形变效应更显

著。许甫荣教授和裴俊琛研究员课题组通过自洽计算发现六阶形变 β6 在超重核区存在，并对正确描述实验转动谱起关键作用，而这么高阶的形变一直没有被发现。这项研究对于超重核的高阶关联效应和能级结构提出了一种新的解释，文章以快讯形式发表在 Physical Review C 86, 011301 (Rapid Communications)(2012)。

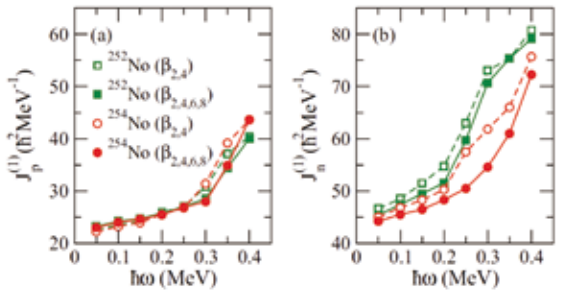

图 1: 252,254No 的运动学转动惯量的 (a) 质子部分，(b) 中子部分。

Figure 1: Proton (a) and neutron (b) components of the calculated kinematic moments of inertia for 252,254No.

高速转动量子体系的转动取向（orientation）稳定性是一个基本的物理问题。目前实验可以到达原子核 Er-158 自旋高于 60 ħ 的极高自旋区域，这是宇宙中已知的转动速度最快的体系。许甫荣教授和裴俊琛研究员课题组，基于微观 Skyrme 力自洽地计算研究了 Er-158 原子核的高自旋态，发现在极高自旋区域，这个原子核会发生大变形三轴形状，即大的非轴对称形变。原则上，三轴形变核态的转动取向可以偏离主轴，但他们的自洽倾斜转动计算发现：这个核的极高自旋态转动取向只能取其中能量最低的一个主轴，绕其它轴的转动是不稳定的，而此前的理论计算认为该转动态有绕不同主轴转动的共存。他们的计算很好地回答了最近的实验观察，定量解释了实验观察到的反常电四极矩。这项工作发表在三月份的国际顶级物理刊物《物理评论快讯》上（Physical Review Letters 108, 092501 (2012)）。

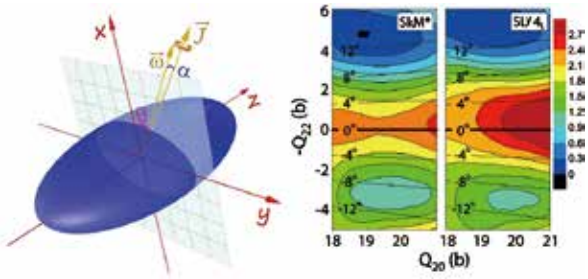

图 2：(左) 原子核三轴转动示意图。（右）Er-158 主轴推转的位能面图。

Figure 2: (left) The scheme picture of the titled-axis rotation of a triaxial nucleus. (right) The potential energy surfaces of Er-158 obtained by principle-axis-cranking calculations.

代表性论文：

[1] Y. Shi, J. Dobaczewski, S. Frauendorf, W. Nazarewicz, J. C. Pei, F. R. Xu, and N. Nikolov "Self-consistent tilted-axis-cranking study of triaxial strongly deformed bands in 158Er at ultrahigh spin", Phys. Rev. Lett. 108, 092501 (2012).

[2] H.L. Liu, F. R. Xu, P. M. Walker, "Understanding the different rotational behaviors of 252No and 254No", Phys. Rev. C 86, 011301(Rapid Communication) (2012).

II. Exotic Shapes of Nuclei

Nuclei as a finite quantum many-body system can have rich multipole deformations and associated exotic structures, corresponding to complex rotational bands. Recently, due to the progress in the experimental spectrum techniques, the studies of higher multipole deformations in superheavy nuclei and the triaxial deformations at ultra-high spin states have brought considerable attention. Generally, superheavy nuclei

have larger level densities and the shapes are more "rigid" compared to medium-heavy and heavy nuclei, and the higher multipole deformations become non-negligible. Prof. Xu's group found the inclusion of the 6-order deformation is important to reproduce the rotation bands in the superheavy region. While such a high order deformation is usually omitted in literatures. This work provides a new possibility to probe the multi-pole correlations and shell structures in superheavy nuclei. This work has been published as a rapid communication in Physical Review C 86, 011301(2012).

In addition, stimulated by recent experimental discoveries, triaxial strongly deformed (TSD) states in Er-158 at ultrahigh spins have been studied by means of the Skyrme-Hartree-Fock model and the tilted-axis-cranking method. Restricting the rotational axis to one of the principal axes—as done in previous cranking calculations—two well-defined TSD minima in the total Routhian surface are found for a given configuration: one with positive and another with negative triaxial deformation gamma. By allowing the rotational axis to change direction, the higher-energy minimum is shown to be a saddle point. This resolves the long-standing question of the physical interpretation of the two triaxial minima at a very similar quadrupole shape obtained in the principal-axis-cranking approach. Several TSD configurations have been predicted, including a highly deformed band, which is a candidate for the structure observed in experiment. This work has been published recently in Physical Review Letters 108, 092501 (2012).

Selected publications:

[1] Y. Shi, J. Dobaczewski, S. Frauendorf, W. Nazarewicz, J. C. Pei, F. R. Xu, and N. Nikolov "Self-consistent tilted-axis-cranking study of triaxial strongly deformed bands in 158Er at ultrahigh spin", Phys. Rev. Lett. 108, 092501 (2012).

[2] H.L. Liu, F. R. Xu, P. M. Walker, "Understanding the different rotational behaviors of 252No and 254No", Phys. Rev. C 86, 011301(Rapid Communication) (2012).

三、 在 BESIII 实验上观察到一个新强子态 X（1870）

寻找非常规强子态（多夸克态、混杂态和胶球态等）是高能实验研究的一个重要研究课题。BESII 实验观察到的 X(1835) 被认为是可能的赝标量胶球的候选者。近日，北京大学物理学院博士生刘坤及其导师冒亚军教授，与中科院高能物理研究所金山研究员合作，利用北京谱仪（BESIII）所收集的 225M J/ψ 数据，在 J/ψ → ωηππ 衰变过程中首次以 7.1σ 观测到一个新的 ηππ 共振结构 X(1870)。该共振结构被认为可能是的赝标量胶球候选者 X(1835) 在 J/ψ 强衰变过程中的对应产物。除此之外，在 ηππ 的不变质量谱上还观察到了另一个清晰的赝标量胶球候选者 η(1405) 的信号。对他们在 J/ψ 强衰变过程中的产生界面的首次精细测量将为他们是否是胶球提供最直接的判据。该工作发表在 Phys. Rev. Lett. 107, 182001 (2011) 上。

北京谱仪 III（BESIII）以及北京正负电子对撞机 II（BEPCII）是对旧的 BESII/BEPC 的全面重大升级，其主要物理目标在于对强子谱学以及 τ - 粲物理的研究。BESIII 从 2008 年 5 月开

始成功取数，目前已经取得世界上最大统计量的 J/ψ 样本。北京大学物理学院高能组在冒亚军教授的领导下从探测器模拟软件的编写、分析软件的开发以及真实物理数据的分析等各方面全面参与了 BESIII 的工作。本文是 BESIII 探测器运行以来发表的第五篇 PRL 文章，同时也是 BESIII 合作组内北大高能组做出重要贡献的第二篇 PRL 文章。

这项工作得到了科技部 973 研究计划、国家自然科学重点基金的资助。

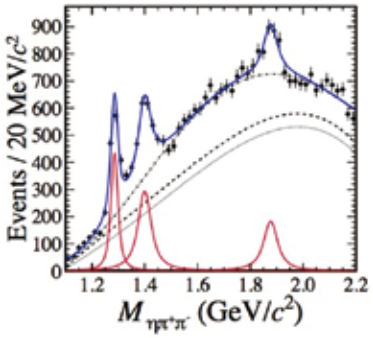

FIG. 4: Results of fit to the $M(\eta\pi^+\pi^-)$ mass distribution for events with either the $\eta\pi^+$ or $\eta\pi^-$ in the $a_0(980)$ mass window. The dotted curve shows the contribution of non-ω and/or non-$a_0(980)$ background, the dashed line also includes the contribution from $J/\psi \to b_1(1235)a_0(980)$, and the dot-dashed curve indicates the total background with the non-resonant $J/\psi \to \omega a_0^{\pm}(980)\pi^{\mp}$ included. $\chi^2/d.o.f$ is 1.27 for this fit.

III. Observation of X(1870) in BESIII Experiment

Searching for the hadron states beyond the convention quark model (multi-quark, hybrid, glueball, etc.) is a major topic in the field of experimental high energy physics. X(1835), which was first observed by BESII, is considered to be the most promising candidate of the pseudoscalar glueball. Recently, Kun Liu and his Ph.D advisor Prof. Yajun Mao from the School of Physics of Peking University, along with their collaborator Dr. Shan Jin from the Institute of High Energy Physics, observed a new η π π resonant structure X(1870) in the channel J/ψ → ω η π π with a significance of 7.1 σ , using the 225M J/ψ decay events accumulated by the BESIII detector. This resonant structure is interpreted to be the counterpart of X(1835) produced in the hadronic decay of J/ψ. Besides X(1870), the η π π mass spectrum also shows a clear signal of η(1405), which is regarded as another hot candidate of the pseudoscalar glueball. The first precise measurement of their production width in the hadronic decay of J/ψ will provide vital information for their glueball possibility. This analysis has been published on Phys. Rev. Lett. 107, 182001 (2011).

BESIII (Beijing Spectrometer III) and BEPCII (Beijing Electron Positron Collider II) is a major upgrade of the old BESII/BEPC, aiming at the study of hadron spectroscopy as well as τ-charm physics. BESIII started its first successful data run at May 2008, and has accumulated the world's largest data sample of J/ψ decay. The high energy physics group of Peking University, under the leadership of Prof. Yajun Mao, participated in every aspects of the BESIII experiment, including detector simulation, development of analysis software and the data analysis. This work is supported by the Minister of Science and Technology under 973 program and National Science Foundation of China.

07 天文学系 Department of Astronomy

北京大学天文学系成立于 2000 年，前身为 1960 年在地球物理系成立的天文专业，2001 年天文学系并入新成立的物理学院。天文学系现有教职工 13 人，其中教授 8 名（包括中国科学院院士 2 名 (兼职), 长江学者特聘教授和讲座教授 2 名，国家杰出青年基金获得者 3 名)，副教授 2 名，百人计划研究员 2 名，办公行政人员 1 名。主要研究领域包括宇宙学与星系形成、高能天体物理、星际介质和恒星与行星系统、粒子天体物理等，涉及各种天文尺度及极端天体环境。

Department of Astronomy of PKU was established in 2000, based on the Astronomy Division in the Department of Geophysics founded in 1960. It was merged into the School of Physics in 2001. Now there are 13 members in the department, consisting of 8 professors, 2 associate professors, 2 Bairen research professors, and 1 secretary for administration. The main research fields include Cosmology and Galaxy Formation, High Energy Astrophysics, Interstellar Medium, Stellar and Planet System, and Astroparticle Physics, covering a wide range of astronomical scales and astrophysical conditions.

一、利用球状星团研究星系际的星族

弥散于星系团内的星系际恒星是星系之间相互潮汐扰动的自然产物。研究这一星系际星族对于理解宇宙中最大质量星系的形成有着重要的意义，然而观测这一星族却并不容易。作为距离我们最近的大质量星系团之一，后发座星系团 (Coma Cluster) 拥有一个庞大的球状星团系统。利用来自哈勃空间望远镜的巡天项目—Hubble Telescope Advanced Camera for Surveys Coma Cluster Survey—的高分辨率成像数据，Peng et al. (2011, Astrophysical Journal, 730, 23) 在国际上首次明确地探测到了一大批弥散于 Coma Cluster 核心区域内的星系际球状星团 (IGCs)，这些新探测到的球状星团现在不属于任何星系。从位于 Coma Cluster 中心处的大质量椭球星系 NGC 4874 向外，球状星团的表面数量密度轮廓在大半径处（直到 520 kpc 的半径处）由新探测到的 IGCs 主导。到 520 kpc 半径为止，Peng et al. 估得的 IGCs 的总数量为 47000 ± 1600 (随机误差) + 4000/-5000 (系统误差)。这些 IGCs 构成了整个核心球状星团系统的 70%，这个核心球状星团系统也成为了近邻宇宙中最大的球状星团系统。将星系团中心区域内其它成员星系的球状星团考虑在内后，这些 IGCs 数量上仍然占了整个球状星团系统的 30% - 45%。结合前人对 Coma Cluster 内星系际弥散恒星发射（ICL）的研究结果，Peng et al. 发现 IGC 的有很高的比频率 (SN, 指单位恒星发射光度所对应的球状星团数)。如果假定 IGCs 的比频率和高比频率的矮星系相当，则 Coma Cluster 核心区域 ICL 的平均表面亮度 $\mu V \approx 27$ mag arcsec^{-2}，对应的总恒星质量约为 1012 个太阳质量。由此可见，如果只考虑星系团核心（NGC4874 + ICL）区域，ICL 贡献了大约一半的总恒星光度，以及三分之一的总恒星质量。颜色偏红的 IGCs 占总 IGCs 的 20%，这

暗示 IGCs 可以来源于比较大质量的 L　星系，而不仅仅来自被破坏的矮星系。彭教授的研究团队，包括博士后张红欣，正继续深入这一工作。利用对近邻室女座星系团（Virgo Cluster）的最新巡天项目—Next Generation Virgo Survey，彭教授的研究团队正在研究室女座星系团内星系际球状星团的分布和性质。（Next Generation Virgo Survey 是由 Canada-France-Hawaii 望远镜完成的大型巡天项目）。

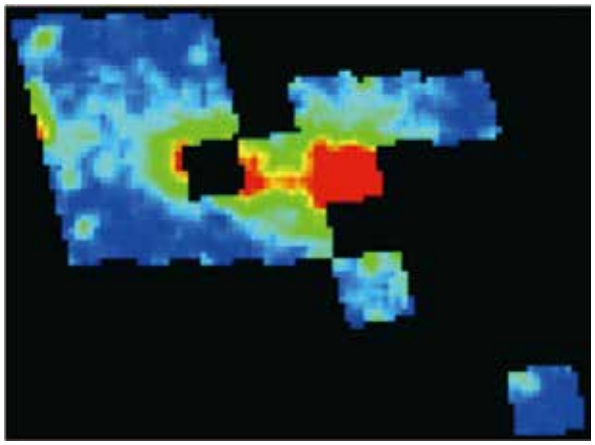

图 1：后发座星系团核心区域内（30.8’ x 23.0’, 900 x 670 kpc ）球状星团空间分布图 （图像已被平滑处理）。图中不同颜色表示不同的球状星团表面数量密度（由蓝到红表面密度依次变高）。星团数量密度分布已做了完备性改正。由图可见，球状星团主要聚集分布在中心星系 NGC 4874 周围。我们也可以看到一个球状星团分布相对延展的结构，这一结构似乎与星系 NGC 4489 相连。总体上，后发座星系团核心区域有较高的球状星团数密度。

Figure 1: Smoothed spatial distribution of globular clusters in the Coma cluster core (30.8’ x 23.0’, 900 x 670 kpc). Color represents the surface density of GCs, corrected for completeness (blue to red denotes low to high density). The dominant concentration of GCs is around NGC 4874, the red density peak at center right. There is also an extended structure of GCs that appears to connect to NGC 4489 (missing tiel of high density). There is generally a high level of GCs throughout the cluster core.

I. Cosmology and Structure Formation

Intracluster stellar populations are a natural result of tidal interactions in galaxy clusters. Measuringthese populations is difficult, but important for understanding the assembly of the most massivegalaxies. The Coma cluster of galaxies is one of the nearest truly massive galaxy clusters, and is hostto a correspondingly large system of globular clusters (GCs). Peng et al. (2011, Astrophysical Journal, 730, 23) used imaging from the Hubble Space Telescope Advanced Camera for Surveys (HST/ACS) Coma Cluster Survey to present the first definitive detection of a large population of intracluster GCs(IGCs) that fills the Coma cluster core and is not associated with individual galaxies. The GC surfacedensity profile around the central massive elliptical galaxy, NGC 4874, is dominated at large radii bya population of IGCs that extend to the limit of the (R < 520 kpc). They estimate that there are47000 ± 1600 (random) +4000/-5000 (systematic) IGCs out to this radius, and that they make up　70% of the central GC system, making this the largest GC system in the nearby Universe. Even including the GC systems of other cluster galaxies, the IGCs still make up ~30–45% of the GCs in the cluster core. Observational limits from previous studies of the intracluster light (ICL) suggest that the IGC population

has a high specific frequency (SN, the number of GCs per unit stellar luminosity). If the IGC population has a specific frequency similar to high-SN dwarf galaxies, then the ICL has a mean surface brightness of $\mu V \approx 27$ mag arcsec^{-2} and a total stellar mass of roughly $1012 M_{\odot}$ within the cluster core. The ICL makes up approximately half of the stellar luminosity and one-third of the stellar mass of the central (NGC4874+ICL) system. The fraction of red IGCs (20%), and the red color of those GCs, implies that IGCs can originate from the halos of relatively massive, Lstar galaxies, and not solely from the disruption of dwarf galaxies. Prof. Peng's group, with postdoc Dr. Hongxin Zhang, is continuing this work and is now studying the intergalactic GC populations in the nearby Virgo cluster of galaxies using the Next Generation Virgo Survey, a Large Program on the Canada-France-Hawaii Telescope.

二、在 SDSS 光谱巡天天区发现新的类星体

类星体自 1963 年被发现以来一直是天文学研究的热点，它形状看起来类似银河系里的恒星，但事实上却是离我们非常遥远的天体。近 20 年来，随着国际上大视场多光纤光谱巡天的开展，越来越多的类星体被发现。美国的斯隆数字巡天计划（SDSS）迄今为止已在约 1 万平方度的天区发现 10 多万个类星体，这一目前最大的类星体样本在研究宇宙早期再电离的特性、星系演化、宇宙大尺度结构和黑洞物理中都发挥了重要作用。但 SDSS 类星体大多是低红移的（即距离较近），只有约 10％的 SDSS 类星体红移超过 2.2。而且，SDSS 类星体样本在红移位于 2.2 到 3 之间存在很大的不完备性，其原因是因为在 SDSS 类星体选源判据中将大多数颜色与恒星类似的点源加以排除所造成的。如何克服 SDSS 类星体选源判据中的缺陷，找到更多在 SDSS 巡天中漏掉的红移在 2.2 到 3 之间的类星体，构造比 SDSS 更完备的类星体样本，已成为我国大科学工程之一的郭守敬望远镜（见图 1）即将开展的类星体巡天的主要目标。

图 1：我国大科学工程之一的郭守敬望远镜（LAMOST）。Figure 1: GuoShouJing Telescope (LAMOST), one of the Chinese Major Scientific Facilities.

发现类星体过程中最重要的一个环节是利用天体的测光观测数据找到很可能像类星体的候选天体，然后再拍摄其光谱来加以证认。在前人已有相关工作的基础上，通过对美国 SDSS 光学巡天（有 ugriz 波段测光数据）和英国 UKIDSS 近红外巡天（有 YHJK 波段测光数据）中数千个类星体和恒星测光数据的分析，我们提出了利

用近红外颜色（Y-K）和光学颜色（g-z）相结合来寻找红移小于 4 的类星体的新判据（Wu & Jia 2010)。利用这一新判据，我们可以很好地将红移小于 4 的类星体和恒星区分开来，这样就避免了 SDSS 类星体选源判据中将红移在 2.2 到 3 之间的类星体遗漏掉的缺陷。在 2009 — 2010 年的郭守敬望远镜（LAMOST）试观测期间，我们利用这一新判据选取了一些类星体的候选体并进行了光谱观测。在对一个 5 度视场天区的一次曝光观测中就发现了 8 颗新的类星体 (其光谱见图 2)，其中 5 颗类星体的红移大于 1.6, 有 2 颗红移大于 2.4 (Wu et al. 2010a,b)。这些类星体的 i 波段星等在 16.44 和 19.34 之间，其中最亮的一颗类星体 (i=16.44) 红移为 2.43，其本征光度达到太阳光度的千万亿倍，属于宇宙中最明亮的类星体之一，经估算其中心黑洞质量可高达 4 百亿太阳质量。这一发现入选 2011 年评选出的“2010 年度中国十大天文科技进展”。这些结果证实了利用我们提出的新的类星体选源判据，我国科学家有能力利用郭守敬望远镜（LAMOST）即使在别人做过光谱巡天的天区也能做出新的发现。这些结果已引起国外同行的高度重视，美国学者利用不同样本重复了我们对类星体近红外颜色和光学颜色的研究，他们在论文 (Peth, Ross & Schneider, 2011) 中明确指出他们的测试很多已被我们做过，而且其结果与我们的已有结果符合很好（very good general agreement)。

此外，利用光变和颜色相结合选出类星体候选体，我们用美国 Arizona 州的两台望远镜证认出 14 颗红移在 2.3 到 2.9 之间的类星体 (Wu et al. 2011)。2012 年我们又利用云南丽江的 2.4 米望远镜成功发现 6 颗高红移类星体 (Wu et al. 2012)，其中最高红移为 4.6 的类星体是中国天文学家至今利用国内望远镜所发现的距离最遥远的天体。

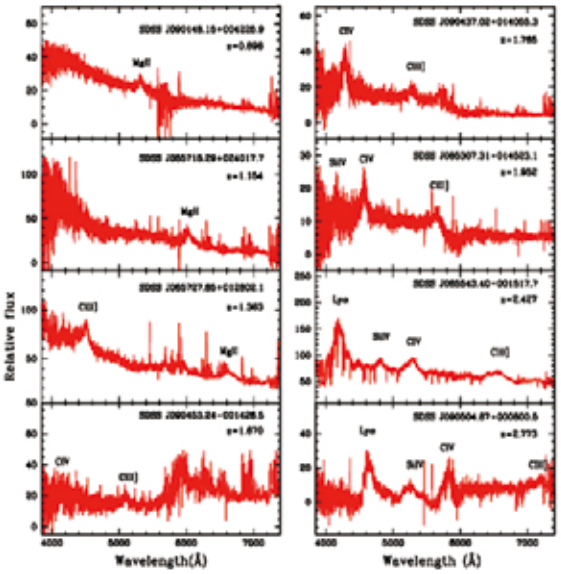

图 2：利用郭守敬望远镜（LAMOST）发现的 8 颗新类星体的光谱。

Figure 2: Spectra of eight new quasars discovered by the GuoSoouJing Telescope (LAMOST)).

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[3] Wu, X.-B., et al., 2010a, Research in Astronomy and Astrophysics, 10,745

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II. Discovering New Quasars in the SDSS Spectroscopically Surveyed Sky Area

Quasar was discovered in 1963 and has been a hot topic in astronomical research since then. Quasars look like stars but they are actually objects far away beyond our Milk Way. More and more quasars have been discovered in the last two decades by the larger sky spectroscopic surveys. The U.S. Sloan Digital Sky Survey (SDSS) has found 100,000 more quasars in the 10,000 square degrees of sky, which form the largest sample of quasars and play an important role in the studies of the cosmic reionization, galaxy evolution, the large-scale structures, and black hole physics. But the SDSS quasars are mostly found at low-redshift (short distance), only about 10% of the SDSS quasars have redshifts larger than 2.2. Moreover, SDSS quasar samples at redshifts between 2.2 to 3 has large incompleteness, especially in the redshift of 2.8, its incompleteness is even as high as 90%. This is mainly because at redshift between 2.2 to 3 the optical colors of quasars are very similar to normal stars due to the appearance of Lyman alpha emission line at the observed optical band, while in the SDSS spectroscopic survey most objects with similar colors as stars were excluded. How to overcome the problems in the SDSS quasar selection criteria, find more missing quasars with redshifts between 2.2 to 3, and construct a more complete sample of quasars than that of SDSS, has become one of the main objectives of the quasar survey with the GuoShouJing telescope (LAMOST), which is one of the Chinese Major Scientific Facilities.

The most important step in discovering quasars is to find the most probable quasar candidates based on their photometric data before taking the spectra to identify their quasar nature. Based on previous related works we have collected thousands of quasars and stars with both photometric data in SDSS optical bands and UKIDSS near-infrared bands. By analyzing the colors of quasars and stars, we proposed a new criterion for selecting quasars with redshifts smaller than 4 using their optical and near-infrared colors (Wu & Jia 2010). In 2009-2010, we carried out spectroscopic observations on the quasar candidates selected based on our new selection criterion with the GuoShouJing Telescope (LAMOST) during its commissioning period. In a 5-degree field of sky, with one exposure we discovered eight new quasars (Wu et al. 2010a,b). Five of them have redshifts greater than 1.6 and two have redshifts greater than 2.4. This is the first time for us to use the GuoShouJing Telescope (LAMOST) to discover new quasars in the SDSS spectroscopically surveyed sky area. The brightest quasar we discovered has redshift of 2.43, and it emits power as quadrillion times of the Sun, making it as one of the brightest quasars in the universe. Its central black hole mass is estimated as 40 billion solar masses. These findings confirm that using our new quasar selection criterion, we are able to make new discoveries of quasars with our GuoShouJing telescope (LAMOST) even in the sky areas already observered by other spectroscopic surveys. Our discovery of new quasars with LAMOST was selected in 2011 as “One of the top 10 Astronomical Advances in China”. These results have aroused great attentions of other foreign colleagues. Some SDSS scholars recently repeated our study of the near-infrared and optical colors of quasars using different quasar samples, and reached the same conclusions (Peth, Ross & Schneider, 2011) as we did. They mentioned that their results are in ‘very good general agreement’ with ours. Their study also supports that with our new selection criterion we are able to discover more quasars missed in the previous SDSS

spectroscopic survey.

In addition, by combining variability with the optical/near-infrared colors to select quasars candidates, we also identified 14 new quasars with redshifts between 2.3 and 2.9 using two telescopes in Arizona, USA (Wu et al. 2011). In 2012, we identified 6 high-redshift quasars with the 2.4meter telescope at Lijiang, Yunnan (Wu et al. 2012). The quasar with redshift of 4.6 is the most distant object discovered by astronomers using a telescope in China.

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

北京大学大气与海洋科学系有着悠久的历史和优良的传统，大气科学最早源于 1929 年在清华大学建立的气象学专业。在经历了 1938-1945 西 南联大的艰苦岁月之后，于 1946 年在清华大学成立了气象系。1952 年，全国院校调整，清华大学气象系的师生并入北京大学物理系成为气象专业。1958 年，北京大学成立地球物理系，气象专业扩展为该系的大气物理和天气动力两个专业。1998 年，大气物理和天气动力两个专业合并为大气科学专业。2001 年 北京大学成立物理学院，大气科学专业进入物理学院，建立大气科学系。2010 年，北京大学决定在大气科学系建立物理海洋专业，并将大气科学系更名为大气与 海洋科学系。

The Department of Atmospheric and Oceanic Sciences at PKU celebrates a long and prestigious heritage. Our Atmospheric Science Program traces its root back to the Meteorology Program originally founded in 1929 at Tsinghua University. After the period of the utmost fortitude at the National Southwest Associated University during World War II (1938-1945), the Department of Meteorology was established at Tsinghua University in 1946. In 1952, the faculty and students of the Department of Meteorology were all moved from Tsinghua University to the Department of Physics of Peking University, as part of the nation-wide restructuring of higher education. In 1958, Peking University established the Department of Geophysics, under which the Program of Meteorology expanded into two programs: Atmospheric Physics and Dynamical Meteorology. The two programs combined to form the Program of Atmospheric Sciences in 1998. In 2001, Peking University established the School of Physics, into which the Program of Atmospheric Sciences was incorporated to become the Department of Atmospheric Sciences. Most recently, Peking University founded the Program of Physical Oceanography under the newly renamed Department of Atmospheric and Oceanic Sciences in 2010.

一、新元古代冰雪地球形成和融化机制的模拟研究

新元古代（10-5.4 亿年前）是地球历史气候和生命演化中的一个关键和特殊时期，大量证据表明，新元古代时期出现过数次全球性冰川（冰雪地球）的极端寒冷气候。在新元古代之前长达 10 亿年的时段里，地球气候变化很小，基本处于温暖的状态，原始生命平稳而缓慢地演化着。新元古代之后是寒武纪，地球真正开始了充满生机的时代，大气中氧含量急剧增加，生命爆发，动物开始出现。新元古代是连结这两个时段一个重要历史时期，原始生命在经历了新元古代时期剧烈的气候和环境变化之后进入了爆发期。因此，新元古代对生命的演化来讲很像一段黑暗的历史隧道，只有那些有幸通过了这段历史隧道的生命才得以延续，并在寒武纪时期迅速繁衍。

冰雪地球是如何形成和融化的？在冰雪地球期间，地球是完全被冰雪覆盖，还是在热带仍有开放的海域？冰雪地球形成和融化时大气中的主要温室气体（CO2）含量分别是多高？这些是冰雪地球研究的重要基本问题。大气与海洋科学系的杨军博士和胡永云教授使用大气辐射 - 对流模式、大气环流模式和海气耦合气候模式对这些基本问题进行了全面和系统性的研究，近两年在 Journal of Climate 和 Climate of the Past 发表了一系列重要的论文。他们的数值模拟发现，只有当大气中二氧化碳（CO2）含量降低到大约 20 ppmv 时（目前的 CO2 含量大约是 380 ppmv），完全冰封的冰雪地球才能够形成。在实际气候系统中，要达到如此低的 CO2 浓度是相当困难的。当冰雪地球形成之后，大气中的 CO2 与地表硅酸钙岩石之间的风化反应被切断，另一方面，火山喷发出的 CO2 不断在大气中累积。他们的模拟研究发现，只有在 CO2 浓度达到 0.4 个大气压时，其强烈的温室效应才能够造成冰雪地球融化。附图所示的是模拟的地表温度随大气中 CO2 含量的变化。按目前火山喷发 CO2 的速度，累积这么多的 CO2 需要数千万年的时间。

这些模拟结果表明，完全冰封的冰雪地球的形成是比较困难的，因此，更可能的气候状态是热带仍维持开放水域的全球性冰川。

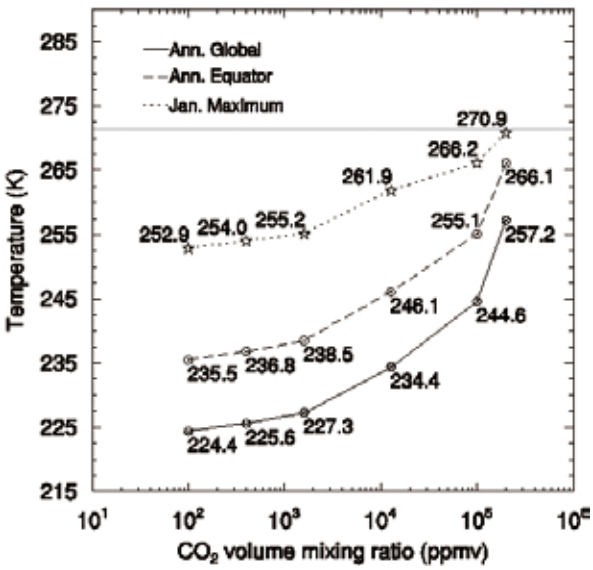


图 1: 1 月份纬向平均最高地表气温、赤道年平均地表气温和全球平均地表气温随大气中 CO_2 浓度的变化。

Figure 1: January zonal-mean maximum, equatorial annual-mean, and global annual-mean near-surface temperatures as a function of CO_2 levels.

I. Mechanisms of formation and melting of the Neoproterozoic Snowball Earth

The Neoproterozoic era, extending from 1000 to 540 millions of years ago, is a particularly critical and important period in Earth’s climate and life evolution history. This period is characterized by extremely cold climate due to several global-scale glaciation events (Snowball Earth). Before the Neoproterozoic

era, climate was warm and varied weakly, and original life evolved slowly. The Neopreterozoic era was followed by the Cambrian period when atmospheric oxygen rose rapidly, life exploded, animals occurred, and Earth really started its vigorous period. As the linkage of two periods with very different climate environments and life evolution, the Neoproterozoic era acted like a dark tunnel, only the original microbes that survived as passing throughout the tunnel were able to reach the light of the metazoan-rich Cambrian world and evolved multifariously and rapidly.

Fundamental questions of the Neoproterozoic Snowball Earth are: how was the Snowball Earth initiated and melted? Was Earth completely covered by snow and ice during the Snowball Earth episodes, or the tropical ocean remained ice free? How high were CO2 concentrations as the Snowball Earth was formed and melted? Using radiative-convective model, atmospheric general circulation model, and coupled atmospheric-oceanic general circulation model, Dr. Jun Yang and Prof. Yongyun Hu have studied these fundamental questions comprehensively and systematically. They have published a series of papers in Journal of Climate and Climate of the Past in the past two years. Their numerical simulations demonstrated that the formation of a complete ice-covered Snowball Earth requires CO2 concentration as low as about 20 ppmv (the present-day CO2 level is about 380 ppmv). For the realistic climate system, it is extremely difficult to reach so low levels of CO2 concentration. As the Snowball Earth is formed, weathering reaction between atmospheric CO2 and surface silicate rocks is ceased due to snow and ice coverage. Thus, CO2 erupted by volcanoes accumulates in the atmosphere and gradually reaches very high levels. Strong greenhouse effect of high levels of CO2 warms the surface and causes melting of the Snowball Earth. Simulations by Yang and Hu showed that the Snowball Earth can be melted as CO2 level reaches about 0.4 bars. The attached figure here shows how surface temperature increases with CO2 concentrations. According to the accumulation rate of CO2 due to volcano eruptions, it takes several tens of millions of years for CO2 reaching 0.4 bars.

These simulation results suggest that formation of a completely ice-covered Snowball Earth is very unlikely. Instead, it is more likely that the tropical ocean remains ice free as sea glaciers reach very low latitudes.

二、高相对湿度下气溶胶吸湿增长特性研究

气溶胶的吸湿特性是理解气溶胶辐射特性，能见度变化和云微物理过程的重要参数，是制约计算大气气溶胶直接气候强迫的主要不确定因素，一直是大气气溶胶研究的前沿课题。而高相对湿度下气溶胶吸湿特性直接与气溶胶活化特性相关，是研究气溶胶和云相互作用的关键。由于技术上的限制，是当前国际上的难题之一，目前还没有有关 90% 以上相对湿度下气溶胶吸湿增长特性的外场观测和相关研究。

最近，北京大学物理学院大气与海洋科学系赵春生教授及其研究生与德国对流层研究所合作，在国家自然科学基金委面上课题的支持下，全面深入地研究了华北地区高相对湿度下的气溶胶吸湿特性、气溶胶核化特性、气溶胶光学和臭氧化学之间的关系。2009 年以来进行了一系列有关气溶胶物理化学比较全面的综合外场

观测，得到了一些非常有意义的研究结果：这是世界上首次在外场对于环境气溶胶进行了相对湿度 90%—99.5% 的增长特性观测实验；发现华北地区的大气气溶胶具有非常强的吸湿特性，该特性对于大气能见度、大气化学和云微物理过程都具有重要的影响。观测显示不同吸湿模态的比例有较为明显的日变化特征，提出了一种新的反演大气气溶胶中黑碳混合状态的方法。这些结果对于研究华北地区雾霾低能见度现象提供了坚实的理论基础。

目前，部分研究结果已经有 10 篇发表在“大气化学与物理（Atmospheric Chemistry and Physics,ACP）”杂志本项目的专辑（Haze in China (HaChi 2009-2010)） 上（http://www.atmos-chem-phys-discuss.net/special_issue134.html）。2011 年 6 月和 10 月，赵春生教授分别在 25 届国际大地测量与地球物理学联合会 (IUGG) 和 13 届美国气溶胶学会（AAAR）做特邀报告，介绍了气溶胶吸湿特性的研究进展。

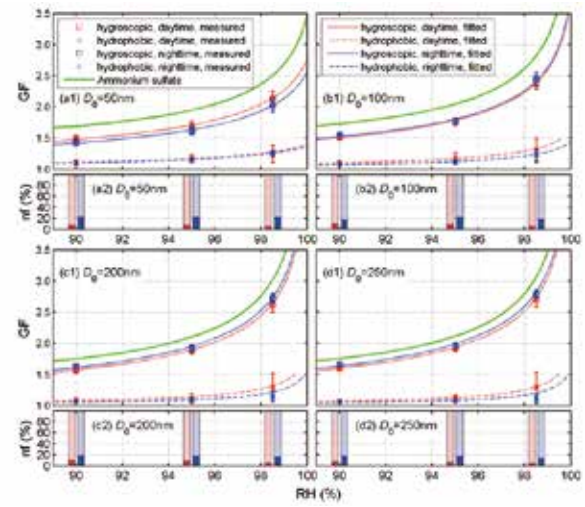


图 1：不同干粒径粒子在高相对湿度下的吸湿增长特征。(a1)-(d1) 强吸湿模态和几乎不吸湿模态粒子的吸湿增长因子；(a2)-(d2) 强吸湿模态，弱吸湿组和几乎不吸湿模态的数目比例（nf）。

Figure 1： (a1–d1) the hygroscopic growth of aerosol particles with different dry diameters of 50 nm, 100 nm, 200 nm and 250 nm, respectively. The growth factors (GF) of nearly-hydrophobic (NH) group and more-hygroscopic (MH) group are the mean values of the measured GFs corrected to their set RHs (90%, 95% and 98.5%); (a2-d2) the mean number fractions of nearly-hydrophobic (NH) group, less-hygroscopic (LH) group and more-hygroscopic (MH) group particles with 50 nm, 100 nm, 200 nm and 250 nm dry diameters.

II. Aerosol Hygroscopic Properties at High Relative Humidity

The aerosol hygroscopic properties are very crucial for the understanding of the aerosol effects on radiative forcing, visibility and cloud microphysics. Inadequate characterization of aerosol hygroscopic properties will induce large uncertainties in the estimation of aerosol direct effect on the climate. Aerosol hygroscopicity at high relative humidity are closely related to the ability of aerosol particles to activate and form cloud droplets. Unfortunately, there is few research reported on field in-situ measurements for aerosol hygroscopic properties at relative humidity above 90%.

Recently, Prof. Chunsheng Zhao with his graduate students from Department of Atmospheric and Oceanic Sciences have made new progress on aerosol hygroscopicity at high relative humidity values above 90% and its roles in aerosol optics and cloud physics. HaChi (Haze in China) is a joint project between German DFG and Chinese NSFC, focuses on investigating the aerosol hygroscopic properties in North China Plain and its relationship to aerosol radiation, activation and ozone chemistry. Since 2009, intensive and comprehensive field campaigns were conducted in a rural station of Wuqing, Tianjin, China. The strong hygrosopicities of aerosol in North

China Plain with a significant diurnal pattern in number fraction of different hygroscopic groups were observed. A new method was proposed to retrieve the ratio of the externally mixed light absorbing carbon mass to the total mass of light absorbing carbon. These results provide insights into the low visibility phenomenon such as haze and fog events in North China Plain.

So far, some results have been published in the Journal of Atmospheric Chemistry and Physics (ACP) on the characterization of the particle number size distribution, the particle optical properties, their hygroscopic properties at high RH below supersaturation, their cloud nucleating properties above supersaturation, ozone chemistry and their relationships with boundary layer processes. More information is available at the web site of journal of ACP special issue （Haze in China(HaChi 2009-2010)): (http://www.atmos-chem-phys-discuss.net/special_issue134.html). Prof. Chunsheng Zhao introduced the scientific findings of HaChi as invited talks in the the 25th Conference of International Union of Geodesy and Geophysics (IUGG) (Melbourne, June, 2011)and the 13th The American Association for Aerosol Research (AAAR) 13th annual conference(Orlando, Oct., 2011).

三、应用集合卡曼滤波优化参数改进气候模式

耦合气候模式中的物理参数的不确定性是产生模式偏差的重要来源之一，从而会使耦合气候模式产生较为严重的气候漂移。随着耦合气候模式和集合耦合数据同化方法的迅速发展，模式中的参数优化问题逐渐成为气候预报领域中的热点问题。在参数优化过程中，如何有效的提高耦合气候模式的状态变量与参数之间的协方差的信噪比，进而提高耦合气候模式对气候的估计和预报精度，是非常具有挑战性的气候学问题。

近年来，刘征宇教授的课题组通过与美国地球流体动力学实验室的合作，在耦合气候模式中的参数优化方面取得了一系列重要突破。2011年他们首次提出了一个提高参数校正的数据同化方案，并将上述方案应用到一个简化的海气耦合模式中进行模式的状态估计和参数优化研究，他们发现使用该方案得到的耦合气候模式的初始场和参数进行气候预报，可以较大的提高耦合模式的预报时效，使大气和海洋的有效气候预报时间分别延长到原来的二倍和三倍。2012 年，他们为了进一步提高参数优化过程中的信噪比，基于已发展的提高参数校正的数据同化方案，进一步提出了一个地形依赖的参数优化方案。他们将该方案应用到一个包含大气 - 陆地 - 海洋的中级耦合气候模式中进行参数优化研究，在数据同化“孪生”试验框架内，探讨了模式敏感性的地形依赖以及观测系统的地形依赖对参数优化的影响。他们发现地形依赖的参数优化方案与传统的单值参数优化方案相比，可以极大的提高耦合模式的气候预报能力，使气候预报技巧提高到原来的两倍以上。

近期，刘征宇教授的课题组基于地形依赖的参数优化方案，研究了耦合气候模式中包含偏差的物理参数化方案情况下的参数优化问题。他们发现利用地形依赖的参数优化方案优化偏差物理方案中的最敏感参数，能够有效的提高偏差耦合模式的气候估计和预测精度，尤其提高了对深海低频信号的估计和预测。该结果帮助我们理解如何在包含偏差的物理参数化方案的海气耦合模式中，进一步提高十年际尺度的气候预报。

刘征宇教授主持的耦合模式中的参数优化研究已经在《气候动力》和《天气评论月报》等国际学报上发表了相关的研究成果。

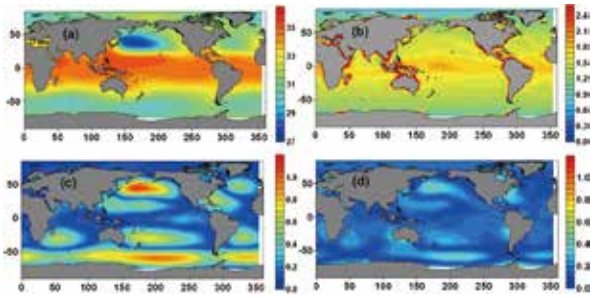


图 1：数据同化孪生试验的海表温度均方根误差的空间分布。(a) 未做状态估计和参数优化的方案，(b) 仅做状态估计的同化方案，(c) 单值的参数优化方案，(d) 地形依赖的参数优化方案。

Figure 1：Spatial distributions of RMSEs of SST for control run (panel a), state estimation only (panel b), singe-value parameter optimization (panel c) and geographic-dependent parameter optimization (panel d).

III. Improve Climate Model using EnKF for parameter optimization

Uncertainties in physical parameters of coupled climate models are an important source of model bias and make the model climate drift away from real world. With the development of coupled climate models and ensemble coupled data assimilation, parameter optimization in a coupled climate model is regarded as a hot topic gradually. The problem that how to enhance the signal-to-noise ratio in covariance between model states and parameters when parameters employed in a coupled climate model are optimized, and thus to improve the accuracy of climate estimation and prediction, still remain a challenge in climatological studies.

In recent years, Prof. Zhengyu Liu’s group has made significant progress in the study of coupled model parameter optimization through the cooperation with GFDL/NOAA. They firstly developed a data assimilation scheme for enhancive parameter correction (DAEPC) in 2011. Then the DAEPC scheme is applied to implement state-parameter optimization using observations with a simplified coupled model. They found that the valid atmospheric and oceanic forecasts are extended two times and three times longer respectively. In 2012, they introduced a geographic-dependent parameter optimization (GPO) scheme on the base of DAEPC through allowing optimized parameter values to vary geographically. Then impacts of the geographic dependence of model sensitivity and observing system on parameter optimization are investigated with an intermediate atmosphere-ocean-land coupled climate model within a twin-experiment framework. They found that GPO is able to significantly improve the ability of climate prediction, and the climate forecast skill is doubled compared to the traditional parameter optimization scheme.

Recently, based on GPO scheme, Prof. Zhengyu Liu’s group investigated parameter optimization in an intermediate coupled model with biased physics. They found the mostly-sensitive parameters are allowed to be optimized geographically by observations significantly enhances the accuracy of climate estimation and prediction, especially for low-frequency signals in the deep ocean. This result helps us gaining some insights for improving decadal predictions in coupled general circulation models that include imperfect physics.

This work has been published in Climate Dynamics and Monthly Weather Review.

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。

The Teaching Center for General Physics is a branch of School of Physics at Peking University. Previously, it was called the Teaching and Research Section of the Physics Department. The main task of the Center is to supervise all the teaching programs of general physics courses, such as mechanics, electrodynamics, thermodynamics and optics, for the sciences major undergraduate students of Peking University. It is also responsible for organizing seminars and arranging foreign exchange activities, which are closely related to teaching and learning. All the members of the Teaching Center have full teaching load each semester. They are heavily involved in making and managing the entire teaching schedule at School of Physics, too. The Teaching Center has one laboratory for demonstration and 10 teaching groups. Each of them is led by a moderator and is dedicated to teaching a specific subject. Their duties cover the whole Physics 01-05 series. Each year, more than 2,000 undergraduate students take these courses. It is equivalent to a working load of 222,000 teaching units (number of students times class hours) per year.

Since its establishment, the Center has set very high standards for each course and made great effort to achieve teaching excellence, as the Teaching and Research Section of the Physics Department did traditionally in the old days. As far as the teaching faculties are concerned, except several full-time members, many professors from other departments of School of Physics participate also in teaching general physics. Since these lecturers are experienced researchers, they make their classes more interesting and illuminating to the students. On the other hand, the Center invites also some retired teachers to be senior advisors. Therefore, each teaching group has an ideal structure with respect to the distributions of faculty ages, specialties, professional ranks and teaching experiences. These teams perform at very high professional levels which are compatible with the academic stature of School of Physics at Peking University. The Teaching Center for General Physics is dedicated to sustain such high teaching standards in future.

一、普物教学中心本科生科研小组研究进展

物理学院普通物理教学中心本科生科研小组由穆良柱老师负责指导，主要目的是为了训练本科生的科研能力。小组致力于量子信息与量子计算相关工作研究。在过去一年多时间里，王一男、史寒朵、熊照熙、靖礼等多名本科生以第一作者身份在 SCI 索引刊物上发表了 4 篇文章。

量子态不可克隆原理是量子力学的一个基本原理，但量子态的克隆在量子信息用有多种应用，如可用来攻击量子保密通讯，所以人们设计了各种特殊应用的量子态克隆机。这些克隆机看起来形式各异，似乎没有联系，但王一男、史寒朵等同学研究后发现存在一种简单统一的克隆过程，可以将各种不同的量子克隆机联系在一起，并由此提出了一种统一的普适的最优化量子克隆机。相关工作发表于 Phys. Rev. A 84, 034302(2011)。

量子保密通讯是量子信息最成功的一个应用，由于窃听行为在量子保密通讯中很容易被检测到，所以量子保密通讯被认为是最安全的通讯方式。量子保密通讯的关键是量子密钥分配协议，现已提出了各种协议，著名的有 BB84 协议（1984 年 Bennett 和 Brassard 提出的协议）和 Ekert91 协议等，但这些协议都是特例，类似的协议可以有很多。熊照熙、史寒朵等同学将这些特例协议推广到了 d 维 g+1 组 MUBs(mutually unbiased bases) 的一般情形，并研究了窃听者实施窃听行为后各不同协议的可靠性。相关工作发表于 Phys. Rev. A 85, 012334(2012)。

其他两篇工作发表于 J. Phys. A 45, 025304(2012) 和 Phys. Rev. A 86, 062315(2012)。

I. Progress of the undergraduate research group at the Teaching Center for General Physics

The undergraduate student research group at the Teaching Center for General Physics of School of Physics is supervised by Dr. Liang-Zhu Mu, who is currently a lecturer of the Center. The main purpose of this program is to introduce some capable undergraduate students to physics research as early as possible. In the past one and half year, the members of this group were dedicated to research on quantum information and quantum computation. Under the effective guide of Dr. Mu, these undergraduate students performed very well. In particular, students Yinan Wang, Handuo Shi, Zhaoxi Xiong and Li Jing have published four papers in some Science Citation indexed journals as the first author, respectively.

For example, the no-cloning theorem is a fundamental principle of quantum mechanics. It states that an unknown quantum state cannot be cloned perfectly. But quantum cloning has many applications in quantum information science, such as attacking an encrypted quantum communication. Various quantum cloning machines have been designed for different purposes. It seems that those cloning machines are quite different and no simple connection exists. But the research of Yinan Wang, Handuo Shi and etc. has manifested that there is a simple and unified cloning transformation that combines all those cloning machines together. Thus a unified universal quantum cloning machine can be designed. This work was published in Phys. Rev. A [84, 034302(2011)].

Secure quantum communication is a promising application of quantum information science. Theoretically, any eavesdropping can be detected by

secure quantum communications. Therefore, quantum communications have been marked as the most secure communications. Secure quantum communication cannot work without quantum key distribution protocol(QKD). So various QKD protocols have been proposed, for example BB84 protocol(proposed by Bennett and Brassard in 1984) , Ekert91 protocol and etc.. Zhaoxi Xiong, Handuo Shi and other collaborators have generalized these protocols in d-dimensional quantum space using g+1 MUBs(mutually unbiased bases). The effect of eavesdropping activities has also been studied. Their work was published in Phys. Rev. A [85, 012334(2012)].

The other works, which were published by these students as the first authors are J. Phys. A 45, 025304 (2012) and Phys. Rev. A 86, 062315 (2012).

二、第一届全国高等学校力学教学研讨会在北京大学成功举行

2011 年 7 月 28 日至 7 月 30 日，经过普通物理教学中心全体教师近半年的精心策划、实施，并在物理学院各系所普通物理教师的积极参与和协助下，第一届全国高等学校力学教学研讨会于北京大学英杰交流中心成功举行。本次研讨会旨在促进高等学校之间普通物理力学教学的交流，加强普通物理力学的教学研究，提高力学的教学质量。此次研讨会得到了全国高校相关教师的热烈响应，参会专家、代表来自全国 22 所高校，4 家出版社，共计 59 人。

会议由北京大学副校长王恩哥院士代表北大致欢迎词，教育部高等学校物理学与天文学教学指导委员会主任赵光达院士致开幕词，并邀请了北京大学赵凯华教授等多位专家做大会特邀报告。

本次研讨会上，代表们就普通物理力学课程建设及教学改革、力学教学中的具体问题、普通物理力学与现代科技前沿等方面进行了深入、广泛且细致的讨论。通过此次会议，高校间的普通物理力学教学加强了交流，互通有无，在许多方面得到了相互了解和认同，增强了深化力学课程建设及教学改革的信心。

会后，在高等学校物理学与天文学教学指导委员会的建议下和全体代表的热烈支持下，成立了全国高等学校普通物理力学教学研究会，并一致推举北京大学物理学院舒幼生教授出任第一届研究会理事长，陈晓林副教授任秘书长。

图 1：代表合影。

Figure 1: Group photo of all the participants.

II. The 1st Nationwide Seminar on Mechanics Teaching in Colleges and Universities was successfully held in the Peking University

After elaborate plan and preparation of six months by the whole faculty of the Teaching Center for General Physics of School of Physics at Peking University, the 1st Nationwide Seminar on Mechanics Teaching in Colleges and Universities was successfully held in the Peking University on 28th to 30th July, 2011. The organizers received also assistances from the teachers, who teach general physics but are associated with other units of the School of Physics. This seminar is dedicated to promote exchange on the Mechanics teaching in the nationwide colleges and universities. It main purpose is to enhance the teaching researches and hence, improve the teaching quality of the Mechanics. The seminar received very warm responses from the college teachers all over the country. Totally, 59 people from 22 universities and 4 publishers participated in this seminar.

First, Professor En-Ge Wang, the vice-principle of the Peking University spoke on behalf of the university. He thanked all the participants for attending this seminar and welcomed them to Peking University. Then, Professor Kuang-Ta Chao, the director of the Physics and Astronomy Teaching Steering Committee (PATSC), gave the Opening speech. Then, Professor Kai-Hua Zhao and the other experts delivered their invited talks.

During the seminar, the participants made wide and intensive discussions on teaching Mechanics, including lecture organization, introduction of the current applications of Mechanics to modern science and technology into teaching and many other related issues. Through these discussions, teachers from different universities got to know each other better. They also reached agreements on how to prepare and deliver lectures in order to make teachings more effectively. Many people said that they learnt a great deal by attending this seminar.

Following the suggestions of the PATSC, the National Association of Mechanics Teaching and Research (NAMTR) was established at the end of this seminar with strong supports from all the participants. Professor You-Sheng Shu and Professor Xiao-Lin Chen were elected to be the chairman and the general secretary of the 1st NAMTR.

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 9 名（教授 2 名，副教授 5 名，讲师 2 名），实验技术人员 6 名（高级工程师 1 名，工程师 5 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, 5 associate professors, 2 lecturers, 1senior engineer, 5 engineers.

国际和亚洲物理奥林匹克竞赛国家队的实验培训

北京大学基础物理实验教学中心参与了2008-2012年的国际和亚洲物理奥林匹克国家队队员的选拔并承担了两队的实验培训任务。中国国际物理奥林匹克代表队的5名队员和中国亚洲物理奥林匹克代表队的8名队员均从全国中学生物理竞赛一等奖的获奖者中选出。为使有潜能但其所在中学实验条件较弱的同学也能有更公平的机会，北京大学基础物理实验教学中心在实验选拔考试前安排了面向全体候选学生的预备轮培训，并通过精心准备的选拔考试题来全面考察学生的物理实验素养，以确保入选队员都是最优秀的。在赛前集训开始前一周，北京大学基础物理实验教学中心即向入选队员开放实验室。这样既培养了队员们的自主学习能力，又给他们提供了加强自己薄弱环节的机会。在赛前集训中，北京大学基础物理实验教学中心注重培养选手物理实验方面的基本思想、基本方法和基本技能。并在出发参赛前，通过全面介绍国际或亚洲物理奥林匹克竞赛的基本情况，使队员们树立必胜的信心和做好应对各种意外情况的充分准备。

五年来的实践表明，北京大学物理实验教学中心对国际和亚洲物理奥林匹克国家队的选拔和培训是比较成功的。首先，几乎每年都有全国竞赛时实验成绩并不突出，甚至排名靠后的同学，因预培训取得很大进步而最后入选国际或亚洲物理奥林匹克国家代表队，这些同学在后来的大学学习中往往还会会显出更大的优势。其次，中国国际或亚洲物理奥林匹克代表队的实验总体成绩也从原来明显弱于理论的进步到和理论的比较接近。

北京大学物理实验教学中心参与培训的队员在国际物理竞赛中均取得了不俗成绩。参加国际物理奥林匹克竞赛的五届共二十五位队员全部都获得了金牌，其中三次获得总分第一，一次获得实验成绩第一，一次获最佳实验解题奖。参加亚洲物理奥林匹克竞赛的选手成绩更为出色，在所参加的四届竞赛中，不仅全部32名同学都获得了金牌，而且每届都至少包揽总分前三名，并在2012年获得了实验成绩第一名。

图1：在墨西哥美里达市举行的第四十届国际物理奥林匹克竞赛中，史寒朵同学成为历史上第一个获得总分第一的女生，她同时还获得了女生第一奖和实验成绩第一奖。

Figure 1: In the 40th IPhO hosted by Merida of Mexico, Ms. SHI, Handuo became the first female Absolute Winner in history of IPhO. She also won the Best girl and the Best in Experiment.

Laboratory for IPhO and APhO national teams

The Teaching Center for Experimental Physics (TCEP) of Peking University not only took responsibility for the laboratory but also participated in the selection of the national team members for International Physics Olympiad (IPhO) and Asia Physics Olympiad (APhO) from 2008 to 2012. Both the 5 members for IPhO and the 8 members for APhO were culled from the first prize winners of the National Physics Olympiad (NPhO). Before the selection, all the candidates were trained for three weeks to offer the students from schools that lacked facilities a fair chance. The selection examinations were well-designed to make the experimental abilities of the candidates evaluated in the round and to ensure every electee to be one of the best. TCEP also opened all laboratories to all the electees for self-studying a week before starting the training, so that they could have a chance to improve their weakness and to develope their ability to teach themselves. The training was focused on culturing the electees the basic thoughts, methods and skills in physics experiments. Before leaving for competition, the regulations and programs of IPhO or APhO were introduced to the electees in detail. Accordingly, they could establish self-confidence and prepared to manage various unexpected events.

The procedure for the selection and the training was proved to be successful by the practice of TCEP in the last five years. First, the pre-training indeed helped some students with common experimental scores in NPhO enhance their experiment ability, and thus enter the national teams for IPhO or APhO. Second, the experimental scores of the whole teams advanced from obviously lower than the theoretical ones before to comparable to those now.

All the team members who took the physics laboratory by TCEP got excellent standing in international physics competitions. All the 25 students in 5 IPhO contests won the gold medals, including three the Absolute Winners, one the Best in Experiment and one the Best Solution of the Experimental. The records in APhO were even better. All the 32 students in four APhO contests won the gold medals. Furthermore, Chinese teams always stood at top three places in APhO if attended and achieved the Best in Experiment in 2012.

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。从创建之初就成为了学校电子显微分析中心。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。在学校“211”“985”等项目的大力支持下，经过近 50 年、几代人的努力，实验室已建设成拥有包括先进的 Tecnai F30 场发射透射电镜、Strata DB235 离子 - 电子双束系统、Quanta 200F 场发射环境扫描电镜等大型电镜 8 台，及完善的电镜制样设备，设备总价值超过 5000 万人民币。

实验室现有包括叶恒强（院士）、俞大鹏（长江特聘教授）在内的教职工 10 名，8 人具有高级职称，6 人具有博士学位。在读博士、硕士研究生 30 余名。以电子显微学及相关领域作为研究方向，涉及到衍射、

衬度理论，电子能带结构；分析电子显微学；纳米结构材料及器件；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等。

实验室努力将：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作为奋斗目标。

Electron Microscopy Laboratory, PKU was first established in 1964 and authorized as State Special Laboratory by the ministry of education, P.R.C. in 1992. Under the support of the "985" and "211" projects, a Tecnai F30 TEM，a Strata DB253 FIB and a Quanta 200F ESEM, the most advanced instrument in the world, have been constructed in the laboratory. Now the laboratory is equipped with 8 sets of TEM & SEMs and consummate sample-preparing facilities with over 50 million Yuan. Now there are 10 staffs and over 20 graduate students in the laboratory including an academician of CAS and a national preeminence youth.

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.

一、低维结构物理性质的应变调控

应力和材料的制备、加工过程与生俱来，在器件使役中无法避免。应变效应在低维尺度被极度放大，能观察到宏观体系中观察不到的新现象。弯曲应变是一种非均匀应变，最大特点是存在着线性的张 - 压应变梯度 β。该应变梯度被定义为弯曲曲率半径的 ρ 倒数，它能够反应弯曲时应变的分布情况。俞大鹏研究团队与电镜实验室同事充分合作，利用电子束激发的阴极荧光光谱（CL）的高空间 / 高能量分辨特性，系统研究了弯曲应变对半导体纳米 / 微米线材料的电导、发光，尤其是对电子结构的显著、精细的调制作用，提出了应变梯度效应概念。他们对不同直径的 ZnO 微米线在液氮温度下沿线的径向扫描可以精确获得多达 38 条的 CL 谱线，每条 CL 谱线呈现出两个主导激子发光峰，能够精准地把不同应变梯度下应变对发光能量的调制作用揭示清楚。他们发现，随着微米线弯曲应变（应变梯度）增加，主导激子峰的能量会随着拉伸应变的增加而发生系统红移、随着压缩应变的增加而发生系统蓝移。在拉伸、压缩应变作用下 ZnO 材料的发光峰能量 ΔE 正比于应变梯度 β（Advanced MaterialsHan X.B., et al. 24, 4707, 2012）。

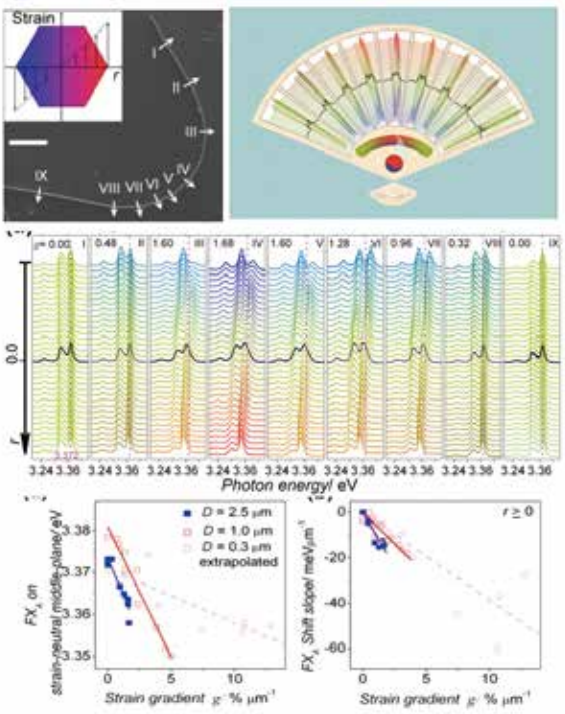


图 1：半导体材料的应变梯度效应。左上：直径 3 微米、长数百微米的单根 ZnO 微米线；中：所选 9 个位置上收集的系列 CL 光谱（液氮温度），两个主导激子峰随应变系统位移；右上：激子发光峰与应变梯度关系的示意图；下：不同直径微米线的激子峰位移与应变梯度的线性关系。

Figure 1: Strain gradient effect in ZnO microwires: Upper-left: SEM image of the bent microwire on substrate; Middle: 9 cross sectional CL spectra measured at the indicated cross-sections along above bent wire, and systematic exciton peak shifts as a function of the strain gradient; Upper-right: Strain-gradient dependence of the FX A energy in the bent wires with different diameters;Bottom: Strain-gradient effect on energy bands in bent ZnO Microwire (Advanced Materials 24, 4707，2012).

为了从微观上了解应变对 ZnO 材料电子结构的调制规律，他们还在液氦温度下（5.5K）系统研究了拉伸 / 压缩应变对发光峰精细结构的调制作用规律。液氦温度下由于热扰动受到抑制，能够保证简单而纯净的物理图谱条件，尤其是可以揭示电子结构所对应的精细发光峰，有助于理解背后的物理本质。液氦温度下 ZnO 微米线的 CL 精细结构系列曲线揭示出，发光峰不仅随拉伸、压缩应变出现系统红移、蓝移，还发现了系统的劈裂现象：在压缩应变最大处，可以观察到三个劈裂峰。与液氦温度不同的是，应变对电子结构的影响是不对称的，亦即在拉伸端，施主束缚激子峰（D0Ax）单调地随拉伸应变增加而红移；在压缩端，施主束缚激子峰不 仅随应变增加而逐渐蓝移，还出现多次劈裂现象。为了理解应变对 ZnO 半导体材料电子结构的这种不对称调制作用，他们与合作者一起，利用第一性原理系统计算研究发现，在压缩端观察到的发光峰劈裂现象是由 ZnO 价带的退简并 - 劈裂引起的。从压缩应变到拉伸应变的变化还会引起 ZnO 价带的交叉，带隙从压缩应变到拉伸应变端逐渐减少，因而在内建电场的作用下载流子会在拉伸应变端聚集，导致能带的填充和实验上仅有一个发光峰的出现（Liao Z.M., Fu Q. et al. Scientific Reports 2， 452, 2012）。

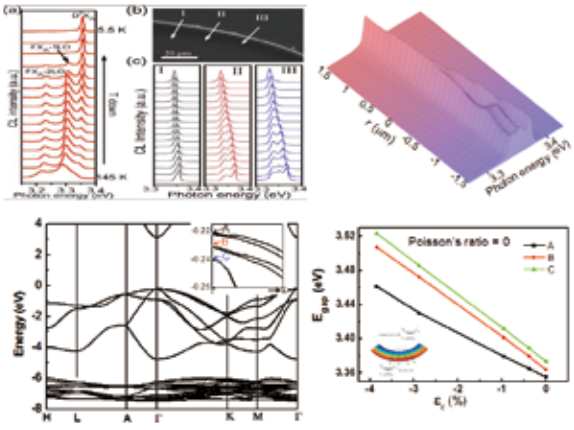


图 2：弯曲应变对 ZnO 材料精细电子结构的调制作用。左上：无应变 ZnO 微米线的阴极荧光光谱与温度的关系，以及三个不同弯曲状态上取得的系列 CL 光谱（5.4K）；右上：位置 III 上发光峰与应变的关系；右下：零泊松比下能隙与单轴应变的关系。

Figure 2: Strain induced exciton fine-structure shift and splitting in bent ZnO microwires. Upper-Left: Line scan CL spectra obtained from positions indicated by white arrows in position III. Upper-Right: A 3-D curves of the relationship between NBE peaks and radial positions (strain) as well as the photon energy, which shows the evolution of the peak position and FWHM more clearly. Lower-Left: Calculated band structures for ideal bulk ZnO without strain from the LDA+U calculations. Lower-Right: The band gap as a function of uniaxial strain for zero Poisson’ s ratio （Scientific Reports 2， 452, 2012）.

I. Strain modification of the opto-electronic properties of the semiconductor micro/nanowires

Strain engineering has long been an important route to tune the band structure and change properties of semiconductors. However, high local strain is accompanied by high strain-gradient in most

situations, especially in flexible electronics and nanodevices. However, to our best knowledge, the intriguing effect of strain-gradient upon the energy bands of semiconductors remains completely unexplored, and how it influences the device optical and electronic performance remains a challenge to both the experimental and theoretical communities. Recently, our group conducted extensive investigation on the spatial distribution of exciton spectra in bent ZnO microwires by high resolution cathodoluminescence (CL) characterizations, revealing a significant non-local strain-gradient effect on the band structure of the bent microwires and beyond the well known strain effect. Bending induced blue-shift in the compressive region is nonlinear while the red-shift in the tensile and strain free region increases linearly with strain-gradient in addition to strain effect, destroying the symmetry of local strain effect shown in ZnO under uniform deformation and leading to overall red-shift in the bent microwires. First principles modeling reveals some physics mechanisms for bending induced red-shift. This novel strain-gradient effect should pave an additional path to the energy band engineering of semiconductors. Figure below illustrates the strain-gradient effect on the optical-electronic properties in a bent ZnO microwire, with a much stronger red-shift on the outer tensile side than a blue-shift on the inner compressive side. The low temperature cathodoluminescence cross-sectional scanning spectra on the strain-neutral middle-plane are highlighted by thicker black lines, which clearly shows a strain-gradient induced red-shift（Han X.B., et al. Advanced Materials 24, 4707，2012）.

Moreover, we extended the study of the strain effect on ZnO near band emission down to liquid helium temperature. The group investigated for the first time the exciton spectra evolution in bent ZnO microwires along the radial direction via high spatial/energy resolution cathodeluminescence spectroscopy at 5.5K. The experiments show that the exciton peak splits into multi fine peaks towards the compressive part while retains one peak in the tensile part and the emission peak displays a continuous blue-shift from tensile to compressive edges. In combination with first-principles calculations, the observed NBE emission splitting is due to the valence band splitting and the absence of peak splitting in the tensile part maybe due to the highly localized holes in the A band and the carrier density distribution across the microwire. These studies may pave the way to design nanophotonic and electronic devices using bent ZnO nanowires. Figure 2. Temperature dependent CL spectra of strain-free ZnO microwire and line scan CL spectra in bent ZnO microwires along the radial direction. (a) Temperature dependent CL spectra of strain-free ZnO microwire from 145K to 5.5K. (b) SEM image of a bent ZnO microwire for CL line scan. The white arrows indicate the positions and the line scan directions for CL measurements. (c) Line scan CL spectra obtained from positions indicated by white arrows in (b). From top to bottom the individual CL spectrums were obtained point by point along the radial directions across the bent ZnO microwire from tensile to compressive edges.

二、利用固体纳米孔显微镜 (Solid-State-Nanopore Microscope) 进行 DNA 单分子的可控检测

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。年轻教师赵清与博士研究生鲁铂等在溶液中电泳驱动分子穿过一个纳米尺度的孔显微镜（solid state nanopores microscope）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。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。

研究 DNA 分子在固态纳米孔中的受力情况对于指导利用纳米孔对 DNA 分子进行探测分析具有重大意义。他们通过分别利用 Boltzman 和 Nernst-Planck 模型对 DNA 在纳米孔中的受力情况进行了数值模拟，发现 DNA 受力随其在纳米孔中位置和溶液浓度的变化规律，并与实验结果高度吻合 (Phys. Rev. E 86,021921,2012)。通过透射电子显微镜细致的表面表征和成分分析，系统研究了不同尺寸的 SiN 纳米孔在不同溶液中的形貌演变过程，发现了奇异收缩行为。研究发现此变化与孔起始尺寸和溶液 pH 值密切相关，并给出了合理机理解释（Nanoscale 4, 1572, 2012）。石墨烯由于其原子级厚度，独特的力学和电学性能，有望显著提高利用纳米孔进行 DNA 测序的空间分辨率。他们进一步利用精确定点转移石墨烯微米级“邮票”的方法，发展了一套可控，高效，快速制备悬空石墨烯纳米孔器件的方法，实现了精确可控制备尺寸在 3-20 nm 之间的纳米孔器件。DNA 单分子探测实验发现探测分辨率与石墨烯纳米孔尺寸密切相关，小孔可显著提高探测分辨率（Nanotechnology 23, 085301 (2012) 。

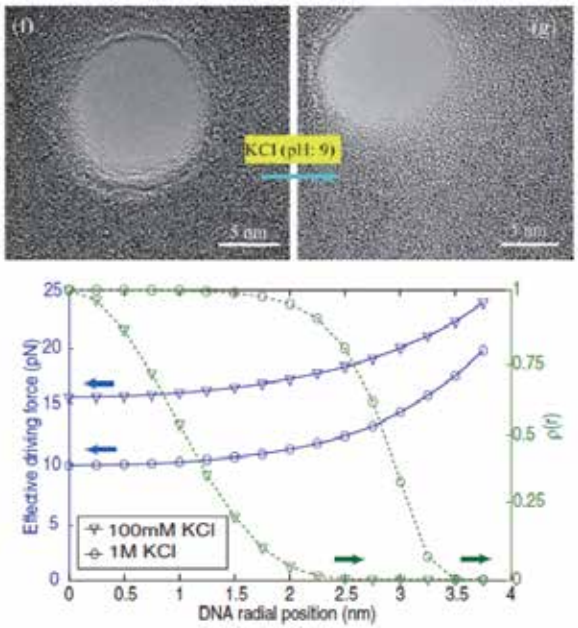


图 1：上图：系统研究纳米孔在不同 pH 值 KCl 溶液中演变行为。发现 pH9 溶液中纳米孔的奇异收缩行为。

下图：系统模拟研究了不同盐浓度下 DNA 分子在纳米孔不同径向位置处的出现概率和有效受力情况。

Figure 1：Upper：TEM images of a nanopore before and after immersion into KCl (pH=9) solution. Lower：Effective Force on DNA and probability function as a function of DNA radial position in nanopores at different solution concentration(Phys. Rev. E 86,021921,2012).

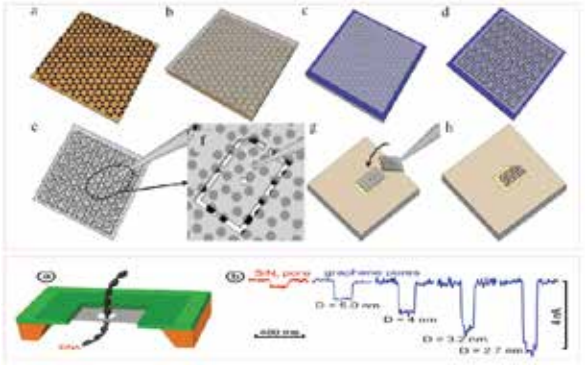


图 2：上图：利用精确定点转移墨烯微米级“邮票”技术制备尺寸可控的悬空石墨烯纳米孔器件示意图 下图：左：利用石墨烯纳米孔进行 DNA 单分子探测器件测量示意图 右：系统研究发现石墨烯纳米孔探测分辨率随纳米孔尺寸变小有显著提高。

Figure 2: Upper: Scheme of the site-specific transfer-printing graphene “microstamp” for fabrication of suspended graphene nanopore devices. Lower left: Scheme of DNA translocation through graphene nanopores. Lower Right: Typical DNA translocation event through different size graphene nanopores, smaller nanopore gives higher detection sensitivity（Nanotechnology 23, 085301 (2012).

II. Single DNA detection/sequencing via Solid-State-Nanopore Microscope

Since the first demonstration of successful detection of DNA molecules in 1996, nanopores have emerged as a promising platform for next generation fast DNA sequencing. In nanopore-based DNA translocation experiments, single DNA molecules in an electrolyte are driven by an electrical field through a nanometer-scale hole in a free-standing dielectric film. In concentrated electrolytes, a DNA molecule in a nanopore inhibits the electrically driven flow of the electrolyte ions; thus, each translocation event of a molecule chain can be characterized by an ionic current blockage and time duration.

A detailed understanding of the origin of the electrophoretic force on DNA molecules in a solid-state nanopore is important for the development of nanopore-based sequencing technologies. Numeral calculations were carried out to simulate the force on DNA as a function of its radial position inside nanopores and found to agree well with experimental findings. Phys. Rev. E 86,021921 (2012).

Studying stability and surface evolution of solid-state nanopores in aqueous solutions are extremely important for DNA analyses. We systematically studied the size evolution of SiN nanopores in diverse solutions by careful surface characterization and composition analyses and found shrinkage behavior. Nanopore size evolution was strongly dependent on initial pore size and solution pH value. Nanoscale 4, 1572 (2012).

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. Suspended graphene nanopore devices have been fabricated by a newly-developed site-specific transfer-printing “micro stamp” method. Graphene nanopores with size from 3-20 nm can be precisely obtained and DNA translocation experiments demonstrated that the detection sensitivity has been significantly improved by using smaller graphene nanopores. Nanotechnology 23, 085301 (2012).

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.

在顶夸克对和暗物质候选者的联合产生过程中测量顶夸克极化

夸克是物质组成的基本粒子，就人类目前的认知水平来看，夸克是无法再分割的基本粒子。顶夸克是夸克家族的巨人，其质量与金原子相差无几，是质子质量的 170 余倍。作为构成世界的基石之一，顶夸克在宇宙起源“大爆炸”后广泛分布在宇宙中。但它异常不稳定，产生后迅速衰变到其他更轻的粒子。时至今日，人们在自然界中已难觅其踪，只有借助高能对撞机才能在实验室中“轰炸”出顶夸克来。在欧洲核子中心的大型强子对撞机上，两个质子被加速到接近光速的情况下发生对撞，要经过百万次的碰撞才有可能观测到一个顶夸克事例。但顶夸克仅昙花一现就衰变了（其寿命约为 10-25 秒），这使得探测工作极具挑战性。事实上我们只能通过测量顶夸克的衰变产物们来间接地确定顶夸克的存在，并进一步测量顶夸克的极化性质。后者反映了丰富的新物理的结构信息。但在众多的新物理模型中，顶夸克对和暗物质候选者们联合产生。因为这些暗物质粒子在对撞机上无法直接观测，所以人们无法重构顶夸克的运动学信息，从而导致传统的测量顶夸克极化的实验方法彻底失效。理论物理研究所的曹庆宏研究员及其合作者发明了一种全新的实验测量方法，可以在不重构顶夸克事例的情况下测量顶夸克的自旋极化。该研究成果发表在物理学领域的顶级刊物《物理评论快报》上 [Phy. Rev. Lett. 109, 152004 (2012)]。此工作得到审稿人们的高度评价：“因为已经有大量的顶夸克事例已经在 LHC 上产生，改进顶夸克极化的测量方法对于 LHC 物理研究是非常重要的，特别是顶夸克可能是我们和新物理联系的唯一纽带”。

此工作是曹庆宏研究员近期关于“利用顶夸克极化性质探测 TeV 能区新物理”的第五篇工作。这一系列研究 [其余四篇工作分别为 PRL 108 (2012) 072002; PRL 106 (2011) 201801; PRD83 (2011) 114026; PRL 105 (2010) 181802] 主要探讨了利用顶夸克极化来探测和甄别不同类型的新物理模型，发展了在有多种不可测粒子的情况下有效地测量顶夸克极化的方法，对围绕顶夸克寻找新物理具有重要的意义。这一工作得到了国家自然科学基金委“主任基金”的赞助。

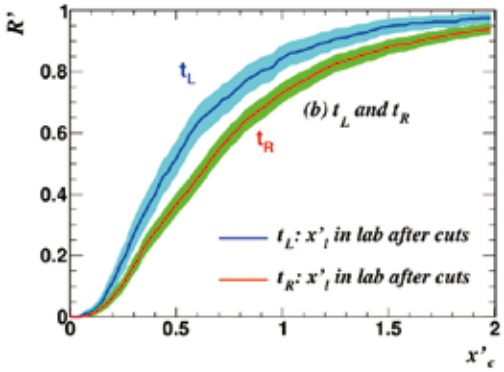


图 1：顶夸克衰变产生的电子的能量分布（R）敏感依赖于顶夸克极化性质，故可作为测量顶夸克极化的有效探针。青色带和绿色带分别代表左手和右手极化的顶夸克衰变产生的电子的能量分布。

Figure 1: The energy of the charged lepton from the top quark is high sensitive to top-quark polarization. The cyan (green) band denotes the energy distribution of the charged leptons from a left-handed (right-handed) top quark, respectively.

Measuring top-quark polarization in the top-quark pair plus missing energy events

To our best knowledge, the quark is an elementary particle and a fundamental constituent of matter. Top quark is the giant in his family (its mass is rough equal to a gold atom). It once existed copiously in our Universe long time ago, according to the "big bang" theory, but it is no longer around us as it flares briefly and then burns out into lighter particles. Today the top quark can be seen only in the laboratory through high-energy collisions. The lifetime of top quark is only about 10-25 second. It is impossible to observe such an ephemerality particle directly or to measure its detailed properties. In fact one has to rely on the top quark decay products to confirm the top-quark event and to reconstruct its kinematics. Unfortunately, the top-quark pair is usually produced in associate with those invisible dark matter candidates in a lot of new physics models. One then has to confront with the incapability of reconstructing top quark event. Dr. Qing-Hong Cao and his collaborators invented a novel method of measuring the top quark polarization in the top-quark pair plus missing energy events. In the method the top quark reconstruction is no longer needed. The method can improve greatly the current experimental search for new physics, as quoted from the referee, “improved methods for measurement of top quark polarization are crucial for the LHC physics since so many top quarks are being produced as expected and might also be via new physics since the top quark is so massive. The top quark is also possibly uniquely related to unknown fundamental electroweak physics.” The work is published in the journal of Physical Review Letters [Phys. Rev. Lett. 109, 152004 (20120].

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

北京大学量子材料科学中心成立于 2010 年，是直属于北京大学的一个新型教学与科研机构，是北京大学“985 工程”总体规划重点建设项目之一。中心依托北京大学深厚学术底蕴和多学科综合优势，致力于营造国际化学术创新环境，建设成为国内领先、国际一流的物理学研究教学平台。量子材料科学中心拥有一支具有国际一流的教师队伍。中心共有教师 23 人，全部为博士生导师，其中 1 人当选中国科学院院士，5 人曾获国家杰出青年科学基金，1 人入选中组部“青年拔尖人才支持计划”。

量子材料科学中心的主要研究领域是凝聚态物理和量子材料科学。目前中心根据研究方法分为低温及量子输运实验、谱学及高分辨探测实验、自旋电子学及低维磁性实验、凝聚态物理理论、凝聚态物理计算五个研究部。具体研究方向包括：量子霍尔效应、凝聚态物理中的拓扑效应、关联电子现象、低维

电子气的量子行为、自旋电子学、异质结构物性研究、介观超导体系、先进扫描探针显微学、中子和光子的散射谱学、表面动力学、纳米材料及器件超快动力学实验、超冷原子气、超高压条件下的材料物理、水的特性研究、软物质材料研究等。每名教师拥有自己独立的研究小组。目前中心共建有独立实验室 13 个及微加工平台 1 个。依托中心还建有北京大学崔琦实验室和全校综合性氦气液化回收车间。

随着软硬件条件逐渐成熟，量子材料科学中心已承担多项国家重点科研项目，涌现出一批高质量科研成果，获得了国际学界广泛关注和认可。截至 2012 年 9 月，量子材料科学中心共发表 SCI 论文 105 篇，其中多篇发表在 Science，Nature 子刊，Physical Review Letters 等国际顶级学术杂志。中心教师牵头承担各类科研项目共计 30 余项，科研经费总计约为 1.6 亿元，包括科技部“973 计划”4 项、国家自然科学基金重大专项 1 项等。自成立以来，中心成员已获得国家自然科学奖、亚洲计算材料科学奖及何梁何利奖等多项国际国内奖励与荣誉。

International Center for Quantum Materials (ICQM) was established in 2010 by Peking University (PKU). ICQM endeavors to develop an open and active intellectual platform and foster a culture of creativity for physics research and education in China that attracts scholars of high caliber from all over the world. ICQM currently has 23 faculty members, which include 6 chair professors, 2 full professors, 14 tenure-track faculty members and 1 visiting professor. Among the senior researchers are 1 member of Chinese Academy of Sciences and 6 fellows of American Physical Society.

The research at ICQM is organized into 5 divisions, namely low temperature and quantum transport experiments, spintronics and low-dimensional magnetism experiments, spectroscopy and high-resolution detection experiments, theoretical condensed matter physics and computational physics. Topics of current interest include, but not limited to, quantum transport, strongly-correlated electron systems, low-dimensional electron systems, topological effects, mesoscopic superconducting systems, spintronics, advanced scanning tunneling microscopy, ultra-fast spectroscopy，neutron spectroscopy, ultra-cold atoms, computational simulations for quantum materials under extremely high pressure, surface dynamics, behavior of water under confinement, soft matter materials. ICQM has 13 individual laboratories and a micro-fabrication facility. ICQM is also in the process of building the Daniel Tsui Laboratory of PKU and a Helium recovery system.

ICQM has published over 100 papers, which include papers published in the most prestigious scientific journals, such as Science，Nature series journals，Physical Review Letters. The funding received by ICQM members as Principle Investigators from Chinese research projects and programs has reached 160 million yuan (roughly 26 million US dollars) . ICQM members are also recipients of many national and international awards, such as ACCMS Award, Ho Leung Ho Lee prize, State Natural Science Award.

一、在亚分子水平上对单个功能化分子内部的化学键进行选择性操纵

可控的对分子内部的化学键进行选择性操纵是科学家们一直以来所追求的目标。经过近二十年的努力，人们利用（超快）激光和扫描隧道显微镜，成功的对一些简单分子实现了选键操纵，比如：甲烷、氧分子、一氧化碳、乙炔、苯分子等，使得和这些分子相关的化学反应可以被人为调

控。近年来，随着分子纳米科技（包括：分子电子学、分子传感器、纳米机器等）的迅速发展，如何在一个复杂功能化分子中实现化学键的选择性操控变得愈加重要。然而，由于分子内部自由度的复杂化以及能量在分子内部的重新分配，在复杂功能化分子中实现化学键的精确控制非常具有挑战性。

最近，北京大学量子材料中心的江颖博士与中科院物理所的郇庆博士和美国加州大学欧文分校的 Wilson Ho 教授等合作，利用自制的低温扫描隧道显微镜，成功的对一种广泛应用于分子电子学研究的巯基 π - 共轭分子 (1,4-bis[4’-(acetylthio)styryl]benzene) 实现了化学键的选择性操纵。通过向分子内部注入空间局域、能量可调的隧道电子，利用共振电子激发技术，他们可以分步把分子中四个不同的官能团逐个剥离，同时在能量空间和实空间中监测每一个化学键的断裂对分子电子结构的影响。基于可控的断键，他们进一步利用扫描隧道显微镜的原子操纵技术，精确的操控表面上的金原子，使其与分子中的硫原子结合并形成化学键，从而人为构造出了一个“电极 - 分子 - 电极”的单分子结。他们发现，Au-S 键的空间构型和分子的对称性共同决定了成键的类型：共价键或者配位键；同时，Au-S 相互作用是非局域的，其对整个分子的电子结构有着很大的影响，表现为共振态的展宽和能级的移动。这些结果将有助于澄清单分子电输运研究中理论和实验长期以来的分歧。

该工作展示了在复杂大分子中实现选键操控的可能性，同时也在单分子水平上揭示了分子的电子结构在化学反应过程中的演化。相关结果以 article 的形式发表在近期的《自然 - 化学 》[Nature Chem. DOI: 10.1038/NCHEM.1488 (2012)] 上，江颖博士为该论文的第一作者。这项工作得到了科技部重大研究计划、国家自然科学基金和教育部博士点基金的资助。

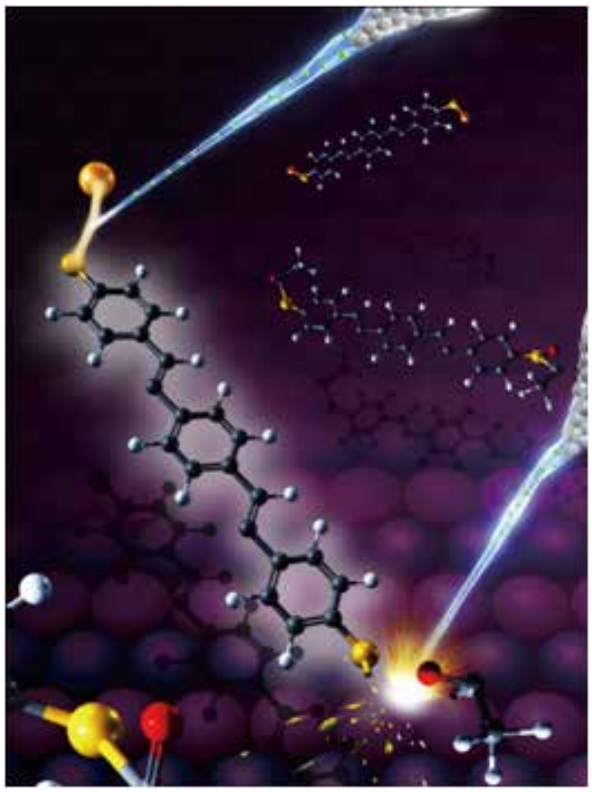


图 1：利用 STM 针尖在单个功能化分子内部进行选择性断键和成键。STM 针尖发射的电子束可以选择性的解离 S-Ac 键（右下角），也可以对 S-Au 键进行焊接（左上角）。背景是分子所吸附的 NiAl(110) 衬底。

Figure 1: Selective bond dissociation and formation in a single functionalized molecule. The electron beams emitted from the tip of a scanning tunneling microscope (STM) selectively cleave the sulfur-acetyl bond (lower-right), and weld the sulfur-gold bond (lower-left) in a 1,4-bis[4’-(acetylthio)styryl]benzene molecule. The background is the NiAl(110) substrate, on which the molecule is adsorbed.

I. Submolecular control of bond-selective chemistry in single functionalized molecules

Bond-selective chemistry, which involves selectively breaking and forming specific bonds, is one of the ultimate goals of chemistry. Achieving bond-selectivity in a complex functionalized molecule is

particularly important for advancing the molecular nanoscience and technologies, such as molecular electronics, organic solar cells, and nanomachines. However, due to the rich internal degrees of freedom and the intramolecular energy redistribution in functionalized molecules, bond-selective control has so far been difficult to realize.

Using a scanning tunneling microscope (STM), Jiang et al. succeed to induce a sequence of target-selective bond dissociation and formation steps in a single thiol-based π-conjugated molecule adsorbed on a NiAl(110) surface. By locally injecting the energy-tunable tunneling electrons into the resonant states derived from the functional groups in the molecule, they are able to selectively abstract different functional groups from the molecule step by step and monitor the evolution of the molecular electronic structure both in energy and real space at each reaction step. Furthermore, the bond-selective dissociations allow them to activate the sulfur functional groups and form different types of Au-S bonds by manipulating and attaching a single gold atom to the sulfur atom each end of the molecule. The microscopic geometry of the Au-S bond at the single molecule level and its influence on the electronic structure of the molecule are determined by the STM, which may underlie the understanding of electron transport in the widely used thiol-based molecular junction.

This work not only opens up the possibility of submolecular control of the bond-selective chemistry in a single functionalized molecule, but also reveals the changes in the molecular electronic structure associated with bond dissociation and formation, which are crucial evidences for orbital hybridization in chemical transformation.

This work is published in Nature Chemistry [Nature Chem. DOI: 10.1038/NCHEM.1488 (2012)]. The referee thinks highly of the work as an "experimental tour de force".

二、探索电子的谷自由度

《自然 - 通讯》（Nature Communications）最近发表了北京大学量子材料科学中心冯济研究员和王恩哥教授等及中国科学院物理研究所、半导体研究所合作的文章"Valley-selective circular dichroism of monolayer molybdenum disulphide"[Nature Communications3, 887 (2012)]。这项研究工作首次从理论上预言，并从实验上证实了单层二硫化钼的谷选择圆偏振光吸收性质，这一结果对新一代电子学—谷电子学的发展意义重大。

对新型材料新奇量子特性的探索在现代科学研究中具有重要意义，它不但帮助人们认识物理学规律，还为高新技术的发展推波助澜。对称性和拓扑结构在近期对新型量子材料的探索备受关注。在这方面，一个著名的例子是石墨烯（graphene）中高度对称的蜂窝结构。这一特殊结构引发了类似相对论量子体系中狄拉克费米子的诸多新奇量子行为。而其发现者获得了2010年的诺贝尔物理学奖。如果我们打破石墨烯的空间反演对称性，理论上可以得到具备手性的低能电子激发。然而，这个极具应用潜力的理论概念一直没有取得实验的验证。

在这篇文章中，冯济研究员等通过第一性原理计算研究，对于单层二硫化钼的光吸收进行了

研究分析。这项工作表明，单层二硫化钼的能带在六边形布里渊区的顶点附近拥有“谷”状结构，而相邻顶点的谷并不等价，它们分别吸收左旋光和右旋光，其选择性近乎完美。这一结论得到了中国科学院合作者在实验上的证实。课题组还对单层二硫化钼的光致谷极化效应以及潜在的谷霍尔效应进行了分析。

这项研究首次发现了材料中谷的旋光选择性，对于新一代电子学—谷电子学的发展具有极其重要的意义。此前，谷电子学应用的最大挑战，即谷极化尚未在单层原子薄膜中实现，而单层二硫化钼的谷选择性圆偏振光吸收特征恰恰解决了这一问题。材料的光霍尔效应更为单层二硫化钼中光电子学与谷电子学应用构筑了桥梁。

尤其值得一提的是，此工作的第一作者为王恩哥教授与冯济研究员指导的元培学院本科生曹霆。该论文的通讯作者为冯济研究员和王恩哥教授。其他作者包括北京大学量子材料科学中心的施均仁教授、牛谦教授。中国科学院物理研究所、半导体研究所的刘保利和谭平衡研究员设计和完成了验证理论的实验工作。这项研究得到了国家自然科学基金委、国家科技部等的资助。

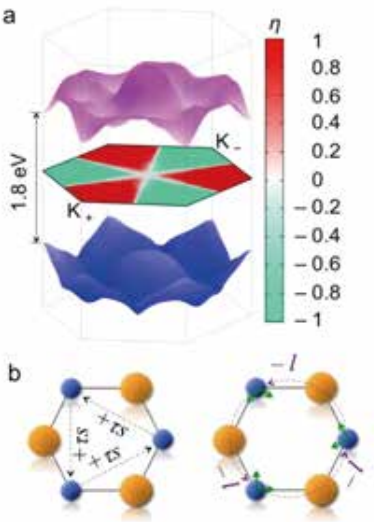


图 1：MoS2 单层中完美的谷旋光选择性（valley selective circular dichroism）。

Figure 1: perfect optical selectivity in monolayer Molybdenum disulphide.

II. En route to exploiting the electronic valley degree of freedom

Nature Communications recently published a paper by Profs. Ji Feng, Enge Wang, Qian Niu and Junren Shi, in collaboration with Profs. Baoli Liu and Pingheng Tan from Chinese academy of Sciences. The paper is titled “Valley-selective circular dichroism of monolayer molybdenum disulphide” [Nature Communications3, 887 (2012)]. In this paper, the authors took a combined theoretical, computational and experimental approach to demonstrate, for the first time, molybdenum disulphide monolayer exhibits valley-selective circular dichroism, which allows for dynamical valley polarization and rich related valley physics.

The exploration of novel quantum behaviors of materials plays a significant role in today’s forefront of scientific research. Progress in this front helps understanding the basic principles of physics, and advancing our technological reserve. Symmetry and topology are but two examples of recent focus in the research of quantum matters. Graphene is one noted example, whose aesthetically pleasing honeycomb lattice with six-fold rotational symmetry leads to the remarkable Dirac Fermion in condensed matter and abundant associated novel quantum phenomena. Of particular interest here is the proposition that if we can break the centrosymmetry of a honeycomb

lattice, we can produce chiral Fermionic excitations, a phenomenon unseen in any hitherto known systems.

In their work, Ting Cao (then an undergraduate student of Yuanpei College and ICQM, who is pursuing his Ph.D. study now at UC Berkeley), advised by Profs. Ji Feng and Enge Wang, employed ab initio calculations to analyze the optical selectivity of monolayer molybdenum disulphide. The team discovered that the electronic structure of this material has a pair of degenerate but inequivalent valleys, at the corners of the Brillouin zone. Remarkably, one of the valleys has nearly perfect selectivity for left-handed photons, and the other valley right-handed photons. The perfect optical selectivity is further supported by the experimental data. The experiments were performed in the lab of Profs. Baoli Liu and Pingheng Tan in the Chinese Academy of Sciences.

This work is the first demonstration of dynamical polarization of valleys in real materials, in both numerical simulation and experiments, providing an important bridge for the theoretical proposal of valleytronics. The work is immediately confirmed by two further experiments, both published in a recent issue of Nature Nanotechnology. This work is also highlighted by the News and Views of Nature Nanotechnology.

三、冰表面结构对吸附特性的影响

冰是自然界中最广泛存在也是最为人们熟知的物质之一。冰对人类生存乃至整个自然界变化都有重要影响，因此对其本质的研究一直吸引着人们的广泛兴趣。尽管上百年来科学界对体冰的各种形态及其相变规律做了大量研究，但对冰表面结构及其相应物理化学性质的了解长期以来仍旧是一个空白。

近几年来，王恩哥教授的课题组在冰表面研究中取得了一系列重要突破。2008 年他们首次发现并提出了冰表面的序参量的概念。人们一般会认为冰的表面相对体内而言会更无序，也就是“热”一些。但是他们的研究却得到了一个令人惊讶的结果：冰的表面在融化前会比体内更有序，就是说要更“冷”，而且冰的（0001）表面在任何温度下都不会发生有序 - 无序相变（Phys. Rev. Lett. 101, 155703 (2008)）。2011 年他们进一步研究并证明冰表面分子空位形成能随序参量的变化分布的非常宽。这个结论表明冰表面上的空位数比之前人们估计的要多得多，从而使冰晶颗粒在物理化学反应中比原来预计的要更加活泼。导致这一反常现象的根本原因是由于冰表面有效电荷所引起的局域电场，它直接影响着表面层水分子的电偶极矩，进而对不同的表面位置可以给出非常不同的空位形成能。这项研究工作对了解冰表面的预溶化过程至关重要（NATURE Material 10, 794 (2011)。

最近，量子中心王恩哥教授、徐莉梅副教授与他们的研究生孙兆茹等一起又在冰表面吸附方面的研究中取得了新的进展。他们首先证明冰表面的吸附不仅仅取决于冰表面最近邻 OH 悬挂键，也与整个冰表面悬挂的 OH 键的相关。这是因为冰表面悬挂键产生的电场是长程的，因此只考虑最近邻 OH 悬挂键对吸附分子的影响不能准确地描述冰表面的吸附特性。他们还发现冰表面的吸附能与序参量之间有一个正比关系，这预示着分子吸附更容易发生在序参量大的冰表面。这项工作不但有助于对直接影响地球环境变化的云层中颗粒物吸附问题给出了解释，还从微观尺度上揭示了冰的生长过程。这个工作近期发表在《美国科学院院刊》PNAS 109, 201206879 (2012)，

已经引起了国内外专家的广泛关注。王恩哥也应邀在美国化学年会（ACS, 2012）和国际计算物理年会 (CCP, 2012) 上做大会报告。

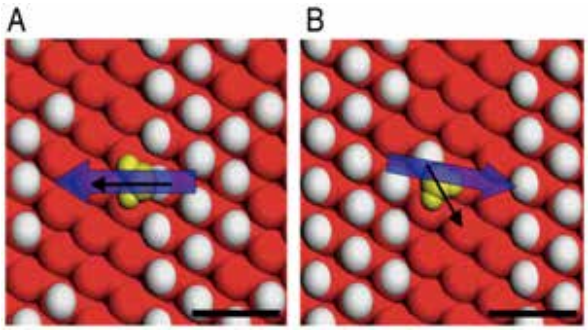


图 1：局域电场和吸附水分子偶极矩的相对方向示意图。（A）两者方向相同，最大限度增强吸附，（B）夹角表明此处吸附较弱。

Figure 1: Orientation of the dipole moment of the adsorbed H2O and the local electric field, strong enhancement of adsorption (A) and weak enhancement of adsorption (B).

III. Role of proton ordering in adsorption preference of polar molecule on ice surface

Ice is one of the most abundant and well-known materials on earth. It plays a critical role in many of the physical and chemical processes throughout the universe, such as interstellar phenomenon, life in cryosphere and regulation in global climate, thus has attracted extensive attentions. Despite progress in understanding the mechanism and formation of ice over the years, our knowledge of the structure and physical/chemical properties of ice surface is still limited.

In the past few years, Prof. Enge Wang’s group has made significant progress in the study of ice, including a new characterization of ice surface order parameter (Phys. Rev. Lett. 101, 155703 (2008)) and observation of amorphous phenomenon of ice surface (NATURE Materials 10, 794 (2011)), which is of curial importance for the understanding the proton order-disorder transition and the pre-melting process of ice surface.

Recently, ICQM faculty member Enge Wang and Limei Xu together with their students Zhaoru Sun and Ding Pan has made new progress on the adsorption properties of ice surface. They showed that adsorption on ice surface is affected not only by local dangling atoms on ice surface, but also by dangling atoms on the entire surface. This is due to the fact that the interaction between the surface and admolecule caused by dangling atoms is long ranged, thus consideration of only the nearest dangling atoms (as in previous studies) is not sufficient enough to describe the adsorption property of ice surface correctly. They further found a positive correlation between adsorption energy and heterogeneity of the ice surface, which suggest that admolecules are more likely to be adsorbed on ice surface with larger heterogeneity. This work helps to reveal the possible mechanism of ice growth on molecular scale, and also helps to explain the adsorption mechanism of polar molecules in clouds associated with global climate.

This work was published in the Proceedings of the National Academy of Sciences (PNAS 109, 201206879 (2012), http://www.pnas.org/cgi/doi/10.1073/pnas.1206879109) and has been received considerable attentions. Prof. Enge Wang is invited to give talk on ice in the ACS meeting 2012 (Philadelphia) and Conference on Computational Physics 2012 (CCP2012, Kobe).

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 2007 年开始运行。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，推动基础科学研究在中国的发展。研究领域包括：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、恒星和行星系统。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。研究所现有访问讲席教授 1 人、教授 3 人、“百人计划”研究员 4 人、博士后 5 人。

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 2007. KIAA's mission is to establish an international center of excellence in astronomy and astrophysics that promotes the development of basic science in China. Its primary goal is to foster frontier research in a vibrant intellectual environment. The program of KIAA focus on 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. KIAA currently has 1 visiting chair professor , 3 tenured research professors, 4 “Bairen” tenure-track research professors and 5 post-doctors.

For more information, please refer to KIAA homepage: http://kiaa.pku.edu.cn/.

一、绕核心强剪切星爆环的高速星团瓦解：不寻常的 NGC7742

旋臂星系中绕核心的环有利于大规模的恒星和星团形成，许多恒星形成环中都发现存在致密的“热斑”，哈勃太空望远镜观测发现，许多年轻（数千万年）和中等年龄（数十亿年）的星团都存在于热斑中。

NGC7742 是一个几乎完全面朝我们的旋臂星系，距离约 22.2 兆秒差距，拥有直径约 2 千秒差距的绕核心星爆环，其气体的旋转方向与恒星盘相反，这被认为它曾与一个富含气体的矮星系发生主合并，因此产生的非对称引力扰动也与星系的棒状结构相关。扰动能在不同半径上改变力矩，从而使气体积累到绕核心的环上。

作为由国家自然科学基金支持的大质量星团的研究课题的一部分，北京大学 Kavli 天文与天体物理研究所的 Richard de Grijs 教授，带领小组对 NGC7742 星爆环中年轻星团的质量分布进行了研究。我们关注的是星爆环中强剪切环境对大质量星团形成和早期演化的影响。

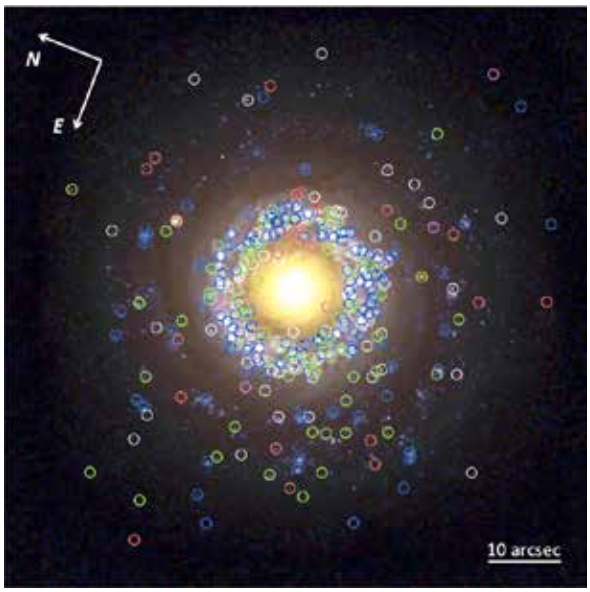


图 1：基于哈勃太空望远镜拍摄的 NGC7742 和它的星爆环的真彩图像，我们观察到的 352 个星团在图中由带颜色的圆圈标示出来，其中颜色代表星团的年龄，蓝色：~10^7 年 绿色：~10^8 年。

Figure 1: Hubble Space Telescope-based true-colour image of NGC 7742 and its circumnuclear starburst ring. The 352 star clusters we detected are indicated by differently coloured circles representing their ages – blue: ~10^7 yr; green: ~10^8 yr.

惊讶的是，不论星团的年龄多大，它们的质量函数（某年龄段星团在不同单位质量范围中的数目）都呈现对数正态形式，这恰是附近那些充分演化的球状星团遵从的。现在已经知道（包含 de Grijs 小组的研究结果）：在恒星（星团）形成时，其质量函数都遵从幂律分布（$dN/dM_{cl} \sim M_{cl}^{-\alpha}$），其中 α 接近 2。

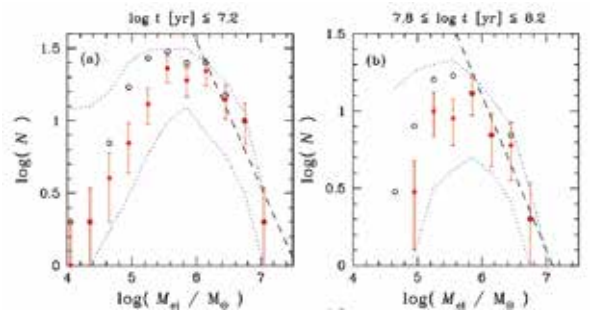


图 2：NGC7742 星团的质量函数和对应的泊松误差，其中左图的星团年龄处于 log(t/yr) ≤ 7.2 范围内，右图中星团年龄处于 7.8 ≤ log(t/yr) ≤ 8.2 范围内，图中所有星系中的星团完备性均在 50% 以上。红色实心点：处于星爆环中的星团（的质量函数）；黑色圆圈：整个星系中所有星团的质量函数。蓝色点线代表了用两种不同的统计方法计算出星团年龄和质量后，星爆环中星团质量函数的上下限。黑色虚线表示幂指数为 2 的理论上的幂律质量函数。

Figure 2: NGC 7742 cluster MFs and their Poissonian uncertainties for ages t of log(t/yr) ≤ 7.2 (left) and 7.8 ≤ log(t/yr) ≤ 8.2 (right), for all clusters in the galaxy above our 50% completeness limit (corrected for incompleteness). Red solid bullets: Clusters in the starburst ring; black open circles: MFs of the full, galaxy-wide cluster populations. The blue dotted lines indicate the upper and lower envelopes of the ring-cluster MFs based on two statistical redeterminations of the cluster ages and masses. The dashed lines represent the expected power-law mass distributions with an index of α = 2.

从疏散，宁静的麦哲伦云到致密，剧烈作用的“天线”星系，幂律质量函数似乎对环境普适，它独立于初始恒星或气体的密度。假设初始的幂律质量函数是合理的，该团队的博士后 Peter Anders 说，如果这些星团还未足够演化，那么 NGC7742 中最大质量的星团就代表了幂律质量函数的大质量末端。而实际观测的对数正态分布表明，大部分的小质量星团“丢失”了。这对当前的研究来说是让人惊讶的。如果我们否认初始的质量函数是幂律的，将与众多研究结果相悖，这一矛盾可能源于三个因素：1、测定年龄和质量的方法还有争议；2、星团在短时间内经历了演化；3、这一星团样本的形成环境与众不同。

我们的研究严格排除了初始的幂律质量函数，发表在 2012 年的天体物理杂志快报上，这表明，一些小质量星团数目的“低谷”，应归因于早期演化和形成环境：星爆环的环境可能加速小质量星团的瓦解和蒸发，这一高瓦解率可能是环中极高的恒星和气体密度共同作用的结果。高密度气体和环上的年轻星团，可能增加了剪切效应和恒星、气体，

星团间的相互作用。此外，环附近的星系旋转曲线已经恒定，其较差转动也将带来剪切效应。

另一种解释是，高剪切效应抑制了小质量星团形成，而大质量星团则没有。这似乎与观测结果相悖，大质量星团通常发现于低剪切环境。而对不规则星系和旋臂星系中的观测表明，星团质量与剪切强度无关。于是我们推断 NGC7742 的绕核心星爆环中，强剪切效应更可能导致星团的快速瓦解，这被另一个对星系中心相似环境的年轻星团的模拟所证实。

参考文献：

[1] de Grijs, R., & Anders, P. 2012, The Astrophysical Journal Letters, vol. 758, p. L22

I. Extremely rapid star cluster disruption in high-shear circumnuclear starburst rings: The unusual case of NGC 7742

Circumnuclear rings in spiral galaxies represent environmental conditions that are conducive to intense star and star cluster formation. Many intensely star-forming rings featuring compact "hot spots" have been identified, while high spatial resolution Hubble Space Telescope observations have revealed the presence of numerous young (a few x 10^7 yr) and intermediate-age (up to a few Gyr) star clusters in these structures.

NGC 7742, an almost face-on spiral galaxy at a distance of 22.2 Mpc that features a ~2 kpc-diameter circumnuclear starburst ring, is an unusual example of this class of galaxies, however. The presence of a global gaseous subsystem that is counterrotating with respect to the global disk-like rotation of the stars, combined with the starburst ring, has been interpreted as the result of a past minor merger with a gas-rich dwarf galaxy. The non-axisymmetric gravitational perturbations resulting from such a merger are similar to those associated with a bar (although NGC 7742 does not exhibit evidence of hosting a dominant bar-like feature in its core). Both types of perturbations can result in a torque change at a particular radius and, hence, accumulation of gas into a circumnuclear ring.

As part of an in-depth investigation (funded by the National Natural Science Foundation of China) of the formation conditions and the subsequent evolution and disruption of massive star clusters, the research group led by Richard de Grijs at Peking University's Kavli Institute for Astronomy and Astrophysics explored the mass distribution of the young star clusters associated with the NGC 7742 starburst ring. Our ultimate aim was to assess the impact of the ring's high-shear conditions on the formation and early evolution of the galaxy's high-mass (~10^5–$10^7 M_\odot$) star cluster population.

Surprisingly, and contrary to expectations, at all ages – including the youngest, < 15 Myr – the cluster mass functions (MFs; i.e., the distributions representing the number of star clusters per unit mass range in a given, narrow, age range) are robustly and verifiably represented by lognormal distributions that resemble those commonly found only for old, evolved globular cluster systems in the local Universe. It is now well established (including through research published by the de Grijs team) that cluster MFs at the time of star (cluster) formation are well described by power-law distributions of the form $dN/dM_{cl} \sim M_{cl}^{-\alpha}$, where α is usually close to 2.

This power-law form seems ubiquitous and

independent of initial stellar or gas density: it is found in environments ranging from the low-density, quiescent Magellanic Clouds (the nearest system of "dwarf" galaxies to our Milky Way) to the high-density, violently interacting system of galaxies dubbed the "Antennae". An initial power-law MF seemed, therefore, a reasonable boundary condition for our discussion of the unexpected results our team at the KIAA, including postdoctoral researcher Peter Anders, obtained. If we assume, not unreasonably given the long timescales involved, that the highest-mass clusters in NGC 7742 essentially represent their formation conditions, we can approximate the high-mass end of the MFs by a power law with a slope of $\alpha = 2$. The approximately lognormal MF shape observed for different (young) age ranges imply that a large fraction of the lower-mass clusters are 'missing' compared to expectations. Based on our current best understanding of the early evolution of cluster MFs, it is particularly surprising that the cluster MF in the youngest age bin resembles a lognormal distribution. Except if we release the assumption that the initial cluster MF was a power law – which would contradict most observational studies in this very active area of current research – three effects could have caused this discrepancy: (i) technical issues related to our age and mass determinations, (ii) evolution of the star cluster population on very short timescales ($<10^7$ yr), and/or (iii) differences in the cluster formation conditions compared to other environments featuring large samples of young star clusters.

Our detailed research, published in The Astrophysical Journal Letters in 2012, firmly rules out an original power-law MF. It thus appears that at least part of the observed 'downturn' toward lower masses may be due to either the effects of star cluster evolution or their formation conditions. From an evolutionary perspective, the conditions in the galaxy's starburst ring appear to speed up the destruction or evaporation of a large fraction of the lower-mass clusters. We speculate that this enhanced cluster disruption rate at very young ages may be caused by a combination of the high stellar and gas density in the starburst ring, and the shear caused by the galaxy-wide counterrotating gas disk. Although the gas and stellar disks rotate in opposite senses globally, the high gas density and filling factor and our detection of very young clusters in the ring (which presumably formed in situ and are hence expected to co-rotate with the gaseous subsystem) may have led to increased shear, as well as star/gas and star (cluster)/star (cluster) interactions in the ring. In addition, at the ring's galactocentric radius, the galaxy's rotation curve has already reached its constant level, so that differential rotation across the ring will induce additional shear.

The only alternative explanation of the derived lognormal MF is that the high shear in the starburst ring has created an environment in which the formation of low(er)-mass clusters (M_{cl} < a few x 10^4 $M_\odot$) is suppressed, while high-mass clusters are formed more readily. However, this seems contrary to observational results, where more massive star clusters are usually found in environments affected by lower shear. On the other hand, the observed similarity of the initial cluster mass functions in irregular and spiral galaxies implies that the process determining the masses of clusters may not depend on galactic shear. We thus conclude that the high shear in the NGC 7742 circumnuclear starburst ring has most likely led to extremely rapid cluster disruption, a view corroborated by the numerical simulations of young clusters in the similarly forbidding environment of the Galactic Center.

References：

[1] de Grijs, R., & Anders, P. 2012, The Astrophysical Journal Letters, vol. 758, p. L22

二、在 SDSS 和 LAMOST 巡天光谱中探测星际弥散带

星际弥散带（Diffuse interstellar bands，下文简称“DIBs”）是源自星际空间的数百条吸收谱线的总称。从上世纪 20 年代首次发现两条 DIBs 以来，迄今为止人们已经在光学、近红外波段发现了超过 400 条 DIBs。DIBs 数量众多的谱线包含了非常丰富的天体物理学信息。但是，令天文学家感到困扰的是，目前还没有一条 DIB 的载体得到证认。DIBs 的证认与起源是天文分光学中长期悬而未决的经典难题之一。该世纪难题的解决将对人类认识星际介质的组成、物理环境及其经历的化学过程具有重要的意义。

DIBs 的强度很弱，为了避免恒星自身吸收线的影响，人们一般通过对红化严重的 OB 型恒星进行高分辨率分光观测来进行 DIBs 的探测和研究。这种观测方式由于耗时严重而大大限制了样本的数量，目前仅积累了约两百个视线方向的数据。最近，北京大学科维理天文与天体物理研究所的苑海波博士和刘晓为教授合作，利用大规模巡天的样本优势，通过模板匹配的方法，成功地在斯隆巡天（SDSS）的两千余条低分辨率（R=1800）恒星光谱中探测到了两条相对较强的 DIBs（λ λ5780, 6283），并对它们的吸收线强度和视向速度进行了可靠测量。这是迄今为止有关 DIBs 的最大样本，也是最无偏的样本。这些恒星在位置空间及恒星基本参数空间上分布广泛，证实了 DIBs 的载体在星际空间普遍存在。这批样本得到的吸收线强度与消光的关系也与前人基于高分辨率观测得到的结果一致。

国家大科学工程郭守敬望远镜（LAMOST）的正式光谱巡天已于 2012 年 10 月启动，将用 5 年左右的时间获得银河系数百万颗恒星的低分辨率（R=1800）光谱。苑海波博士和刘晓为教授在 LAMOST 光谱中也成功地探测到了 DIBs。仅在一条调试阶段拍摄的早型发射线恒星光谱中，就有 9 条 DIBs 被探测到。他们预期在数十万条的 LAMOST 恒星光谱中，特别是在银河系反银心方向，探测到 DIBs。基于 LAMOST 巡天获得的海量数据将为研究 DIBs 的分布、性质及起源和利用 DIBs 做为探针研究星际介质及尘埃的分布及性质提供一个史无前例的的机遇。

该研究成果已于 2012 年 9 月发表在《英国皇家天文学会月刊》上（Yuan & Liu, 2012, MNRAS, 425, 1763）。

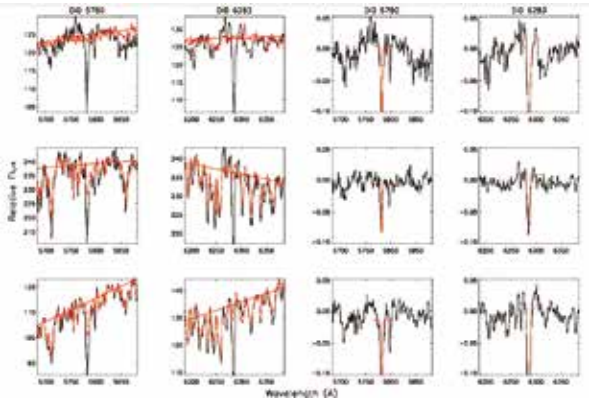


图 1：三条具有代表性的 SDSS 光谱中的星际弥散吸收带。左边两列图中黑线和红线分布代表目标源的光谱和模板光谱。右边两列图中黑线代表经过归一化后目标源光谱和模板谱的差异，红线代表对两条 DIBs 的拟合结果。

Figure 1: The DIB features λ λ5780, 6283 detected in the SDSS spectra of three representative stars. For each row, segments of the target (black) and the scaled template (red) spectra centered at 5780Å and 6300 Å are shown in the left two panels, respectively. The lines in red show fitted continuum levels of the scaled template spectra, assumed to be equally applicable to

the target spectra. The residuals are plotted in the right two panels in black, with the Gaussian fitting to the DIB λ5780 and Voigt fitting to the DIB λ6283 over-plotted in red.

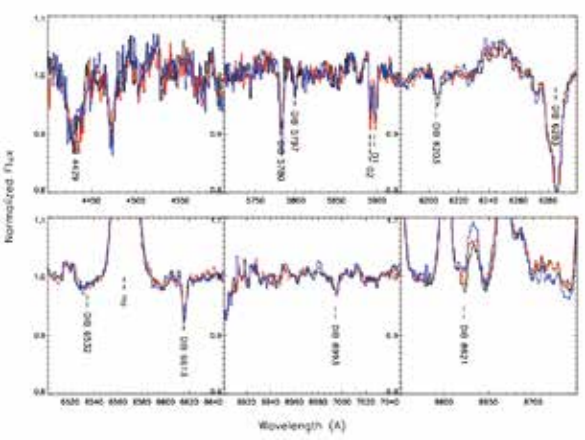


图 2. 在一颗发射线恒星的 LAMOST 测试光谱中探测到的弥散星际吸收带。

Figure 2. Nine DIBs have been detected in the LAMOST commissioning spectrum of an emission line star.

II. Detections of diffuse interstellar bands in the SDSS and LAMOST low-resolution spectra

Diffuse interstellar bands (DIBs) are weak absorption features detected in the spectra of reddened stars from the near UV to the near infrared. DIBs have been discovered for almost a century, and to date over 400 DIBs have been detected in Galactic and extragalactic sources, but none of their carriers is identified. The nature of DIBs remains one of the most challenging problems in astronomical spectroscopy.

Most recent work to identify and investigate the properties and carriers of DIBs concentrates on high-resolution spectroscopy of a small number of selected sight-lines. Using a template subtraction method, Yuan & Liu (2012) have successfully identified the DIBs λλ5780, 6283 in the Sloan Digital Sky Survey (SDSS) low-resolution spectra of a sample of about 2,000 stars and measured their strengths and radial velocities. The sample is by far the largest ever assembled. The targets span a large range of reddening, E(B V) 0.2 - 1.0, and are distributed over a large sky area and involve a wide range of stellar parameters (effective temperature, surface gravity and metallicity), confirming that the carriers of DIBs are ubiquitous in the diffuse interstellar medium (ISM). The sample is used to investigate relations between strengths of DIBs and magnitudes of line-of-sight extinction, yielding results (i.e., EW(5780) = 0.61 × E(B V) and EW(6283) = 1.26 × E(B V)) consistent with previous studies.

DIB features have also been detected in the commissioning spectra of the Guoshoujing Telescope (LAMOST) of resolving power similar to that of SDSS. Detections of DIBs towards hundreds of thousands of stars are expected from the on-going LAMOST Galactic surveys, particularly from the LAMOST Digital Sky Survey of the Galactic Anti-center (DSS-GAC). Such a huge database will provide an unprecedented opportunity to study the demographical distribution and nature of DIBs as well as using DIBs to probe the distribution and properties of the ISM and the dust extinction.

This work has been published in Monthly Notice of the Royal Astronomical Society (Yuan & Liu, 2012,

MNRAS, 425, 1763).

三、行星状星云 NGC 7009 的深度分光分析以及基于重元素离子光学复合线的星云等离子体诊断

在气体星云物理学研究中，有两个长期存在的基本问题：用传统的碰撞激发线方法测得的重元素相对于氢的丰度比用光学复合线测得的值要低；用碰撞激发线测得的电子温度比用中性氢复合连续谱测得的值要高。为解释这两个问题，天体物理学家提出了多种模型和机制。目前最为成功的解释是双丰度星云模型，即星云中很可能存在一种过去不为人知的低温（~1000 K）、贫氢（即富金属）的等离子体成分，重元素离子光学复合线主要来自这种冷成分，碰撞激发线则来自周围的正常金属丰度的热气体。大量观测证据表明这种冷成分很可能存在。

我们利用最新的一次电离氮（N II）和一次电离氧（O II）复合谱有效复合系数，对银河系高面亮度行星状星云 NGC7009 的宽波段、深曝光长缝光谱进行细致分析。在整个光学波段（3000–11000Å）用多高斯轮廓对 NGC7009 的光谱进行拟合并得到 1000 多条发射线，并测得较为准确的发射线流量（图 1）。用 N II 和 O II 光学复合线测得的电子温度都接近 1000 K，比用传统重元素离子碰撞激发线方法测得的电子温度要低将近一个量级。这表明重元素复合线起源于该星云中低温电离区。测得碳、氮、氧和氖的复合线丰度比它们相应的碰撞激发线丰度要系统地高出 5–7 倍。通过分析 NGC7009 的光学复合谱，还进一步检验了当前原子复合理论的可靠性。结合最新的原子参数，我们利用 N II 和 O II 光学复合线对一百多个行星状星云和电离氢区做离子体诊断。对每一个发射线天体，用同一种重元素离子的多条有着可靠观测流量的复合线同时限制得到其电子温度和密度（图 2），并将用复合线定出的温度与用其它方法定出的温度作了比较，所得结果与双丰度模型的预言一致。

工作结论如下：1）利用最新的原子参数并通过细致的定量分光分析，揭示了行星状星云 NGC 7009 中贫氢冷成分的存在；2）结合最新原子参数第一次利用重元素离子光学复合线对大样本行星状星云做等离子体诊断，所得结果与双丰度星云模型预言一致。基于该工作的三篇文章已经发表在了英国皇家天文学会月刊上“(Fang X. & Liu X.-W. 2011, MNRAS, 415, 181; McNabb I.A., Fang X., Liu X.-W., et al. 2013, MNRAS, 428, 3443; Fang X. & Liu X.-W. 2013, MNRAS, 429, 2791)”。工作结果于 2012 年 8 月在北京举行的第 28 次国际天文联合会大会上进行了口头报告。这项工作得到国家自然科学基金支持。

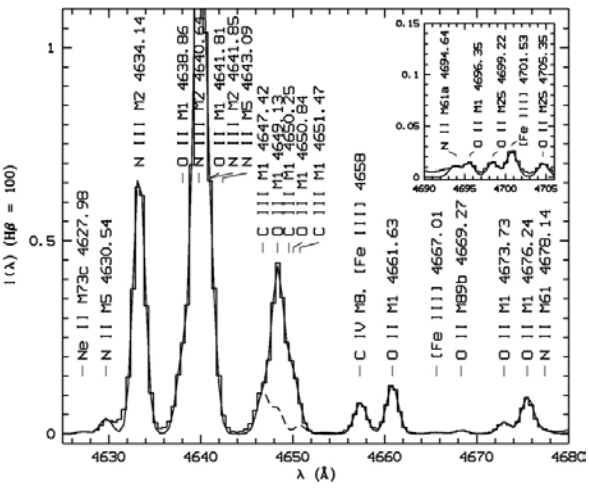


图 1：行星状星云 NGC 7009 从 4625Å 到 4680Å 的光谱图，显示了 O II 最强的多重线系 M1 (2p3p 4Do – 2p3s 4P) 中部分复合线与其它发射线混在一起。图中的连续光滑曲线为多高斯成分拟合结果；虚线则是与两条 O II M1 复合线（ 4649.13 和 4650.84）混在一起的三条 C III M1（2s3p 3Po – 2s3s 3S）复合线的高斯轮廓之和。右上角的小图

则显示了 O II M1 线系中最暗弱的 λ4696.35 线，其流量只有 Hβ 的万分之一。

Figure 1: Spectrum of planetary nebula NGC7009 from 4625 to 4680Å, showing the optical recombination lines of the O II M1 multiplet, which is the strongest transition of O II. The continuous curve is a sum of Gaussian profile fits. The dashed curve shows the two C III M1 lines which are blended with two O II M1 lines 4649.14 and 4650.84. The inset in the upper right corner shows the weakest fine-structure component λ4696.35 of O II M1, whose flux is 10^{-4} of Hβ.

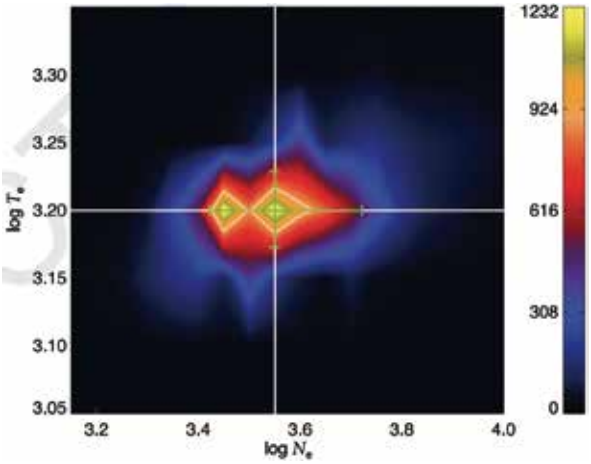


图 2：利用测量最准确的四条 O II 发射线 λ4649, λ4662, λ4089 和 λ4087 进行限制得到的行星状星云 NGC7009 的电子温度和密度：logTe [K] = 3.20，logNe [cm-3] = 3.55。所用的 O II 复合线有效复合系数来自 P. J. Storey 未发表的计算结果。四条 O II 复合线的观测流量来自已发表的工作（Fang & Liu 2012, MNRAS, 415, 181）。

Figure 2: Electron temperature [logTe (K) = 3.20] and density [logNe (cm-3) = 3.55] of planetary nebula NGC7009, which are optimized by using four O II optical recombination lines (λ λ4649, 4662, 4089 and 4087) with the most accurate fluxes. The effective recombination coefficients for O II lines are adopted from the unpublished calculation of P. J. Storey, and fluxes of the four O II lines are from a published paper (Fang X. & Liu X.-W. 2011, MNRAS, 415, 181).

III. Very deep spectroscopy of planetary nebula NGC7009 and plasma diagnostics for gaseous nebulae using the heavy-element optical recombination lines

In nebular astrophysics, there are two long-standing problems: a) The dichotomy of abundance determinations whereby heavy element abundances relative to hydrogen from collisionally excited lines (CELs) are systematically lower than those from optical recombination lines (ORLs); and b) The dichotomy of temperature determinations whereby Te derived from CELs is systematically higher than that derived from the hydrogen recombination continuum. A number of mechanisms have been proposed to explain those problems. The most successful one so far is the bi-abundance nebular model, which suggests that in planetary nebulae (PNe) there is a cold (~1000 K), H-deficient component where heavy element ORLs mainly arise, while CELs come from hot ambient gas with “normal” abundances. Observations have provide evidence for the existence of such cold component.

Using the new effective recombination coefficients of N II and O II, we carried out detailed analysis of the deep long-slit spectrum of bright Galactic PN NGC7009. Multi-Gaussian profile fits to the whole optical spectrum (3000–11000Å) yielded more than 1000 emission lines and reliable line fluxes were obtained (Figure 1). Electron temperatures yield by the N II and O II ORLs are both close to 1000 K, lower than the temperature derived from CELs by nearly an order of magnitude. That indicates heavy element ORLs originate from very cold regions. Elemental abundances of C, N, O and Ne derived from ORLs are systematically higher, by a factor of 5-7, than the corresponding values derived from CELs.

Recombination theories are also assessed by the ORL analysis. We have carried out plasma diagnostics for more than 100 PNe and H II regions using the N II and O II ORLs. For each object, a group of ORLs of the same ion with the most reliable measurements were used to determine Te and Ne simultaneously (Figure 2). The recombination-line temperatures were compared with the temperatures derived with other methods, and the results are consistent with predictions from the bi-abundance nebular model.

Conclusions are: 1) Detailed quantitative spectroscopy using new atomic data has proved the existence of a cold, H-deficient component in NGC7009; 2) For the first time, plasma diagnostics for a large PN sample using the heavy element ORLs were carried out, and the results are consistent with predictions from the bi-abundance nebular model. Three papers based on this work have been published in Monthly Notices of the Royal Astronomical Society（Fang X. & Liu X.-W. 2011, MNRAS, 415, 181; McNabb I.A., Fang X., Liu X.-W., et al. 2013, MNRAS, 428, 3443; Fang X. & Liu X.-W. 2013, MNRAS, 429, 2791）, and the results were also presented in the International Astronomical Union 28th General Assembly held in Beijing in August 2012. This work was supported by the National Science Foundation of China (NSFC).

IV. Magnetic turbulence: implication and new technique to study

1、Turbulence reconnection model for gamma ray bursts

Understanding of the nature of gamma-ray bursts (GRBs) is one of the challenging problems facing the astrophysics community.

The recent Fermi observation of GRB 080916C shows that the bright photosphere emission associated with a putative fireball is missing, which suggests that the central engine likely launches a Poynting-flux-dominated (PFD) outflow. In this case, magnetic energy may be sufficient to feed GRBs.

Magnetic reconnection was suggested as a component for GRBs. The problem lied, however, in the intrinsic difficulty of reconnection as it is a very slow process in ordered fields. As with the case for solar flares, both a slow phase of accumulation of the oppositely directed flux and a fast bursty phase are required for reconnection.

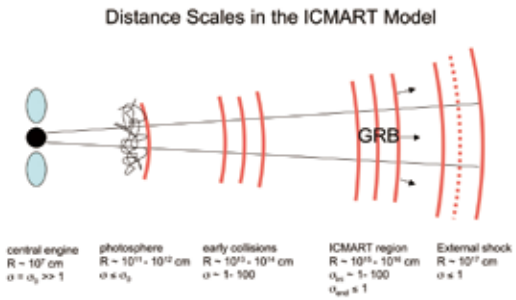


Figure 1: Schematic of the ICMART model. The typical distances and σ values f various events are marked (from Zhang & Yan 2011).

Huirong Yan from KIAA together with Bing Zhang from UNLV, proposed a model of gamma-ray burst (GRB) prompt emission in the PFD regime, namely, the Internal-Collision-induced MAgnetic Reconnection and Turbulence (ICMART) model based on the scenario proposed in Lazarian, Petrosian, Yan & Cho (2003). It is envisaged that the GRB central engine launches an intermittent, magnetically

dominated wind, and that in the GRB emission region, the ejecta is still moderately magnetized. Similar to the internal shock (IS) model, the mini-shells interact internally at the radius R IS ~ Γ 2 c Δ t. Most of these early collisions, however, have little energy dissipation, but serve to distort the ordered magnetic field lines entrained in the ejecta. At a certain point, the distortion of magnetic field configuration reaches the critical condition to allow fast reconnection seeds to occur, which induce relativistic MHD turbulence in the interaction regions. The turbulence further distorts field lines easing additional magnetic reconnections, resulting in a runway release of the stored magnetic field energy (an ICMART event). Particles are accelerated either directly in the reconnection zone, or stochastically in the turbulent regions, which radiate synchrotron photons that power the observed gamma rays. Each ICMART event corresponds to a broad pulse in the GRB light curve, and a GRB is composed of multiple ICMART events. This model retains the merits of IS and other models, but may overcome several difficulties/issues faced by the IS model (e.g., low efficiency, fast cooling, electron number excess, Amati/Yonetoku relation inconsistency, and missing bright photosphere). Within this model, the observed GRB variability timescales could have two components, one slow component associated with the central engine time history, and another fast component associated with relativistic magnetic turbulence in the emission region. The model predicts a decrease of gamma-ray polarization degree and Ep in each ICMART event (broad pulse) during the prompt GRB phase, as well as a moderately magnetized external reverse shock. The model may be applied to the GRBs that have time-resolved, featureless Band-function spectra, such as GRB 080916C and most GRBs detected by Fermi LAT.

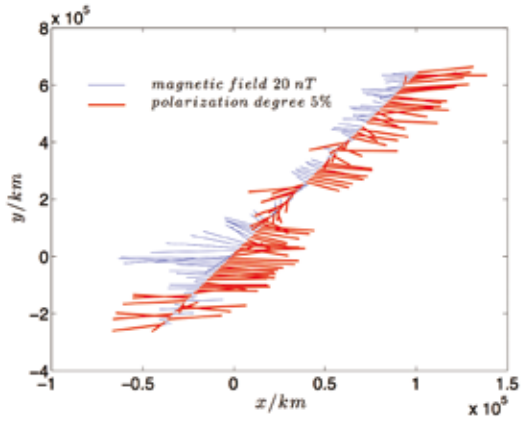
The paper has made high impact since publication, cited > 90 times in both GRB community and other related field in high energy astrophysics.

2、study of Interplanetary Magnetic Field with Ground State Alignment

Astrophysical magnetic fields are ubiquitous and extremely important, especially in diffuse media, where there energy is comparable or exceed the energy of thermal gas. In contrast, only a few techniques are available for the studies of magnetic field in diffuse medium and each of them has its own limitation. For instance, the Zeeman splitting can sample only relatively strong magnetic fields in dense and cold clouds.

Even for objects as close as interplanetary magnetic field, we still do not have a good understanding of its structure. With her student J. Shangguan, Huirong Yan from KIAA demonstrated a new way of studying interplanetary magnetic field—Ground State Alignment (GSA) based on their earlier studies in Yan & Lazarian (2006, 2007, 2008). Instead of sending thousands of space probes, GSA allows magnetic mapping with any ground telescope facilities equipped with spectropolarimeter. The polarization of spectral lines that are pumped by the anisotropic radiation from the Sun is influenced by the magnetic realignment, which happens for magnetic field (<1 G). As a result, the linear polarization becomes an excellent tracer of the embedded magnetic field. The method is illustrated by our synthetic observations of the Jupiter’s Io and comet Halley. Polarization at each point was constructed according to the local magnetic field detected by spacecrafts. Both spatial and temporal variations of turbulent magnetic field can be traced with this technique as well. The influence of magnetic field on the polarization of scattered light is discussed in detail. For remote regions like the IBEX ribbons discovered at the boundary of interstellar medium, GSA provides a unique diagnostics of magnetic field.

Figure 2: The Magnetic field and polarization along the trajectory of vega1 encountering the comet Halley.



The blue thin lines represent magnetic field and the red thick lines represent the polarization vectors. The x-y plane is the plane of celestial coordinates. The x-axis has the direction perpendicular to the ecliptic plane of the solar system (from Shangguan & Yan 2012).

The first author of the paper J. Shangguan was an undergraduate at the time and Huirong Yan at KIAA is the corresponding author. A proposal for observation of Jupiter’s Io based on the prediction of the paper has been accepted at CFHT and the actual observation is under way.

学生活动
Students

2012 年，物理学院共有毕业生 350 名，其中本科生 175 名，出国深造比例为 41%，国内深造比例为 44%，直接工作比例为 6.9%。硕士研究生 64 名，博士研究生 76 名，硕士研究生出国攻读博士的占 35%，博士研究生出国做博后的占 24%，直接就业行业主要分布在出科研单位、高等教育单位、国有企业等。

In 2012, 350 students graduated from the School of Physics, Peking University. Of the 175 Bachelor graduates, 41% applied for overseas studies, 44% applied for inland further studies and 6.9% was directly employed upon graduation. 35% of 64 Master graduates and 24% of 76 Doctoral graduates went abroad for further studies. Employment areas mainly include research institutes, universities and colleges, state-owned companies, etc.

2012 年物理学院迎新

Welcoming New students in 2012

2012 届物理学院北京市优秀毕业生合影

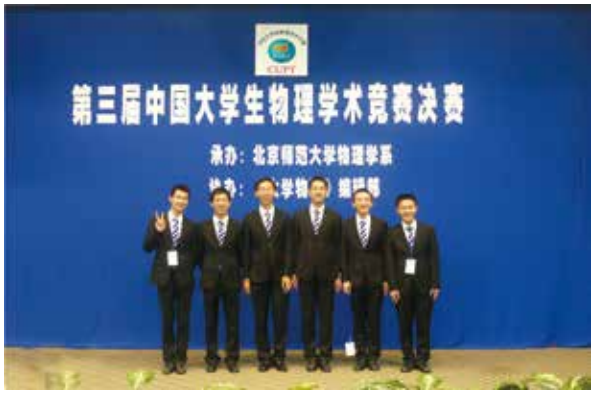
Beijing Excellent Graduates in 2012

2012 年度，学院在“爱乐传习”合唱比赛中获得近年来最好成绩，甲组第四名；辩论队一路闯关，获得新生杯辩论赛第三名，也是近年来最好成绩；举办学院首届大学生物理竞赛，并以获胜团队为班底，参加 8 月举行的全国大学生物理学术竞赛，获得唯一特等奖，为北大争取了至高荣誉；体育中心统筹协调，运动会取得全校第五的佳绩；挑战杯方面，本年度共上报 6 件作品，最终获特等奖 1 项，二等奖 3 项，三等奖 2 项，俞大鹏、赵清获优秀指导教师。

Students at the School of Physics earned many awards and honors in 2012. They ranked 3rd at the “Freshmen Cup” Debating Contest and 4th in team at the Chorus Competition, which were their best scores in recent years. They scored 5th in the university sports game. They held the 1st Physics Contest for College Students and won the top prize at the 2012 National Physics Contest. At the “Challenge Cup” Science Competition, they won one special prize, three 2nd prizes and two 3rd prizes.

2012 年度 12•9 合唱比赛

The 12•9 Chorus Contest 1in 2012



学院获中国大学生物理学术竞赛特等奖

Top Prize at 2012 National Physics Contest

社会实践方面，学院启动“青茁计划”，在校友和在校生之间形成帮扶小组，第一期共有 57 名大二本科生获益此项计划，29 名来自不同行业的物理校友积极参与，为学生提供多元化的实习实践平台。组建了赴江苏大丰市、浙江杭州市，怀柔大榛峪村和河北张家口市三支暑期实践团队，开展了富有成效、各具特色的实践活动。其中，“江浙团队”获先进团队称号，“大榛峪村团队”作为北大重点团队入选团市委优秀团队评比；“张家口团队”与当地中学建立起长期共建合作关系。

The school launched the “Qingzhuo” Project to set up small groups with alumni and students, providing the latter with knowledge outside school and opportunities in social areas. 57 sophomore students and 29 physics alumni participated in the 1st session of the project. The school also established three teams to engage in summer social practices in urban and rural areas. The “Jiangsu-Zhejiang” team won the “Advanced Team” title; the “Large Hazel Valley” team was chosen to compete in the municipal excellent team evaluation; the “Zhangjiakou” team started a cooperative relationship with local schools.

“青茁计划”启动仪式

The Launching Ceremony of the “Qingzhuo” Project

大榛峪暑期实践

Summer Social Practice in the Large Hazel Valley

第十届北大物理“钟盛标”研究生学术论坛

The 10th “Shengbiao Zhong” Academic Forum for Graduate Students

北大物理百年学生志愿者团队成立仪式

The Launching Ceremony of the Student Volunteer Group for Centennial Celebration of Physics at PKU

为使来自边贫地区的经济困难生更好适应大学生活，学院经过研究决定为他们单独举行入学前新生培训。学院于今年 8 月举办了首届本科新生训练营，共有 34 名 12 级新生同学参加培训。培训历时五天半，内容涵盖数学、物理专业课程、上级实操练习、团队素质拓展、专题报告与学习方法指导等。学生通过培训，不仅接受了北大核心价值教育，感受到校园生活的丰富多彩，同时对大学物理、高等数学等课程的提前学习也助于他们尽早适应紧张忙碌的物院生活。

To help students from undeveloped areas to better adapt to college life, the school decided to offer them special assistance through customized training. 34 freshmen students attended the 1st session of undergraduate freshmen training camp in Aug. 2012. The students attended courses in mathematics, physics, communication skills, study and research methods, etc. which not only familiarized them with university values and campus life, but also prepared them for the busy and uptight academic schedule in advance.

2012 年物院奖学金颁奖会

2012 Scholarship Awarding Ceremony at the School of Physics

2012 年本科生年终交流会

Undergraduate Students' Exchange Meeting in 2012

物理学院首届本科新生暑期训练营

The 1st Summer Training Camp for Freshmen

物理学院首届心理健康文化月

The 1st Season of Mental Health Development

校运会 1

Students at the Sports Games

校运会 2

Students at the Sports Games

校运会 3

Students at the Sports Games

军训剪影

Students in Military Training

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“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 Hundred Researchers Project,” etc.; new ways such as “The Weiming Lake Physics Students’ Class” were created to prepare students with all-round development; a free and active research atmosphere was maintained by introducing the “Centennial Physics Lecture Series,” “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 in order to exert a greater impact upon the world.

校友与基金
Alumni and Funds

2011 年，举办沈克琦先生九十寿辰庆祝会暨“沈克琦物理教育基金”成立仪式。举办王竹溪先生诞辰一百周年纪念会。

In 2011, the School of Physics celebrated Prof. Keqi Shen’s 90th Birthday and held the 100th Anniversary Commemoration for Prof. Zhuxi Wang.

沈克琦先生九十寿辰庆祝会

Prof. Keqi Shen at his 90th Birthday Celebration Party

王竹溪先生诞辰一百周年纪念会

Dean Xincheng Xie at the 100th Anniversary Commemoration for Prof. Zhuxi Wang

2012 年，召开北京大学物理学院校友会第三次理事会，会议通过北京大学物理学院校友会会长更换，讨论了《北京大学物理学院校友会章程（建议稿）》，商议了《北大物理百年庆典策划草案》。

In 2012, the 3rd Board Meeting of Peking University Physics School Alumni Association was held. The meeting acknowledged Dean Xincheng Xie as the new President of Physics Alumni Association. The meeting also discussed the tentative draft of association regulations and the celebration proposal of Centennial Physics at PKU.

物理学院校友会第三次理事会合影

The 3rd Board Meeting of Physics Alumni Association

会场

The meeting room

举办 2012 年物理学院企业界校友报告会，搭建校友事业发展支撑体系。先后举办 01 级、02 级校友入学十周年返校活动暨“十年”系列迎新座谈会。

Seminar for PKU Physics Alumni in the Industrial Field was held in 2012 to provide support and platform for alumni career development. Meantime, alumni were invited back to school for talks and experience sharing with students.

80 级胡晖、85 级胡才勇、98 级邓志峰作为企业界校友代表上台交流

Industrial Alumni Representatives Hui Hu, Caiyong Hu and Zhifeng Deng

80 级校友胡晖做“事业之路”报告

`80 Alumnus Hui Hu Reports his Career Path and Experience

01 级本科生校友入学十周年交流会

`01 Physics Class Meet with `11 Physics Class

01 级研究生校友入学十周年交流会

`01 Physics Graduate Class Meet with `11 Physics Graduate Class

02 级本科生校友入学十周年交流会

`02 Physics Class Meet with `12 Physics Class

02 级研究生校友入学十周年交流会

`02 Physics Graduate Class Meet with `12 Physics Graduate Class

同时，学院协办多场校友年级聚会，为校友的返校活动和基金设立提供必要支持。

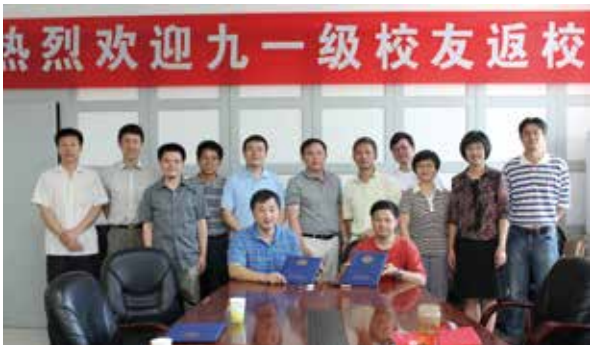
Moreover, the school co-organized many alumni class reunions.

61 级技物系校友入学五十周年返校活动

`61 Technical Physics Class Gather after 50 Years

87 级物理系校友毕业二十周年聚会

`87 Physics Class Gather after 20 Years



91 级物理系校友入学二十周年返校活动暨物理 91 基金成立仪式举行

`91 Physics Class Gather after 10 Years and Launch the `91 Class

52 级物理系校友入学六十周年聚会

`52 Physics Class Gather after 60 Years

62 级物理系校友入学五十周年聚会

`62 Physics Class Gather after 50 Years

62 级地球物理系校友入学五十周年聚会

`62 Geophysics Class Gather after 50 Years

56 级校友毕业五十周年聚会

`56 Class Gather after 50 Years

77 级物理系校友毕业三十周年聚会

`77 Physics Class Gather after 30 Years

“周末职业发展”校友座谈会举办六期活动，先后邀请到 98 级校友邓志峰、80 级校友何端峰、01 级校友陶鸥、王硕　、02 级校友谢辉、94 级校友张林、李果锋、90 级程磊和 86 级校友汪浩与学生座谈交流。

The school launched the “Weekend Career Talk” program to promote exchange and interaction between alumni and students. Many excellent alumni were invited to meet with students, alumni including Zhifeng Deng, Duanfeng He, Ou Tao, Shuojun Wang, Hui Xie, Lin Zhang, Guofeng Li, Lei Cheng and Hao Wang, etc.

98 级校友邓志峰与同学交流

Zhifeng Deng Meets with Students

80 级校友何端峰与学生座谈

Duanfeng He Talks with Students

01 级陶鸥、王硕　、02 级谢辉与学生座谈

Ou Tao, Shuojun Wang and Hui Xie

王硕

Shuojun Wang

94 级校友张林、李果锋、90 级程磊与学生座谈

Lin Zhang, Guofeng Li and Lei Cheng

86 级校友汪浩分享会

`86 Alumnus Hao Wang's Exchange Meeting

2011 年度，学院校友基金收到捐赠￥2,259,193.90，发放奖教金、奖助学金及其他支出总计￥334,894.80，申请配比基金￥593,919.00。2012 年度收到捐赠￥2,294,336.25，发放奖教金、奖助学金及其他支出总计￥373,000.00，申请配比基金￥624,922.16。截止 2012 年底，学院校友基金项目余额总计￥8,968,618.39。

In 2011, the Physics School alumni funds received ￥2,259,193.90 in donation, spent ￥334,894.80 in awarding scholarship, aid and supporting student activities, applied for and were granted ￥593,919.00 in matching fund. In 2012, we received ￥2,294,336.25, spent a total of ￥373,000.00, and were granted ￥624,922.16 in matching. Until the end of 2012, the school had accumulated about ￥8,968,618.39 in alumni funds.

校友基金项目：
Alumni Funds:

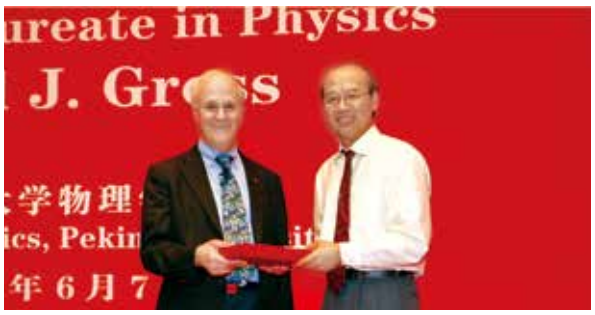
校友捐赠基金 Alumni Funds	创立时间 Time of Establishment
叶企孙实验物理基金 Qisun Ye Experimental Physics Fund	1987
冯溪乔奖学金 Shechao Charles Feng Scholarship	1996
谢义炳基金 Yibing Xie Fund	1996
77 物理班级基金 `77 Physics Class Fund	2002
钟盛标物理教育基金 Paul Shin-Piaw Choong Educational Fund for Physics	2002
80 物理兰怡女子助学金 `80 Ellen Yi Lan 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
北大物理 91 基金（助） `91 Physics Class Fund	2011
物理学院学生发展基金 Students' Development Fund	2011
沈克琦物理教育基金 Keqi Shen Educational Fund for Physics	2012
北大物理百年专项基金 Special Fund for Centennial Physics PKU	2012
近代物理研究所奖学金 Institute of Modern Physics Scholarship	2012
北大物理念恩奖学金 Nian En Scholarship	2012

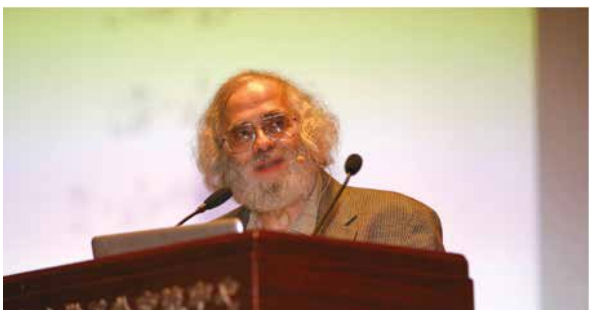
合作与交流
Cooperation

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

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）、Qi Cui（美国普林斯顿大学）、Johannes. Georg. Bednorz（瑞士 IBM）、David J. Gross（美国加州大学）、Isaac M. Held（美国大气海洋管理局）、Paras N. Prasad（美国纽约州立大学）、Yuri Oganessian（俄罗斯科学院院士）等九位诺贝尔物理学奖得主和国际顶尖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。

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 recent years, we invited nine Nobel laureates and worldly-renowned physical scientists to give lectures and exchange ideas at the school, including Anthony. J. Leggett, Robert. W. Wilson, James. W. Cronin, Qi Cui, Johannes. Georg. Bednorz, David J. Gross, etc. This series of academic exchanges serves as a prelude for the celebration of centennial physics at Peking University in 2013.





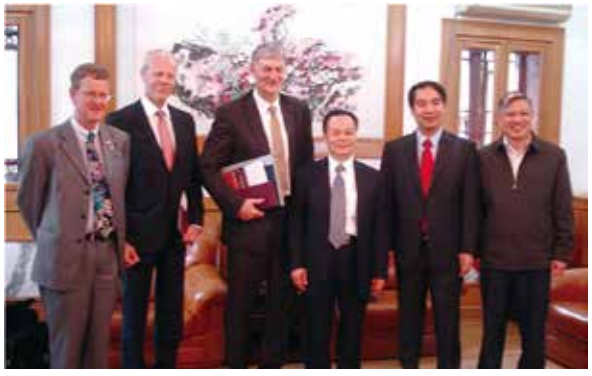
二、 邀请报告与合作交流 Invited Talks and Exchange Conferences

2011-2012 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 2011 and 2012, the school held many international talks and meetings to activate academic exchange and international cooperation.

2011 年 4 月，承办中国科学院“爱因斯坦讲席教授”讲座，邀请物理学诺贝尔奖获得者 Dr. Klaus v. Klitzing 做学术报告并参观交流。

In April 2011, the School of Physics co-organized the Chinese Academy of Sciences (CAS) “Einstein Professorship Lecture” and invited Nobel Laureate in Physics Dr. Klaus v. Klitzing to give lectures and exchange with professors and students.

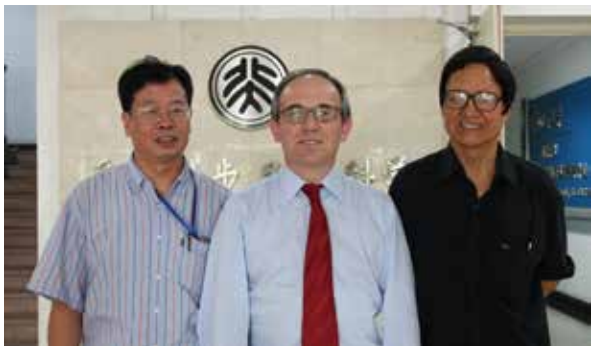


德国亚琛工业大学校长 Dr. Ernst Schmachtenberg 一行访问我校，北京大学校长周其凤院士在临湖轩会见了来宾，陪同会见的有物理学院副院长龚旗煌教授、介观物理国家重点实验室常务副主任李焱教授。会谈后，Schmachtenberg 校长一行参观访问了北京大学物理学院人工微结构和介观物理国家重点实验室，并与学院探讨进一步合作可能。

Dr. Ernst Schmachtenberg, President of Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH Aachen) in Germany visited Peking University. After meeting with Prof. Qifeng Zhou, President of Peking University, at Linhuxuan, Dr. Schmachtenberg visited the State Key Laboratory for Artificial Microstructure and Mesoscopic Physics. The Vice Dean of Physics School Prof. Qihuang Gong and the Executive Deputy Director of State Key Laboratory Prof. Yan Li accompanied Dr. Schmachtenberg through his visit.

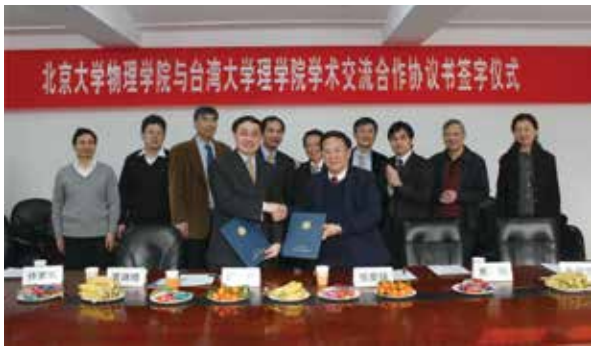
伦敦大学学院校长兼教务长 Prof. Malcolm Grant 一行访问我院。北京大学物理学院副院长王宇钢教授代表学院接待了来宾，俞大鹏教授和陈志坚教授等参与了会面。

Prof. Malcolm Grant, President and Head of Educational Administration of University College London, visited our school. Prof. Yugang Wang, Vice Dean of School of Physics, Peking University, met with Prof. Malcolm Grant and exchanged with the delegation. Prof. Dapeng Yu and Prof. Zhijian Chen also attended this meeting.



意大利米兰 • 比可卡大学 Prof. Giuseppe Gorini 访问学院并探讨建立正式合作关系。刘玉鑫副院长参加了会见。双方一致认为两校有很大合作空间，对今后深入交流与合作充满期待。双方初步达成以研究生互换为主要方式开展合作交流。

Prof. Giuseppe Gorini with University of Milano – Bicocca in Italy visited our school to discuss the possibility of establishing official bilateral relations. Vice Dean of Physics School Prof. Yuxin Liu met with Prof. Giuseppe Gorini. Both sides held high expectations for future collaborations. They agreed to launch graduate student exchange programs.



2012 年 2 月，台湾大学理学院院长张庆瑞教授率团访问我院，签署《北京大学物理学院与台湾大学理学院学术交流合作协议书》，双方就 2013 年科研教学合作研讨会、联合暑期学校和学生交换等项目达成具体共识。作为北京大学物理学院与台湾大学理学院签署的《协议书》的一项重要决定，北京大学物理学院代表团于 2013 年 1 月 27-30 日访问台湾大学理学院，并举行“台湾大学理学院与北京大学物理学院科研教学合作研讨会”。

In February 2012, Dean Qingrui Zhang of the College of Sciences of Taiwan University led a delegation to the School of Physics Peking University in order to sign the “Bilateral Agreement of Academic Exchange and Cooperation.” The two sides also agreed upon issues such as seminars, joint summer schools and student exchange programs. As a result, a delegation of the Physics School of Peking University led by Dean Xincheng Xie arrived at the College of Sciences of Taiwan University on Jan. 27, 2013 to co-organize the “Seminar on Bilateral Cooperation in Research and Education.”

以色列特拉维夫大学校长 Joseph Klafter 教授一行访问我院。北京大学物理学院蒋红兵教授接待了来访外宾，并带领参观了超快光谱和有机光子学实验室。Klafter 教授希望与北京大学物理学院开展多项学生互换和联合培养合作，加强两校之间的学术交流。

Prof. Joseph Klafter, President of Tel Aviv University in Israel, visited our school. Prof. Hongbing Jiang from the Physics School Peking University met with our guests and guided them to the ultrafast spectroscopy and Organic Photonics laboratories. Prof. Klafter expressed his hope to develop student exchange and joint cultivation programs between two universities.

荷兰格罗宁根大学数学与自然科学学院院长、物理学教授 Jasper Knoester 访问我院。北京大学物理学院副院长、人工微结构和介观物理国家重点实验室主任龚旗煌教授代表学院接待了来宾，王新强教授、廖志敏副教授和王树峰副教授分别陪同 Knoester 教授参观了光学实验室、宽禁带实验室和电镜实验室等。

Jasper Knoester, Physics Professor and Dean of College of Mathematics and Natural Sciences at University of Groningen, visited our school. Prof. Qihuang Gong, Vice Dean of the Physics School Peking University and Director of the State Key Laboratory of Artificial Microstructure and Mesoscopic Physics, met with our guest. Prof. Xinqiang Wang, Zhimin Liao and Shufeng Wang guided Prof. Knoester respectively on his visit to the Optics Lab, the Wide Bandgap Lab and the Electron Microscope Lab.

2011-2012 年度举办国际 / 港澳台会议
International/Hong Kong/Macao/Taiwan Conferences in 2011-2012

会议名称 /Title of Meeting	日期 /Time	地点 /Venue
北京大学 - 宾州州立大学物理学联合会议 Joint Workshop of Penn State University and Peking University on Frontiers of Condensed Matter and Atomic Physics	2011 年 5 月 18 日至 19 日 May 18-19, 2011	北京大学 PKU
“霍尔物理的世界”国际研讨会 1st ICQM-ICQD-ICQS Joint Annual Workshop: World of Hall Physics	2011 年 6 月 21 日至 22 日 Jun 21-22, 2011	北京大学 PKU

会议名称 /Title of Meeting	日期 /Time	地点 /Venue
“量子霍尔系统中的演生现象”国际研讨会 4th Internation Workshop on Emergent Phenomena in Quantum Hall Systems	2011 年 6 月 23 日至 26 日 Jun 23-26, 2011	北京大学 PKU
第十六届绝缘体辐照效应国际会议 16th International Conference on Radiation Effects in Insulators	2011 年 8 月 14 日至 19 日 Aug 14-19, 2011	北京大学 PKU
第一届北京大学 - 韩国高丽大学纳米科技研讨会 1st Joint Workshop on Nanoscience and Nanotechnology between Korea University and Peking University	2011 年 12 月 16 日至 17 日 Dec 16-17, 2011	北京大学 PKU
第六届国际纳米光子学会 6th International Conference on Nanophotonics Peking University	2012 年 5 月 27 至 30 日 May 27-30, 2012	北京大学 PKU
“超对称 2012”国际学术大会 20th International Conference on Supersymmetry and the Unification of Fundamental Interactions	2012 年 8 月 13 至 17 日 Aug 13-17, 2012	北京大学 PKU
第二届海峡两岸纳米光子学研讨会 2nd Joint Workshop on Nanophotonics between Both Sides of the Taiwan Straits	2012 年 9 月 22 日至 27 日 Sep 22-27, 2012	北京大学 PKU
中英纳米光子学与特异介质物理研讨会 Sino-UK Workshop on Nanophotonics and Metamaterials	2012 年 12 月 6 日至 9 日 Dec 6-9, 2012	北京大学 PKU

三、外籍专家 Foreign Experts

两年来，学院大力推进外籍专家引进计划，聘请外籍专家 160 余人，外专经费逐年上升。同时，协助办理签证及延期、劳务领取和报账、餐宿预订、博士后进出站等事宜，为外籍优秀人才创造了良好的工作和生活环境。

In the recent two years, the School of Physics vigorously promoted foreign experts introducing projects with over 160 foreign experts invited for talks and meetings. School funds in support of introducing foreign experts were also on the rise. Besides, every effort was made in arrangement work such as visa application and extension, recompense management, dining and accommodation appointment and etc. to create a good working and living environment for foreign experts.

四、学生的国际化培养 Student Internationalization Cultivation

两年来，学院按照国务院、教育部的统一部署，积极配合国际合作部等有关部门，做好学生联合培养计划的宣传和北京大学留学生教育管理工作。学院参与的国际交流项目包括美国 UCLA 本科生暑期科研项目、耶鲁大学 2012 暑期实习项目、斯坦福 UGVR 暑期项目、戴维斯加州大学暑期研究项目、韩国庆熙大学 2012 暑期项目、加拿大 MITACS 暑期实习项目、日本工业大学暑期项目以及北京大学学生海外学习项目等。此外，组织学生参与北京大学第九届国际文化节等。

The school worked cooperatively with the Office of Foreign Affairs to promote students' joint cultivation programs, including 2012 UCLA Undergraduate Summer Project, 2012 Yale University Summer Internship, Stanford University UGVR Summer Project, California University (Davis) Summer Research Program, 2012 Kyung Hee University Summer Program, Canada MITACS Summer

Internship, Nippon Institute of Technology and so on. Besides, our students took active parts in the 9th Peking University International Cultural Festival.

五、对外宣传

2011 年度，学院设计完成《物理学院 2009-2010 年度报告》（中英双语版），涵盖学院人事概况、下属机构、系所中心研究亮点、校友与基金、合作与交流等内容，有力推动学院对外交流工作的开展，为促进科研成果的输出和提升学院的国际地位作出积极努力。

In 2011, the school published "The Bi-annual Report 2009-2010" in the bilingual edition. The report covered the school's Personnel, Divisions, Highlights, Students, Alumni and Funds, Cooperation, Awards and Honors. The purpose of the report was to promote international exchange and cooperation of the school and elevate its international status in the academic field.

奖励与荣誉
Awards & Honors

2011 年度：
In 2011,

- 物理学院被教育部批准为北京大学唯一的高校体制改革试点学院
  The School was approved by the Ministry of Education as the pilot school of Peking University for Structural Reform in Higher Schools
- 龚旗煌等"电荷转移分子体系光学非线性及超快全光开关实现"获国家自然科学二等奖
  Qihuang Gong's Group won the Second-class State Natural Science Award, P.R.China
- 王恩哥等"轻元素新纳米结构的构筑、调控及其物理特性研究"获国家自然科学二等奖
  Enge Wang's Group won the Second-class State Natural Science Award, P.R.China
- 吴月芳"恒星形成活动和恒星形成区的观测研究"获"高等学校科学技术奖"自然科学二等奖
  Yuefang Wu won the Second-class Natural Science Award of "Science and Technology Awards in Higher Schools"

- 谢心澄所在研究团队获科技部授予的 2010 中国科学十大进展（2011 年评出）
  Xincheng Xie’s Group won the Ten Major Scientific Progresses in China in 2010 by the Ministry of Science and Technology (awarded in 2011)

- 吴学兵等利用 LAMOST 发现新类星体的成果入选我国十大天文科技进展
  Xuebing Wu’s Group won the Ten Major Scientific and Technological Progresses in Astronomy in China

- 甘子钊获国华杰出学者奖
  Zizhao Gan won the Guohua Distinguished Scholar Award

- 王恩哥荣获亚洲计算材料科学奖
  Enge Wang won the Asian Computational Materials Science Award （ACCMS）

- 付遵涛获“赵九章优秀中青年科学奖”
  Zuntao Fu won the “Zhao Jiuzhang Outstanding Youth Science Award”

- 戴伦、刘运全获国家杰出青年科学基金
  Lun Dai and Yunquan Liu were awarded the National Funds for Distinguished Young Scientists

- 吴成印入选教育部新世纪人才
  Chengyin Wu was included into the New Centennial Talents Project by the Ministry of Education

- 凝聚态物理马仁敏（导师 戴伦）获全国优秀博士论文
  Renmin Ma (Lun Dai as mentor) in condensed matter physics won the National Excellent Doctoral Dissertation

- 王恩哥当选为中国物理学会第十届理事会副理事长
  Enge Wang was appointed as Vice Chairman of the Tenth Board of the Chinese Physical Society

- 朱星当选为物理名词委员会主任
  Xing Zhu was appointed as Director of Commission on Physical Terminology

- 龚旗煌当选为中国物理学会国际交流工作委员会主任
  Qihuang Gong was appointed as Director of Commission on International Exchange of the Chinese Physical Society

- 叶沿林当选为物理教学委员会主任
  Yanlin Ye was appointed as Director of Commission on Physical Education

- 刘征宇当选为“美国地球物理学会会士”
  Zhengyu Liu was elected as Fellow of the American Geophysical Union

- 王晓钢当选为“美国物理学会会士”
  Xiaogang Wang was elected as Fellow of the American Physical Society

- 叶沿林当选亚洲核物理联合会主席
  Yanlin Ye was appointed as Chairman of the Asian Federation of Nuclear Physics

- 龚旗煌入选 IUPAP 专业委员会委员
  Qihuang Gong was appointed as Member of the IUPAP Committee

2012 年度：
In 2012,

- 刘式适课题组发表的论文获中国物理学会“最有影响论文奖”一等奖
  Shigua Liu’s Group won the First-class Award of “Dissertation of Most Impact” by the Chinese Physical Society

- 龚旗煌课题组“飞秒光物理和介观光学”研究群体发表的论文获中国物理学会“最有影响论文奖”一等奖
  Qihuang Gong’s Group won the First-class Award of “Dissertation of Most Impact” by the Chinese Physical Society

- 龚旗煌领导“飞秒光物理和介观光学”研究团队获得“中国侨界贡献奖”
  Qihuang Gong’s Group won the “China’s Overseas Chinese Contribution Award”

- 刘晓为当选为国际天文学联合会副主席
  Xiaowei Liu was appointed as Vice Chairman of the International Astronomical Union

- 龚旗煌担任美国光学学会 Fellow 遴选委员会委员
  Qihuang Gong was appointed as Member of Fellow Committee of the Optical Society of America

- 孟杰当选为“美国物理学会会士”
  Jie Meng was elected as Fellow of the American Physical Society

- 龚旗煌课题组研究成果入选“2012 年度中国高等学校十大科技进展”
  Qihuang Gong’s Group won the Ten Major Scientific and Technological Progresses in Higher Schools of China 2012

- 基础物理实验教学中心的“非线性热对流斑图实验仪”获全国高校物理实验仪器评比一等奖
  The School’ Teaching Center for Experimental Physics won the First-class Award in Physical Experimental Instrument Rating in Higher Schools of China

- 刘富坤等关于“超大质量双黑洞与吸积盘相互作用的理论预言得到射电观测证实”被评选为我国 2011 年度十大天文科技进展（2012 年评出）
  Fukun Liu’s Group won the Ten Major Scientific and Technological Progresses in Astronomy in China 2011 (awarded in 2012)

- 徐仁新、胡小永和王新强获国家杰出青年科学基金
  Renxin Xu, Xiaoyong Hu and Xinqiang Wang were awarded the National Funds for Distinguished Young Scientists

- 肖云峰、吴孝松、王健、傅宗玫获国家优秀青年科学基金
  Yunfeng Xiao, Xiaosong Wu, Jian Wang and Zongmei Fu were awarded the National Funds for Excellent Young Scientists

- 彭良友、廖志敏入选教育部新世纪人才
  Liangyou Peng and Zhimin Liao were included into the New Centennial Talents Project by the Ministry of Education

- 谢心澄应邀将于 2013 年至 2015 年出任物理评论快报编委
  Xincheng Xie was invited to be Member of Editorial Board of the Physical Review Letters from 2013 to 2015

- 龚旗煌当选中国光学学会副理事长兼秘书长；李焱和杨宏当选中国光学学会副秘书长
  Qihuang Gong was appointed as Vice Chairman and Secretary General of the Chinese Optical Society; Yan Li and Hong Yang were appointed as Deputy Secretary General of the Chinese Optical Society

- 何锐思当选为国际天文学联合会东亚地区天文促发展办公室首任主任
  Richard de Grijs was formally appointed as the Founding Director of the IAU's East Asian regional Office of Astronomy for Development

- 何锐思获澳大利亚科学院塞尔比科学卓越奖
  Richard de Grijs was awarded the 2012 Selby Award for excellence in science by the Australian Academy of Science

- 郭之虞再次当选中国粒子加速器学会副理事长
  Zhiyu Guo was appointed once again as Vice Chairman of the Chinese Particle Accelerator Society

- 龚旗煌再次当选北京光学学会副理事长
  Qihuang Gong was appointed once again as Vice Chairman of the Beijing Optical Society

- 陈晓林获“北京市师德先进个人”荣誉称号
  Xiaolin Chen won the honor of “Advanced Individual in Teachers’ Code of Morality in Beijing”

- 方哲宇（导师 朱星）获北京市优博论文
  Zheyu Fang (Xing Zhu as mentor) won the Excellent Doctoral Dissertation in the City of Beijing

- 荀坤、胡晓东获北京大学教学优秀奖
  Kun Xun and Xiaodong Hu won the Excellent Teaching Awards in Peking University