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本期推荐报道 2022 年 9 月 Nature、Science 期刊上材料科学领域的部分最新论文。

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物理学 9 月 Science 论文

[1]**On the origins of fatigue strength in crystalline metallic materials**
晶体金属材料疲劳强度的来源

出版信息：Science, 2 Sep 2022,VOLUME 377 ISSUE 6610

作者：J. C. STINVILLE, M. A. CHARPAGNE, A. CERVELLON, S. HEMERY, F. WANG, P. G. CALLAHAN, V. VALLE, T. M. POLLOCK

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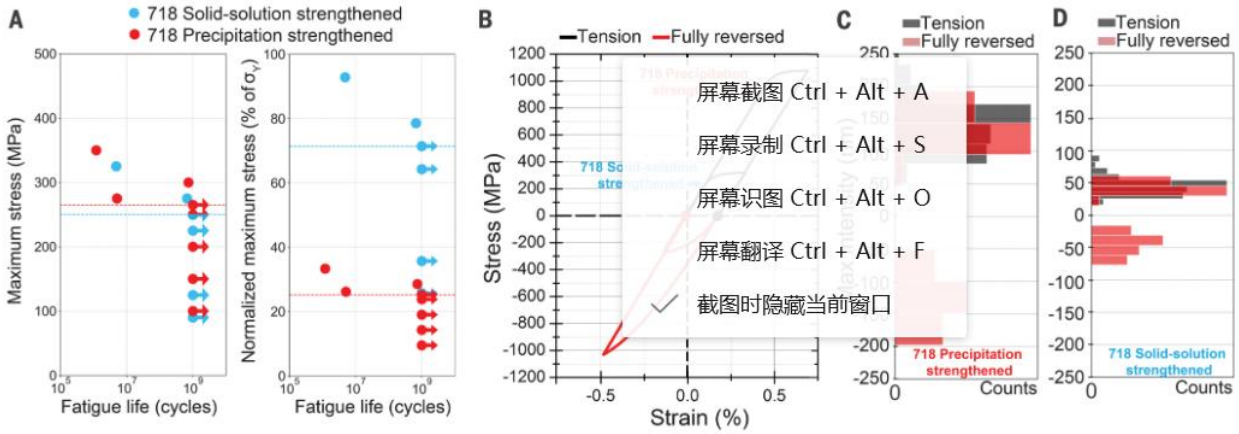
University of California, Santa Barbara, CA, USA.

全文链接：https://www.science.org/doi/10.1126/science.abn0392

Abstract： Materials that are cyclically deformed become easier to break due to fatigue. However, tying fatigue strength to microstructure has been challenging. Stinville et al. used nanometer-resolution digital image correlation to observe the slip localization on the surface of a wide range of alloys. They found that after one deformation cycle, the amplitude of the early slip localization events determines fatigue strength. This observation helps to provide a physical basis for well-known fatigue laws and paves the way to easily predicting fatigue strength.

摘要翻译：循环变形的材料更容易因疲劳而断裂。然而，将疲劳强度与微观结构联系起来一直是一个挑战。作者利用纳米分辨率的数字图像相关技术观察了各种合金表面的滑移定位。他们发现，在一个变形周期后，早期滑移局部化事件的振幅决定了疲劳强度。这一发现有助于为众所周知的疲劳规律提供物理基础，并为容易预测疲劳强度铺平了道路。

文中插图：



[2]

Magnetoelectric transfer of a domain pattern

磁畴模式的磁电转移

出版信息：Science, 2 Sep 2022,VOLUME 377 ISSUE 6610

作者：EHSAN HASSANPOUR, YANNIK ZEMP, YUSUKE TOKUNAGAYASUJIRO TAGUCHI, YOSHINORI TOKURA, THOMAS LOTTERMOSER , MANFRED FIEBIG, AND MADS C. WEBER

第一作者单位：Department of Materials, ETH Zurich, 8093 Zürich, Switzerland.

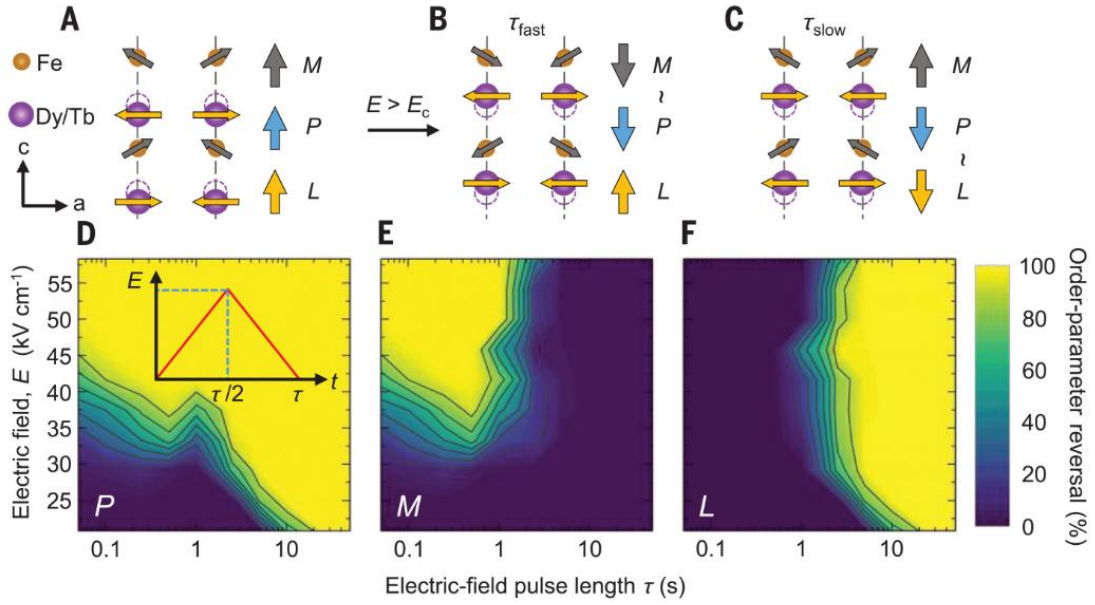
Department of Physics, ETH Zurich, 8093 Zürich, Switzerland.

全文链接：https://www.science.org/doi/10.1126/science.abm3058

Abstract：Multiferroic materials are often characterized by two coupled order parameters, magnetization and electrical polarization, which can be controlled by external fields. Hassanpour et al. studied the multiferroic Dy0.7Tb0.3FeO3, which has an additional order parameter stemming from in-plane antiferromagnetic ordering. The researchers created a ferromagnetic multidomain pattern and applied an external magnetic field, which erased the existing pattern but created one of the same shape in the system’s polarization, minimizing the free energy. The process could be reversed by applying an electric field.

摘要翻译：多铁性材料通常具有磁化和电极化两个耦合序参量，这两个参量可以由外部场控制。作者研究了多铁性 Dy0.7Tb0.3FeO3，它有一个额外的序参量，源于面内反铁磁序。研究人员创造了一个铁磁多畴模式，并施加了一个外部磁场，消除了现有的模式，但在系统的极化中创造了一个相同的形状，最大限度地减少了自由能。这个过程可以通过施加电场来逆转。

文中插图：



[3]

Chiral emission from resonant metasurfaces

共振超表面手性发射

出版信息：Science, 9 Sep 2022, VOLUME 377 ISSUE 6611

作者：XUDONG ZHANG, YILIN LIU et al.

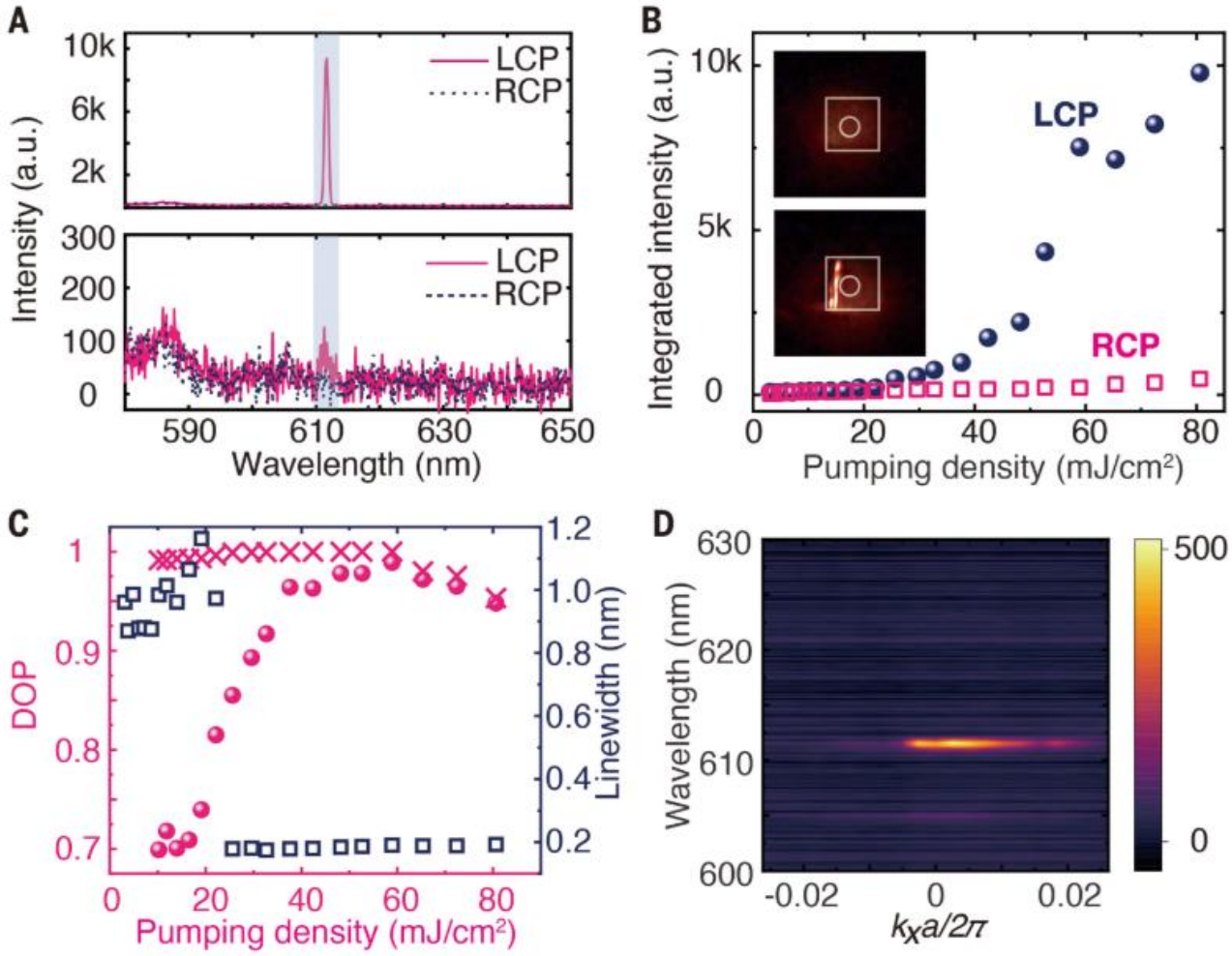
第一作者单位：Department of Chemistry - Ångström Laboratory, Uppsala University, SE 75120 Uppsala, Sweden.

全文链接：https://www.science.org/doi/10.1126/science.abq7870

Abstract：Ultracompact sources of circularly polarized light are important for classical and quantum optical information processing. Conventional approaches for generating chiral emission are restricted to excitation power ranges and fail to provide high-quality radiation with perfect polarization conversion. We used the physics of chiral quasi-bound states in the continuum to demonstrate the efficient and controllable emission of circularly polarized light from resonant metasurfaces. Exploiting intrinsic chirality and giant field enhancement, we revealed how to simultaneously modify and control spectra, radiation patterns, and spin angular momentum of photoluminescence and lasing without any spin injection. The superior characteristics of chiral emission and lasing promise multiple applications in nanophotonics and quantum optics.

摘要翻译：超紧凑型圆偏振光在经典和量子光学信息处理中具有重要意义。传统的手性发射产生方法受到激发功率范围的限制，不能提供具有完美极化转换的高质量辐射。我们利用手性准束缚态在连续介质中的物理特性，证明了共振超表面圆偏振光的有效和可控发射。利用本征手性和巨场增强，我们揭示了如何在没有自旋注入的情况下同时修改和控制光致发光和激光的光谱、辐射模式和自旋角动量。手性发射和激光的优越特性为纳米光子学和量子光学提供了多种应用前景。

文中插图：



[4]

Systematic electronic structure in the cuprate parent state from quantum many-body simulations

量子多体模拟中铜母态的系统电子结构

出版信息：Science, 9 Sep 2022, VOLUME 377 ISSUE 6611

作者：ZHI-HAO CUI, HUANCHEN ZHAI et al.

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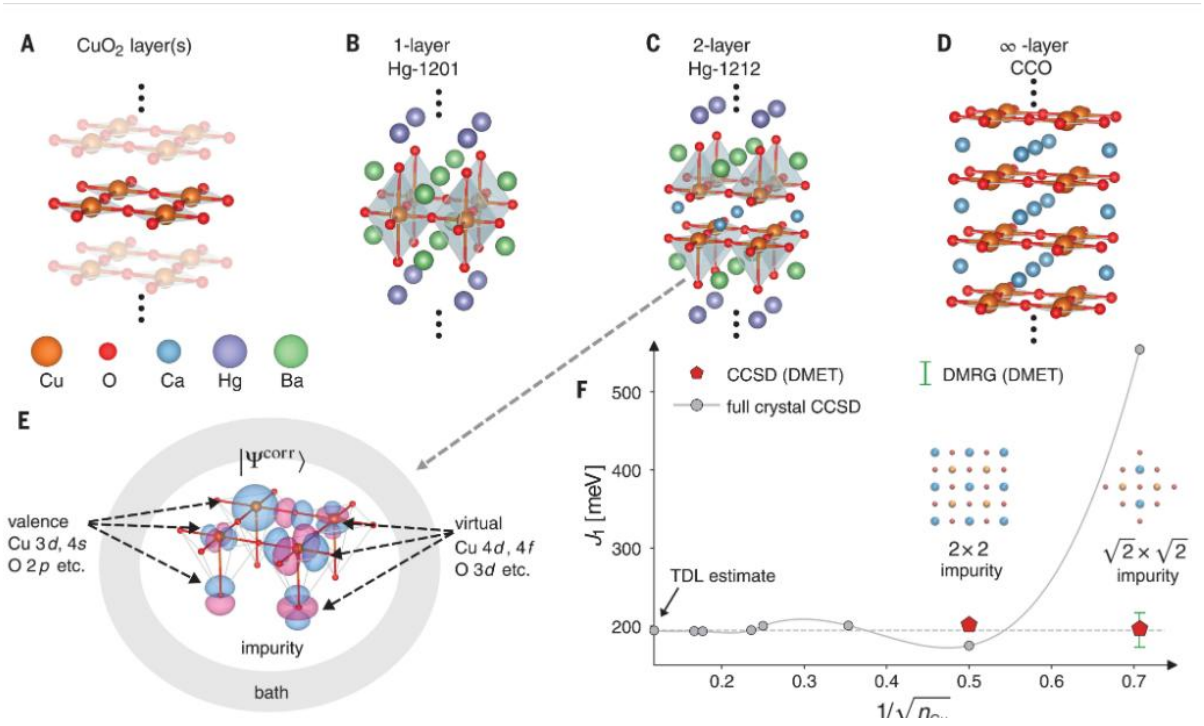
全文链接：https://www.science.org/doi/10.1126/science.abm2295

Abstract：The quantitative description of correlated electron materials remains a modern computational challenge. We demonstrate a numerical strategy to simulate correlated materials at the fully ab initio level beyond the solution of effective low-energy models and apply it to gain a detailed microscopic understanding across a family of cuprate superconducting materials in their parent undoped states. We uncover microscopic trends in the electron correlations and reveal the link between the material composition and magnetic energy scales through a many-body picture of excitation processes involving the buffer layers. Our work illustrates a path toward a quantitative and reliable understanding of more complex states of correlated materials at the ab initio many-body level.

摘要翻译：相关电子材料的定量描述仍然是现代计算的一个挑战。我们展示了一种数值策略，在完全从头算的水平上模拟相关材料，超出了有效的低能模型的解，并应用它来获得对母体未掺杂态的铜类超导材料家族的详细微观理解。我们揭示了电子相关性的微观趋势，并通过涉及缓冲层的激发过程的多体图像揭示了材料组成和磁能尺度之间的联系。我们的工作阐明了一条从头计算多体水平对相关材料的更复杂状态进行定量和可靠理解的道路。

文中插图：



[5]

Few-cycle vacuum squeezing in nanophotonics

在哈伯德区晶格中的镊子可编程二维量子行走

出版信息：Science,16 SEPTEMBER 2022, VOL 377, ISSUE 6612

作者：RAJVEER NEHRA, RYOTO SEKINE, LUIS LEDEZMA, QIUSHI GUO, ROBERT M. GRAY, ARKADEV ROY, ET AL.

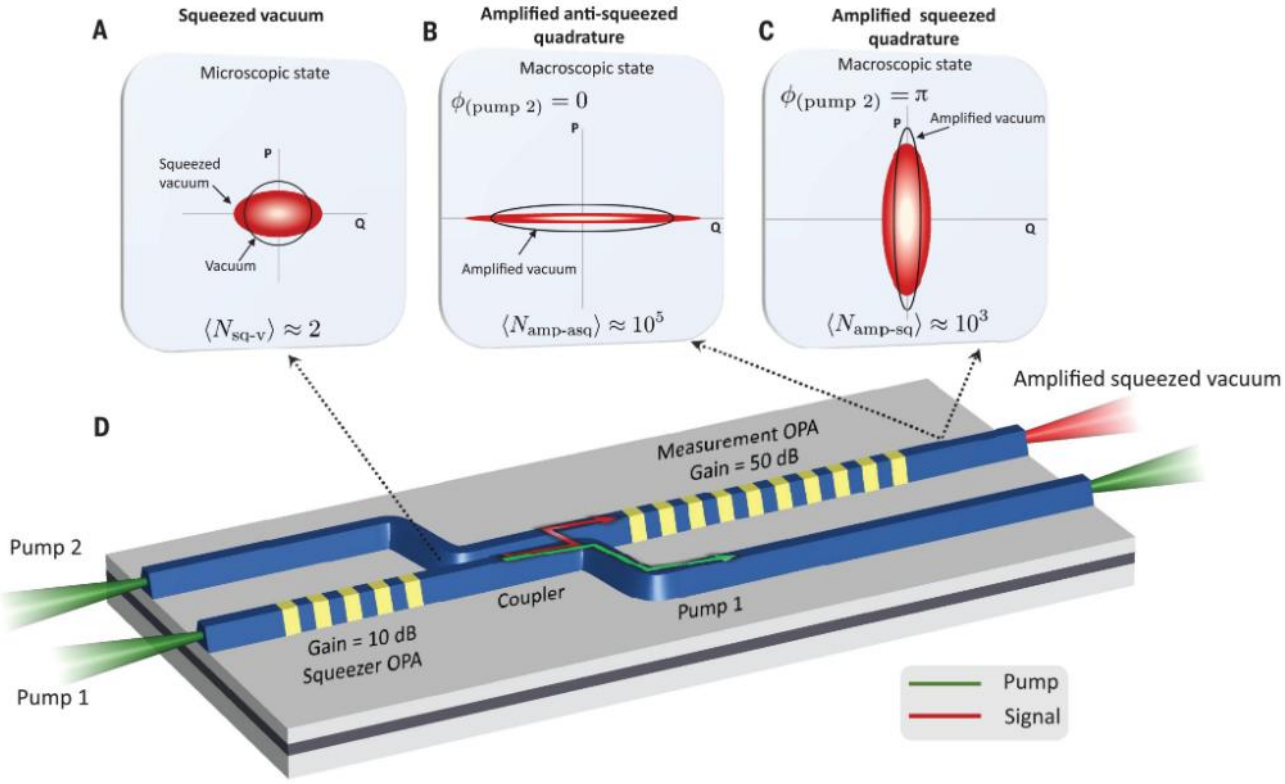
第一作者单位：Department of Electrical Engineering, California Institute of Technology, Pasadena, CA 91125, USA.

全文链接：https://www.science.org/doi/10.1126/science.abo6213

Abstract: One of the most fundamental quantum states of light is the squeezed vacuum, in which noise in one of the quadratures is less than the standard quantum noise limit. In nanophotonics, it remains challenging to generate, manipulate, and measure such a quantum state with the performance required for a wide range of scalable quantum information systems. Here, we report the development of a lithium niobate – based nanophotonic platform to demonstrate the generation and all-optical measurement of squeezed states on the same chip. The generated squeezed states span more than 25 terahertz of bandwidth supporting just a few optical cycles. The measured 4.9 decibels of squeezing surpass the requirements for a wide range of quantum information systems, demonstrating a practical path toward scalable ultrafast quantum nanophotonics.

摘要翻译：光最基本的量子态之一是压缩真空，其中一个正交噪声小于标准量子噪声极限。在纳米光子学中，要产生、操纵和测量这种具有广泛可扩展量子信息系统所需性能的量子态，仍颇具挑战性。研究组报道了基于铌酸锂的纳米光子平台开发，以演示在同一芯片上压缩态的产生和全光学测量。产生的压缩态跨越超过 25 太赫兹的带宽，仅支持几个光周期。测量到的 4.9 分贝压缩超过了广泛量子信息系统的要求，展示了一条可扩展超快量子纳米光子学的实用路径。

文中插图：



[6] Direct geometric probe of singularities in band structure

能带结构中奇点的直接几何探测

出版信息：Science,16 SEPTEMBER 2022, VOL 377, ISSUE 6612

作者：CHARLES D. BROWN, SHAO-WEN CHANG, MALTE N. SCHWARZ, TSZ-HIM LEUNG, VLADYSLAV KOZII, ALEXANDER AVDOSHKIN, ET AL.

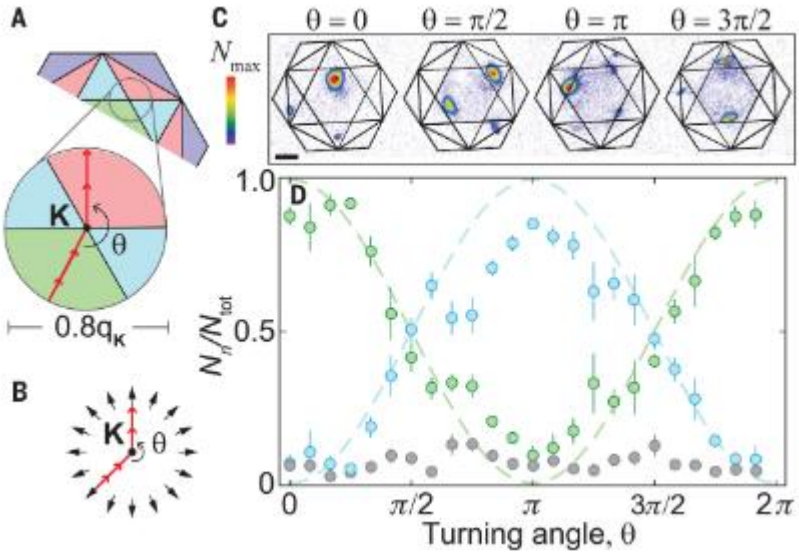
第一作者单位：Department of Physics, University of California, Berkeley, Berkeley, CA 94720, USA. Challenge Institute for Quantum Computation, University of California, Berkeley, Berkeley, CA 94720, USA. Department of Physics, Yale University, New Haven, CT 06520, USA.

全文链接：https://www.science.org/doi/10.1126/science.abm6442

Abstract：A quantum system’s energy landscape may have points where multiple energy surfaces are degenerate and that exhibit singular geometry of the wave function manifold, with major consequences for the system’s properties. Ultracold atoms in optical lattices have been used to indirectly characterize such points in the band structure. We measured the non-Abelian transformation produced by transport directly through the singularities. We accelerated atoms along a quasi-momentum trajectory that enters, turns, and then exits the singularities at linear and quadratic band-touching points of a honeycomb lattice. Measurements after transport identified the topological winding numbers of these singularities to be 1 and 2, respectively. Our work introduces a distinct method for probing singularities that enables the study of non-Dirac singularities in ultracold-atom quantum simulators.

摘要翻译：一个量子系统的能量景观可能有多个能量面简并的点，并表现出波函数流形的奇异几何结构，这对系统的性质产生重大影响。光学晶格中的超冷原子可间接表征能带结构中的这些点。研究组测量了通过奇点直接传输所产生的非阿贝尔变换。他们沿着一个准动量轨迹加速原子，该原子进入、转向，然后离开蜂巢晶格的线性和二次能带接触点处的奇点。传输后的测量确定了这些奇点的拓扑绕组数分别为 1 和 2。该工作介绍了一种探测奇点的独特方法，有助于研究超冷原子量子模拟器中的非狄拉克奇点。

文中插图：



[7]

Provably efficient machine learning for quantum many-body problems

量子多体问题的可证明有效的机器学习

出版信息：Science, 23 September 2022, Volume 377 Issue 6613

作者：HSIN-YUAN HUANG, RICHARD KUENG, GIACOMO TORLAI , VICTOR V. ALBERT, AND JOHN PRESKILL

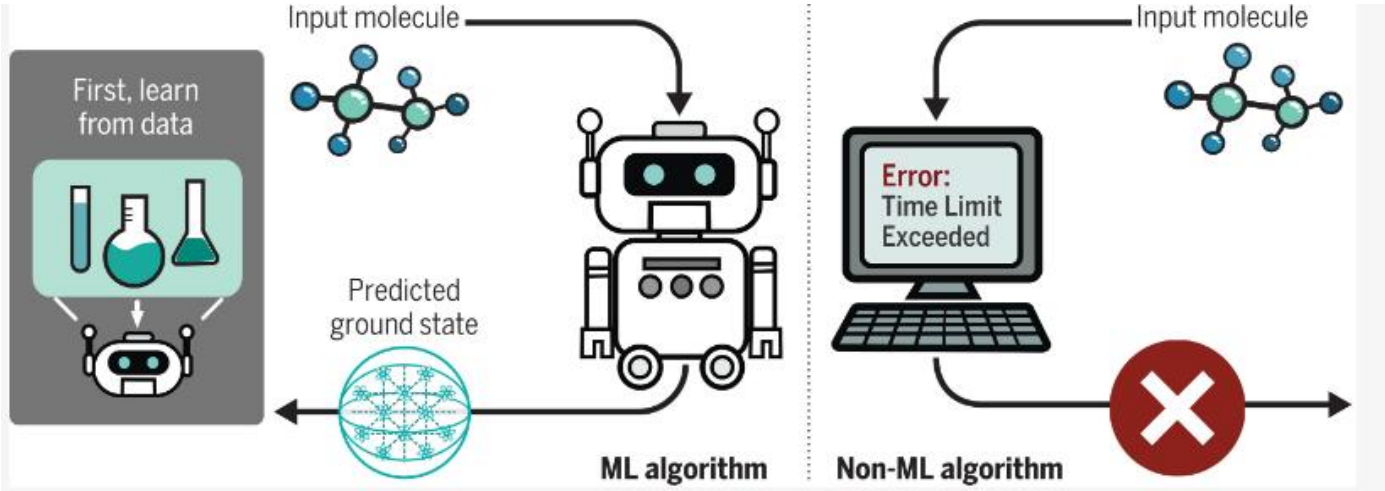
第一作者单位：Institute for Quantum Information and Matter and Department of Computing and Mathematical Sciences, Caltech, Pasadena, CA, USA.

全文链接：https://www.science.org/doi/10.1126/science.abk3333

Abstract：Predicting the properties of strongly interacting many-body quantum systems is notoriously difficult. One approach is to use quantum computers, but at the current stage of the technology, the most interesting problems are still out of reach. Huang et al. explored a different technique: using classical machine learning to learn from experimental data and then applying that knowledge to predict physical properties or classify phases of matter for specific types of many-body problems. The authors show that under certain conditions, the algorithm is computationally efficient.

摘要翻译：预测强相互作用多体量子系统的性质是出了名的困难。一种方法是使用量子计算机，但在目前的技术阶段，最有趣的问题仍然无法触及。作者探索了一种不同的技术：使用经典机器学习从实验数据中学习，然后应用这些知识来预测物理性质或对特定类型的多体问题的物质相进行分类。结果表明，在一定条件下，该算法具有较高的计算效率。

文中插图：



[8]

Water vapor injection into the stratosphere by Hunga Tonga-Hunga Ha'apai

汤加洪阿哈阿帕伊岛火山向平流层注入水汽

出版信息：Science, 23 September 2022, Volume 377 Issue 6613

作者：HOLGER VOMEL, STEPHANIE EVAN, AND MATT TULLY

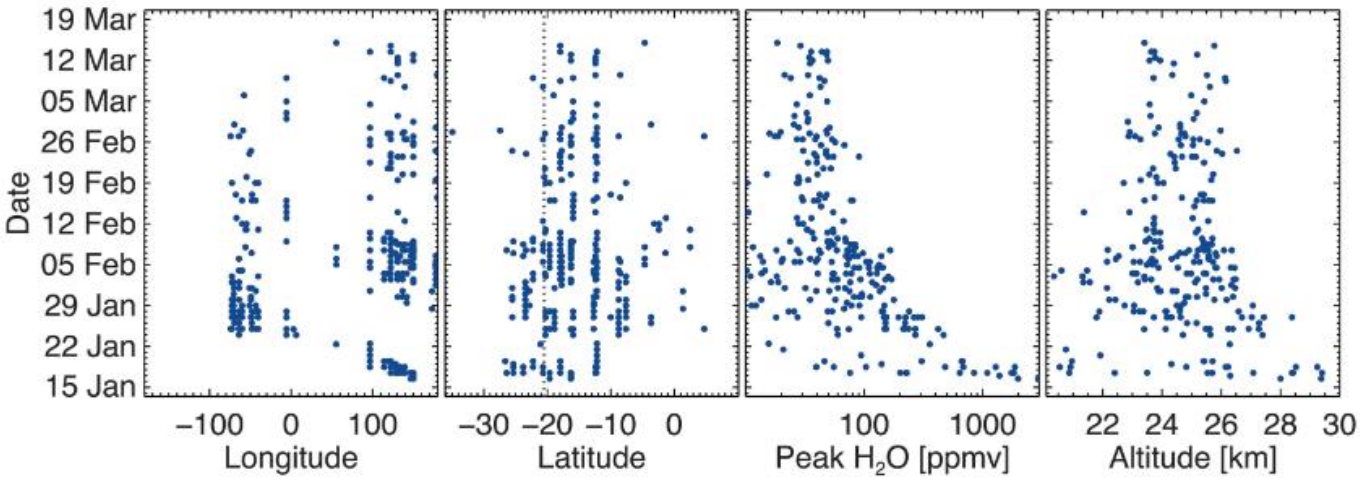
第一作者单位：National Center for Atmospheric Research, Boulder, CO 80301, USA.

全文链接：https://www.science.org/doi/10.1126/science.abq2299

Abstract：2022 年 1 月，汤加海底火山洪阿哈阿帕伊岛火山的喷发非常猛烈，其羽流渗透到平流层。作者研究了无线电探空仪（气象气球）的现场测量结果，结果表明这一事件向平流层注入了至少 50 太克的水蒸气。因为火山是在水下的，在发展的平流层羽流中的水蒸气量很高，而且，与其他大型喷发不同的是，它可能使全球平流层水蒸气量增加了 5%以上。

摘要翻译：非厄米光子学的一个关键见解是，诸如激光器之类的成熟概念可以反向操作以实现相干完美吸收体（CPA）。尽管在概念上很吸引人，但迄今为止，此类 CPA 仅限于单一的、形状合理的波前或模式。研究组演示了如何通过时间反转简并腔激光器来克服这一限制，该激光器基于一个独特的腔，它可以自我成像任何入射光场。将一个弱的、临界耦合的吸收体放置在该腔中，任何入射波前（即使是一个复杂的、动态变化的散斑图案）在大规模平行干涉过程中都以接近完美的效率被吸收。这些特性为光采集、能量传输、光控制和成像等领域的应用开辟了吸引人的新可能性。

文中插图：



[1]

A sustained high-temperature fusion plasma regime facilitated by fast ions

快离子促进的持续高温聚变等离子体机制

出版信息：Nature, 4 AUG 2022, Volume 608，Issue 7921

作者：H. Han, S. J. Park, C. Sung, J. Kang, Y. H. Lee, J. Chung, et al.

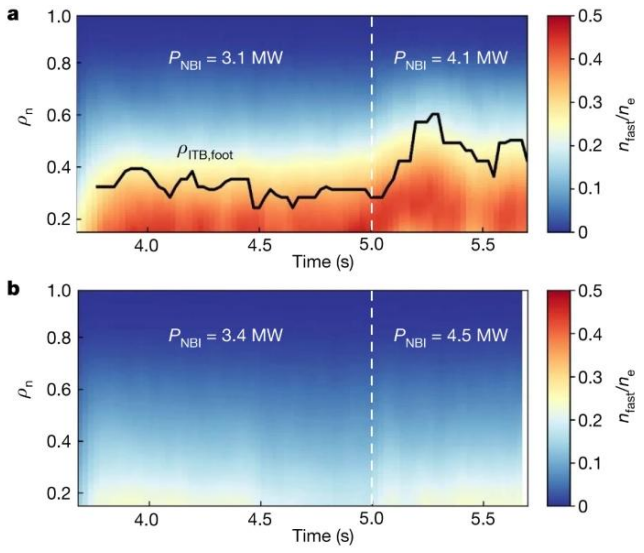
第一作者单位：Korea Institute of Fusion Energy, Daejeon, Republic of Korea

全文链接：https://www.nature.com/articles/s41586-022-05008-1

Abstract：Nuclear fusion is one of the most attractive alternatives to carbon-dependent energy sources. Harnessing energy from nuclear fusion in a large reactor scale, however, still presents many scientific challenges despite the many years of research and steady advances in magnetic confinement approaches. State-of-the-art magnetic fusion devices cannot yet achieve a sustainable fusion performance, which requires a high temperature above 100 million kelvin and sufficient control of instabilities to ensure steady-state operation on the order of tens of seconds. Here we report experiments at the Korea Superconducting Tokamak Advanced Research device producing a plasma fusion regime that satisfies most of the above requirements: thanks to abundant fast ions stabilizing the core plasma turbulence, we generate plasmas at a temperature of 100 million kelvin lasting up to 20 seconds without plasma edge instabilities or impurity accumulation. A low plasma density combined with a moderate input power for operation is key to establishing this regime by preserving a high fraction of fast ions. This regime is rarely subject to disruption and can be sustained reliably even without a sophisticated control, and thus represents a promising path towards commercial fusion reactors.

摘要翻译：核聚变是碳依赖能源最具吸引力的替代品之一。然而，尽管磁约束方法已经有了多年研究和稳步进展，但在大型反应堆中驾驭核聚变产生的能量仍面临许多科学挑战。目前最先进的磁聚变装置尚不能实现可持续的聚变性能，这需要超过 1 亿开尔文的高温和对不稳定性的充分控制，以确保在数十秒量级上的稳态运行。研究组报道了在韩国超导托卡马克先进研究装置上进行的实验，产生了满足上述大多数要求的等离子体聚变机制：由于大量快离子稳定了核心等离子体湍流，他们在 1 亿开尔文的温度下产生等离子体，并持续了 20 秒，且没有等离子体边缘不稳定或杂质累积。低等离子体密度与适当的操作输入功率相结合是通过保持高比例快离子来建立该机制的关键。这种机制很少受到干扰，即使没有精密控制也能稳定维持，因此代表了一条走向商业聚变反应堆的希望之路。

文中插图：



[2]

Imaging hydrodynamic electrons flowing without Landauer–Sharvin resistance

无 Landauer-Sharvin 电阻的流体动力学电子流成像

出版信息：Nature, 8 September 2022, VOL 609, ISSUE 7926

作者：C. Kumar, J. Birkbeck, J. A. Sulpizio, D. Perello, T. Taniguchi, K. Watanabe, et al.

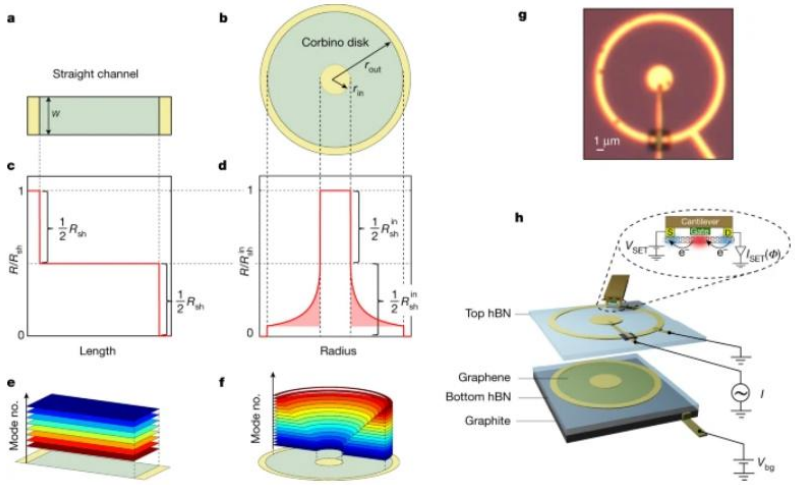
第一作者单位：Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel

全文链接：https://www.nature.com/articles/s41586-022-05002-7

Abstract：Electrical resistance usually originates from lattice imperfections. However, even a perfect lattice has a fundamental resistance limit, given by the Landauer conductance caused by a finite number of propagating electron modes. This resistance, shown by Sharvin to appear at the contacts of electronic devices, sets the ultimate conduction limit of non-interacting electrons. Recent years have seen growing evidence of hydrodynamic electronic phenomena, prompting recent theories to ask whether an electronic fluid can radically break the fundamental Landauer–Sharvin limit. Here, we use single-electron-transistor imaging of electronic flow in high-mobility graphene Corbino disk devices to answer this question. First, by imaging ballistic flows at liquid-helium temperatures, we observe a Landauer–Sharvin resistance that does not appear at the contacts but is instead distributed throughout the bulk. This underpins the phase-space origin of this resistance—as emerging from spatial gradients in the number of conduction modes. At elevated temperatures, by identifying and accounting for electron–phonon scattering, we show the details of the purely hydrodynamic flow. Strikingly, we find that electron hydrodynamics eliminates the bulk Landauer–Sharvin resistance. Finally, by imaging spiralling magneto-hydrodynamic Corbino flows, we show the key emergent length scale predicted by hydrodynamic theories—the Gurzhi length. These observations demonstrate that electronic fluids can dramatically transcend the fundamental limitations of ballistic electrons, with important implications for fundamental science and future technologies.

摘要翻译：电阻通常源于晶格缺陷。然而，即使是完美晶格也有一个基本电阻极限，由有限数量的传播电子模式引起的 Landauer 电导给出。Sharvin 揭示的出现在电子设备触点处的电阻，设定了非相互作用电子的最终传导极限。近年来，流体动力学电子现象的证据越来越多，促使最近的理论开始质疑电子流体是否能从根本上突破基础 Landauer-Sharvin 极限。研究组使用高迁移率石墨烯科比诺圆盘设备中的电子流实现单电子晶体管成像，回答了这个问题。首先，通过对液氦温度下的弹道流成像，他们观察到一个 Landauer-Sharvin 电阻，它未出现在触点，而是分布在整个块体中。这支持了从传导模式数量空间梯度中出现电阻的相空间起源。在高温下，通过识别和解释电子-声子散射，研究组展示了纯流体动力学流动的细节。值得注意的是，他们发现电子流体动力学消除了块体 Landauer-Sharvin 电阻。最后，通过对螺旋磁流体动力学科比诺流的成像，研究组展示了流体动力学理论预测的关键涌现长度尺度——Gurzhi 长度。这些观察表明，电子流体可以极大地超越弹道电子的基本限制，这对基础科学和未来技术具有重要意义。

文中插图：



[3]

Femtosecond laser writing of lithium niobate ferroelectric nanodomains

飞秒激光写入铌酸锂铁电纳米畴

出版信息：Nature, 15 September 2022, VOL 609, ISSUE 7927

作者：Xiaoyi Xu, Tianxin Wang, Pengcheng Chen, Chao Zhou, Jianan Ma, Dunzhao Wei, Huijun Wang, Ben Niu, Xinyuan Fang, Di Wu, Shining Zhu, Min Gu, Min Xiao & Yong Zhang

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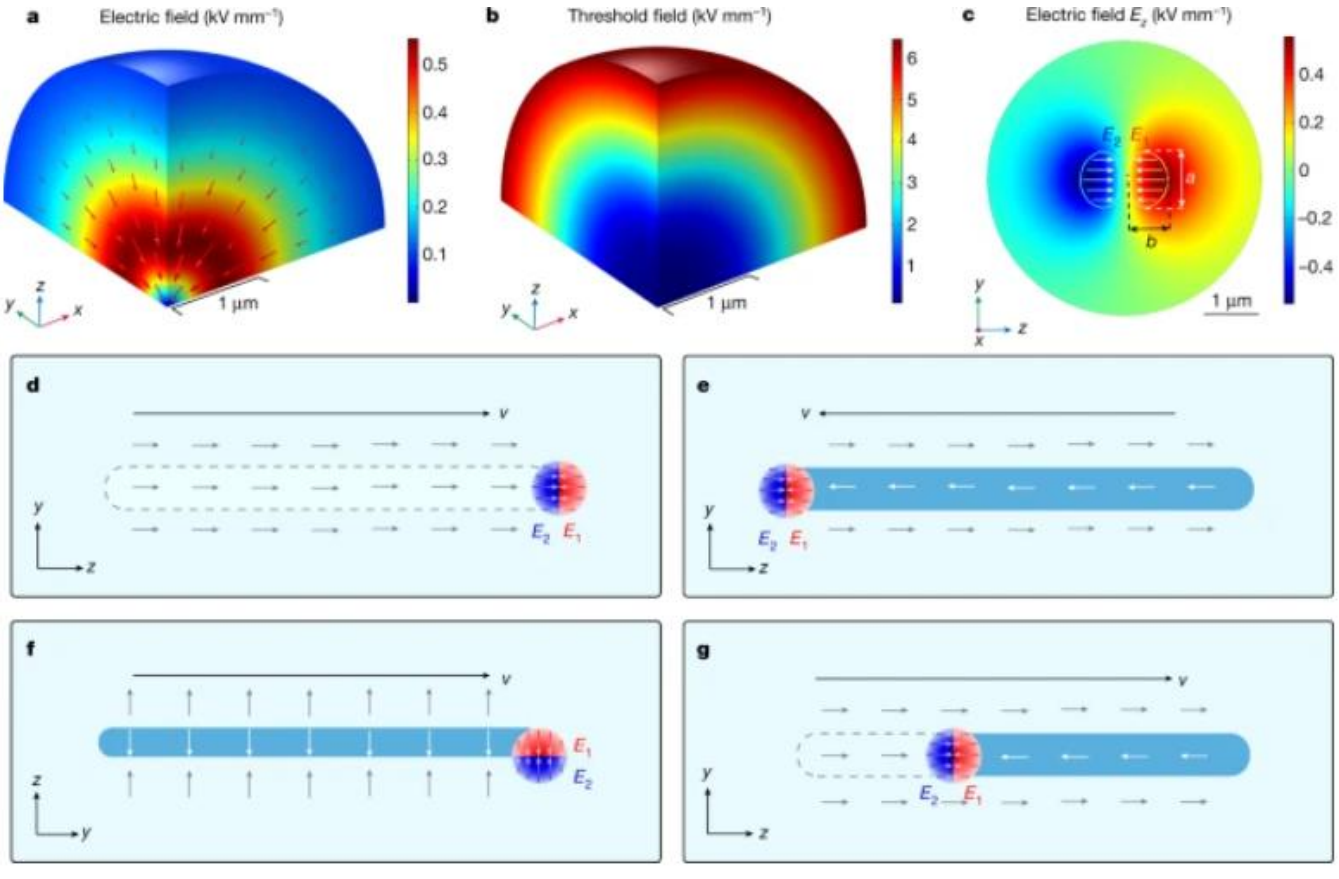
全文链接：https://www.nature.com/articles/s41586-022-05042-z

Abstract：Lithium niobate (LiNbO3) is viewed as a promising material for optical communications and quantum photonic chips. Here we demonstrate a non-reciprocal near-infrared laser-writing technique for reconfigurable three-dimensional ferroelectric domain engineering in LiNbO3 with nanoscale resolution. The proposed method is based on a laser-induced electric field that can either write or erase domain structures in the crystal, depending on the laser-writing direction. This approach offers a pathway for controllable nanoscale domain engineering in LiNbO3 and other transparent ferroelectric crystals, which has potential applications in high-efficiency frequency mixing, high-frequency acoustic resonators and high-capacity non-volatile ferroelectric memory.

摘要翻译：铌酸锂（LiNbO3）是一种很有前途的光通信和量子光子芯片材料。作者展示了一种非互易的近红外激光书写技术，用于在 LiNbO3 中具有纳米级分辨率的可重构三维铁电畴工程。提出的方法是基于激光诱导电场，根据激光写入的方向，可以写入或擦除晶体中的畴结构。该方法为 LiNbO3 等透明铁电晶体的可控纳米畴工程提供了一条途径，在高效混频、高频声谐振器和大容量非易失性铁电存储器等方面具有潜在的应用价值。

文中插图：



[4]

Attosecond spectroscopy of size-resolved water clusters

大小分辨水团簇的阿秒光谱

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作者：Xiaochun Gong, Saijoscha Heck, Denis Jelovina, Conaill Perry, Kristina Zinchenko, Robert Lucchese & Hans Jakob Wrner

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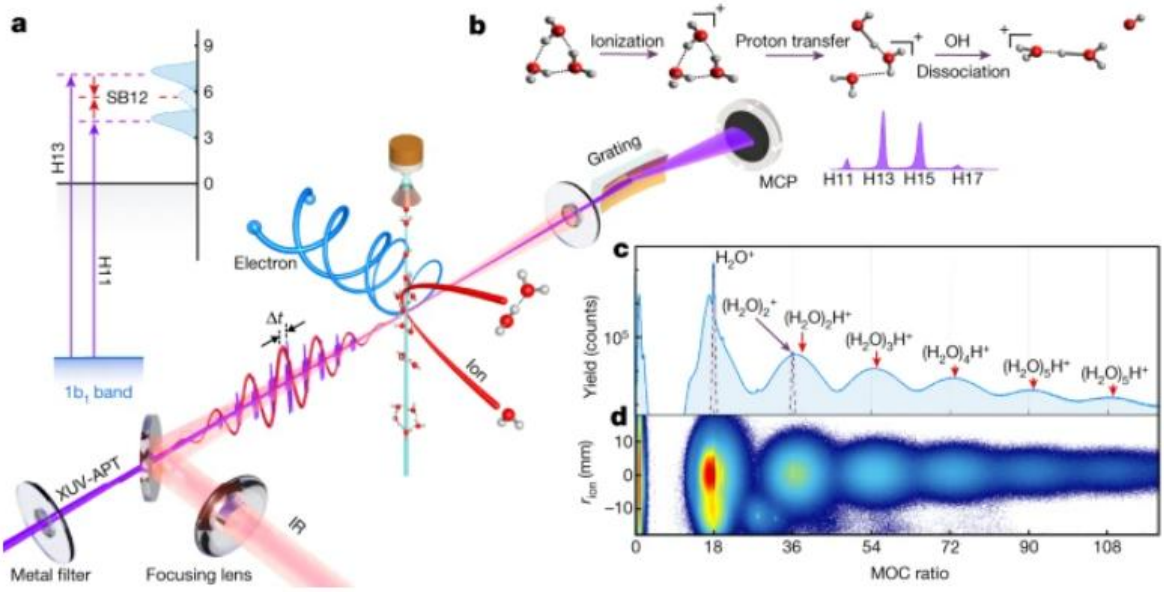
全文链接：https://www.nature.com/articles/s41586-022-05039-8

Abstract：Electron dynamics in water are of fundamental importance for a broad range of phenomena, but their real-time study faces numerous conceptual and methodological challenges. Here we introduce attosecond size-resolved cluster spectroscopy and build up a molecular-level understanding of the attosecond electron dynamics in water. We measure the effect that the addition of single water molecules has on the photoionization time delays of water clusters. We find a continuous increase of the delay for clusters containing up to four to five molecules and little change towards larger clusters. We show that these delays are proportional to the spatial extension of the created electron hole, which first increases with cluster size and then partially localizes through the onset of structural disorder that is characteristic of large clusters and bulk liquid water. These results indicate a previously unknown sensitivity of photoionization delays to electron-hole delocalization and indicate a direct link between electronic structure and attosecond photoionization dynamics. Our results offer new perspectives for studying electron-hole delocalization and its attosecond dynamics.

摘要翻译：水中电子动力学对许多现象具有基础性的重要性，但其实时研究面临着许多概念和方法上的挑战。作者介绍了阿秒大小分辨聚类光谱，建立对水中阿秒电子动力学的分子水平的理解。他们测量了单个水分子的加入对水簇光离时延的影响，结果发现对于含有 4 到 5 个分子的团簇，延迟持续增加，而对于更大的团簇，延迟变化不大。研究者证明了这些延迟与所产生的电子空穴的空间扩展成正比，电子空穴首先随着团簇的大小而增加，然后通过大团簇和大体积液态水的结构紊乱的出现而部分定位。这些结果表明光离延迟对电子空穴离域的敏感性是未知的，也表明电子结构和阿秒光离动力学之间的直接联系。该结果为研究电子空穴离域及其阿秒动力学提供了新的视角。

文中插图：



[5]

Extended Bose–Hubbard model with dipolar excitons

带有偶极激子的扩展玻色-哈伯德模型

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作者：C. Lagoin, U. Bhattacharya, T. Grass, R. W. Chhajlany, T. Salamon, K. Baldwin, L. Pfeiffer, M. Lewenstein, M. Holzmann & F. Dubin

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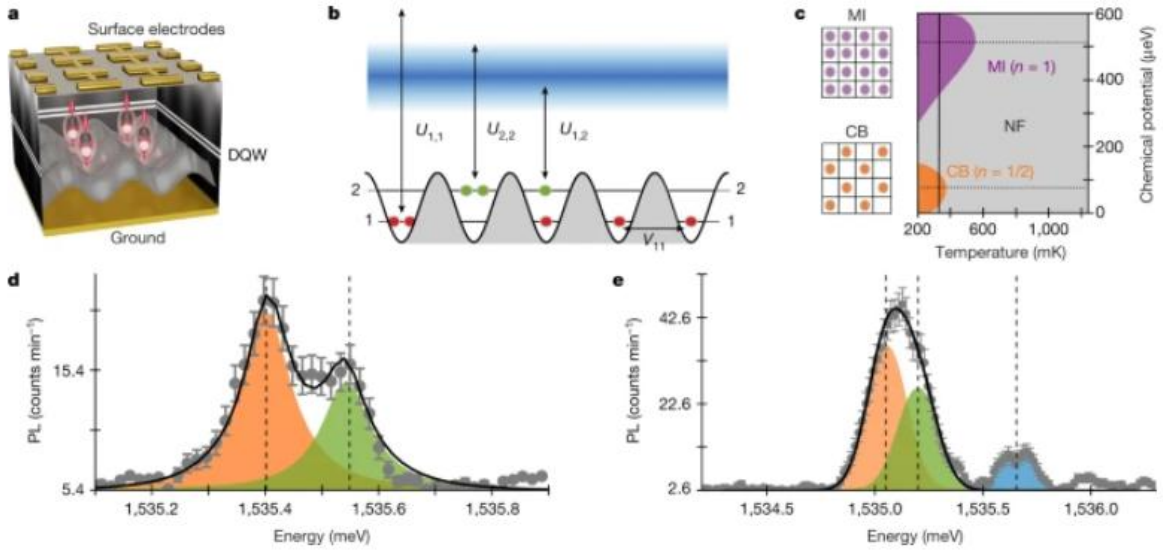
全文链接：https://www.nature.com/articles/s41586-022-05123-z

Abstract：The Hubbard model constitutes one of the most celebrated theoretical frameworks of condensed-matter physics. It describes strongly correlated phases of interacting quantum particles confined in lattice potentials. For bosons, the Hubbard Hamiltonian has been deeply scrutinized for short-range on-site interactions. However, accessing longer-range couplings has remained elusive experimentally. This marks the frontier towards the extended Bose–Hubbard Hamiltonian, which enables insulating ordered phases at fractional lattice fillings. Here we implement this Hamiltonian by confining semiconductor dipolar excitons in an artificial two-dimensional square lattice. Strong dipolar repulsions between nearest-neighbour lattice sites then stabilize an insulating state at half filling. This characteristic feature of the extended Bose–Hubbard model exhibits the signatures theoretically expected for a chequerboard spatial order. Our work thus highlights that dipolar excitons enable controlled implementations of boson-like arrays with strong off-site interactions, in lattices with programmable geometries and more than 100 sites.

摘要翻译：哈伯德模型是凝聚态物理最著名的理论框架之一。它描述了限制在晶格势中的相互作用量子粒子的强相关相。对于玻色子，哈伯德哈密顿量已经被深入研究了近距离现场相互作用。然而，在实验上，获得更远距离的耦合仍然难以捉摸。这标志着向扩展的玻色-哈伯德哈密顿量的前沿，它使得在分数点阵填充中隔离有序相成为可能。作者通过限制半导体偶极激子，在一个人工的二维方形晶格实现这个哈密顿量。最强的偶极排斥力在最近邻的晶格位之间使半填充状态稳定在绝缘状态。扩展玻色-哈伯德模型的这一特征显示了棋盘格空间顺序的理论特征。因此，这项研究强调了偶极激子在具有可编程几何结构和超过 100 个位点的晶格中，使具有强站外相互作用的类玻色子阵列的受控实现成为可能。

文中插图：



[6]

Photonic topological insulator induced by a dislocation in three dimensions

三维位错诱导的光子拓扑绝缘体

出版信息：Nature, 29 September 2022, VOL 609, ISSUE 7929

作者：Eran Lustig, Lukas J. Maczewsky, Julius Beck, Tobias Biesenthal, Matthias Heinrich, Zhaoju Yang, et al.

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全文链接：https://www.nature.com/articles/s41586-022-05129-7

Abstract：The hallmark of topological insulators (TIs) is the scatter-free propagation of waves in topologically protected edge channels. This transport is strictly chiral on the outer edge of the medium and therefore capable of bypassing sharp corners and imperfections, even in the presence of substantial disorder. In photonics, two-dimensional (2D) topological edge states have been demonstrated on several different platforms and are emerging as a promising tool for robust lasers, quantum devices and other applications. More recently, 3D TIs were demonstrated in microwaves and acoustic waves, where the topological protection in the latter is induced by dislocations. However, at optical frequencies, 3D photonic TIs have so far remained out of experimental reach. Here we demonstrate a photonic TI with protected topological surface states in three dimensions. The topological protection is enabled by a screw dislocation. For this purpose, we use the concept of synthetic dimensions in a 2D photonic waveguide array by introducing a further modal dimension to transform the system into a 3D topological system. The lattice dislocation endows the system with edge states propagating along 3D trajectories, with topological protection akin to strong photonic TIs. Our work paves the way for utilizing 3D topology in photonic science and technology.

摘要翻译：拓扑绝缘体（TIs）的特征是波在拓扑保护边缘通道中的无散射传播。这种传播在介质的外缘是严格手性的，因此即使存在大量的无序，也能够绕过尖角和缺陷。在光子学中，二维（2D）拓扑边缘态已在几个不同的平台上得到了证明，并正在成为鲁棒激光器、量子器件和其他应用中的一种颇有前景的工具。最近，3D TIs 在微波和声波中被证实，后者的拓扑保护是由位错诱导的。然而，在光学频率下，3D 光子 TIs 迄今仍未通过实验证实。研究组演示了一个在三维中受保护拓扑表面态的光子 TI。拓扑保护由螺型位错实现。为此，研究组在 2D 光子波导阵列中使用合成维数的概念，通过引入另一个模态维数，将系统转化为 3D 拓扑系统。晶格位错使系统具有沿 3D 轨迹传播的边缘态，以及类似于强光子 TIs 的拓扑保护。该研究工作为 3D 拓扑在光子科学和技术中的应用铺平了道路。

文中插图：