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Dirac mass induced by optical gain and loss

光学增益和损耗引起的狄拉克质量

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链接：

<https://www.nature.com/articles/s41586-024-07664-x>

摘要：

质量通常被认为是物质的内在属性，但现代物理学揭示粒子质量有着复杂的起源，例如高能物理学中的希格斯机制。在像石墨烯这样的晶格中，相对论性狄拉克粒子可以以低能准粒子的形式存在，其质量是由晶格对称破缺扰动赋予的。这些产生质量的机制都假定了厄米性，或者说是能量守恒。

利用光子合成晶格，作者通过实验证明了基于光学增益和损耗的非厄米微扰可以产生狄拉克质量。他们探讨了增益和损失诱导狄拉克质量的时空工程如何影响准粒子。研究表明，准粒子在空间边界处经历克莱因隧穿，但非厄米对称的局部破缺可以在畴壁处产生新的通量非守恒效应。

在狄拉克质量符号突然翻转的时间边界上，研究者观察到时间反射现象的一种变体：在非相对论性极限下，狄拉克准粒子的速度反转，而在相对论性极限下，原始速度保持不变。

Abstract：

Mass is commonly considered an intrinsic property of matter, but modern physics reveals particle masses to have complex origins¹, such as the Higgs mechanism in high-energy physics. In crystal lattices such as graphene, relativistic Dirac particles can exist as low-energy quasiparticles with masses imparted by lattice symmetry-breaking perturbations. These mass-generating mechanisms all assume Hermiticity, or the conservation of energy in detail. Using a photonic synthetic lattice, we show experimentally that Dirac masses can be generated by means of non-Hermitian perturbations based on optical gain and loss. We then explore how the spacetime engineering of the gain and loss-induced Dirac mass affects the quasiparticles. As we show, the quasiparticles undergo Klein tunnelling at spatial boundaries, but a local breaking of a non-Hermitian symmetry can produce a new flux non-conservation effect at the domain walls. At a temporal boundary that abruptly flips the sign of the Dirac mass, we observe a variant of the time-reflection phenomenon: in the non-relativistic limit, the Dirac quasiparticle reverses its velocity, whereas in the relativistic limit, the original velocity is retained.

A hot-Jupiter progenitor on a super-eccentric retrograde orbit

超偏心逆行轨道上的热木星祖星

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Cochran, Paul Dalba, ... Carl Ziegler Show s

链接：

<https://www.nature.com/articles/s41586-024-07688-3>

摘要：

巨大的系外行星绕着其主恒星运行，不太可能形成它们现在的形状。相反，这些“热木星”行星被认为是从冰线以外向内迁移的，并且提出了几种可行的迁移通道，包括通过与第三个天体的角动量交换来激发偏心，然后是潮汐驱动的轨道圆化。

极偏心($e = 0.93$)的巨型系外行星HD 80606 b的发现提供了观测证据，证明热木星可能是通过这种高偏心潮汐迁移路径形成的。然而，尚未发现类似的热木星祖先，模拟预测影响这一机制有效性的一个因素是系外行星的质量，因为低质量的行星更有可能在近天通道期间被潮汐破坏⁶。

研究者介绍了对TIC 241249530

b的光谱和光度观测结果，这是一颗高质量的、轨道偏心率 $e=0.94$ 的温暖木星。TIC 241249530 b的轨道与离心振荡的历史和未来的潮汐圆化轨迹一致。研究对变暖木星人口的质量和偏心率分布的分析进一步揭示了高质量和高偏心率之间的相关性。

Abstract：

Giant exoplanets orbiting close to their host stars are unlikely to have formed in their present configurations¹. These ‘hot Jupiter’ planets are instead thought to have migrated inward from beyond the ice line and several viable migration channels have been proposed, including eccentricity excitation through angular-momentum exchange with a third body followed by tidally driven orbital circularization. The discovery of the extremely eccentric ($e=0.93$) giant exoplanet HD 80606 b provided observational evidence that hot Jupiters may have formed through this high-eccentricity tidal-migration pathway. However, no similar hot-Jupiter progenitors have been found and simulations predict that one factor affecting the efficacy of this mechanism is exoplanet mass, as low-mass planets are more likely to be tidally disrupted during periastron passage^{6,7,8}. Here we present spectroscopic and photometric observations of TIC 241249530 b, a high-mass, transiting warm Jupiter with an extreme orbital eccentricity of $e=0.94$. The orbit of TIC 241249530 b is consistent with a history of eccentricity oscillations and a future tidal circularization trajectory. Our analysis of the mass and eccentricity distributions of the transiting-warm-Jupiter population further reveals a correlation between high mass and high eccentricity.

High-performance 4-nm-resolution X-ray tomography using burst ptychography

高性能的纳米分辨率X射线断层扫描

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链接：

<https://www.nature.com/articles/s41586-024-07615-6>

摘要：

科学、医学和工程的进步依赖于成像方面的突破，特别是在从集成电路或哺乳动物大脑等功能系统获取多尺度三维信息方面。实现这一目标通常需要结合基于电子和光子的方法。电子显微镜通过对表层的连续破坏性成像提供纳米级的分辨率，而X射线计算机断层摄影提供非破坏性成像，并且最近在小体积上实现了低至7纳米的分辨率。

作者实现了突发平面摄影，它克服了实验不稳定性并实现了更高的性能，具有4纳米分辨率和170倍的采集速率，即每秒14,000个分辨率元素。另一项关键创新是层析成像反向传播重建技术，它能够对比传统景深大10倍的样本进行成像。

通过结合这两项创新，研究者成功地成像了一个最先进的(7纳米节点)商业集成电路，其特点是由硅和金属等低和高密度材料制成的纳米结构，在选定的x射线波长下具有良好的辐射稳定性和对比度。这些能力使得对芯片的设计和制造进行详细的研究，直到单个晶体管的水平。

研究者预计，在下一代X射线源中，纳米分辨率和更高X射线通量的结合将在从电子学到电化学和神经科学等领域产生革命性的影响。

Abstract：

Advances in science, medicine and engineering rely on breakthroughs in imaging, particularly for obtaining multiscale, three-dimensional information from functional systems such as integrated circuits or mammalian brains. Achieving this goal often requires combining electron- and photon-based approaches. Whereas electron microscopy provides nanometre resolution through serial, destructive imaging of surface layers¹, ptychographic X-ray computed tomography offers non-destructive imaging and has recently achieved resolutions down to seven nanometres for a small volume. Here we implement burst ptychography, which overcomes experimental instabilities and enables much higher performance, with 4-nanometre resolution at a 170-times faster acquisition rate, namely, 14,000 resolution elements per second. Another key innovation is tomographic back-propagation reconstruction⁴, allowing us to image samples up to ten times larger than the conventional depth of field. By combining the two innovations, we successfully imaged a state-of-the-art (seven-nanometre node) commercial integrated circuit, featuring nanostructures made of low- and high-density materials such as silicon and metals, which offer good radiation stability and contrast at the selected X-ray wavelength. These capabilities enabled a detailed study of the chip's design and manufacturing, down to the level of individual transistors. We anticipate that the combination of nanometre resolution and higher X-ray flux at next-generation X-ray sources will have a revolutionary impact in fields ranging from electronics to electrochemistry and neuroscience.

Magnetic field expulsion in optically driven YBa₂Cu₃O_{6.48}

光驱动YBa₂Cu₃O_{6.48}的磁场驱逐

作者：S. Fava, G. De Vecchi, G. Jotzu, M. Buzzi, T. Gebert, Y. Liu, B. Keimer A. Cavalleri

链接：

摘要：

量子固体中的相干光驱动正在成为一个研究前沿，有许多有趣的非平衡量子相和瞬态光致功能现象的报道，如铁电性、磁性和超导性。在高温铜超导体中，某些声子模式的相干驱动导致了具有类似超导光学性质的瞬态，远远高于它们的转变温度 T_c ，并且贯穿赝隙相。

然而，关于这种瞬态的微观性质以及如何将其与具有增强载流子迁移率的非超导状态区分开来的问题仍然存在。例如，目前尚不清楚在这种时尚中驱动的铜是否表现出迈斯纳抗磁性。

研究者通过测量放置在样品附近的磁光材料中的法拉第旋转来研究光驱动 $\text{YBa}_2\text{Cu}_3\text{O}_{6.48}$ 晶体周围的时间相关磁场。在恒定的外加磁场和相同的驱动条件下，产生类似超导的光学特性，观察到瞬态抗磁响应。

这种响应在尺寸上与具有相似形状和尺寸的平衡型II超导体的响应相当，其体积磁化率 χ_v 为 ~ 0.3 阶。这个值与光诱导的没有超导性的迁移率增加是不相容的。相反，它强调了赝隙相的概念，其中早期的超导相关性被驱动器增强或同步。

Abstract：

Coherent optical driving in quantum solids is emerging as a research frontier, with many reports of interesting non-equilibrium quantum phases and transient photo-induced functional phenomena such as ferroelectricity, magnetism and superconductivity. In high-temperature cuprate superconductors, coherent driving of certain phonon modes has resulted in a transient state with superconducting-like optical properties, observed far above their transition temperature T_c and throughout the pseudogap phase. However, questions remain on the microscopic nature of this transient state and how to distinguish it from a non-superconducting state with enhanced carrier mobility. For example, it is not known whether cuprates driven in this fashion exhibit Meissner diamagnetism. Here we examine the time-dependent magnetic field surrounding an optically driven $\text{YBa}_2\text{Cu}_3\text{O}_{6.48}$ crystal by measuring Faraday rotation in a magneto-optic material placed in the vicinity of the sample. For a constant applied magnetic field and under the same driving conditions that result in superconducting-like optical properties, a transient diamagnetic response was observed. This response is comparable in size with that expected in an equilibrium type II superconductor of similar shape and size with a volume susceptibility χ_v of order ~ 0.3 . This value is incompatible with a photo-induced increase in mobility without superconductivity. Rather, it underscores the notion of a pseudogap phase in which incipient superconducting correlations are enhanced or synchronized by the drive.

气候与生态 Climate Ecology

Groundwater-dependent ecosystem map exposes global dryland protection needs

地下水依赖生态系统图揭示了全球旱地保护需求

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链接：

<https://www.nature.com/articles/s41586-024-07702-8>

摘要：

地下水是全球最普遍的液态淡水来源，但它在支持多种生态系统方面的作用却很少得到承认。然而，许多地区地下水依赖生态系统的位置和范围尚不清楚，缺乏相应的保护措施。

作者以高分辨率(大约30米)绘制了地下水依赖生态系统(GDE)图，发现它们存在于所分析的全球三分之一以上的旱地，包括重要的全球生物多样性热点地区。

在地下水耗竭率较低的以畜牧业为主导的景观中，GDE更为广泛和连续，这表明许多GDE可能已经由于水和土地利用方式而丧失。然而，53%的GDE存在于地下水下降趋势的区域，这突出表明迫切需要保护GDE免受地下水枯竭的威胁。

然而，研究者发现只有21%的GDE存在于受保护的或具有可持续地下水管理政策的司法管辖区，从而呼吁采取行动保护这些重要的生态系统。此外，研究了大萨赫勒地区GDE与文化和社会经济因素的联系，其中GDE在支持生物多样性和农村生计方面发挥着重要作用，以探索政治不稳定地区保护GDE的其他手段。

研究者表示，GDE地图为在不同的地方、区域或国际尺度上优先考虑和制定政策和保护机制提供了关键信息，以保护这些重要的生态系统和依赖于它们的社会。

Abstract：

Groundwater is the most ubiquitous source of liquid freshwater globally, yet its role in supporting diverse ecosystems is rarely acknowledged. However, the location and extent of groundwater-dependent ecosystems (GDEs) are unknown in many geographies, and protection measures are lacking. Here, we map GDEs at high-resolution (roughly 30m) and find them present on more than one-third of global drylands analysed, including important global biodiversity hotspots. GDEs are more extensive and contiguous in landscapes dominated by pastoralism with lower rates of groundwater depletion, suggesting that many GDEs are likely to have already been lost due to water and land use practices. Nevertheless, 53% of GDEs exist within regions showing declining groundwater trends, which highlights the urgent need to protect GDEs from the threat of groundwater depletion. However, we found that only 21% of GDEs exist on protected lands or in jurisdictions with sustainable groundwater management policies, invoking a call to action to protect these vital ecosystems. Furthermore, we examine the linkage of GDEs with cultural and socio-economic factors in the Greater Sahel region, where GDEs play an essential role in supporting biodiversity and rural livelihoods, to explore other means for protection of GDEs in politically unstable regions. Our GDE map provides critical information for prioritizing and developing policies and protection mechanisms across various local, regional or international scales to safeguard these important ecosystems and the societies dependent on them.

A holistic platform for accelerating sorbent-based carbon capture

加速吸附剂碳捕获的整体平台

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链接：

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摘要：

减少二氧化碳(CO₂)排放迫切需要大规模部署碳捕获技术。这些技术必须从不同的来源分离二氧化碳，并将其输送到不同的汇。寻求特定源汇对的最佳解决方案是一项复杂的、涉及多个利益攸关方的多目标挑战，并取决于社会、经济和区域背景。

目前，研究遵循一个顺序的方法：化学家专注于材料设计，工程师专注于优化工艺，然后在影响经济和环境的规模上进行操作。评估这些影响，比如电厂生命周期内的温室气体排放，通常是最后的步骤之一。

研究者介绍了定制吸收材料的工艺信息设计 (PrISMa) 平台，集成了材料、工艺设计、技术经济和生命周期评估。他们比较了全球5个地区使用不同技术从不同来源捕获二氧化碳的60多个案例研究。

该平台同时向各利益相关者通报技术的成本效益、工艺配置和位置，揭示高性能吸附剂的分子特征，并提供有关环境影响、协同效益和权衡的见解。通过在早期研究阶段联合利益相关者，PrISMa有助于加速碳捕集技术的发展，推动实现净零排放的世界。

Abstract：

Reducing carbon dioxide (CO₂) emissions urgently requires the large-scale deployment of carbon-capture technologies. These technologies must separate CO₂ from various sources and deliver it to different sinks. The quest for optimal solutions for specific source – sink pairs is a complex, multi-objective challenge involving multiple stakeholders and depends on social, economic and regional contexts. Currently, research follows a sequential approach: chemists focus on materials design and engineers on optimizing processes, which are then operated at a scale that impacts the economy and the environment. Assessing these impacts, such as the greenhouse gas emissions over the plant’s lifetime, is typically one of the final steps. Here we introduce the PrISMa (Process-Informed design of tailor-made Sorbent Materials) platform, which integrates materials, process design, techno-economics and life-cycle assessment. We compare more than 60 case studies capturing CO₂ from various sources in 5 global regions using different technologies. The platform simultaneously informs various stakeholders about the cost-effectiveness of technologies, process

configurations and locations, reveals the molecular characteristics of the top-performing sorbents, and provides insights on environmental impacts, co-benefits and trade-offs. By uniting stakeholders at an early research stage, PrISMa accelerates carbon-capture technology development during this critical period as we aim for a net-zero world.

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