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编者按：2024浦江创新论坛——量子科技论坛“未来之光：量子计算和量子器件的科技创新”为主题，来自全球量子科技的顶尖专家、学者和企业代表围绕攻克量子科技的关键核心技术，推动量子科技的产业化发展展开深入研讨。本期专报对量子科技论坛的嘉宾观点进行梳理，供参考。

Editor's note: With the theme of "Light of the Future: Technological Innovation in Quantum Computing and Quantum Devices", the 2024 Pujiang Innovation Forum - Quantum Technology Forum invited top experts, scholars and corporate representatives from global quantum technology fields to conduct in-depth discussions on achieve breakthroughs in core and key quantum technologies and promoting the industrialization of quantum technology. This special report synthesizes the viewpoints of the guests at the Quantum Technology Forum for your information.

**2024 浦江创新论坛专报之十九**

**Special Report 19 of the 2024 Pujiang Innovation Forum**

# 加速量子科技从技术到市场的进程

# Accelerating the Process of Quantum Technology from Technology to Market

量子科技涵盖了量子计算及模拟、量子通信、量子测量以及量子技术等未来应用前景，作为世界科技最前沿、最具颠覆性的领域之一，正引领着新一轮科技革命和产业变革的浪潮，不断改变着世界的面貌。**与会嘉宾一致认为，量子计算、量子通信和量子精密测量等关键领域已经实现了显著的进展和新的突破。面向未来，多学科交叉融合研究将为量子科技的创新提供更为广阔的前景。应加强高校、科研机构与企业之间的紧密合作，加速量子科技完成从理论到实践、从实验室到市场的转变。**

Quantum technology covers future application prospects such as quantum computing and simulation, quantum communication, quantum measurement and quantum technologies. As one of the most cutting-edge and disruptive fields in world science and technology, quantum technology is leading a new round of technological revolution and industrial transformation, and constantly changing the face of the world. **The guests present unanimously agreed that significant progress and new**

**breakthroughs have been achieved in key fields such as quantum computing, quantum communication, and quantum precision measurement. Looking ahead, multidisciplinary cross-integration research will provide a broader prospect for the innovation of quantum technology. We should strengthen close cooperation among universities, research institutions, and enterprises, and accelerate the transformation of quantum technology from theory to practice, and from laboratory to market.**

## 一、发展量子科技的重要作用

### 1. The importance of developing quantum technology

**一是量子科技是未来科技竞争新高地已达成共识。**量子科技已经引起了全球范围内的广泛关注和高度重视，各国政府纷纷将其纳入国家科技战略的核心，通过加大投入和支持，力图在这一领域取得领先地位。**科技部前沿技术司副司长傅小锋**指出，全球各国都将量子科技视为国家战略科技力量的关键组成部分，并将其融入国家科技创新的整体规划之中。这种全球性的战略布局不仅凸显了量子科技的重要性，也预示着未来科技竞争的新高地。

**Firstly, a consensus has been reached that quantum technology is a new arena for future technological competition.** Quantum technology has attracted widespread attention and serious

concern worldwide. Governments around the world have incorporated quantum technology into the core of their national science and technology strategies, striving to gain a leading position in this field by increasing investment and support. **Fu Xiaofeng, Deputy Director-General of the Frontier Technology Department of the Ministry of Science and Technology,** pointed out that countries around the world take quantum technology as a key component of their national strategic scientific and technological strengths, and integrate it into the overall planning of their national scientific and technological innovation. Such global strategic layout not only highlights the importance of quantum technology, but also heralds a new arena for future technological competition.

**二是量子技术在多学科领域中应用将产生颠覆性影响。中国科学院院士、中国科学院量子信息与量子科技创新研究院院长潘建伟**指出，快速是量子计算具有的压倒性巨大优势，传统计算机无法在合理时间内完成同样任务，将对经济社会产生颠覆性的改进。**上海市人民政府副秘书长尚玉英**强调，量子精密测量不仅是量子科学领域的核心技术，更是推动科技前沿发展的关键。量子精密测量技术能够提高测量的灵敏度和精度，这对于基础物理研究、引力波探测、全球定位系统等需要高精度测量的领域至关重要。

**Secondly, the application of quantum technology will have a**

**disruptive impact in multidisciplinary fields. Pan Jianwei, Member of the Chinese Academy of Sciences and President of the CAS Center for Excellence in Quantum Information and Quantum Physics,** pointed out that fast speed is the overwhelming advantage of quantum computing, while traditional computers cannot complete the same task in a reasonable time, which will bring about disruptive improvements to the economy and society. **Shang Yuying, Deputy Secretary-General of Shanghai Municipal People's Government**, emphasized that quantum precision measurement is not only the core technology in the field of quantum science, but also the key to promoting the development of the frontiers of science and technology. Quantum precision measurement technology can improve the sensitivity and accuracy of measurements, which is crucial for basic physics research, gravitational wave detection, global positioning systems and other fields that require high-precision measurements.

**三是量子科技的发展将催生新的产业和商业模式。**麦肯锡预测量子计算到 2035 年可能达到 3000-7000 亿美金市场价值，尤其在 AI、药物研发、材料研发等领域有明确需求。**中科创星合伙人米磊**提出，自 2016 年以来，全球量子公司经历了显著的增长。据 2023 年中国信息通信研究院发布的《量子计算发展态势研究报告（2023 年）》数据显示，全球量子计算公司的数量已超过 400 家，反映出全球对于量子科技潜力的高度认可和积极投

资。上海在《上海打造未来产业创新高地发展壮大未来产业集群行动方案》中特别围绕量子计算、量子通信、量子测量，出台了相关政策，强化全链条布局支持，积极培育量子科技产业。

**Thirdly, the development of quantum technology will give birth to new industries and business models.** McKinsey predicts that quantum computing may reach a market value of US$300-700 billion by 2035, with clear demand in areas such as AI, drug development, and materials R&D. **Mi Lei, a partner of CASSTAR,** proposed that global quantum companies have experienced significant growth since 2016.According to the data in the "Research Report on the Development Trend of Quantum Computing (2023)" released by China Academy of Information and Communications Technology in 2023, the number of global quantum computing companies has exceeded 400, reflecting the high recognition and active investment of the potential of quantum technology worldwide. In the "Action Plan for Shanghai to Build a Future Industrial Innovation Highland and Develop and Expand Future Industrial Clusters", Shanghai has specially introduced relevant policies centering quantum computing, quantum communication, and quantum measurement, for the purpose of strengthening support for the entire chain layout and actively fostering the quantum technology industry.

## 二、量子科技创新的最新进展与态势

## 2. The latest progress and trend of quantum technology innovation

**1、量子计算领域：聚焦光在量子计算中的作用研究。韩国科学技术院教授、韩国物理学会分会主任 Jaewook Ahn** 指出，光镊作为强聚焦的激光束，可以实现整个光阱打造，从而以便捷的方式实现原子加速、单原子抛接以及里德堡原子碰撞之后的原子飞行。**匈牙利科学院院士、匈牙利 HUN-REN Wigner 物理学研究中心副主任 Peter Domokos** 指出，原子可以与光进行相互作用，可以与光对话，也可以成为光的操作对象，这就是原子的重要意义。**德国科学院院士、慕尼黑大学教授、马普量子光学研究所主任 Immanuel Bloch** 指出，通过晶格与光镊的结合，并在晶格中对原子进行分类，可以实现原则上对原子阵列的无期限连续操控，证明了晶格与光镊结合的可行性。**加州大学伯克利分校教授，劳伦斯伯克利国家实验室材料科学部教职科学家，加州量子计算挑战研究院主任 Dan Stamper-Kurn** 指出，镧系原子在光作用下可以观测到旋转，并会出现包括排斥、不稳态等各种各样的反应，有望通过这样的介导方式找到更多新的元素。

**(1) In the field of quantum computing: Research focusing on the role of light in quantum computing. Jaewook Ahn, Professor of the Korean Academy of Science and Technology (KAST) and Branch Director of the Korean Physical Society,** pointed out that as a strongly focused laser beam, the optical tweezer can achieve the construction of the entire light trap, thereby

achieving atomic acceleration, single atom throwing and catching, and atomic flight after Rydberg atomic collisions in a convenient way. **Peter Domokos, Member of the Hungarian Academy of Sciences (HAS) and Deputy Director of the Hungarian HUN-REN Wigner Research Centre for Physics**, pointed out that atoms can interact with light, communicate with light, and become objects of light manipulation, which is the important significance of atoms. **Immanuel Bloch, Member of the German National Academy of Sciences, Professor of the Ludwig-Maximilians University of Munich, and Director of the Max-Planck-Institute of Quantum Optics,** pointed out that by combining crystal lattices with optical tweezers and classifying atoms in the crystal lattice, we can achieve indefinite continuous manipulation of atomic arrays in principle, proving the feasibility of combining crystal lattices with optical tweezers. **Dan Stamper-Kurn, Professor of the University of California, Berkeley, Faculty Scientist of the Materials Science Department of Lawrence Berkeley National Laboratory, and Director of the Challenge Institute for Quantum Computation in California,** pointed out that we can observe the rotation of lanthanide atoms under the action of light, and various reactions including repulsion and instability can arise. It is expected that more new elements can be found through this mediating method.

**2、量子通讯领域：通讯安全是需要重点突破的关键。潘建伟**指出，我们所面临大规模安全量子通信的挑战，来自于因为现实设备不完美所造成的安全漏洞，这样的漏洞可能来自于不完美的单光子源或者不完美的单光子探测器，这都是我们可能面对的安全漏洞。**英国皇家学会院士、牛津大学教授、新加坡量子中心创始主任 Artur Ekert** 指出，若信息来自于你不信任的设备或实体，你根本不会使用它的通信手段，反之如果信息来自于你信任的实体设备，即拿即插即用就好，这让我们从另一个新颖视角反观当今的通信手段。

**(2) In the field of quantum communication: Communication security is a key area that requires breakthroughs. Pan Jianwei** pointed out that the challenge we face in large-scale secure quantum communication comes from security vulnerabilities caused by imperfect real devices. Such vulnerabilities may come from imperfect single photon sources or detectors, which are the security vulnerabilities we may face. **Artur Ekert, Fellow of the Royal Society, Professor of the University of Oxford, and Founding Director of the Center for Quantum Technologies (CQT) in Singapore,** pointed out that if the information comes from a device or entity that you do not trust, you will not use its communication methods at all. Conversely, if the information comes from a device or entity that you trust, you can plug and play and use it straight out of the box. This makes us to reflect on today's

communication methods from another novel perspective.

**3、量子精密测量领域：利用量子纠缠态提升量子测量精度。清华大学教授尤力**指出，多比特量子纠缠可以从无关联经典态通过相互作用演化产生，此状态下单个比特（粒子）的测量结果互相关联，多粒子系综平均的误差有可能小于经典极限或散粒噪声，从而超越经典精度极限。**加拿大量子谷创意实验室首席科学家 James Shaffer** 指出，里德堡原子传感器利用高度激发的原子作为天线，拥有自动校准能力，可以测量并读出光学数值，具有射频传感领域的高精度和稳定性。

**(3) In the field of quantum precision measurement: Take advantage of the entangled quantum state to improve quantum measurement accuracy. Professor You Li from Tsinghua University** pointed out that multi-bit quantum entanglement can be generated through the evolution of unrelated classical states through interactions. In this state, the measurement results of individual bits (particles) are interrelated, and the average error of multi-particle ensembles may be less than the classical limit or shot noise, thereby exceeding the classical accuracy limit. **James Shaffer, Chief Scientist of the Quantum Valley Ideas Laboratories in Canada,** pointed out that the Rydberg atomic sensor uses highly excited atoms as antennas, has automatic calibration capabilities, can measure and read optical values, and has high precision and stability in the field of RF sensing.

## 三、推进量子科技发展的相关建议

## 3. Recommendations for promoting the development of quantum technology

**一方面，强化多学科交叉融合，通过促进物理学、计算机科学、工程学等不同学科领域的深入合作与知识共享，激发出新的研究思路和解决方案。**这种跨学科的合作不仅能够拓宽研究视野，还能够促进创新技术的开发，为量子科技的突破性进展提供坚实的基础。通过构建多元化的研究团队和协同工作机制，可以更有效地整合各方资源，共同探索量子科技的无限可能，推动这一领域的持续繁荣和实际应用的快速发展。

**On the one hand, we should strengthen multidisciplinary cross-integration, and stimulate new research ideas and solutions by promoting in-depth cooperation and knowledge sharing in different disciplines such as physics, computer science, and engineering.** Such interdisciplinary collaboration not only can broaden research horizons, but also can promote the development of innovative technologies, providing a solid foundation for achieving breakthrough progress in quantum technology. By building diversified research teams and collaborative work mechanisms, we can more effectively integrate resources from all parties, jointly explore the infinite possibilities of quantum technology, and promote the sustained prosperity and rapid development of practical

applications in this field.

**另一方面，完善政策引导、资金支持和产学研深度融合，有效地推动量子科技从科研成果到实际应用的转化，加速量子产业的发展。米磊**认为，量子计算是量子科技产业化发展的关键领域，它在满足人工智能技术发展对算力的不断追求方面具有显著优势。因此，为了实现量子计算的广泛应用和商业价值，需要构建一个强大的产业生态，这包括政策支持、资金投入、人才培养、技术研发和市场需求等多个方面的协同努力。通过这样的多元主体深度融合，量子计算将有望在解决复杂科学问题和推动产业升级中发挥重要作用。

**On the other hand, we should improve policy guidance, financial support and the in-depth integration of industries, academia and research, effectively promote the transformation of quantum technology from scientific research results to practical applications, and accelerate the development of the quantum industry. Mi Lei** believes that quantum computing is a key area for the industrialization of quantum technology, and it has significant advantages in meeting the continuous pursuit of computing power in the development of artificial intelligence technology. Therefore, in order to achieve the widespread application and commercial value of quantum computing, it is necessary to build a strong industrial ecosystem, which includes coordinated efforts from multiple aspects such as policy support,

capital investment, talent cultivation, technology research and development, and market demand. Through such in-depth integration of multiple entities, quantum computing is expected to play an important role in solving complex scientific problems and promoting industrial upgrading.

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