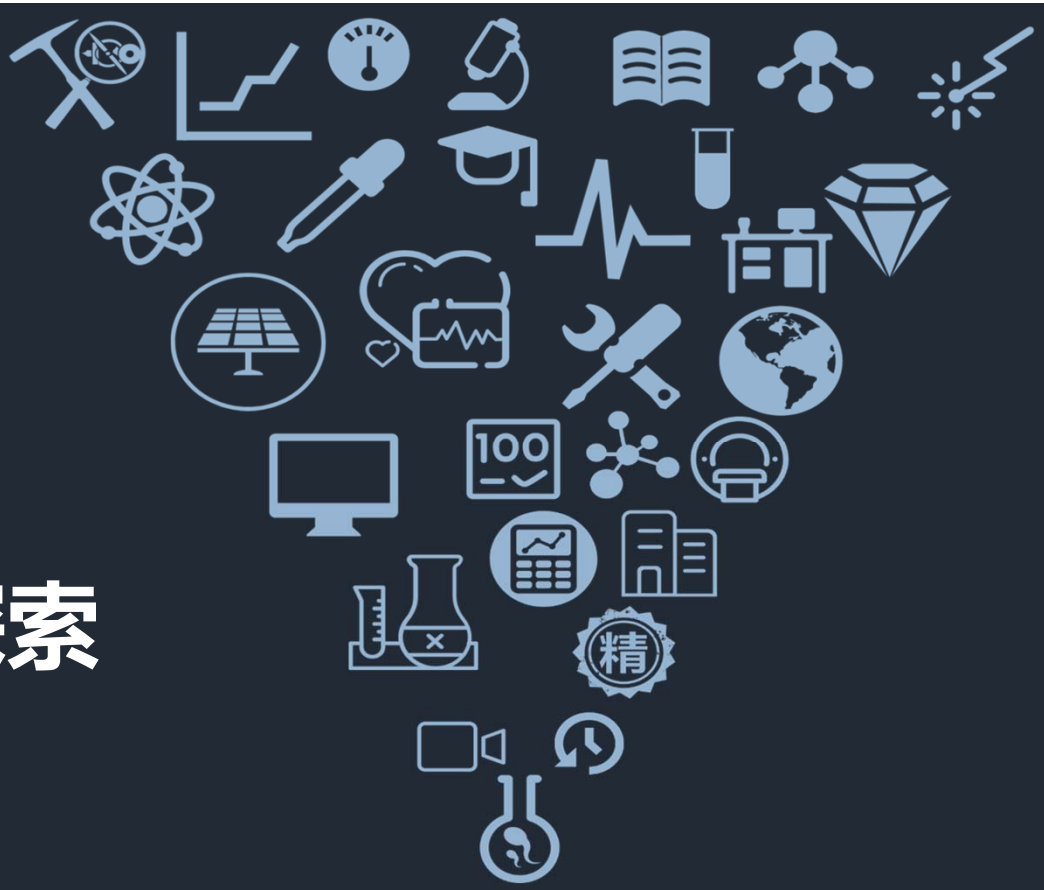


量子计算实验教学的实践探索

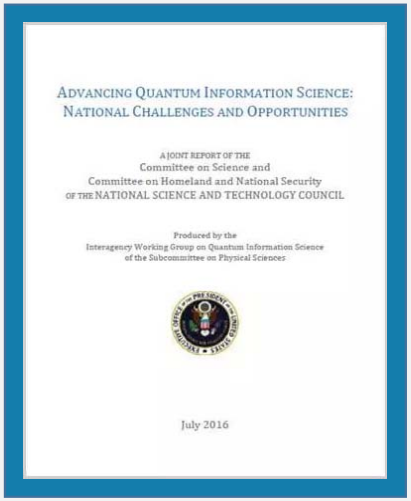
2019.08 / 吴亚

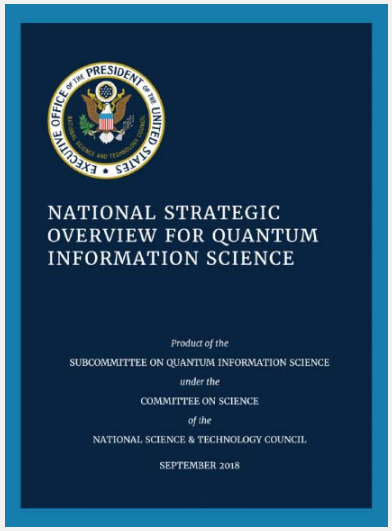
国仪量子（合肥）技术有限公司

多国重视量子产业布局

美国 2016年7月

《推进量子信息科学：国家挑战与机遇》

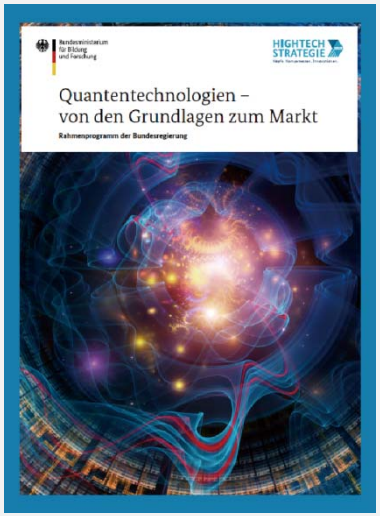




2018年9月
国会批准了为期10年的“量子研究加速计划”。
第一个三年拨款13亿美元。

德国 2018年11月

德国政府 《量子技术：从基础到市场》国家计划。
计划在本届政府内投入6.5亿欧元。
为量子技术的发展打下牢固的基础。

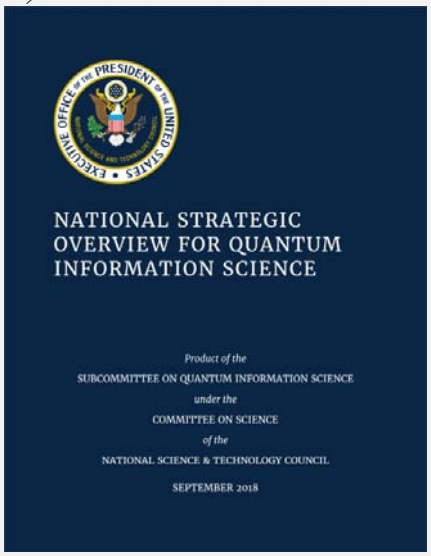


国内外企业投入量子产业

投入量子技术研发的企业

人才缺口
十分严重

急需培养量子技术人才



National Strategic Overview for Quantum Information Science

5 Creating a quantum-smart workforce for tomorrow

Growing an American quantum-smart workforce with expertise in a broad range of physical, information, and engineering sciences is crucial for assuring sustained progress in QIS. However, America's current educational system typically focuses on discrete disciplinary tracks, rarely emphasizing cross-disciplinary study that equips graduates for complex modern questions and challenges, prominently including QIS. While the responsibility of training students traditionally resides within the academic community, Government agencies and industry can partner with academia to meet the nation's future needs.

Experimental Quantum Physicist / Engineer
Mitre Corporation - Bedford, MA 4.1
Experimental Quantum Physicist / Engineer - (00050060). In this role, you will apply your technical experience in quantum physics and photonics to develop...
Estimated: $110,000 - $140,000 a year

Quantum Engineer
Rigetti Computing - Berkeley, CA
As a Quantum Engineer you will drive systematic improvements through Rigetti Computing's full stack quantum computing architecture....
Estimated: $120,000 - $160,000 a year

Quantum Engineer - Computational Modeling
Rigetti Computing - Berkeley, CA
As a quantum engineer for computational modeling you will be part of the team responsible for developing scalable and efficient simulation software....
Estimated: $100,000 - $140,000 a year 10d

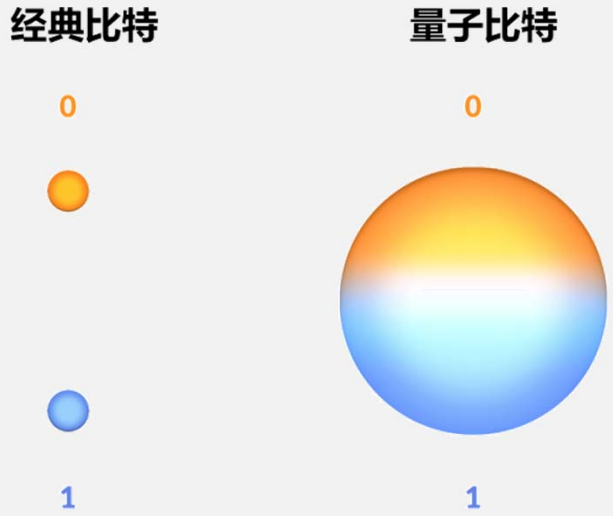
Quantum and Exotic Sensor Engineer
Mitre Corporation - McLean, VA 4.1
Quantum and Exotic Sensor Engineer - (00052476). In Physics, Chemistry, Electrical Engineering, or related fields with expertise in experimental quantum sensors...
Estimated: $74,000 - $110,000 a year

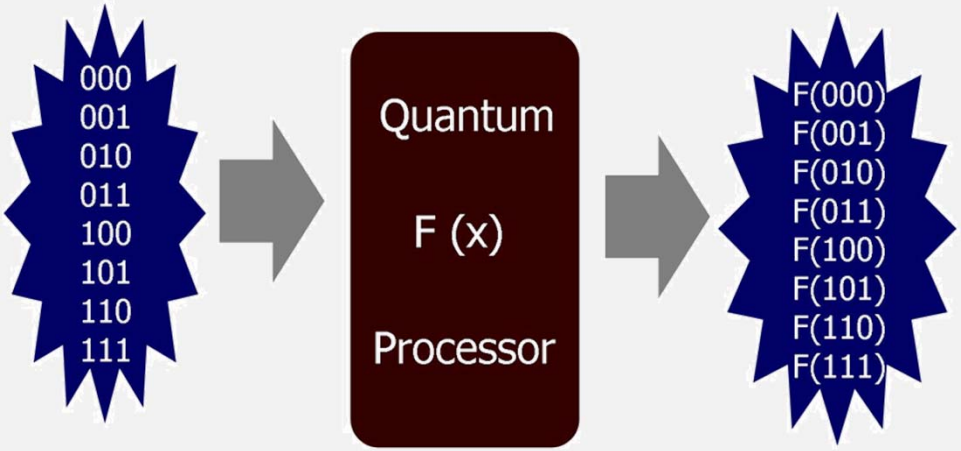
Quantum Engineer
Lawrence Livermore National Laboratory - Livermore, CA 4.2
We have an opening for a Quantum Engineer to support a full range of well-defined research in the areas of quantum computation, materials, and sensing....
Estimated: $89,000 - $120,000 a year

美国2018年发布《量子信息科学国家战略概述》
强调量子技术人才的培养

新兴量子产业需要量子科学家/量子工程师

什么是量子计算?





并行计算能力，处理某些问题更有优势

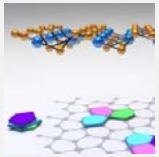
量子计算---引领未来发展

人工智能

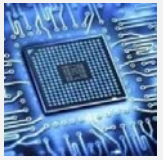
新药研发

飞船轨道计算

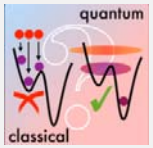
云计算



新材料发现



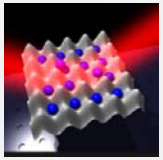
芯片缺陷仿真



退火算法

精准天气预报

投资组合优化

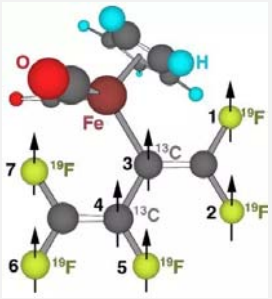


分子结构模拟

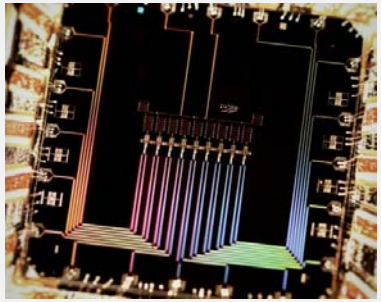
物流优化

解决交通拥堵

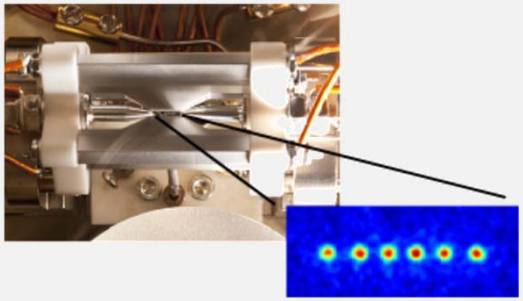
常见的量子计算体系



核磁



超导



离子阱

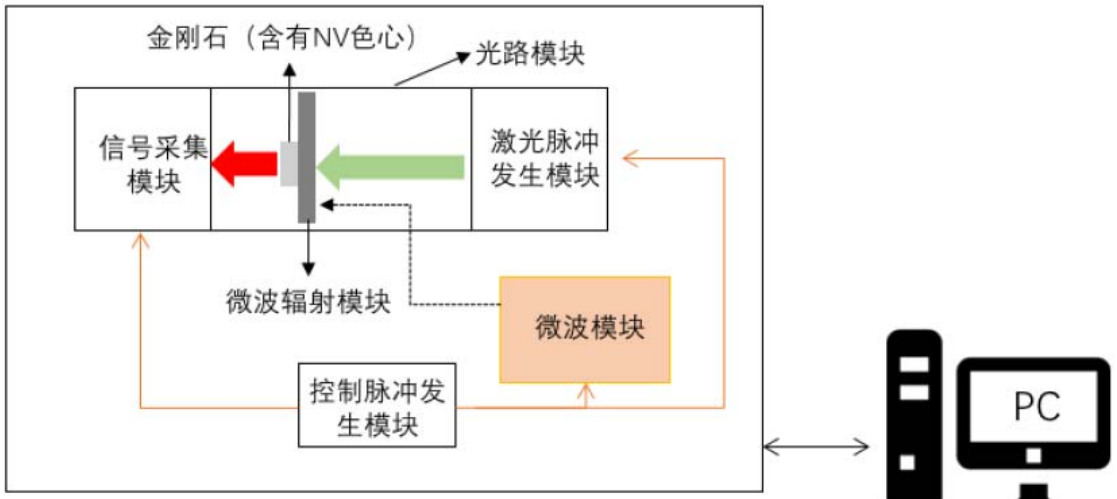
金刚石

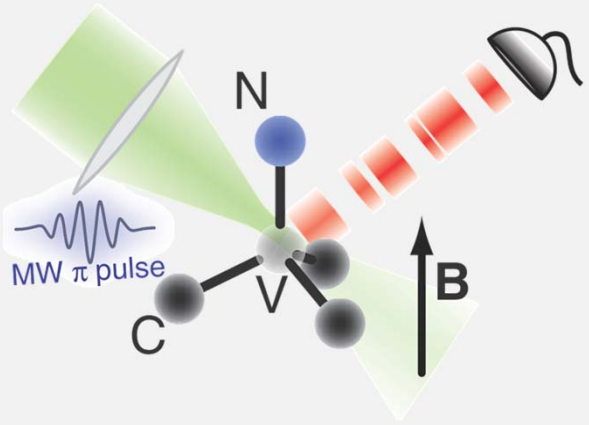
金刚石量子计算教学机

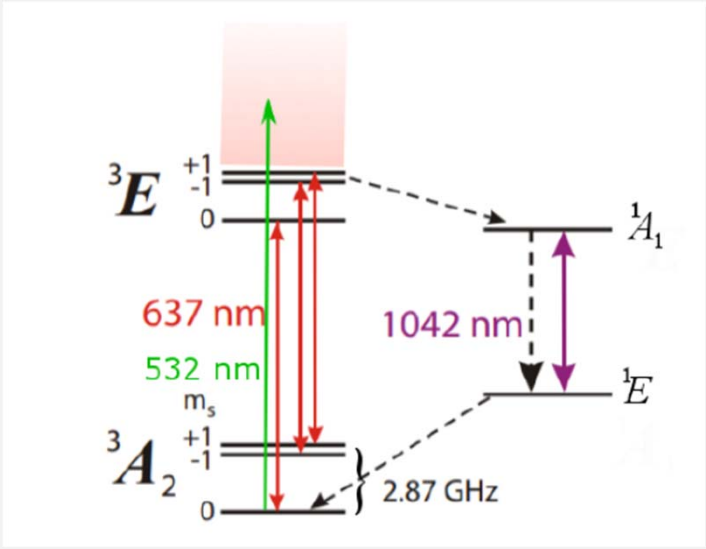
创新量子计算教育方式

- ✓ 基于金刚石NV色心体系
- ✓ 室温大气条件运行
- ✓ 零运行费用支出
- ✓ 桌面型更自由的使用环境
- ✓ 真实可感知两比特量子计算机

仪器原理


金刚石（含有NV色心）
光路模块
信号采集模块
激光脉冲发生模块
微波辐射模块
微波模块
控制脉冲发生模块
PC


N
MW π pulse
V
B
C


^3E
+1
-1
0
637 nm
532 nm
m_s
$^3A_2$
+1
-1
0
2.87 GHz
$^1A_1$
1042 nm
^1E

成体系的知识教学

◆丰富的配套实验

- 仪器调节实验
- 连续波实验
- 拉比振荡实验
- 回波实验
- T2实验
- D.J.算法实验

科学素养的培养同样重要！

◆量子力学基本概念教学

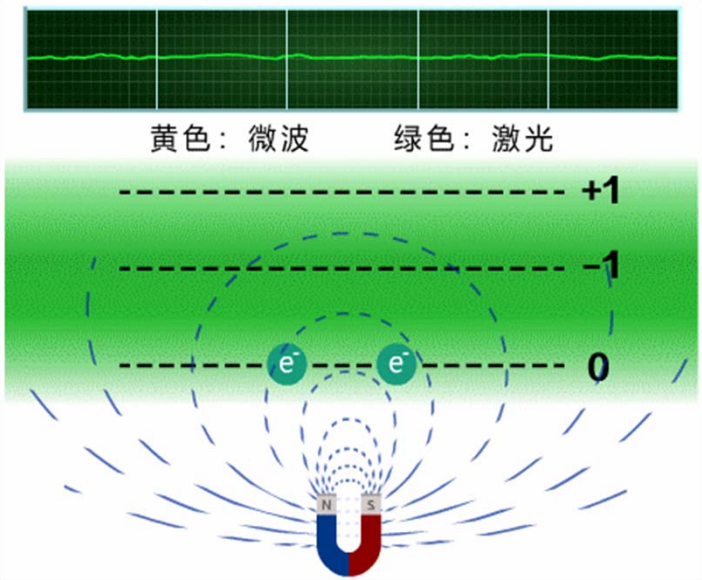
- 量子态
- 量子态演化
- 电子自旋

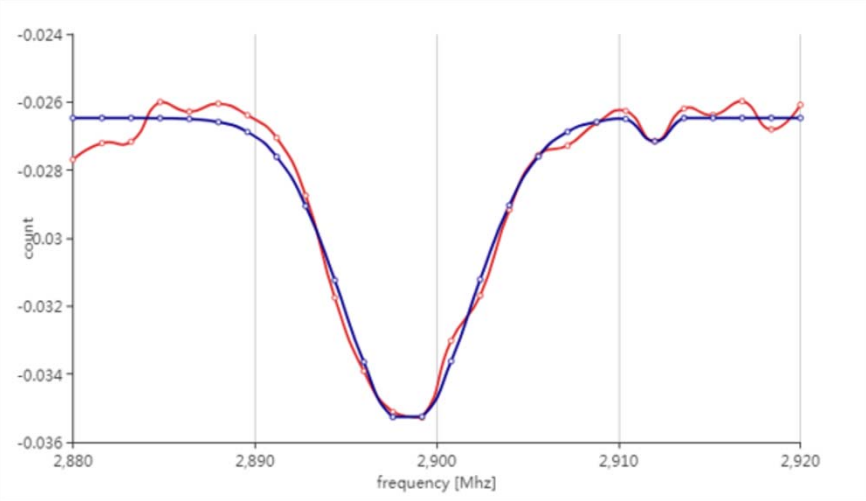
◆ 量子计算教学

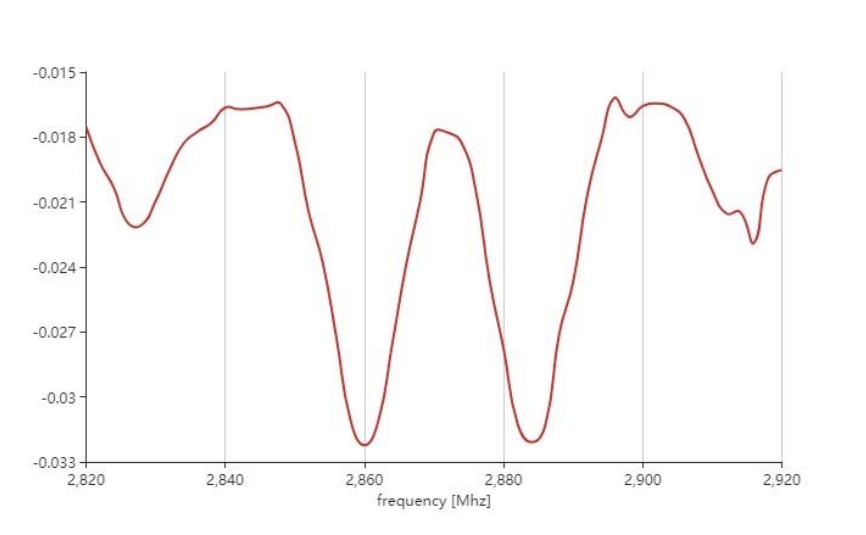
- 量子比特
- 量子逻辑门操作
- 量子算法

连续波实验

- 塞曼效应
- 量子比特





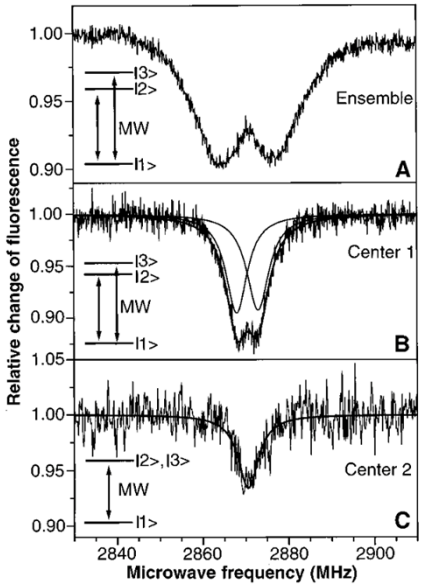


连续波实验

Science

Scanning Confocal Optical Microscopy and Magnetic Resonance on Single Defect Centers

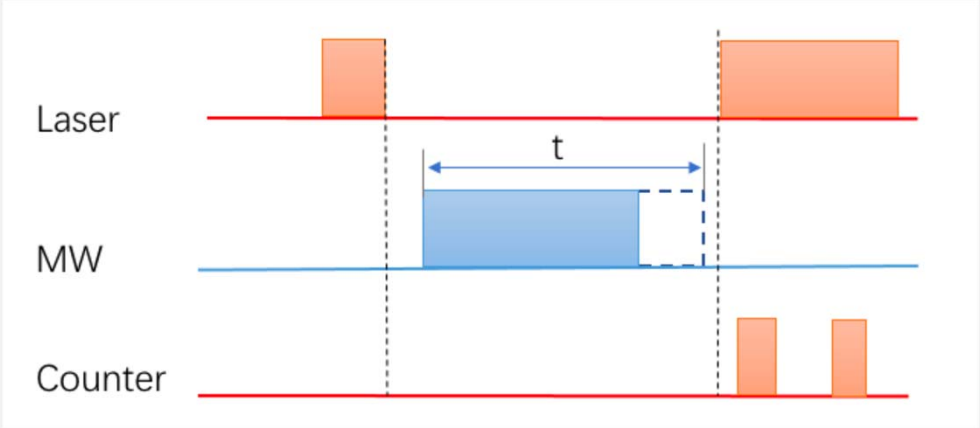
A. Gruber, A. Dräbenstedt, C. Tietz, L. Fleury, J. Wrachtrup and C. von Borczyskowski

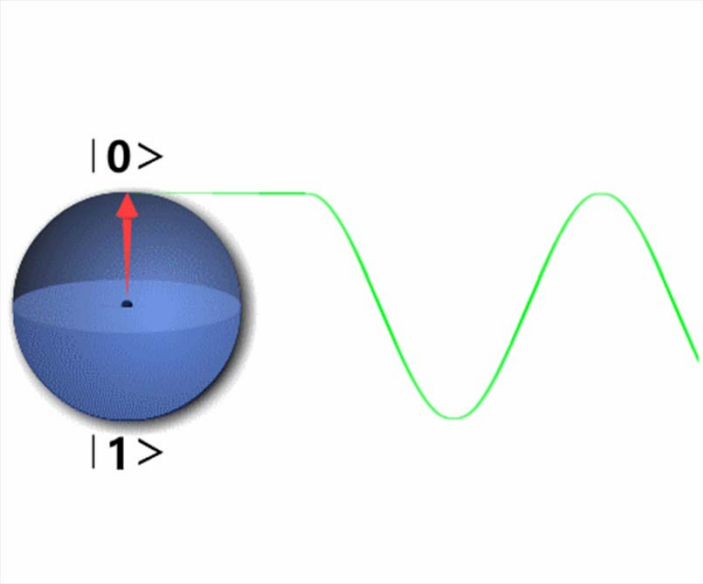


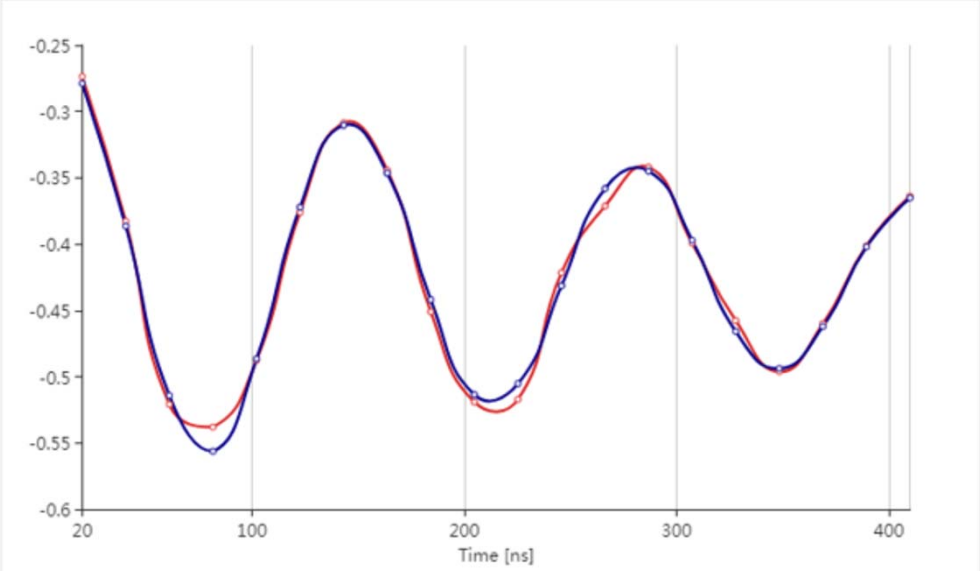
基于NV色心的连续波实验

拉比振荡实验

- 拉比振荡现象
- 量子比特操控



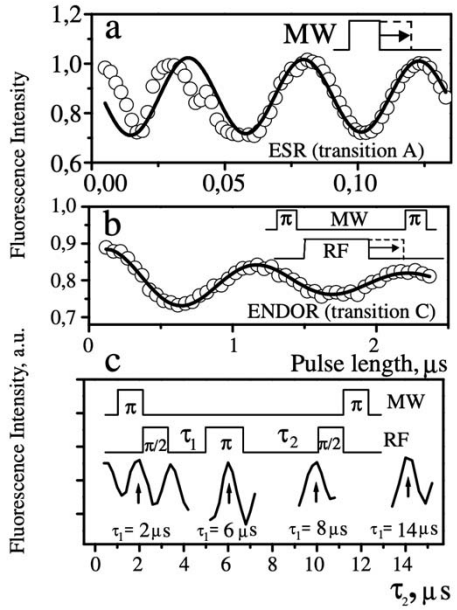




拉比振荡实验

VOLUME 93, NUMBER 13 PHYSICAL REVIEW LETTERS week ending 24 SEPTEMBER 2004

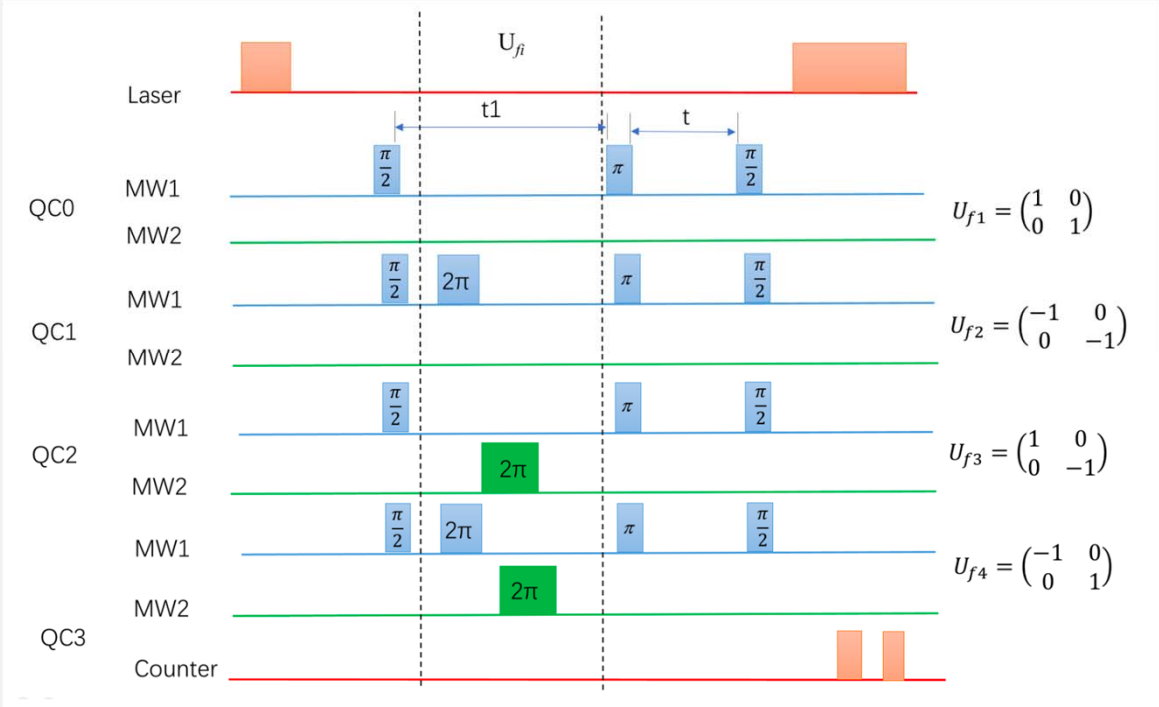
Observation of Coherent Oscillation of a Single Nuclear Spin and Realization of a Two-Qubit Conditional Quantum Gate



基于NV色心的拉比振荡实验

D.J.算法实验

- 经典量子算法
- 学习量子算法的并行性
- 理解量子算法的原理
- 源于优秀的科研成果



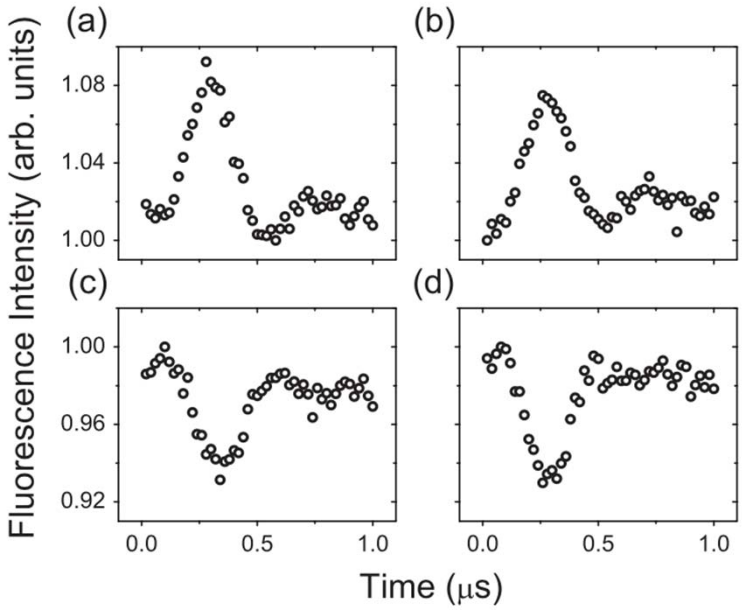
$$U_{f1} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \Leftrightarrow f(x) = 0 \qquad U_{f3} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \Leftrightarrow f(x) = x$$

$$U_{f2} = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix} \Leftrightarrow f(x) = 1 \qquad U_{f4} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \Leftrightarrow f(x) = 1 - x$$

D.J.算法实验

PRL 105, 040504 (2010) PHYSICAL REVIEW LETTERS week ending 23 JULY 2010

Room-Temperature Implementation of the Deutsch-Jozsa Algorithm with a Single Electronic Spin in Diamond



第一个基于NV色心的量子算法

成体系的知识教学

◆提供更多扩展教学的可能性

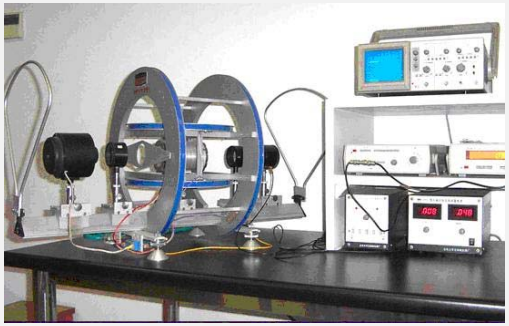
- 动力学去耦实验
- 磁共振知识教学
- 光探测磁共振教学
- 量子精密测量教学
- ……

针对教学的量子计算教学机

- 成体系的量子力学与量子计算知识教学
- 经典实验的直观再现
- 系统性的学习量子计算
- 学习做实验同时也是在学习做科研

=

+



量子计算教学设备

应用案例

中科大率先开设量子计算实验课程


综合教务系统 | 公共信息查询平

课表查询

开课学期：2018年春季学期　选课类别：本科生课程　查询方式：课程编号

序号	课堂号	课程名称	学分	周学时	教师
1	00407401	物理学专业基础实验	2.0	6	张增明,刘磁辉
2	00407402	物理学专业基础实验	2.0	6	张增明,刘磁辉
3	00407404	物理学专业基础实验	2.0	6	孙腊珍,孙金华
4	00407405	物理学专业基础实验	2.0	6	孙腊珍,孙金华

123名学生自主报选


2018-2019学年第二学期

量子计算实验课

荣星/石发展

中国科学技术大学

4, 2019

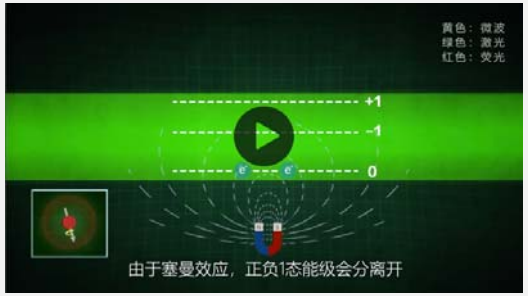
1

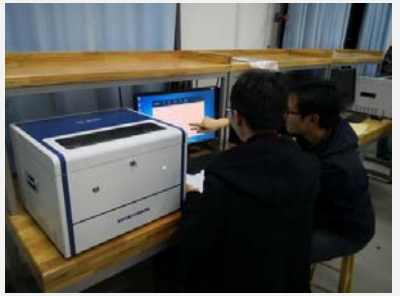
教学形式

理论

实验

物理实验教学完整解决方案





教学讲义　　教学视频　　教学课件　　示范课培训

Thank you

用量子改变世界

Change the world in a quantum way