

Physical Society of Hong Kong
50th Anniversary of the Laser
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Laser in Quantum Technology

激光 於 量子 工业技术

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Laser for Future Quantum Technology

激光为未来量子工业技术

Laser can control a single atom or electron

- Therefore engineering and processing quantum states.

Is Current Laser Technology Quantum?

- Information controlled is classical (e.g. laser disc).
- Underlying physics is quantum of a large system.

Advantages of Q Tech

- A revolution
- Exponentially more capacity and higher speed

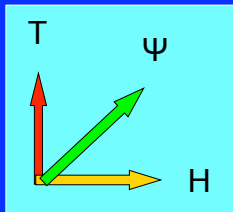
Coin: Quantum versus Classical



http://en.wikipedia.org/wiki/Hong_Kong_Dollar



<http://plainview.files.wordpress.com/>



State 状态	Classical coin	Quantum coin
On the table	H or T	H or T
Information bit 信息单位	0 or 1	Simultaneous 0, 1
State in the air	Rigid body motion	$\Psi = H + T$
Probabilities 或然率	50 : 50	50 : 50
Difference 差别	Missing knowledge	A pure state at 45°

Electron Spin in Self Assembled Quantum Dots

电子自旋

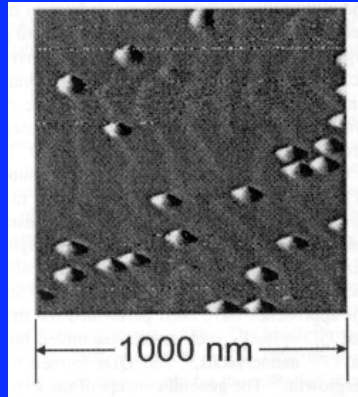
自组装量子点

Strain-induced
quantum dots
(3-10 nm)

InAs lattice mismatch



Scanning probe image of SAQD



A.Zrenner, et al.
J.Chem.Phys. **112**, 7790 (2000).

Three Basic Issues for Q Tech

量子 工业技术 三关键

State: Its coherence 相干性 (quantum-ness 量子性)

- Losing the excited state (energy loss 能量损失)
- Losing the superposition (the vector sum 矢量和)

Processing 处理 : Precision control 精度控制

- Scalability 可扩展性
- Precision of small angle rotations 小角度旋转

Readout 读出 : Reliability 可靠性

- Quantum measurement by classical instrument
- Interface between the micro and the macro

Relaxation & Decoherence of q-Coin by Environment

Decoherence

相干性损失

Prepare state

Coin + Environment 环境

$$(\beta |H\rangle + \alpha |T\rangle) |J\rangle$$

In time

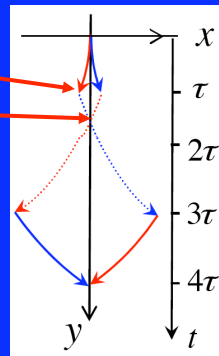
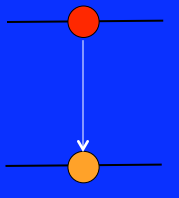
$$\beta |H\rangle |J^H\rangle + \alpha |T\rangle |J^T\rangle$$

Maxwell angel 天使 flips the coin at τ

Coherence recovery

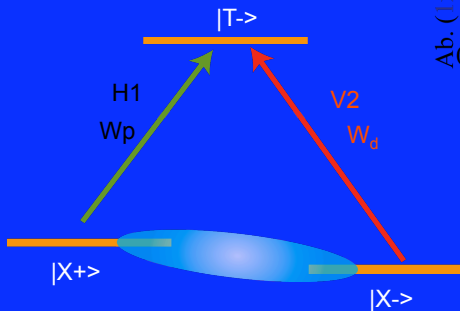
Relaxation 能量损失

Irreversible but state quantum



Stabilizing electron spin coherence by nuclear spins 安定相干性

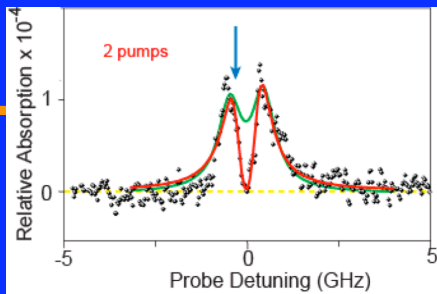
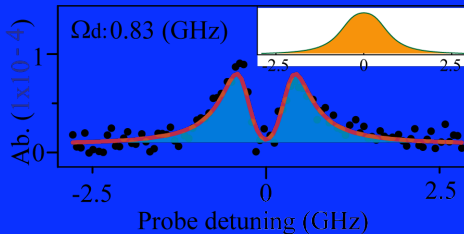
Formation of a Dark State



Xiaodong Xu, Wang Yao, Bo Sun, Steel, Bracker, Gammon & Sham, Nature 2009

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Probe absorption vs frequency



High Precision Rotation of Small Angle 高精度小角度旋转

Define two axes

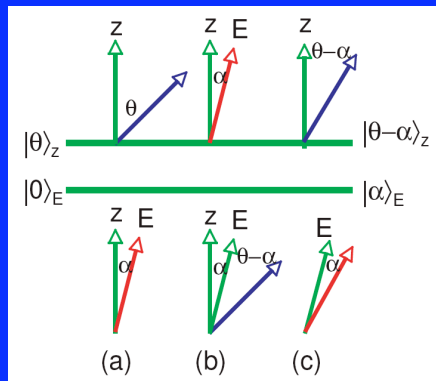
- Global 全体的
- Local 地方性的

Rotation $\theta \rightarrow \theta - \alpha$

- Swap 交换 by global axes
- Swap by local axes

High precision

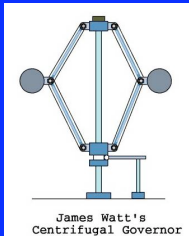
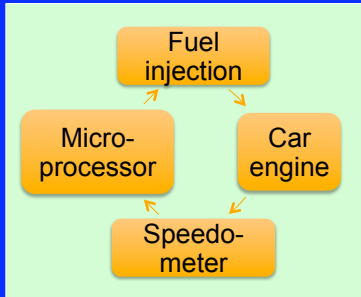
- Next slide



Classical

Control 控制 & Feedback 反馈

Quantum



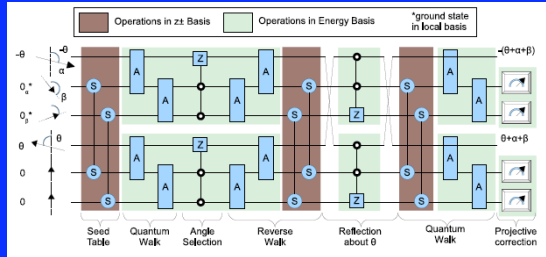
<http://www.cai.cam.ac.uk/people/dmh/engineering/engineer03/cefirstrleng.htm>

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Quantum error correction



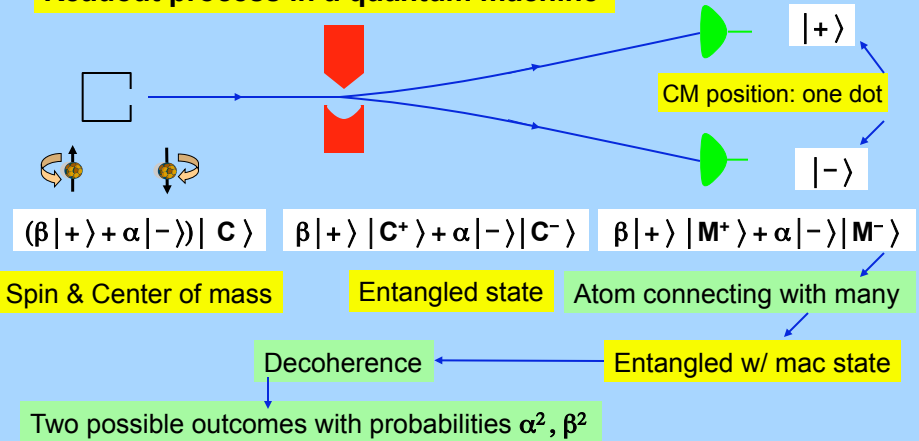
Quantum feedback



Parin Dalal thesis 2009

A textbook example of the measurement process 测量过程

Readout process in a quantum machine



The measurement problem: how does one describe the step to actual readout

Summary: Solutions for Issues in Q Tech 关键解答

State: Its coherence 相干性 (quantum-ness 量子性)

- Protected or reversed: Maxwell Angel vs Maxwell Demon

Processing (operations): Precision control 精度控制

- Precision by swaps + efficient all-quantum feedback

Readout 表现 : Reliability 可靠性

- Not done justice to quantum + statistical methodology
- Measurement problem by informational metaphysics

Recommended reading 推荐读物

- B. Schumacher and M. Westmoreland, "*Quantum Processes, Systems, and Information*", (CUP 2010)
- Luciano Floridi, "*Information – A Very Short Introduction*" (OUP 2010)

Collaborators: Cast of Thousands – A 12 year production

UCSD
Theory

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Sophia Economou
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