Netural Atom Quantum Computation introduction

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main reference

1). Henriet, Loic, Lucas Beguin, Adrien Signoles, Thierry Lahaye, Antoine Browaeys, Georges-Olivier Reymond, and Christophe Jurczak. **Quantum Computing with Neutral Atoms**. Quantum 4 (21 September 2020): 327. `https://doi.org/10.22331/q-2020-09-21-327`.

2). Bluvstein, Dolev, Simon J. Evered, Alexandra A. Geim, Sophie H. Li, Hengyun Zhou, Tom Manovitz, Sepehr Ebadi, et al. **Logical Quantum Processor Based on Reconfigurable Atom Arrays**. Nature 626, no. 7997 (1 February 2024): 58–65. `https://doi.org/10.1038/s41586-023-06927-3`.

Outline

1. **principle**

2. device

3. synthess

Outline

1. **principle**
   - control
   - operation

2. **device**
   - scalability
   - error correction

3. **synthess**

optical tweezers[1]

1. the diameter of a trapped particle $\gg$ the wavelength of light

2. the diameter of a trapped particle $\ll$ the wavelength of light

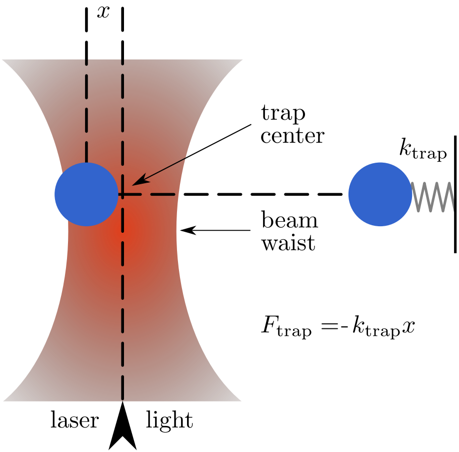

Figure: Dielectric objects are attracted to the center of the beam, slightly above the beam waist

[1] https://en.wikipedia.org/wiki/Optical_tweezers

Electric dipole approximation

1). Induction by light (assume the dielectric particle is linear):

$$p = \alpha \cdot E_{light}$$

p is the induced dipole moment, E_{light} is the electric field of the light, and α is the polarizability of the atom

2). Gradient Force:

$$F_{gradient} = \nabla(p \cdot E_{light})$$

optical lattice / optical tweezers array[2]

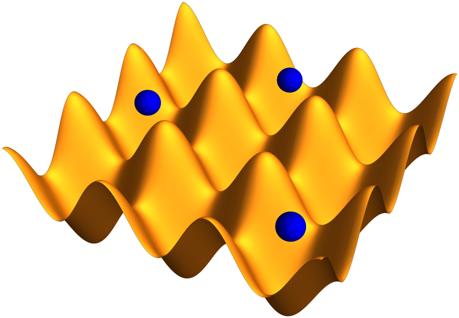

Figure: Atoms (represented as blue spheres) pictured in a 2D-optical lattice potential (represented as the yellow surface)

[2] https://en.wikipedia.org/wiki/Optical_lattice

AOD VS. SLM

1). **Amplitude Object Design (AOD):**

Operating Principle: Uses acoustic waves to diffract and control light's amplitude.

Advantages: Features high-speed modulation and scanning capabilities, low power consumption, and robustness for long-term use.

Limitations: Restricted to amplitude modulation without phase control, possible noise from acoustic wave generation, and efficiency dependent on material properties.

2). **Spatial Light Modulator (SLM):**

Operating Principle: Modulates light's amplitude, phase, or polarization through an array of individually adjustable pixels, enabling complex light pattern generation.

Advantages: Capable of intricate wavefront shaping and modulation across amplitude, phase, and polarization.

Limitations: Higher complexity and cost, potential diffraction artifacts due to its pixelated nature, and limited refresh rate for dynamic applications.

develop histroy

1). Bose-Einstein condensate

2). Endres, Manuel, Hannes Bernien, Alexander Keesling, Harry Levine, Eric R. Anschuetz, Alexandre Krajenbrink, Crystal Senko, Vladan Vuletic, Markus Greiner, and Mikhail D. Lukin. "Atom-by-atom assembly of defect-free one-dimensional cold atom arrays." Science 354, no. 6315 (2016): 1024-1027. `https://www.science.org/doi/abs/10.1126/science.aah3752`.

3). Barredo, Daniel, Sylvain de Léséleuc, Vincent Lienhard, Thierry Lahaye, and Antoine Browaeys. "An atom-by-atom assembler of defect-free arbitrary two-dimensional atomic arrays." Science 354, no. 6315 (2016): 1021-1023. `https://www.science.org/doi/abs/10.1126/science.aah3778`.

work flow

1). metal

2). atomic beam

3). cooling

   1). zeeman slower

   2). 2D MOT

   3). 3D MOT

4). optical lattice

5). rearrange

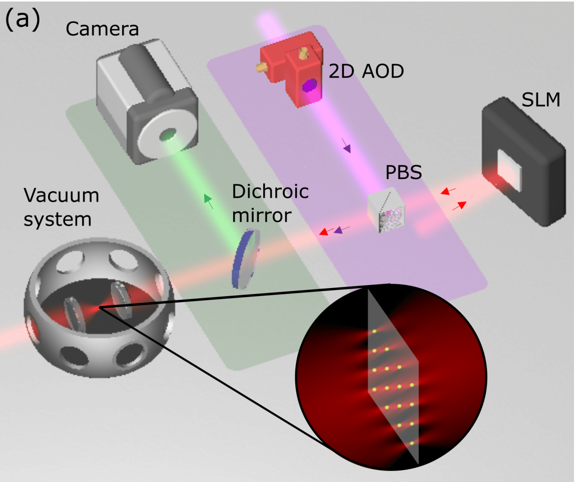

Figure: Overview of the main hardware components constituting a quantum processor

rearrange

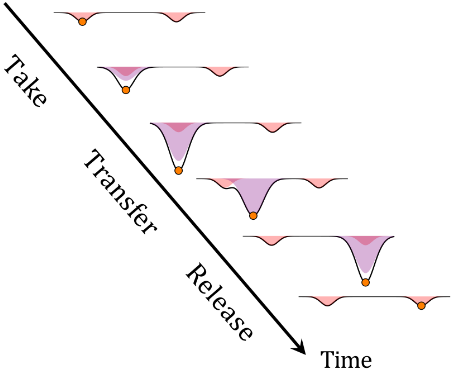

Figure: Moving a single atom from one site to another (both in red) in the register

some confused words

1). qubit sites

2). a mean number of loading individual atoms

3). defect-free atomic qubit clusters

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readout

single-qubit gate

multi-qubit gate

Hamilition operation

summarize

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breakthrough

1). Pause, Lars, Lukas Sturm, Marcel Mittenbühler, Stephan Amann, Tilman Preuschoff, Dominik Schäffner, Malte Schlosser, and Gerhard Birkl. **Supercharged Two-Dimensional Tweezer Array with More than 1000 Atomic Qubits**. Optica 11, no. 2 (7 February 2024): 222. `https://doi.org/10.1364/OPTICA.513551`.

2). Norcia, M. A., H. Kim, W. B. Cairncross, M. Stone, A. Ryou, M. Jaffe, M. O. Brown, et al. **Iterative Assembly of ^{171}Yb Atom Arrays in Cavity-Enhanced Optical Lattices**. arXiv, 9 February 2024. `http://arxiv.org/abs/2401.16177`.

3). Gyger, Flavien, Maximilian Ammenwerth, Renhao Tao, Hendrik Timme, Stepan Snigirev, Immanuel Bloch, and Johannes Zeiher. **Continuous Operation of Large-Scale Atom Arrays in Optical Lattices**. arXiv, 10 February 2024. `http://arxiv.org/abs/2402.04994`.

Atom Computing

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summarize

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set up

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discussion