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, Harry Levine, Giulia Semeghini, Tout T. Wang, Sepehr Ebadi, Marcin Kalinowski, Alexander Keesling, et al. **A Quantum Processor Based on Coherent Transport of Entangled Atom Arrays**. Nature 604, no. 7906 (21 April 2022): 451–56. https://doi.org/10.1038/s41586-022-04592-6.

Outline

1. **principle**
   - control
   - operation
2. **device**
3. **computation**
   - compilition
   - eror correction

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

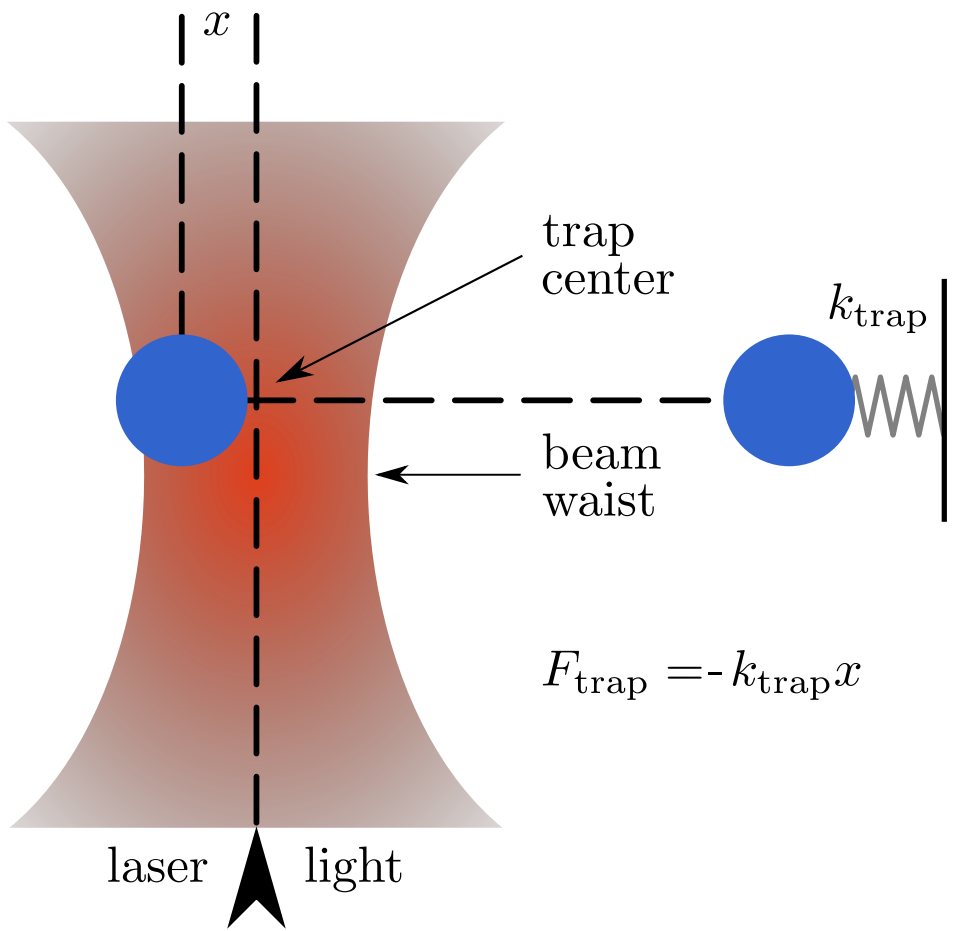

Figure: Dielectric objects are attracted to the center of the beam, slightly above the beam waist

[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[2]

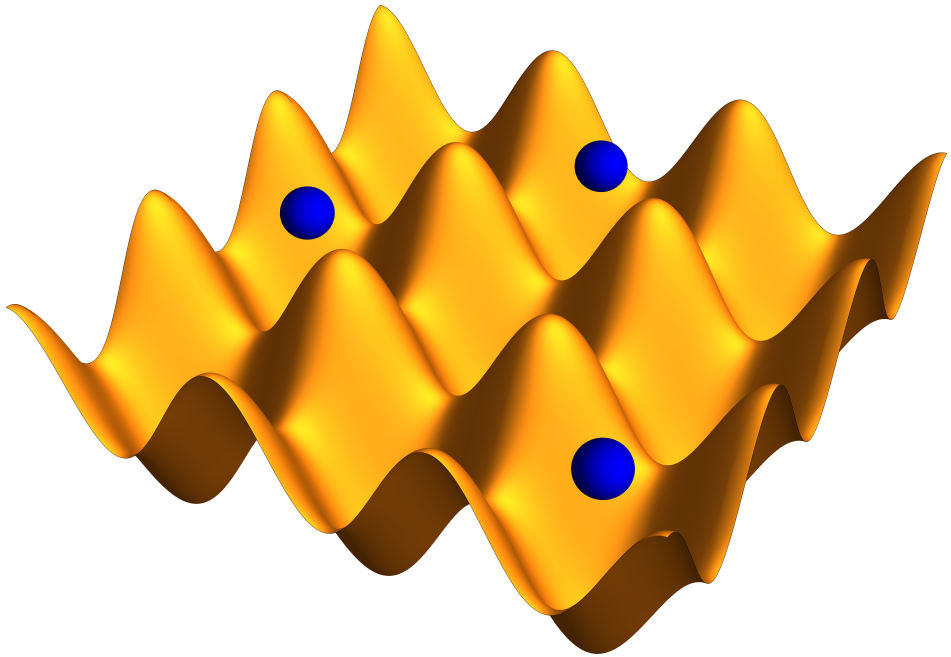

Figure: Atoms (represented as blue spheres) pictured in a 2D-optical lattice potential (represented as the yellow surface)

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

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

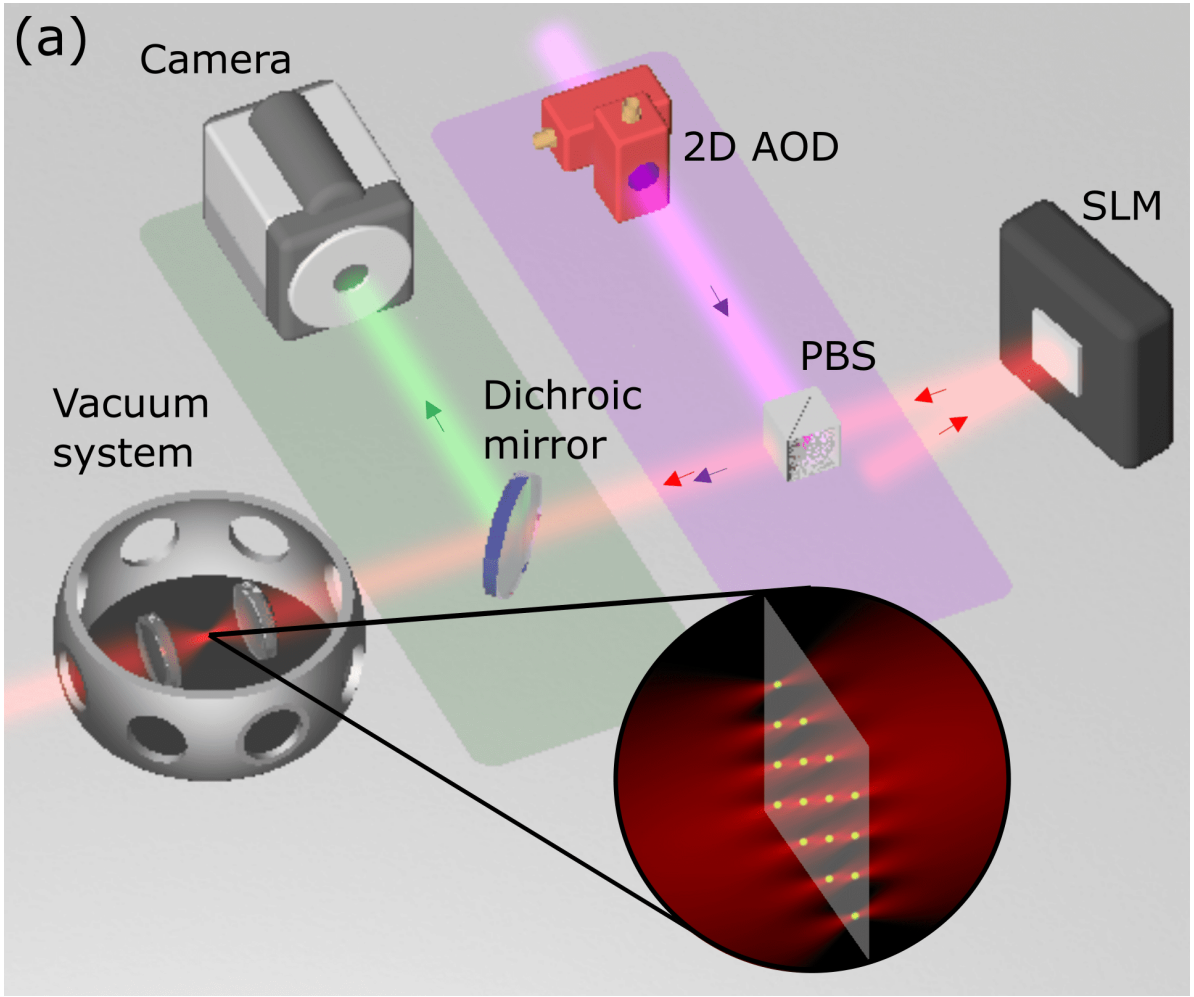

Figure: Overview of the main hardware components constituting a quantum processor

rearrange

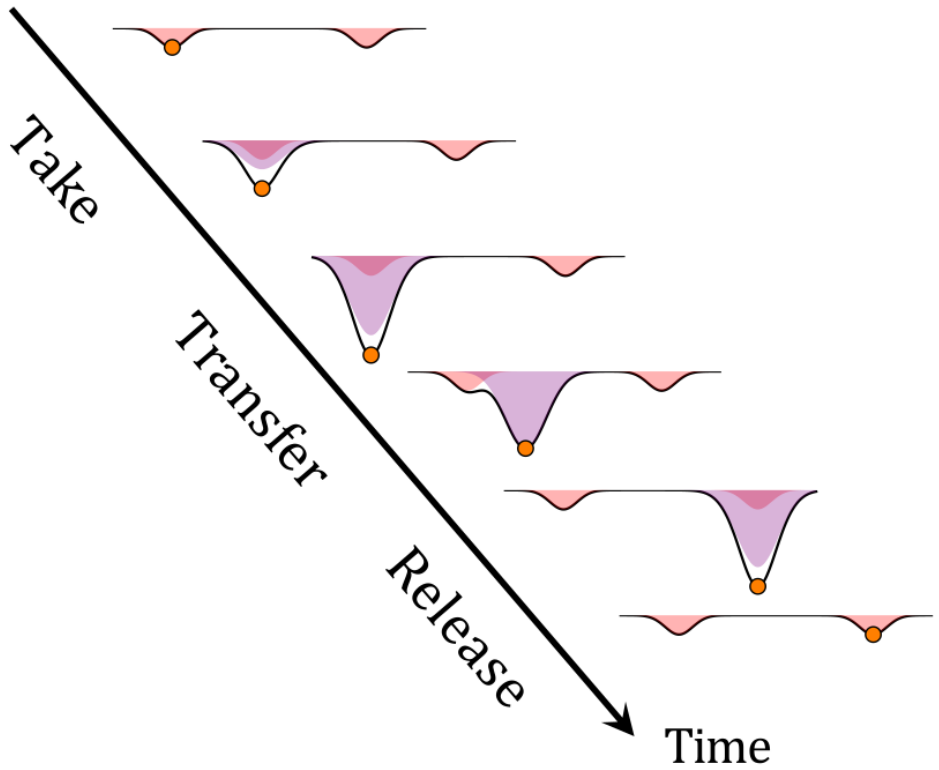

Figure: Moving a single atom from one site to another (both in red) in the register

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.

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readout

single-qubit gate

multi-qubit gate

Hamilition operation

summarize

breakthrough

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set up

Outline

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discussion