

# 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

- control
- operation

## 2. device

## 3. computation

- compilation
- error correction

# Outline

## 1. principle

- control
- operation

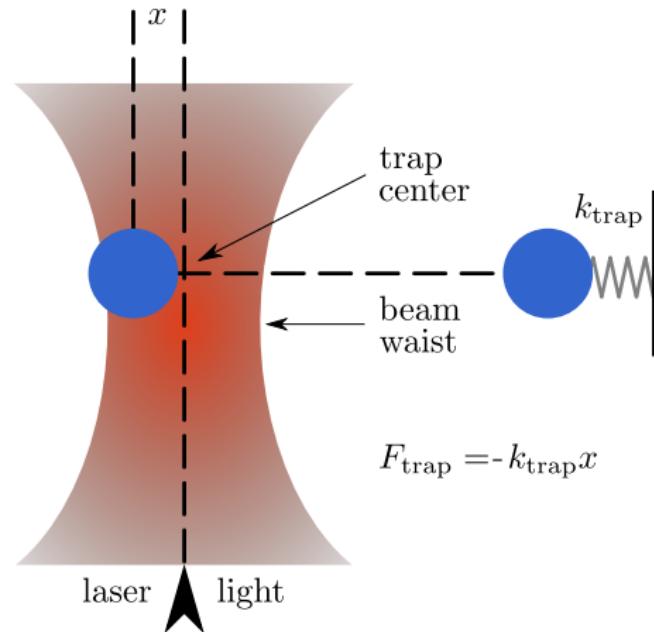
## 2. device

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# optical tweezers<sup>1</sup>

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

<sup>1</sup>[https://en.wikipedia.org/wiki/Optical\\_tweezers](https://en.wikipedia.org/wiki/Optical_tweezers)

# Electric dipole approximation

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

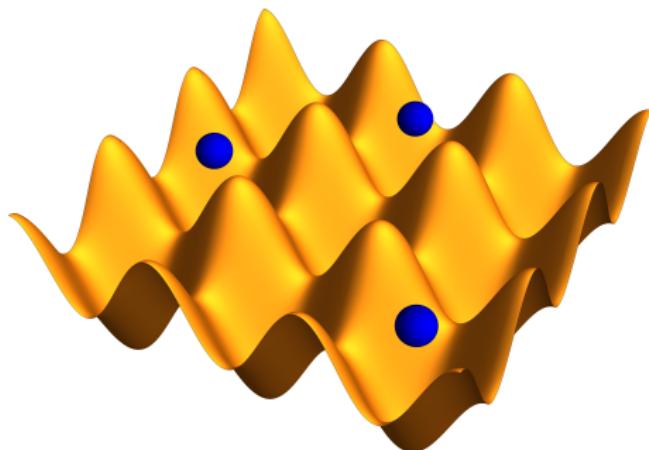
$$p = \alpha \cdot E_{light}$$

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

- 2). Gradient Force:

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

# optical lattice<sup>2</sup>



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

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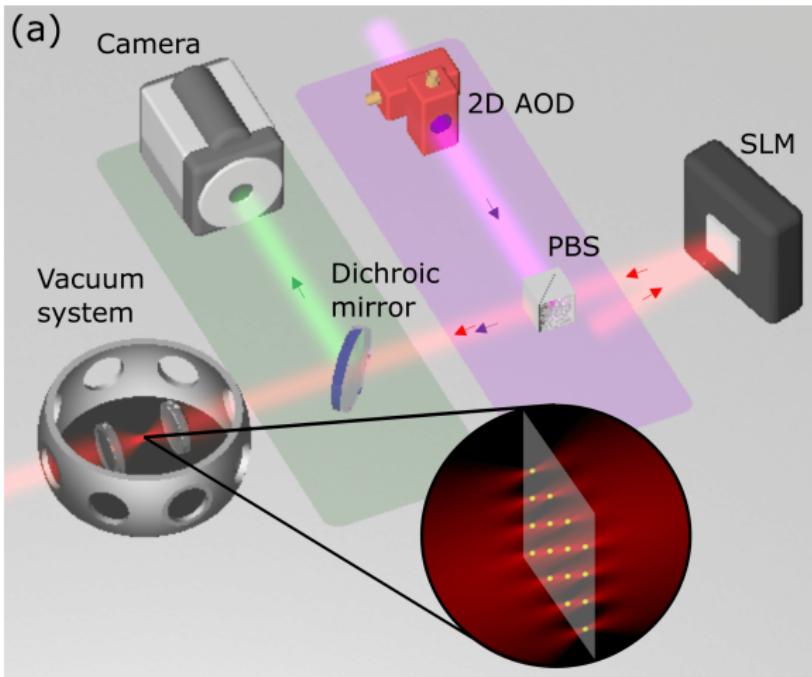
<sup>2</sup>[https://en.wikipedia.org/wiki/Optical\\_lattice](https://en.wikipedia.org/wiki/Optical_lattice)

# 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>.

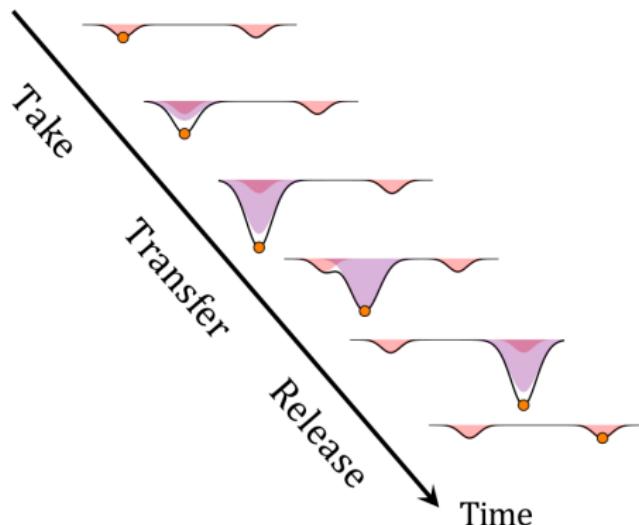
# work flow

- 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

# Hamiliton operation

# summarize

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# breakthrough

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# set up

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# discussion