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In order to overcome the limitations of classical computing

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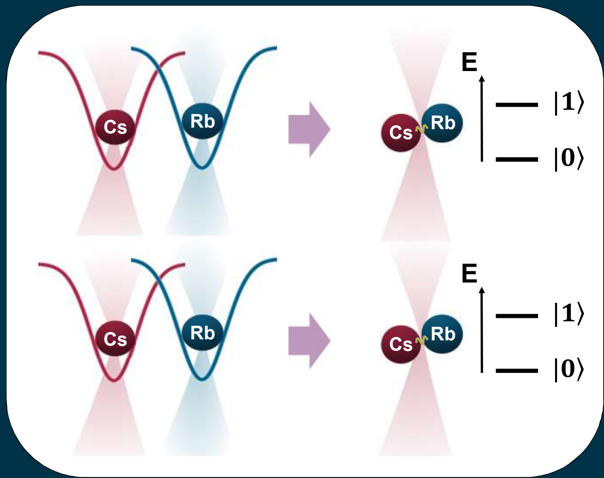
Assembling a Molecular Quantum Computer with Optical Tweezers



Quantum computing is an attractive solution to complex problems that are slow or unsolvable on classical computers:

- Quantum machine learning algorithms [1]
  - Facial recognition
  - Self-driving vehicles
  - Speech recognition
- Deep learning neural networks used in AI [2]
- Simulations of chemical interactions between drugs and targets to determine candidates for drug development [3].
- Pricing financial derivatives and analysing risk [4].
- Optimisation of reaction processes for fertiliser production [5]

Why use molecules in tweezers?

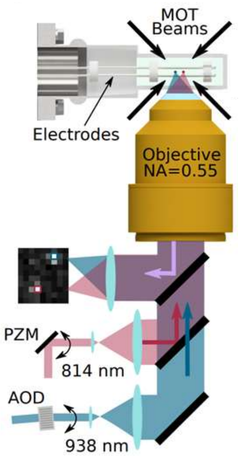
Molecules have a diverse set of quantum states [6]. These can be controlled with microwaves and lasers. Interactions between molecules can act like computer processors [7]. Superposition and entanglement can be used to design fast algorithms.

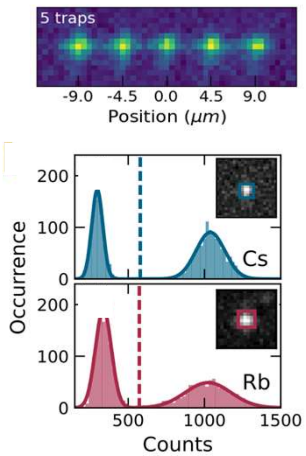
Optical tweezers are formed from lasers focused down to a spot on the order of ~1μm. Atoms held in this small trap collide until either 1 or 0 atoms remain [8]. Optical tweezers are used to:

- trap single particles.
- precisely control their position.
- arrange them in arbitrary geometries.

Step 1: trap single atoms

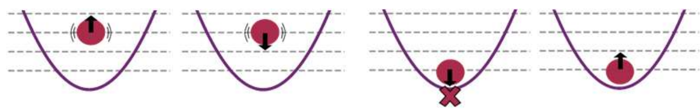
A vapour of atoms is contained in a glass cell under vacuum. The objective lens focuses 814nm and 938nm lasers to form optical tweezers. An atom is trapped in the tweezer after initial laser cooling. The lens also collects light emitted by the atoms to form an image.

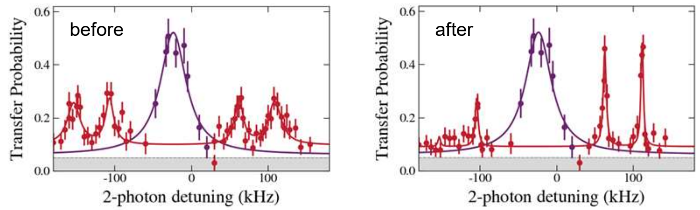




Step 2: remove motional energy

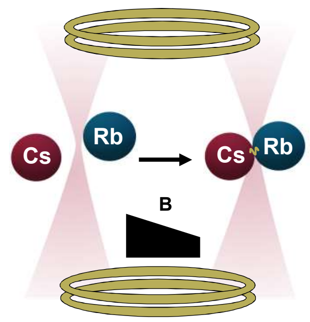
The atoms are moving in the trap. To get them close enough to form molecules, we must cool them down. We use Raman sideband cooling to iteratively dissipate quanta of energy from the atom [9]. After cooling, the possibility of removing energy vanishes.

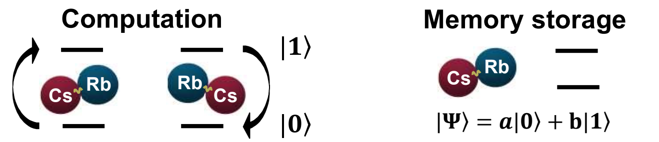




Outlook: producing molecules

Two atoms are merged into the same trap and combined into a molecule by varying a magnetic field. The process is scaled up to produce an array of molecules simultaneously. Molecules can be held for up to ~1s, during which time they can each complete thousands of interactions.





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