Cold Atoms: A Way To Quantum Computing?

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Purpose:

- Computers are advanced, but they are limited by scale.
- The components which make a computer work, (circuits chips, basic modules, logic gates, transistors and more) can only become so small until **quantum mechanics**[9] break the mechanisms of traditional computers.[6]
- Additionally, traditional computers use **bits** to perform one set of computations.[6]
- While this process is efficient, the future quantum computing presents is one that approaches the characteristics of traditional computers in a different manner.
- This provides both advantages (for the simulation of quantum processes and encryption) and disadvantages (mainly through decoherence).[3,8]

Introduction:

How does one go about the construction of a quantum computer?

- Through the utilization of **qubits**. Qubits are like bits, except qubits have **quantum properties**.[3,6,8]
- With the use of **superposition** qubits can hold the value of both 0 and 1 at the same time.[6]
- This is a useful property when compared to bits, as bits can only represent one value at a time. Qubits on the other hand can represent both values at the same time, which can therefore create a computer which can efficiently calculate certain problems in ways that classical computers don't have the capacities to.[4]

Figure 1: Rubidium 85, as represented by the periodic table of elements. [10]

- In the LeBlanc lab, the quantum properties that are studied are the **energy levels of rubidium 87**.[4,5]
- This is done by cooling atoms of rubidium to extremely cold temperatures, about 25 μK (corresponding to a speed of about 10 cm/s), or even colder.[4]

Procedure:

- **Lasers**[2] emit photons at a certain wavelength and frequency, stimulating the atoms.[4]
- The electrons within atoms can absorb photons, (with the condition that the frequency of the photon matches the energy required for the electron to jump energy levels) but this process is challenging because of the **Doppler effect.**[4]
- Because atoms have velocities, (and electrons within atoms are also have velocities) they perceive frequencies differently and are off resonance.[4]

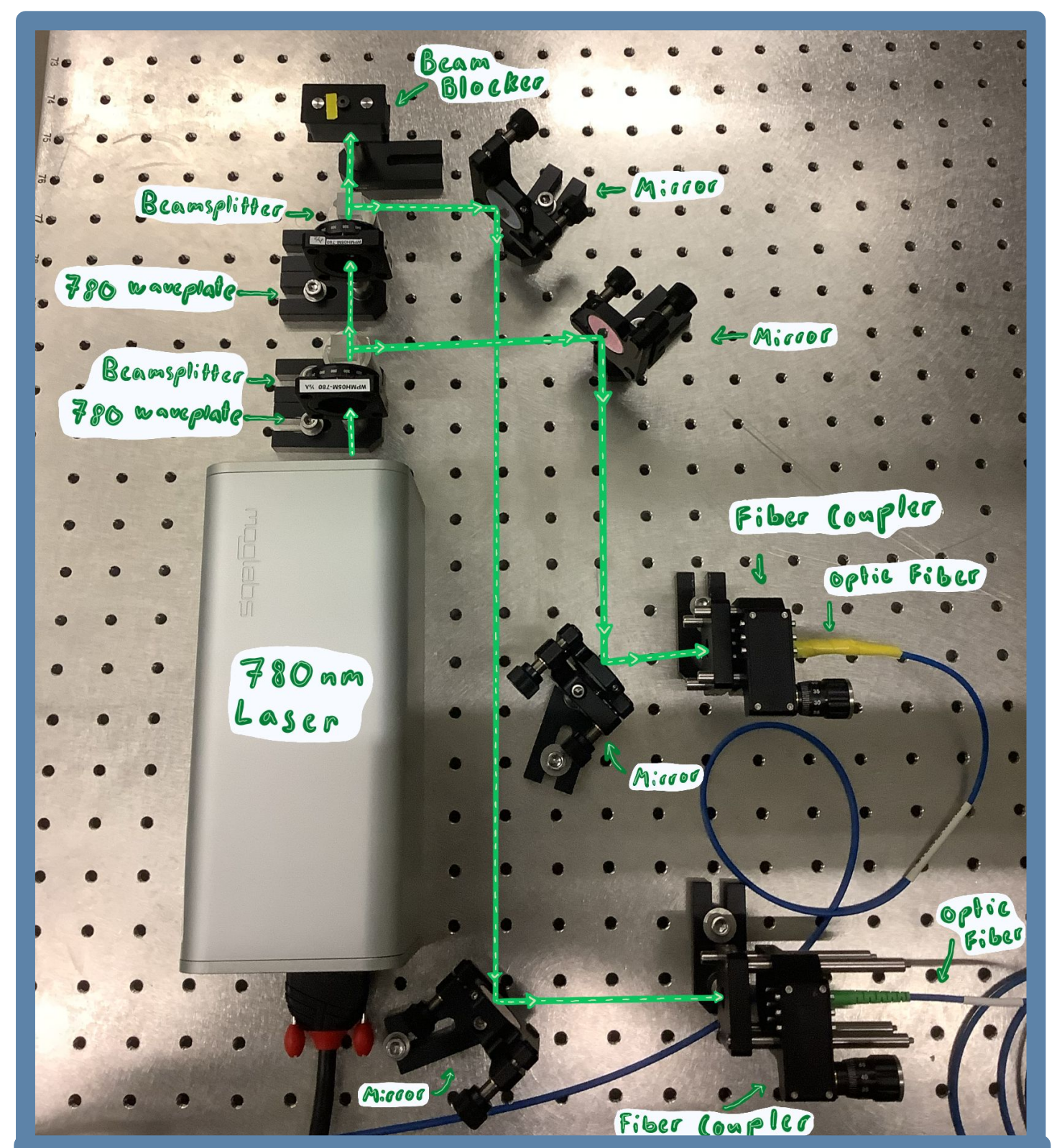

Figure 2: Optical set up of a 780 nm lasers. Labeled are two beamsplitters, two waveplates, four mirrors, two fiber couplers, two optical fibers and one beam blocker.[7]

- In order to set up laser cooling, it is crucial that the laser's frequency can be adaptive to the changes in the motion of atoms. (So most of the atoms will be on resonance with the frequency of the laser beam).
- This is done on the optics table, with the use of beam-splitters, waveplates, mirrors and fibers.

- A fiber is connected to a **saturation absorption setup box.**[1] Inside there is a rubidium vapor cell surrounded by a solenoid coil.[1]
- Photons transmitted from the fiber come into the vapor cell, are absorbed by the rubidium atoms if the frequency is resonant and then re-emitted in a random direction.[1]
- Because of this random re-emission, some of the energy from the original beam is lost and that change is monitored by a photodetector.[1] This then determines at what frequency the most energy is absorbed.[1]

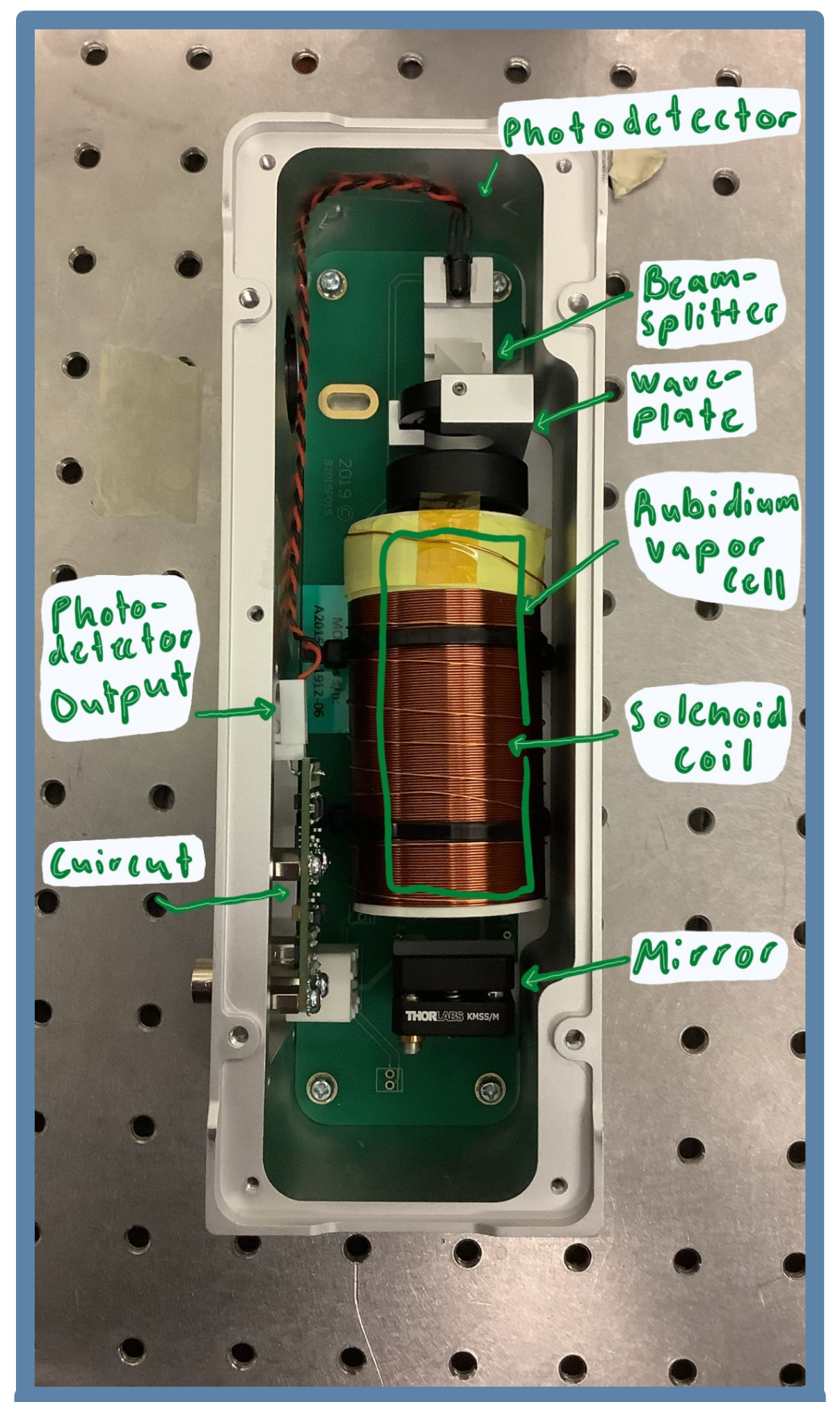

Figure 3: The interior components of a saturation absorption set up box.[1]

Results:

- An **oscilloscope** is used to get a graphical representation of the change in absorption, which depends on frequency.[1]
- From this, the waveplates, fiber couplers, or even the laser beam itself can be adjusted, to find the frequency which is best for the most absorption.

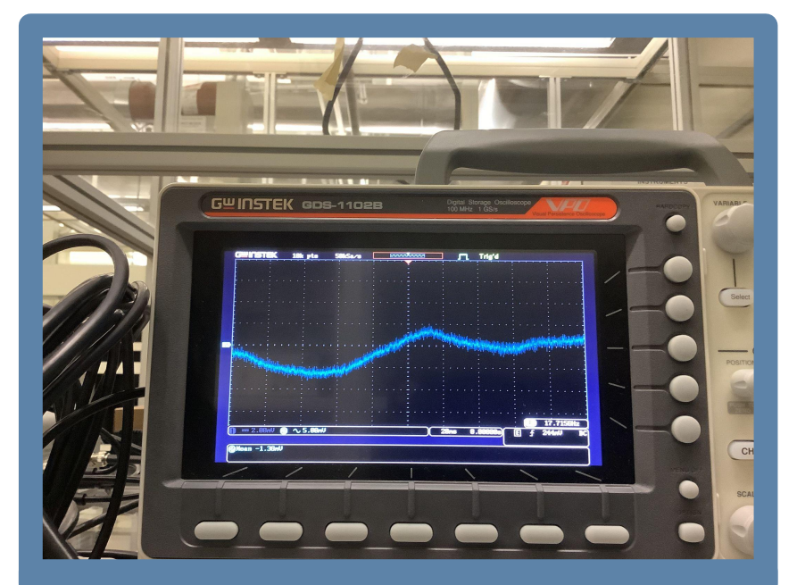

Figure 4: Oscilloscope, showing the frequency of the laser beam.

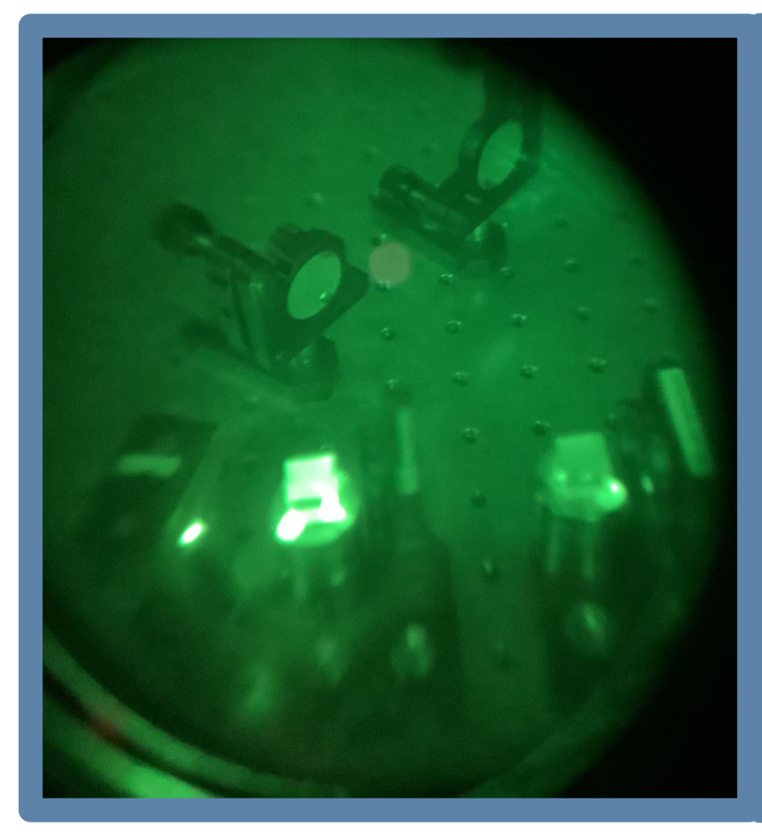

Figure 6: Photo taken by an infrared viewer. Visualization of the laser beam going through a beam splitter.

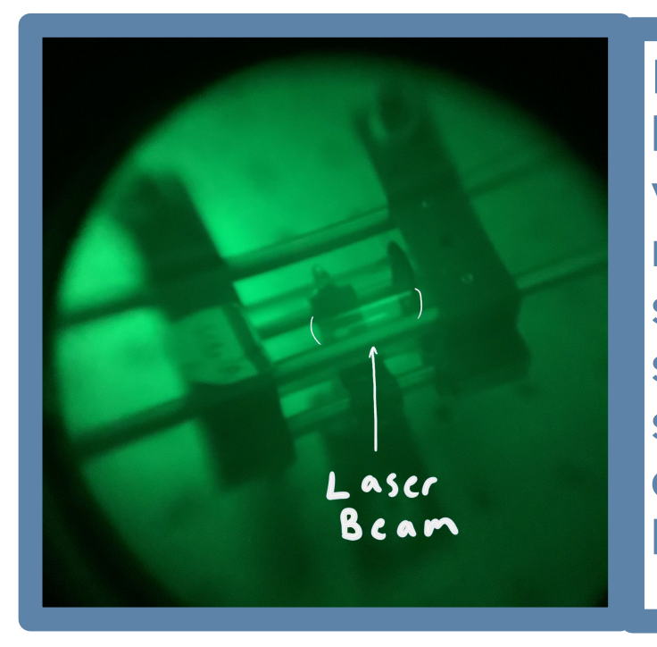

Figure 5: Photo taken by an infrared viewer. A separate rubidium vapour cell, simulating a similar set up to the saturation absorption set up box.

Figure 7: Oscilloscope, with axes. (Y is transmission, X is laser frequency).

Applications:

- This system is progressing towards the construction of a magneto-optical trap.[4]
- Other cooling techniques can also be used.
- When atoms are cooled, physicists can examine their quantum properties more effectively, hopefully leading to the beginning of the construction of a quantum computer

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