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**Honors Project – Copper Chloride Laser**

**Purpose**

The aim of this project is to construct a copper chloride laser to demonstrate several aspects of physics such as optics, circuits, and light. A copper chloride laser has been chosen as it requires little specialized glass work, uses somewhat readily available parts, and produces a laser in the visible light spectrum (no invisible lasers blinding students).

**Introduction**

Copper halide lasers originate from the first attempts of scientists to create copper based lasers. The natural issue with these pure copper lasers, as scientists soon found out, is that they require a temperature of above 1500 C to operate. Scientists quickly realized, however, that using copper halides, the operational temperature could be brought down to between 300 and 600 C.

The original idea for the project lies in the Scientific American article "A Homemade Laser That Emits Powerful Bursts of Green and Yellow Light". In it are detailed plans for the construction of a copper chloride laser that emits the said colors of light – yellow and green. The laser has three key parts – the circuitry, the pulsar, and the actual laser, the last of which will be discussed in this paper.

One of the main differences between a copper chloride laser and other traditional lasers is the need of two quick, successive electrical pulses to lase the copper gas. The idea of the double discharge is to first vaporize, sublime, and dissociate the copper then excite the copper's valence electrons. The first discharge dissociates the copper chloride molecules while also ionizing some of copper atoms. The second discharge, assuming it is sent before the molecules can recombine, excites the copper atoms into the proper energy level for lasing by bombardment with electrons. As these reactions happen, the copper atoms come down in energy level, emitting photons. The wavelength of light produced then encourages other atoms to drop down to the same energy level, emitting the same wavelengths, and thus strengthening the signal. This bumping of energy levels by electrons and then electromagnetic wave production by photon release is the idea behind lasers.

There are two main excited states for the copper atoms to initially jump to, meaning two different wavelengths should be produced. The laser should emit visible lights in two colors green and yellow – 510.6 nm and 578.2 nm respectively (Page 2 “A Homemade Laser...”).

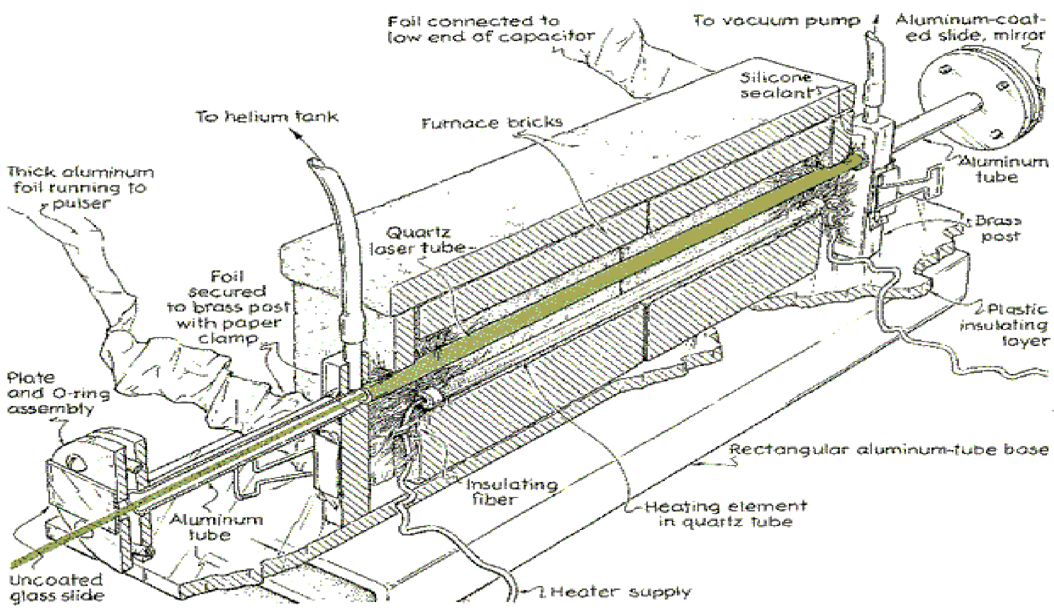
At this point, the paper will assume the construction of the laser element assuming that a pulsar capable of delivering the pulsed charges and proper circuitry are constructed. The guidelines for this construction and assumption come directly from the Scientific American article. The circuitry is constructed primarily from a 15 kV transformer and capacitors. The AC current is converted to DC by passing through a homemade diode rectifier. An elegant pulsar solution (as opposed to expensive switches) is constructed from a rotating disk that completes the circuit at certain times in the cycle of its spin.

Most copper halide lasers are of similar design. A lasing tube is run through a high temperature oven. At the ends are electrical leads as well as metal piping allowing cooling of the copper before contact with the laser windows. Contact of lasing vapor would coat the window and mirror discontinuing lasing. There are also leads to both a vacuum pump and helium supply.

Of additional interest is the use of helium as a buffer gas. Buffer gases are vital when running a laser under high temperatures. If pure copper chloride was used, it would reach the far ends of the tube and condense on the cool windows, blocking laser transmission. By allowing copper chloride to be vaporized in a stable noble gas, the ends of the tube can be at a cooler temperature then the middle. The copper chloride lases in the middle where it is heated and cools to inoperable temperatures on the far ends before it reaches the mirrors. No vacuum is created by this cooling of gas as the noble gases used do not condense and thus still provide pressure. While other noble gases are good options, if not better (Xeon), they are also far more expensive.

**Design**

The design of the laser is heavily based off of the Scientific American Design. In the article, an oven is constructed from silica bricks. Two quartz tubes are contained in the oven – one for the laser and one for a heating element. The temperature is controlled via thermometer and either a current controller or resistor. The lasing tube extends out of the oven into brass posts. The posts are the sort of crossroads. They are where the electrical connection is made, as well as a sort of junction. The lasing tube enters the two posts on the insides. On the outsides extend the aluminum cooling pipes. On the tops are connections to the vacuum pump and helium gas. On the ends of the aluminum tubes are a sort of adjustable mirror and window area.



*From "A Homemade Laser That Emits Powerful Bursts of Green and Yellow Light", Scientific American by Jearl Walker*

The design employed for the project will differ slightly. The oven is constructed of firebricks. Inside is one quartz tube wrapped in a heating wrap. The rest of the space in the oven is filled with fiberglass insulation. Fiberglass will be used as it is readily available and has a melting point far above the operational temperature of the oven. A thermometer is placed touching the quartz tube allowing temperature readings. A power controller is attached to vary the current to the heating wrap to maintain a steady 400 C.

As the tube exits the oven, it extends into two aluminum posts. The aluminum posts replace the brass posts as aluminum is a much more readily available material. Aluminum cooling pipes as well as the same mirror and window design are used. All of this is done on a cement board for non-conductivity as well as support.

The top of the posts will be drilled allowing one end to lead to a vacuum pump and the other to helium. To use the laser, the tube will be flushed with helium and pumped down to 1 to 2 Torres pressure several times after adding copper chloride. The oven is then heated to 400 C at which point it is time to lase.

**Plans**

As of now, the project is in the mail state. Parts are on the way. Following is a brief "schedule".

- Early January – Construction and completion of actual laser tube
- January – Tracking down helium and vacuum pumps. Gathering CuCl
- Early February – Any final changes to lasing element of laser hopefully followed by shooting a laser.

## Calculations/Important Design Changes

At this point there are almost no calculations. Ultimately the goal would be to find out the power output/intensity of the laser beam.

Wrapping an electrical wrap around the lasing tube poses some dangers. In the original article, care is taken to ensure enough space is between the heating element and the lasing tube so that no arcing occurs. Arcing is a salient hazard due to the 15kV going through the tube. According to several reference sites, fused quartz has a breakdown voltage of 8kV/mm for a low end estimation ("Dielectric Strength of Fused Quartz" from *The Physics FactBook*). Thus, to ensure no arcing, a 2 mm thick quartz tube will be used.

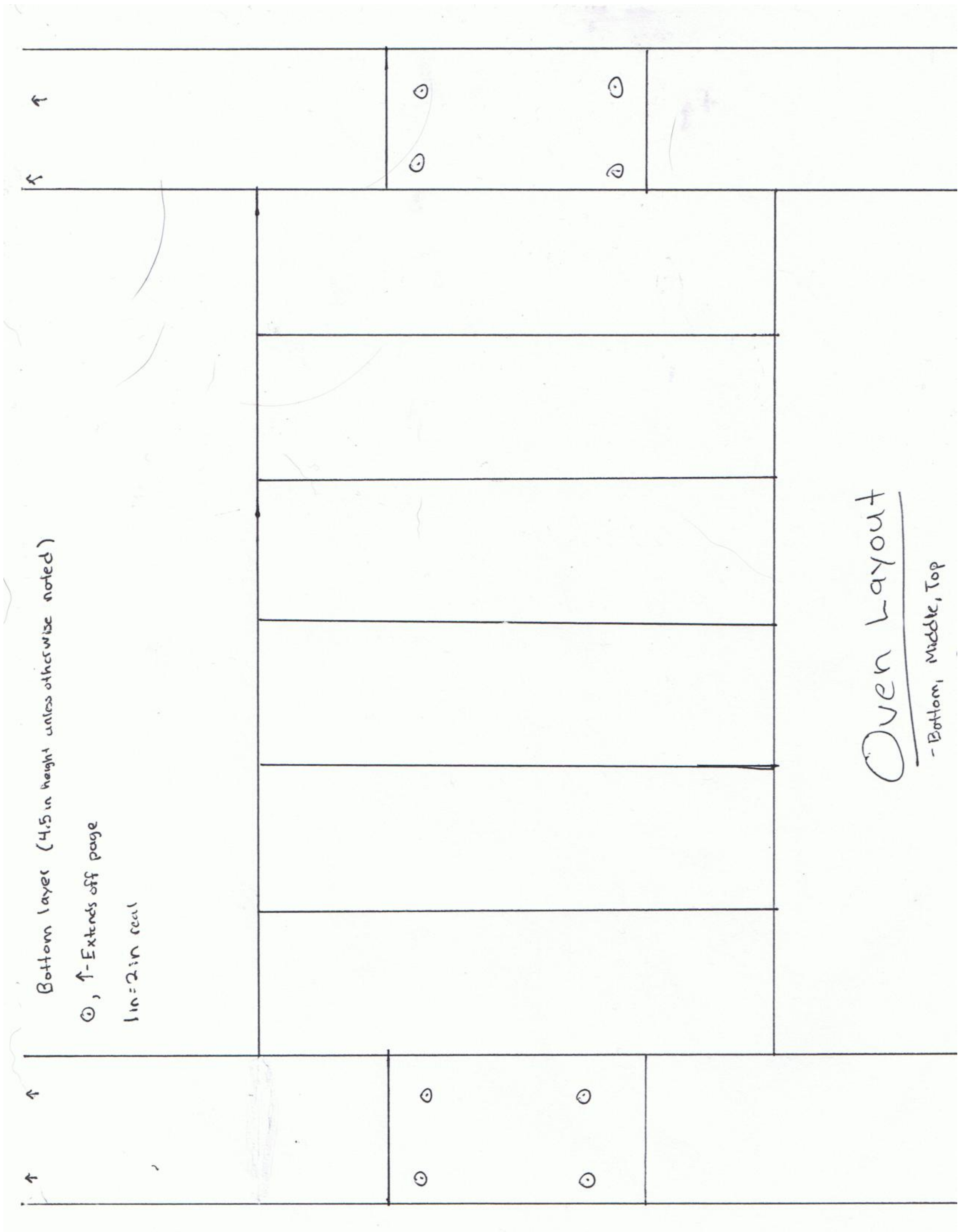
## Construction

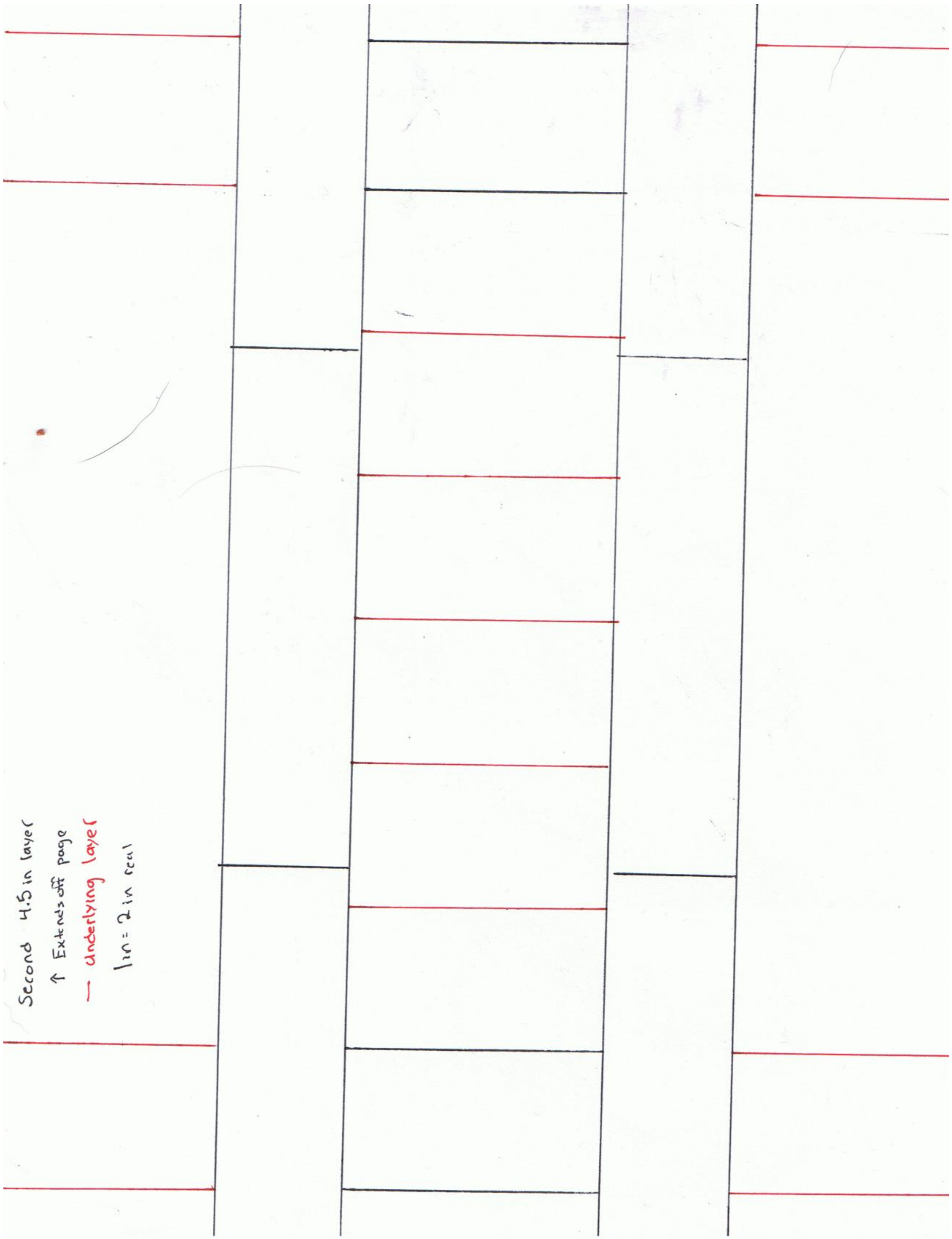
The first step is to set up the base. A cement board like those found at a home construction store will be placed on the wood cart to help separate the two thermally and electrically. Then the first layer of bricks will be laid. As the bricks are laid, the cracks will be sealed with a fire sealant such as those used in chimneys. On each end of the laid bricks will be a central brick that is vertical – two 2 cm holes are to be drilled into the ends allowing the laser tube, thermal wrap, and thermometer to be run into the oven. The fused quartz tube – 24 in length – will have an inner diameter of 10 mm and an outer diameter of 14 mm. An Amptek heating wrap (1.3 cm wide 120 cm long) will wrap around the tube. A thermocouple will be placed near the tube to measure temperature. Once the lasing tube is secured the second layer of the oven should be built and sealed. Then fiberglass insulation will be packed in, a final layer of bricks added, and the oven sealed.

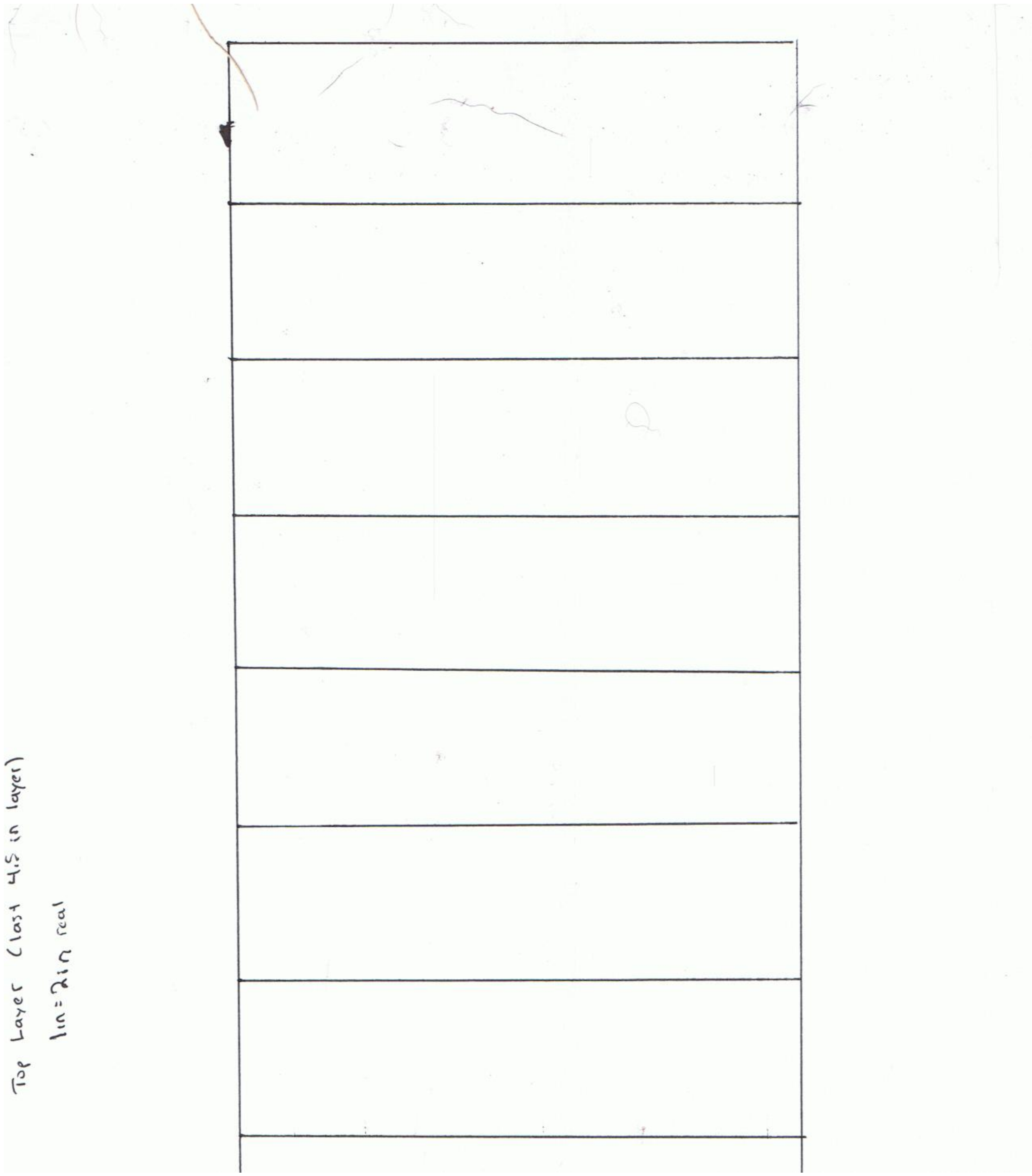
The glass tube will protrude from the oven on both sides. It is then to be secured into an aluminum post of the dimension (5 cm by 5cm by 12 cm in height). Three holes should be drilled in the post – they should connect. On the inner sides of the posts will 14 mm drilled holes where the quartz lasing tube is attached. At the same height on the opposite side should be similar holes where a 10 mm inner diameter, 13 cm long aluminum tube is to be secured on both ends. A hole is also to be drilled from the top of the tubes to accommodate a vacuum pump and helium.

Once the aluminum tubes are attached and sealed, the windows must be built. These are going to be made of a sort of two piece system, where one round metal piece is attached to the aluminum tube and the other piece, containing either the microscope slide or mirror, is attached with three screws. A silicone ring will go between allowing the adjustment of the mirror and window angles via the screws as well as a method of opening the laser tube,

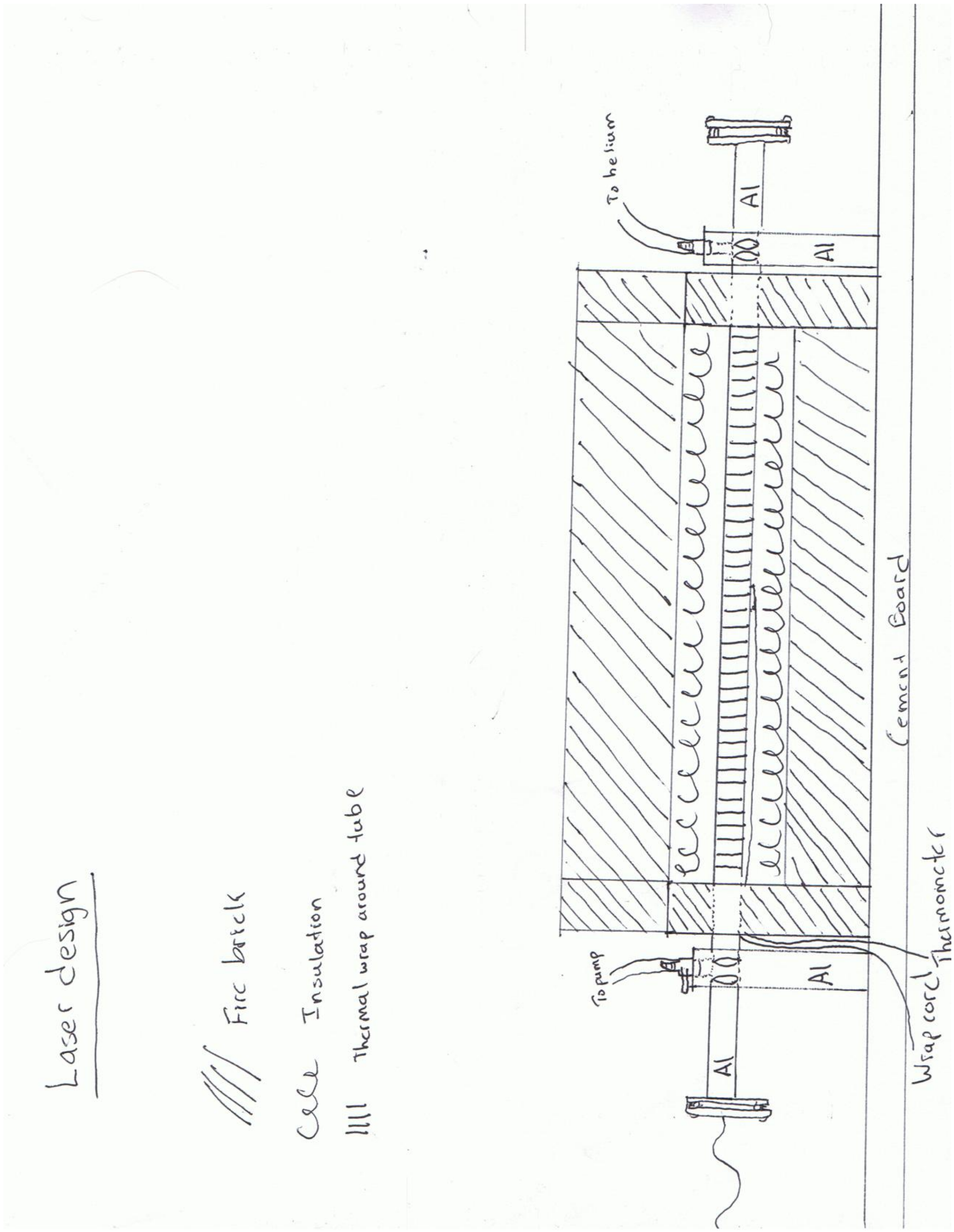
The following depicts the planned brick layouts in three layers – bottom, middle, and top. Note that some of the rectangles extend off the picture. Standard firebricks are 2.5 by 4.5 by 9 in. The pictures were originally to scale hence the key.


Oven Layout
-Bottom, Middle, Top
Bottom layer (4.5 in height unless otherwise noted)
⊙, ↑-Extends off page
1in:2in scal


Second 4.5 in layer
↑ Extends off page
— underlying layer
1in = 2 in real




The next image shows how the laser design looks from the side. It is not to scale.


Laser design
Fire brick
Insulation
Thermal wrap around tube
To helium
Al
Al
To pump
Al
Al
Wrap cord
Thermometer
Cement Board

**Bibliography**

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