Experiment E94-010 Polarized ^{3}He Target Operation and Safety Procedure

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Abstract

We describe in this procedure all aspects of the Polarized ^{3}He target operation in Hall A during experiment E94-010. We have identified and addressed personnel as well as fire safety issues related to the normal operation of the target during the experiment. We explain how safety issues are alleviated and provide a detailed description of the Target operation within the framework of running experiment E94-010 in Hall A.

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Chapter 1

Introduction and overview

Experiment E94-010 will use the polarized beam and a polarized ^{3}He target to perform the measurement of the spin structure function of ^{3}He as well as extract the neutron spin structure function in the resonance and deep inelastic region. The experiment is scheduled to be performed in Hall A during the fall of 1998 from september 25th to december 24th, while its setup is planned for the period August 24th to September 24th, 1998. The polarized ^{3}He target will be operated during the same period when the experiment is scheduled. Its operation involves many aspects related to its setup and alignment prior to the experiment as well as its routine operation.

At the heart of the setup is a 40 cm long aluminosilicate glass (Corning 1720 or GE 180) high pressure (15 atm) double chamber cell. It contains a mixture of helium-3, rubidium and nitrogen. It is polarized by optically pumping the rubidium alkali when in its vapor phase which in turn exchanges its polarization with the ^{3}He nuclei by collision. The nitrogen increases the pumping efficiency of the system. The polarized target comprise several components beyond its target cell (see Fig. 1.1) related to its operation, they are in section:

1. A double set of Helmholtz coils which provide the target spins with a holding magnetic field of few tens of Gauss as well as define the orientation of the polarization in any required direction.

2. A pair of RF coils which allow for the measurement of the target polarization using the Adiabatic Fast Passage (AFP) technique and the Electron Paramagnetic Resonance (EPR) technique.

3. A multi purpose RF enclosure which holds the RF coils but more importantly is crucial for the containment of the target cell in case of explosion. It also provides a containment volume for the ^{4}He gas to cool the target windows with cooling jets, minimizing the radiation length crossed by the electron beam.

4. An oven with all its related components for providing the necessary temperature to the pumping cell in order to bring the rubidium in its vapor phase and control its number density.

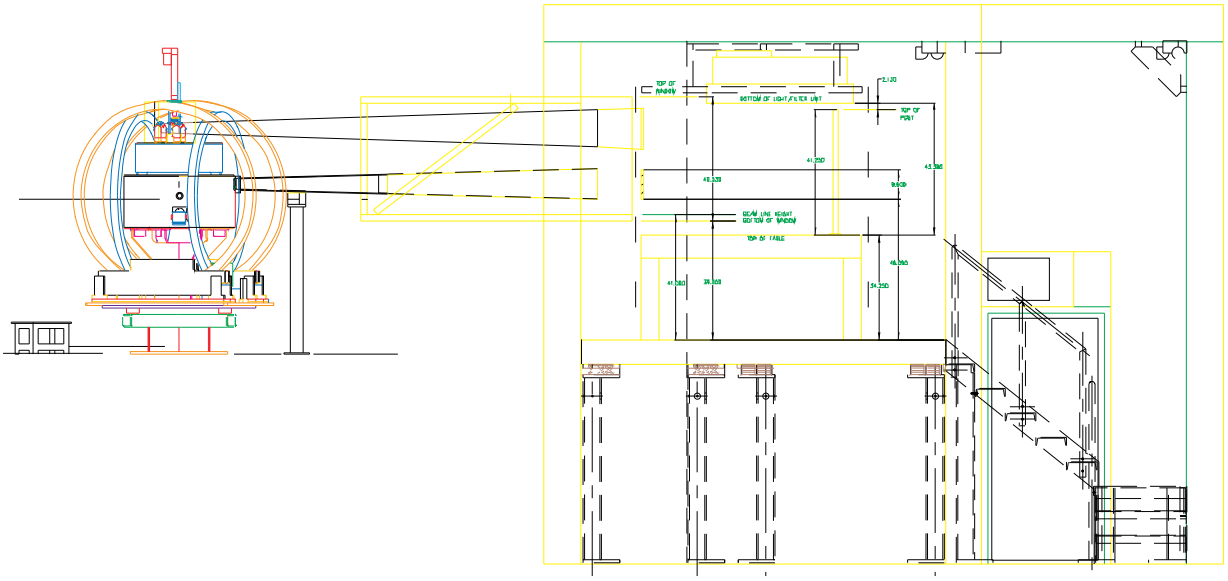

Figure 1.1: Overview of the target setup. Contained in the figure are the laser hut, the beam pipes covering the laser beam line extending to the target area and the Helmholtz coils with RF assembly as well as the support sub-assembly.

5. A target ladder subassembly which supports the target cell, reference cell, Be0 beam viewer and the oven. It also includes the full mechanism for positioning the targets and bears the target cell viewing mirrors and the optical beam line mirrors.

6. A laser shielding house known as "laser hut" where two laser beam lines are formed by seven 30 Watt diode lasers. These laser beam lines are used for optical pumping of the rubidium alkali atoms in both the longitudinal (along the electron beam) and transverse (90° off the electron beam) directions.

1.1 Hazards and Safety Issues

The main potential hazards encountered in the overall operation of the target are listed below. As we address the operation of each subsystem, a description on how to alleviate the potential hazards is reported.

- Personnel sight damage due to a laser light exposure;
- Fire due to the operation of the high power lasers;
- Fire due to the operation of the target oven;

- Explosion of the high pressure target cell;
- Explosion of the reference cell;
- Irradiation of the target by the electron beam.

For personnel safety to be effective all personnel authorized to operate any subsystem of the target will be required be familiar with that specific subsystem as well as read this OSP.

Chapter 2

Laser Beam Line

To protect the lasers from the electron beam radiation damage and provide for a controlled access area for the laser safety a laser hut was built. It positioned adequately in Hall A as not to interfere with the spectrometers at all angular positions needed during the experiment and close enough to the target to allow for efficient optical pumping. The optical setup for two laser beam lines starts in the hut and is shown in Figure 2.1. It comprises the following items:

1. An optical table supporting all lasers and a large part of the optics;
2. Seven infra-red diode lasers (four for longitudinal pumping and three for transverse pumping) located on one side of the table, with optical fiber bundles;
3. Seven lenses to have each laser beam focussed at the pumping cell;
4. Seven beam splitters to split each laser beam to two beams;
5. Fourteen $\lambda/4$ plates to transform each beam from linear polarization to circularly right or left polarization;
6. Fourteen dielectric mirrors to reflect each split beam back into the pumping cell;
7. One transparent window on the RF enclosure and one transparent window on the oven to allow the combined transverse laser beam to pass through;
8. Two dielectric mirrors to reflect the combined longitudinal laser beam into the pumping cell;

The laser beams will be about 30 cm above the table. Each of the 795 nm diode laser light, after passing through the lens, will split into two beams. Each one will go through a $\lambda/4$ plate to transform their linear polarization to circularly right or left polarization. The longitudinal pumping beam after passing through some windows and being reflected by some mirrors, will shoot onto a glass pumping

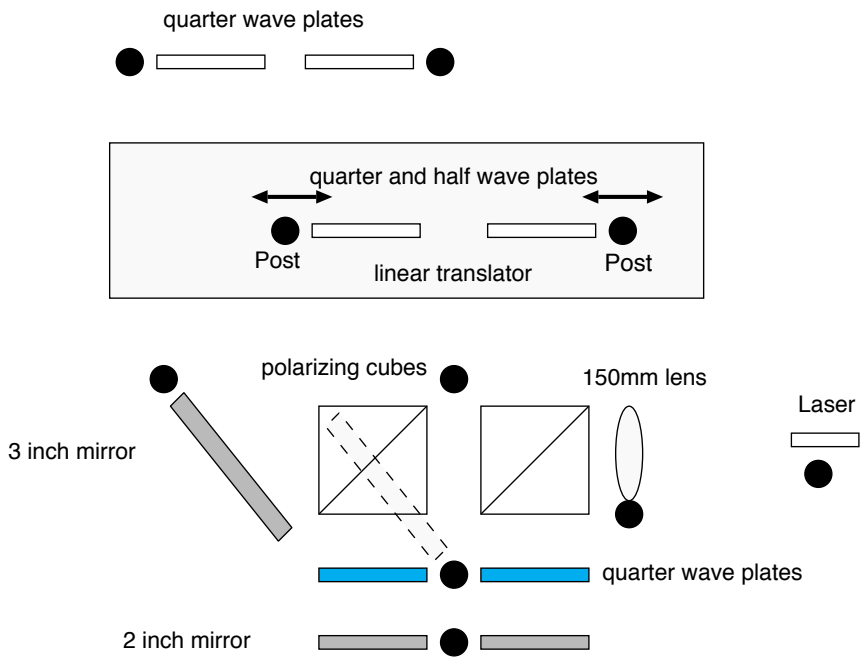

Figure 2.1: Top view of the optics setup inside the laser hut. All items are on a laser table which is sitting on a mezzanine inside the laser hut

cell filled with a mixture of Rb vapor and ^{3}He gas. The transverse pumping beam line after passing through few windows goes directly onto the pumping cell.

The laser beams will be completely absorbed by the pumping cell. The total path length from the lasers to the pumping cell is about 5 meters. After passing through the optical setup, the laser beams are directed into the pumping cell and terminated there. The laser beam line is protected by beam pipes that extend from the laser hut to the target top cover. It is important to point out that the laser beam lines are fully enclosed from the rest of the hall.

2.1 Laser Hut

Since the diode lasers and the associated devices will be located in the laser hut, The entire room is a laser controlled area. Its organization is shown in Figure 2.1 and 1.1. The setup will not be visible from the entrance door.

Apart from direct beam hazards to eyes and skin, since the diode lasers are Class IV lasers, there exists a potential fire hazard. Operations of the lasers in the laser hut are covered by the laser safety operation procedure included in Appendix F

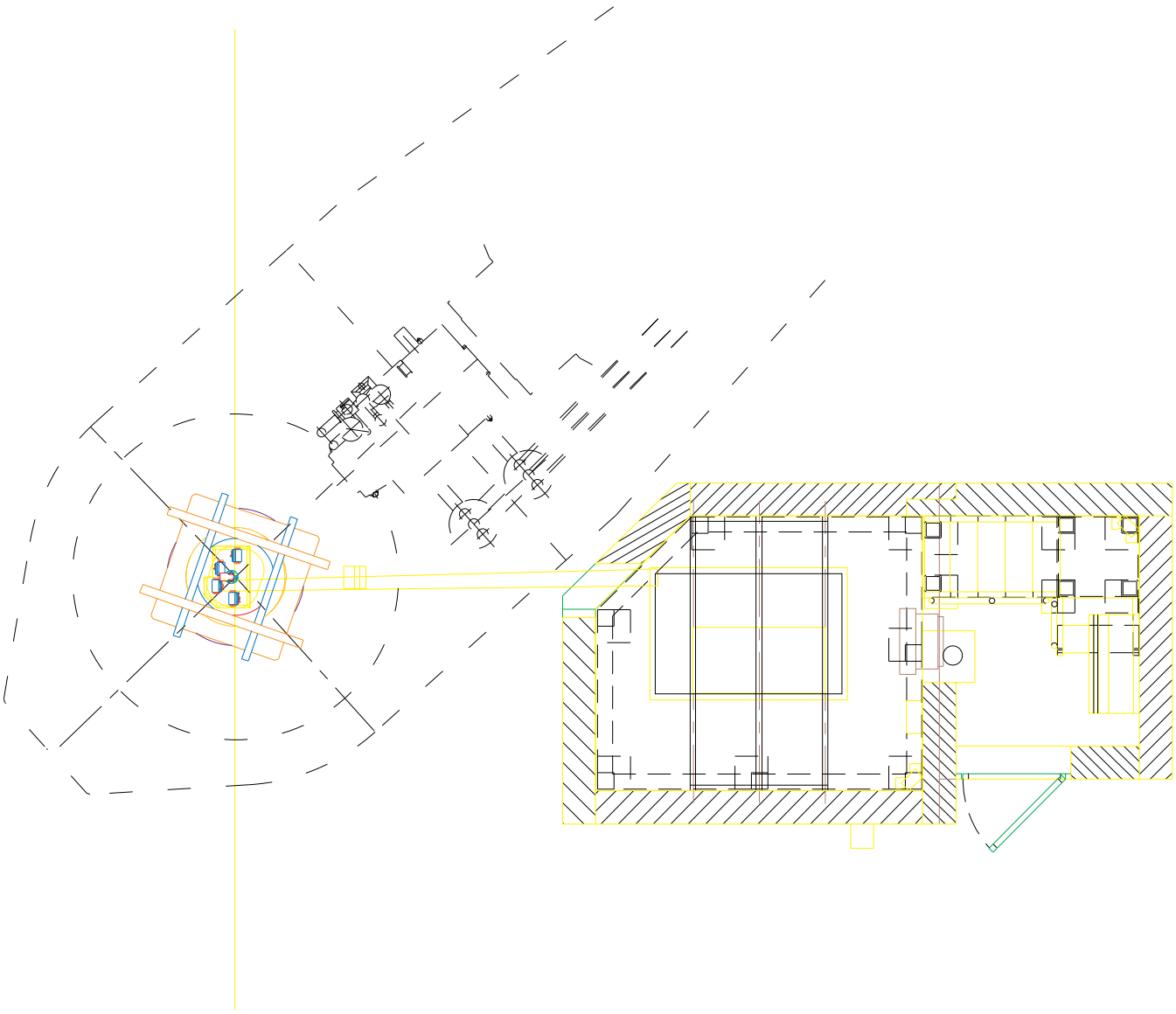

Figure 2.2: A topview of the laser hut shows the location of the interlocked door as well as the position of the laser table where all lasers and optics will be setup.

2.2 Lasers Operations

The lasers will be operated sequentially for the two pumping modes, longitudinal and transverse. During the experiment and for a given spectrometer setting, antiparallel as well as parallel cross sections are measured by flipping the helicity of the polarized beam. When the measurement is finished the data acquisition is paused and the four longitudinal lasers are switched to the "STANDBY" position. The target spin is rotated to the transverse direction and the three transverse lasers switched from "STANDBY" to "ON" position for transverse pumping. The data taking resumes until adequate statistics is achieved.

2.2.1 Fire Hazards and Safety

The fire and safety in the laser hut is covered in the LOSP (Appendix) for the laser hut area, however, in the target area where the laser beam is directed, there is a case where a potential fire hazard exists.

In case the target cell explode during the transverse pumping the full power of the three transverse lasers is not absorbed by the pumping cell. Laser light split in three parts. One part is trapped in the oven which is made out of high temperature resistant materials and maintained at 170° while the remaining light will exit from two separate windows to hit a laser dump area setup within the RF enclosure. An interlock system has been set to insure the shutoff of the lasers when the temperature of the laser beam dump rises beyond a well chosen setpoint provided by temperature sensors.

2.2.2 Personnel Safety/ Working in the Hall

When the installation of the full target setup is finished working in the hall shall be safe from laser light hazards or target explosion hazards because laser light as well as the target cell will be safely enclosed. Therefore when considering the overall aspects of the safety of personnel working in the Hall two distinct periods are to be considered.

1. One period is during the laser beam alignment because the laser beam pipes from the laser hut to the target need to be removed. During this time period we will ensure that no other person except those people who are laser trained and qualified for laser beam alignment are in the hall. This will be arranged by using a controlled access to the Hall provided by the MCC controlled key interlock safety system. This alignment will be performed only during the night time. Clear warning signs will be posted at the entrance of the Hall when the alignment is under progress.

2. One period is during the setup of the high pressure target cell in its final position. In this case the "target platform" which is a natural perimeter around the target area will be marked and signs posted requiring the wearing of ear protection and faceshield. Beyond that defined perimeter all personnel working in the hall will not be affected in case of explosion of the cell if they are

not wearing a faceshield. Nevertheless, it is strongly recommended to have ear protection when working anywhere in the Hall.

Chapter 3

Target Operation Overview

In normal operation the target will be under one of the following situations described below.

1. The target is in "beam position", the fast raster set to a minimum of 2 mm $\times$ 2 mm area coverage and the experiment is running to collect physics data. In this configuration the monitoring of the target consists of reading a set of temperatures of the pumping cell, target cell and reference cell. The one temperature in the pumping cell will provide feedback for the temperature controller. Two viewing cameras which look the pumping cell will be on. All interlocks of electron beam and laser beam should be on.

2. The beam is turned off and the target is moved to a position between the NMR pickup coils and a polarization measurement is performed using the NMR (AFP) method. If the pumping cell is under longitudinal pumping the laser beam will be kept on. If the pumping cell is under transverse pumping the laser beam will be stopped first. A rotation of the polarization to the longitudinal direction is performed (procedure described in Appendix B). Once the measurement is completed the target cell is moved back to the "beam position". The beam interlock is reset and the fast raster enabled before turning the beam back on target. The physics data taking should resume.

3. The target is in "beam position" while physics data taking is underway. The data taking is stopped and the beam is turned off. An access to the Hall is requested to setup for the EPR measurement (procedure described in Appendix C). After the measurement is completed and the fast raster enabled, the beam is put back on and data taking resumes.

4. The electron is changed from the continuous mode to the pulse mode and the beam current lowered as not to damage the BeO target. The BeO target is moved to "beam position". The monitoring of the beam position is performed by looking at the TV monitor which displays the view of the target.

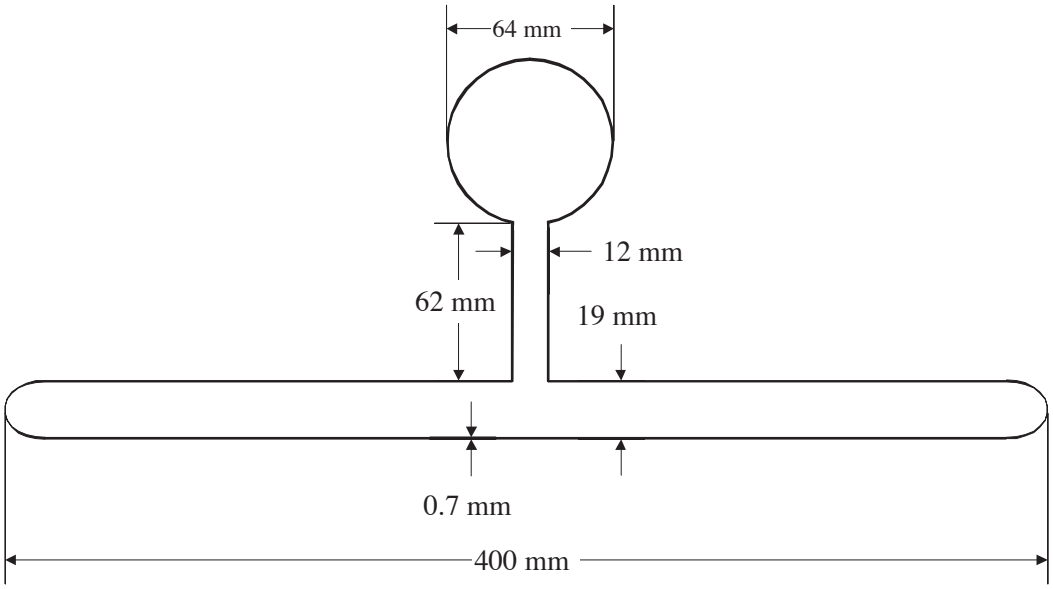

Figure 3.1: Typical 40 cm polarized ^{3}He target cell used in this experiment. All dimensions in mm.

5. The target ladder empty frame is moved to "beam position" whenever beam tuning is performed, and when checking for possible beam halo background.

6. The reference cell target is in "beam position" with the beam fast raster on and and data on the reference cell are taken for calibration.

3.1 Target Cell

The target cell is a 40 cm long aluminosilicate glass (Corning 1720 or GE180) high pressure (15 atm) double chamber cell (see figure3.1. It is a closed system filled with a gas mixture which consists of ^{3}He, rubidium and nitrogen. The the tritium contamination in our ^{3}He bottles used to fill the cell is less then 10^{-11} specifications from Spectra Gases.

3.2 Target Enclosure and Target Area

Because the explosion of the cell presents a potential hazard we have designed a target enclosure which allows three functions. Firstly, it provides a safe containment volume in case of explosion of the target cell and limits the potential hazard working area. Secondly, it holds the RF coils in a stable position an provides a strong frame for the support assembly. Thirdly, it allows for a helium atmosphere around the target minimizing ionization and energy losses of the electron beam when crossing the target area.

The RF enclosure windows have three type of windows. The incident electron beam entrance and exit windows to the enclosure made out of 0.005" thick aluminum , the scattered electron beam windows and the laser beam windows. The largest windows are those of the scattered electron beam made out of 0.10" thick aluminum.

If any of the RF enclosure windows are open, people working in a close *perimeter* of the target enclosure (target platform) must wear ear protection and faceshield. This *perimeter* will be designated as target area, and signs will be posted around that the windows are open and that work is in progress. If the windows are closed the target area is no longer restricted except maybe for reasons related to radiation safety.

3.3 The Electron Beam Line Near the Target

The electron beam crosses two windows before reaching the target, the electron beam pipe window and the target RF enclosure beam entrance window. Similarly it crosses two similar windows as it leaves the target area. The electron beam line is under vacuum and separate from the target enclosure for both upstream and down stream of the target enclosure. This beam line extends upstream close to the RF enclosure beam window inlet. It is terminated with a 0.010" thick beryllium window. It starts over and continues just after the downstream of the RF enclosure with another beryllium entrance window. The beam inlet and outlet windows at the RF enclosure are made of aluminum. They are strong enough to stop any flying glass shreds from exiting the RF enclosure in case of target cell explosion.

3.4 Cell Installation and Replacement

The target installation is a delicate procedure and should be done by only a limited number of people. The list of names of qualified personnel will be provided all of whom are radiation II trained. Only the first time installation does not require the monitoring of radiation around the pivot area. Subsequently, after the electron beam has been used in the Hall any replacement of the cell should be done with in mind the possible radiation hazard. In what follow we describe the procedure we will follow to replace a cell. Where only designated and qualified people should perform the procedure. The procedure we describe is valid whether the replacement is after a routine change of the target cell or a change because of the explosion of the previous target.

3.4.1 Procedure

The planned procedure we must follow to replace a target cell is itemized in what follows.

- If the replacement of the cell is prompted by its explosion a new Q curve of the pickup coils

should be measured and an assessment for its replacement should be made.

- Make sure the replacement target and if necessary a new set of pickup coils have been prepared. Request the Hall access authorization to MCC, and wait for a member from the RADCON team to accompany the group of qualified people authorized to change a target cell.
- The member of the RADCON group will evaluate the radiation level around the target area. If safe levels of radiations are observed, the work can proceed otherwise Radiation Work Permit will be written.
- All personnel within the target area platform must now wear ear protection and faceshield in preparation to access the inside of the target enclosure.
- Raise the target top assembly support and if necessary remove the scattering windows of the RF enclosure to provide for a comfortable access to the target. Monitor the radiation level close to the target ladder and oven. Determine what conditions are required to comply with a radiation safe work condition. In other words determine whether radiation II trained people should replace the target.
- Qualified personnel should proceed to replace the target and align it according to well defined reference lines of the target ladder. The motion of the target and clearance as it moves between the pickup coils should be tested. The RF enclosure should then be closed back to its initial state.
- The working personnel moves out of the target working platform. Faceshields and ear protection can be removed. Previous target should be stored in a wooden box with a screwed lid. It must be left in the hall with "Do Not Open, Pressurized Glass Cell" warning sign on the box.

3.5 Nuclear Magnetic Resonance Adiabatic Fast Passage

In this section we refer the reader NMR operation guide, Appendix B, which addresses operation as well as safety concerns and their mitigation for the NMR measurement.

3.6 Electron Paramagnetic Resonance Measurement (EPR)

In this section we refer the reader to EPR operation guide in appendix C for how to operate the EPR system.

3.7 Reference Cell System

In this section we refer the reader to the reference cell system guide described in appendix D

3.8 Target Cell Heater Control

In this section we refer the reader to the target cell heater control guide described in appendix E

3.9 Laser Operation in the Laser Hut

In this section we refer the reader to Laser Operation and Safety Procedure described in appendix F

Appendix A

Alignment and Operation of the Lasers

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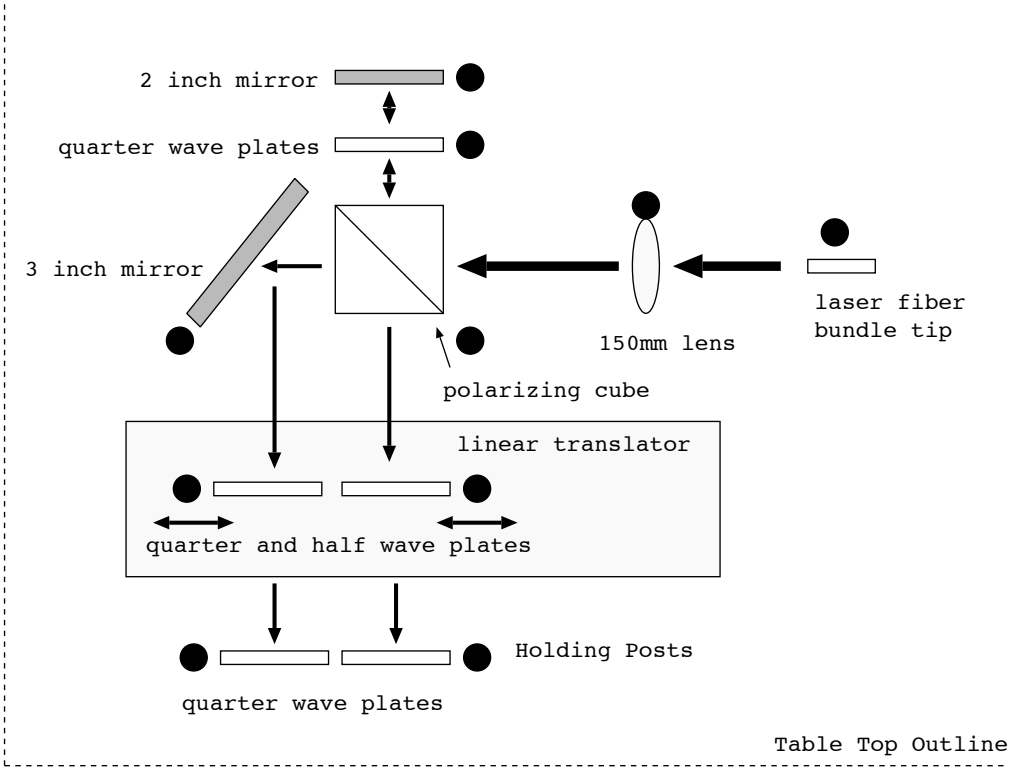

Figure A.1: Top view of the laser and optics setup for longitudinal pumping.

A.1 Laser Safety

1. Always have your safety goggle on when the laser is on!
2. When the yellow beacon is flashing, have goggle on when you enter the hut.
3. Alignment should be done at low power.
4. Be sure that the beam is hitting the target.
5. Do not turn the beam up to full power unless the oven temperature is at 150 degrees Celsius.
6. Do not look directly into the beam even with safety goggle on.
7. Do not stand in the way of a beam that is at full power.
8. Understand where the beam is and where the reflections are.

A.2 Laser Alignment

1. Set the height of the diode laser, the center of the polarizing cube, the two-inch mirror, the quarter wave plates, the lens, and the three-inch mirror to be at the same height.
2. Place diode alignment laser such that it passes through the center of the polarizing cube and the center of the rubidium cell.
3. Rotate the cube and change the angle such that the back reflection hits the alignment laser and such that the reflection hits the diode laser simultaneously.
4. Place the collimating lens in its mount with the flat side away from the diode laser. Adjust it so that the back reflection goes back on itself.
5. Turn the diode laser on at LOW POWER.
6. Adjust the head of the diode laser such that the light goes through the center of the lens.
7. Rotate the cube mount such that the light passes through the center. Be sure that the cube is mounted so that the light enters the marked side and is reflected towards the two-inch mirror.
8. Turn off the diode laser.
9. Place the two-inch mirror into its mount and move such that the alignment diode hits the center.
10. Place a quarter wave plate between the cube and the two-inch mirror.
11. Turn the laser on at LOW POWER.
12. Adjust the quarter wave plate so that the laser passes through the center.
13. Adjust the two-inch mirror so that the reflected light hits the near the target.
14. Rotate the quarter wave plate so that the light that passes through the cube from the two-inch mirror is a minimum.
15. Rotate the quarter wave plate forty-five degrees.
16. Adjust the two-inch mirror so that the light hits the target.
17. Check to see where the back reflection of the diode is hitting. It should be near the head of the diode laser but not directly on top of it. If it is then rotate the cube slightly and realign the two-inch mirror. Repeat if necessary.
18. Place the three-inch mirror in its mount.

19. Check to see that the diode light is hitting the mirror.
20. Adjust the three-inch mirror so that the light is hitting the target.
21. Center a quarter wave plate in the path of the each beam.
22. Place a polarizing cube after the quarter wave plate.
23. Rotate the quarter wave plate such that the reflected light coming from the cube is at a minimum.
24. Rotate the plate forty-five degrees.
25. Repeat for all beams heading towards the target.
26. Be sure that the helicity of each beam line is the same.

A.3 Laser Operation

To turn on the laser:

1. Be sure to connect the laser control box to the interlock and to the correct laser.
2. Turn the key on the laser to turn on the power.
3. Set the temperature by pressing the set button next the temperature read out, and turn the temperature dial until the correct setting is obtained.
4. Press the Ready button. Wait a couple of seconds.
5. Press the On/Off button. The laser should now be on.
6. Set the current to the correct value by turning the current control knob.

To turn off the laser:

- Press the Standby button.

A.4 Laser Settings

Laser	Set Temperature	Read Current
H9803-004	29.7	26.4
H9803-005	25.5	28.2
H9803-127	25.5	27.5
H9803-129	25.8	27.3
H9803-134	24.2	28.8
H9804-146	26.1	28.8
H9803-128	28.0	23.3

Appendix B

NMR AFP Sweep User Operation and Safety Guide

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B.1 Longitudinal pumping

This guide explains briefly how to perform safely an AFP sweep on the polarized ^{3}He target. Please, refer to **Figure** B.1 showing the target setup and explaining the angle conventions.

When in state of longitudinal pumping, namely **if the Holding field is pointing towards 0°** then

- Before the NMR AFP sweep, check that the target cell is verticall yaligned with the pick-up coils by reading the target encoders position in the Counting room. Make sure all the NMR devices are turned on.
- Make sure the Kepco power supplies display the following currents : 6.49 A ± 0.01 for Kepco 3 (Large coils) and -2.00 ± 0.01 A for Kepco 4 (Small coils). The field points towards the 0∘ direction displayed on the **Coil orientation** drawing on the side of the left hand side rack.
- Open the **NMR Helium Main Panel** Vi in the Apple menu. Just run the Vi when you are ready. Data will be saved by default. That Vi works by default in the autocancel mode. Look at the STAGE indicator when running to determine the starting point of the cancellation

procedure. You can follow it on the oscilloscope display, located in the right hand side rack. The curve #1 is the signal coming from the pick-up coils. The curve #2 is the canceling signal created by the HP function generator. The M curve is simply the difference between curve #1 and curve #2. Do not hesitate to change the vertical scale of the oscilloscope to see the three curves together on the screen. The autocancel procedure will try to minimize the M curve. It first starts by adjusting their phase and then adjusts the amplitudes. The whole procedure takes approximately 5 minutes. At the end of the procedure, you will be asked to start again the procedure or to go on (and start the sweep). If the M curve is minimal, do not restart the procedure. If not, you have the choice to let the Macintosh do it again or to do it by hand (should never occur, dont worry !).

- At the end, dont try to fit the data. They are saved and can be used later.
- When you are done, you can close the Vi, or run it again to sweep one more time.

If the holding field is pointing towards 180°, then the DC currents displayed on the Kepco power supplies simply change of sign.

B.2 Transverse pumping

In this configuration, the holding field can point towards 90° or towards 270°.

If the holding field is pointing towards 270°, then :

- Before the NMR AFP sweep, the target cell has to be aligned with the pick-up coils. Make sure all the NMR devices are turned on.
- Make sure the Kepco power supplies display the following currents : -2.34 ± 0.01 A for Kepco 3 (large coils) and -6.05 ± 0.01 A for Kepco 4 (small coils). Then the field points towards the 270° direction and has a magnitude of 24 G. Please, check that the laser beam is in the transverse configuration.
- To measure the polarization, the field needs to be rotated back to the 0° direction.
- To rotate the field, open the **Field Rotation** Vi, located in the Apple menu. Before running that Vi, choose **Return to 0 from 270°**. Then press the Run arrow using the mouse. Confirm the rotation to 0 from 270° by clicking ROTATE. The WAVETEK function generator sends square burst to the Latch box to get rid of any holding field glitch occurring during the rotation.
- The field starts to rotate after a few minutes. The whole rotation is rather slow. You can now close that Vi.

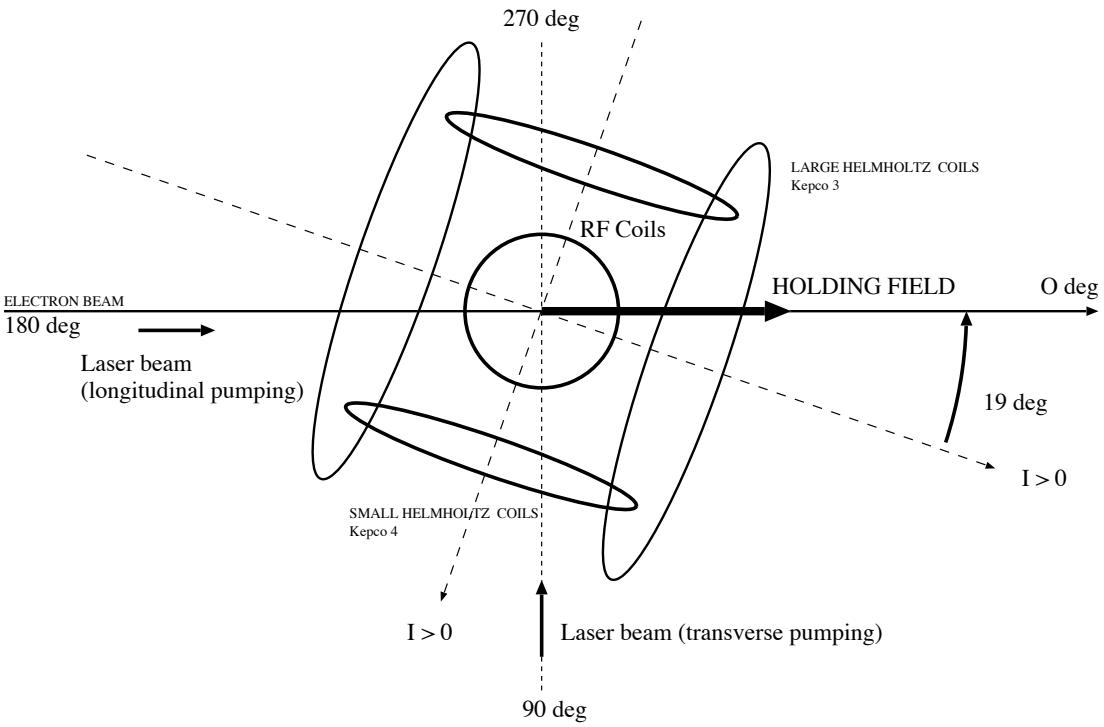

Figure B.1: Top view of the longitudinal and transverse Helmholtz coils used in the polarized ^{3}He target setup. The RF coils are needed to perform NMR as well as EPR measurements. The 0° angle gives the incident electron beam direction. Both sets of coils are rotated by 19°. The dashed lines indicate the coils main axis, the B arrow the holding field direction which can be rotated from 0° to 360°. We also show the laser beam longitudinal and transverse directions.

- Make sure the Kepco power supplies display the following currents : 6.49 A ± 0.01 for Kepco 3 (large coils) and -2.00 ± 0.01 A for Kepco 4 (small coils). In that case, the holding magnetic field is aligned with the electron beam. The field points towards the 0∘ direction displayed on B.1.

- Open the **NMR Helium Main Panel** Vi in the Apple menu. Just run the Vi when you are ready. Data will be saved by default. That Vi works in the autocancel mode. Look at the **STAGE** indicator when running to determine the starting point of the cancellation procedure. You can follow it on the oscilloscope display, located in the right hand side rack. The curve #1 is the signal coming from the pick-up coils. The curve #2 is the canceling signal created by the HP function generator. The M curve is simply the difference between curve #1 and curve #2. Do not hesitate to change the vertical scale of the oscilloscope to see the three curves together on the screen. The autocancel procedure will try to minimize the M curve. It first starts by adjusting their phase and then adjusts the amplitudes. The whole procedure takes approximately 5 minutes. At the end of the procedure, you will be asked to start again the procedure or to go on (and start the sweep). If the M curve is minimal, do not restart the procedure. If not, you have the choice to let the Macintosh do it again or to do it by hand (should never occur, do not worry !).

- You can close the Vi, or run it again to sweep again.

- When you are done, you must return in the 270° configuration. Open the **Field Rotation** Vi, located in the Apple menu. Before running that Vi, choose **Go from 0 to 270**° . Then press the Run arrow using the mouse.

- The field starts to rotate after a few minutes. The whole rotation is rather slow. After the rotation, you can close that Vi.

- Make sure the Kepco power supplies display the following currents : -2.34 ± 0.01 A for Kepco 3 (Large coils) and -6.05 ± 0.01 A for Kepco 4 (Small coils).

B.3 Other Useful Features

- If you wish to change the values of the ramping speed, the minimum starting field (B_{min}) and the maximum field (B_{max}), displayed in the FG DS345 table on the NMR Helium Main Panel, do it before pumping. Before running the NMR Helium Main Panel Vi, set the Waveform Download switch on that panel to YES. Do not change the angle value (-19°). Any change of the holding field minimum value will definitely change the holding field.

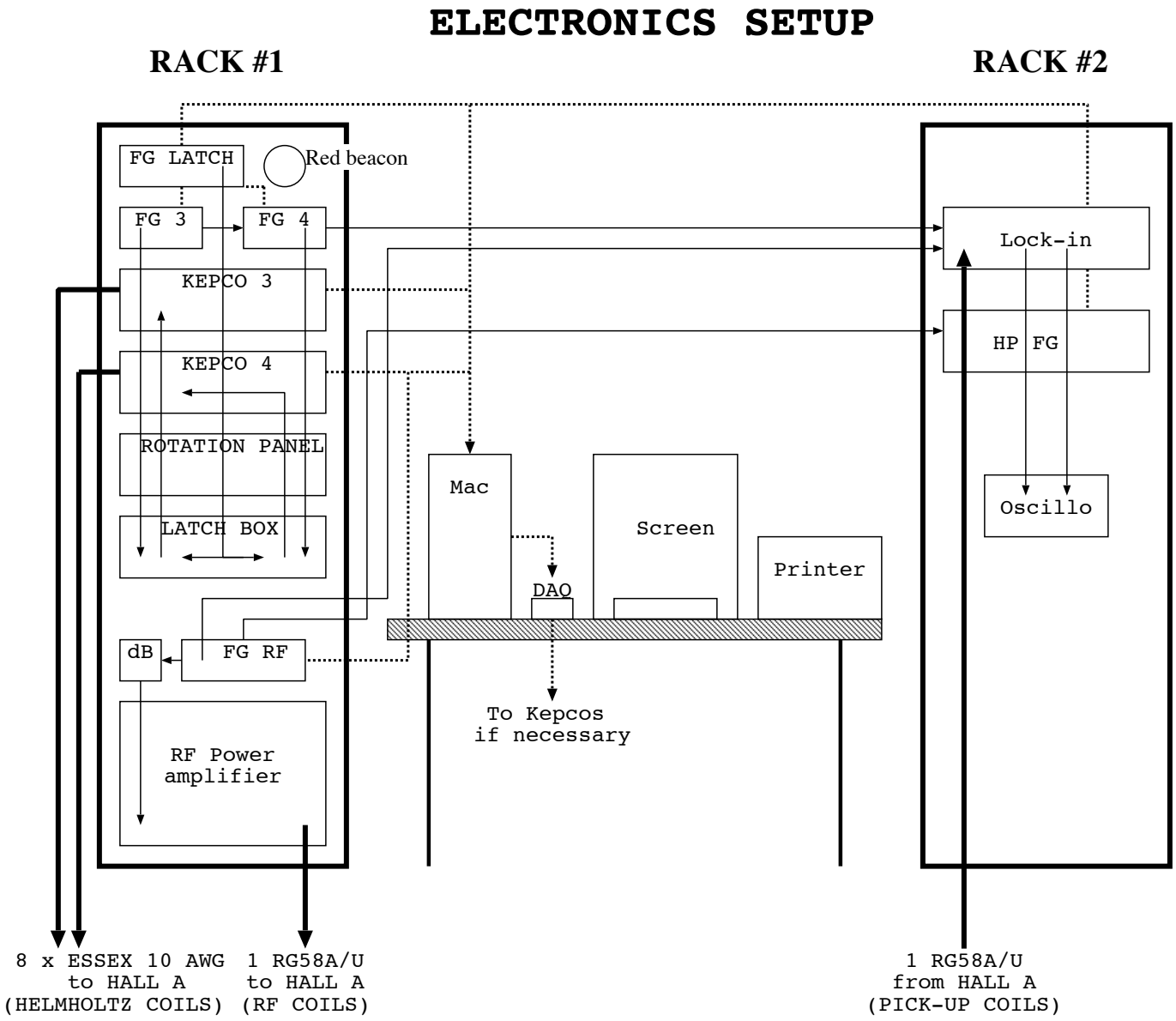

Figure B.2: Description of the electronics located on the second floor of the Counting House A. Two racks need to be used. 10 cables will go from the second floor to the target location in the hall : 8 (main+sensing) ESSEX AWG 10 for the Helmholtz coils, 1 RG58A/U for the RF coils and 1 RG58A/U for the pick-up coils.

- To fit NMR data, open the **NMR Helium Fit** Vi in the Apple menu. Run it. You will be asked to choose a data file. The data files are located in the following directory :

  Desktop:HD3:NMR:Helium:Data

  When the panel opens, the UP and DOWN curves are displayed and the Vi will try to fit them using default parameters. To try your estimation of these parameters, stop the Vi, switch the controls from the UP Default and DOWN Default positions to the UP User and DOWN User positions. Enter your estimations of : - FWMH at resonance (in G). - Background slope (in μV/G). Leave it to zero for simplicity. - Resonance field (in G). - Peak height (in μV). Can be positive or negative ! - Background at resonance (in μV). according to the following Lorentzian parameterization of the signal :

$$Signal = PeakHeight \times \left[4(\frac{B - ResonanceField}{FWMH})^2 + 1\right]^{-1} + Slope \times (B - ResonanceField) + Background \quad \text{(B.1)}$$

The whole process can take five minutes.

NMR AFP Safety

The NMR AFP system provides the DC current in the holding coils (up to 10 A) and the AC current in the RF coils (usually 1 A rms) of the target setup. Any human contact with the wires could be fatal and should therefore be avoided. All the electronic devices and the Macintosh used to sweep are located on the 2^{nd} floor of the Counting House A. Refer to **Figure B.3** for a description of the electronics.

B.4 The DC current

It is produced by the two Kepco power supplies. One drives the large coils, and the other the small ones, as stamped on their front panel. The output of each Kepco consists of four wires, two to lead the current, and the two others used for sensing. The four output plugs are located on the back panel of each power supply which can only be reached through the back panel of the rack. The connections are protected by a plastic strip and can not be touched by hands. In the hall, simple copper screws are used to connect those wires to the coils. They should never be touched. The grounding of the system is achieved in the hall.

How to turn the Kepco Power Supplies off in an emergency ?

1. Turn the Function Generators SRS DS345 off (one for each Kepco) by pressing the on/off switch.

2. Turn the Kepco power supplies off by setting the manual on/off switch to the off position. The digital displays should turn off.

B.5 The AC current

It is produced by the EIN RF Power Amplifier located at the bottom of the same rack. When its running, the manual switch is set to the ON position, the red LED is steady and the needle on the display is above zero. The AC current comes out from the BNC OUTPUT plug, goes through a current monitor (looks like a small toroid) and finally goes to the RF coils. In the hall, the cable is connected to the RF coils along the RF mounting using simple connectors with screws. Those are protected by electrical black tape. They should never be touched when the RF Power Amplifier is running. The grounding of the system is provided by the RF Power Amplifier.

How to turn the RF Power Amplifier off in an emergency ?

1. Turn the Function Generator SRS DS345 connected to the RF Power Amplifier off.
2. Turn the RF Power Amplifier off by setting the manual on/off switch to the off position. The red LED should turn off and the needle should go back to the zero position.

A general on/off switch is also available on the back side of the rack. It should be used only after the Kepco Power Supplies and the RF Power Amplifier have been turned off.

A red beacon located on the top of the rack is running every time one of the power supplies (Kepco power supplies and/or RF Power Amplifier) is running. For more safety, we will use a second red beacon in the hall, located close to the coil assembly, so workers will be warned if some current is running in the coils.

Appendix C

Electron Paramagnetic Resonance Measurement (EPR)

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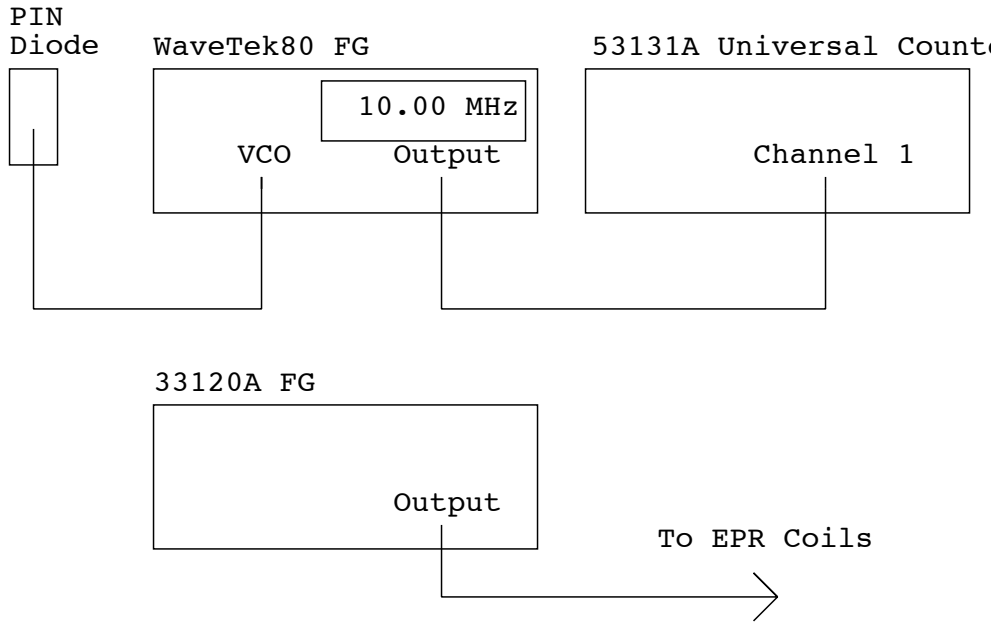

Figure C.1: Basic EPR circuit to find the frequency of the signal without tracking it

In what follows we describe two methods to setup and perform an EPR measurement of the the target polarization.

C.1 Minimal Circuit Method:

Use this configuration when you wish only to find the Electron Paramagnetic Resonance (EPR) frequency, not actually track its position. This method allows the user to observe the intensity of the EPR transition light emitted from the cell as a function of applied frequency to the EPR coil.

First, construct the circuit described in figure C.1 by following these steps:

1. Position the PIN diode so that it looks directly at the light beam coming from the cell.
2. Connect the diode to the VCO input on the Wavetek. Be sure that the VCO indicator is lit above this connection. (The VCO is used because it is very sensitive to small changes in voltage. At a carrier frequency of 10MHz, a 1mV input will produce a 400Hz shift in the output frequency.)
3. Set the main frequency of the Wavetek to 10MHz. A large carrier frequency insures a large response from the VCO.
4. Connect the output of the Wavetek to the Counter. Make sure that the output is not in standby mode.

5. Connect the cable leading to the EPR coils to the normal output of the 33120A frequency generator.

Now that the circuit is in place, open the LabView program called "Sweep of EPR Coils.vi." Go to the "operate" option in the toolbar, and place the program in run mode. This step fully enables the program.

1. Input the start and stop frequency for your sweep in the upper left of the screen. At the start of pumping, the resonance frequency should be around the number given by this formula:

   EPR base resonance = (466000 * holding field in Gauss)

   Thus, your sweep should begin below and end above this number, or vice versa.

2. Input the voltage at which you will run the EPR coils. Typically, this is 10Vpp, but it can go as high as 15Vpp.

3. Next, enter the number of sweeps you wish to run.

4. Submit the number of points per sweep, as well as the sweep duration. The maximum speed yielded by these inputs should not exceed two points per second. Also keep in mind that the peak you are looking for is about 40kHz in width.

5. Finally, enter the location where you wish to store the data generated by the program.

After all of the necessary data has been entered, the sweep may begin. To start the program, simply click on the large white arrow in the upper left corner of the screen. The three red readouts in the lower left should begin displaying current information. At the completion of each sweep, a scatter plot will be generated, displaying the collected data.

C.1.1 Common Problems

1. The plots show no peak, or multiple peaks. This is often the case with this method of measurement. Noise is a big problem, since no lock-in is used. To get better results, run multiple sweeps and average the results. If everything is working properly, one peak should stand out from the rest.

2. The Counter shows an error message. This is probably caused by a sweep rate that is too fast. Reset the sweep parameters and restart the Counter. Begin the program again. If it still errors, try checking the Gate from the front panel. Smaller Gates (.1s) often work better.

3. How do I use the output data? The data is saved in a text file consisting of two columns. The first column contains the frequency of the EPR coil, while the second column holds the corresponding signal from the PIN diode. Its format is read by such programs as SigmaPlot, Excel, and Paw.

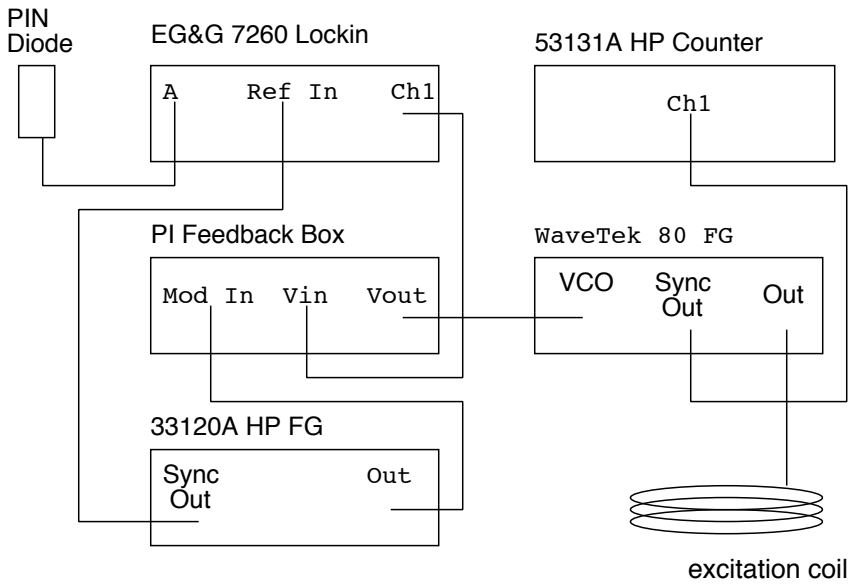

Figure C.2: Feedback EPR circuit which allows to track the track the EPR resonance.

C.2 Feedback Circuit Method

This configuration uses the lock-in with a PI feedback box to latch onto the EPR resonance frequency and then track its behavior. This is useful for tracking the pump-up curve or monitoring the AFP spin-flip operation.

Construct the circuit described in figure C.2.

Steps:

1. Position the PIN diode to look directly at the incoming light, and connect it to the "A" input of the lock-in.
2. Connect Channel 1 of the lock-in (actually on the back panel) to Vin of the PI feedback box.
3. Connect the sync-out of the 33120A function generator to the reference input located on the front of the lock-in.
4. Connect the normal output of the 33120A function generator to the modulation input located on the PI feedback box.
5. Wire the Vout of the PI feedback box to the VCO input of the Wavetek 80. Make sure it is set to VCO mode. It is probably useful to "T" this connection, so that you may simultaneously observe it on an oscilloscope.
6. Connect the Sync-out of the Wavetek 80 to Channel 1 of the Universal Counter.

7. Finally, connect the cable that leads to the EPR coils to the normal output of the Wavetek 80.

Now that the circuit is built, you can begin the initialization of the setup.

1. Set the modulation amplitude to approximately 3.5 volts. The waveform should be a sine wave of about 140Hz. (This frequency is arbitrary. You may actually choose any frequency that you like. 140Hz is good, since it is far away from most noise sources.)

2. You must now find the current resonance frequency by hand, so that the circuit will not have far to "look" for the largest signal. To do this, temporarily remove the connection to Vin on the PI feedback box, and turn off the integration function. Manually adjust the carrier frequency on the Wavetek, while observing the lock-in. Look in the area given by the formula:

   EPR base resonance = (466000 * holding field in Gauss)

   This is typically about 10MHz.

3. You have found the resonance when the lock-in signal is small, and it becomes very large when shifted to either a higher or lower frequency. Keep in mind that the lock-in will read zero when you are far from resonance as well, so be sure to look for this characteristic resonance behavior.

4. Once the lock-in is minimized, reconnect the Vin input.

5. Turn on the integration on the PI feedback box. The lock-in signal may increase, but it should still be rather stable.

6. Observe the Vout output on an oscilloscope. If it is "jumping around" erratically, or looks as if the Opamps have been saturated, you must adjust the gains. The best advice is to begin with the relative gain, and if this does not rectify the problem, move on to the absolute gain. Basically, adjust these parameters until the undesirable behavior ceases.

7. Once this is done, the circuit should take care of itself. Left alone, it will track the movement of the resonance peak.

To make use of this data, open the LabView program CounterA.vi. This program simply reads the counter and graphs its output as a function of time. All the user must enter is the location where the output data file will be stored, as well as the width of the gate on the counter (default is .1s). To begin data taking, simply click on the large white arrow in the upper left corner of the panel.

C.2.1 Common Problems

1. The lock-in does not remain stable. This effect can be caused by several things. First, it is possible that the frequency to which you are locked is not the true resonance. This happens

because there are smaller signal peaks near to the main peak. The solution is again to find manually the resonance, looking for the most pronounced signal. Second, it could be that the modulation amplitude is too small. The size of this amplitude determines how far from the central frequency the circuit looks for the resonance. Try increasing the modulation amplitude, or if possible, lower the attenuation at the VCO. The problem could also be caused by reading the wrong channel from the lock-in. For example, you are reading "X" when you need "Y". Adjust the output channel accordingly, or change the reference phase by 180 degrees. Finally, it could be that the PI Feedback box is improperly set. Adjust the gains until the lock-in becomes more stable. Admittedly this method is not very quantitative, but is often successful.

2. The lock-in remains stable, but does not seem to track the resonance. Most likely, you are not locked to resonance, but are completely out of the peak region. Again, manually find the resonance.

3. The counter gives error 420. The problem is with the gate. Make sure that the program and hardware have the same gate. (Note: the program does not set the gate, this must actually be done on the Counter front panel.)

C.3 Spin-Flip Detection

This method observes the change in the EPR resonance frequency as the direction of ^{3}He spin is reversed. This is the method to use to obtain an accurate polarization measurement.

First, complete the Feedback Circuit Method, discussed above. Next, make sure that the SR DS345 function generator is on your GPIB network, since it controls the flipping of the spins. (In the test lab, it is not currently connected to the PC.) Once resonance is locked, open either Manual Spin Flip.vi or Automatic Spin Flip.vi in LabView.

1. Enter the location of the place where the output data will be stored.

2. In the Automatic program, also enter the time between spin flips.

3. Click the white arrow in the upper left corner to begin data collection.

4. In the Automatic program, the spin flips are executed automatically, as the name would suggest. In the Manual program, the user determines when a flip takes place. To initiate a flip, click on the large blue start button. (It may be necessary to hold this button for a second to get the program to recognize your request.)

5. Once a flip is done, a shift in frequency, read by the Counter should be observed. From this shift, the polarization can be determined.

C.3.1 Common Problems

1. See the problems in the previous section.

2. The circuit becomes unlocked during the spin flip.

This is common, since the frequency shift during the spin flip can be quite large, on the order of 10-20kHz. Currently, it is suggested that lowering the attenuation at the VCO or increasing the modulation amplitude would aid the circuit in surviving this quick leap.

Appendix D

The Reference Cell System Operation and Safety Procedure

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D.1 Description of the Reference Cell System

The reference cell system is comprised of three subsystems—the reference target cell, the gas handling system, and the control electronics. The reference target cell is mounted inside the target enclosure, which is located in the beam path immediately upstream of the spectrometers. The gas handling system consists of a gas manifold, which is located next to the laser hut, and a series of gas lines that connect the manifold to the reference cell. The main control electronics are mounted on the back of the gas manifold. A series of cables connect the local electronics to a set of remote controls installed upstairs of the counting house. A schematic of the entire system is shown in figure D.1. The individual subsystems are depicted in figures D.1, D.1 and D.1.

Under normal operating conditions, the manifold, the reference cell, and the intervening gas lines will be filled with either ^{3}He or N_2 gas at high pressure (typically $\approx$ 10 atm). The system may be operated either locally (at the panel) or remotely (via switches mounted in the counting house). A switch on the gas panel itself allows one to toggle between local and remote control. All switches, local and remote, are equipped with LED displays so that one can readily determine the status of any switch. In addition, the valves are also outfitted with status indicator lights on the panel. A logic level signal runs from each valve to the remote control room where it activates an LED. Thus, in both the

Condition	action description	valves activated open
C1	**Slow pump-out**	V1+V4+V6
C2	**Fast pump-out**	V1+V4+V5+V6
C3	**Slow vent**	V4+V5+V7
C4	**Fast vent**	V4+V5+V6+V7
C5	**Slow ^{3}He fill**	V3+V4+V6
C6	**Fast ^{3}He fill**	V3+V4+V5+V6
C7	**Slow N_2 fill**	V2+V4+V6
C8	**Fast N_2 fill**	V2+V4+V5+V6

Table D.1: Action of the remote-control switch panel

remote and local mode, one has information both on which valves should be open, and which actually are.

The reference cell consists of a very thin-walled glass flask. An outlet at the opening is joined to an aluminum tube by means of a glass-to-metal seal. The aluminum tube is connected to a 1/4" dia. flexible hose with compression fittings. The other end of the hose is joined to the gas manifold by about 7 meters of 1/8" dia. copper tube.

The manifold consists of 7 solenoid-controlled, air-actuated valves, one hand-set needle valve, one baratron pressure gauge (0–1000 torr and 0–1000 psi), two pressure relief valves, a 450 ml bottle of high-pressure ^{3}He gas, a bottle of high pressure N_2 gas, a scrolls pump, and sufficient tubing and pipe fittings to connect them all together. There are 4 basic actions that the manifold must accomplish; pump-out, vent, fill with N_2, and fill with ^{3}He. Each of these actions can be carried out at two different speeds—fast and slow. Fast typically means on the order of a fraction of a second. The slow speed is set by adjusting the aperture on the needle valve. It can be made agonizingly slow if desired. In all, there are 8 distinct "permitted" valve configurations, plus one default condition (all valves closed).

The reference cell control panel is comprised of 8 pushbutton switches, which activate the 8 possible valve setting conditions, a baratron pressure gauge which reads between 0–1000 psia, and a toggle switch that enables or disables the pushbutton switches. The eight active conditions may be set by means of the remote control panel. The actions are described in Table D.1.

If the toggle switch is in the enable position (up), the valves will be configured according to the pushbutton switch that is depressed, which will be illuminated. If the toggle switch is in the disable position (down), all of the valves will be closed, and an LED below the toggle switch will be illuminated. At present the default mode (all valves closed), is set by disabling the 5V output signal from the switch panel. The remote switch panel is *implicitly* interlocked, in that inherently catastrophic valve configurations (like pumping out \$180.00/liter ^{3}He gas through the scrolls pump) cannot be activated.

However, certain sequences of valve configurations may not be wise. For example, one should ordinarily not initiate a high-pressure fast gas fill from vacuum.

The local valve control system, by contrast, has NO INTERLOCKS WHATSOEVER. It is only there to provide a backup in case, for some reason, the remote control circuit malfunctions and one must assume manual control of the valves in order to relieve an emergency situation. THE LOCAL CONTROL VALVES SHOULD NOT BE USED UNDER ORDINARY RUNNING CONDITIONS. The pressure at the location of the gas manifold is measured by a baratron gauge. The baratron pressure is read into the data stream and is also output to a remote sensing unit located in the counting house.

D.2 Operation

Ordinarily, the toggle switch should be kept in the disable condition. In order to change valve configurations, one should start with the toggle switch on the disable position. The appropriate switch should be pressed (it will lock in place) and the toggle switch should then be set to enable. This will activate the desired condition. One should leave the toggle switch enabled until the desired condition is reached (for example, on slow N_2 fill, until the pressure reaches the desired level as read on the baratron pressure gauge.) The toggle switch should then be disabled.

D.3 Cautions

1. Be careful with the ^{3}He, we have a limited supply.

2. If the system is above atmospheric pressure, always vent it before pumping. Begin a pumping sequence on slow pump. Note, however, that slow pump is *very* slow. The aim is to not burn out the turbopump.

3. The reference cell is fragile. Therefore, one should fill most of the way to one's target pressure on the slow fill conditions. The slow fill is set so that it fills at about 1 psia/s at near atmospheric pressure. The rate of fill on the slow fill may be adjusted (but probably shouldn't be) with the metering valve located on the reference cell panel in the "triangle" formed by valves 5, 6 and 7.

D.4 Potential Hazards

The principal hazards associated with the reference cell are flying material and loud noise if the gas panel or reference cell fails catastrophically under high pressure. Of the two subsystems, the reference cell subsystem presents the greater hazard, both because it is more likely to fail, and because it is likely to be more dangerous if it does. While paying due attention to the risks of being hit with high-velocity

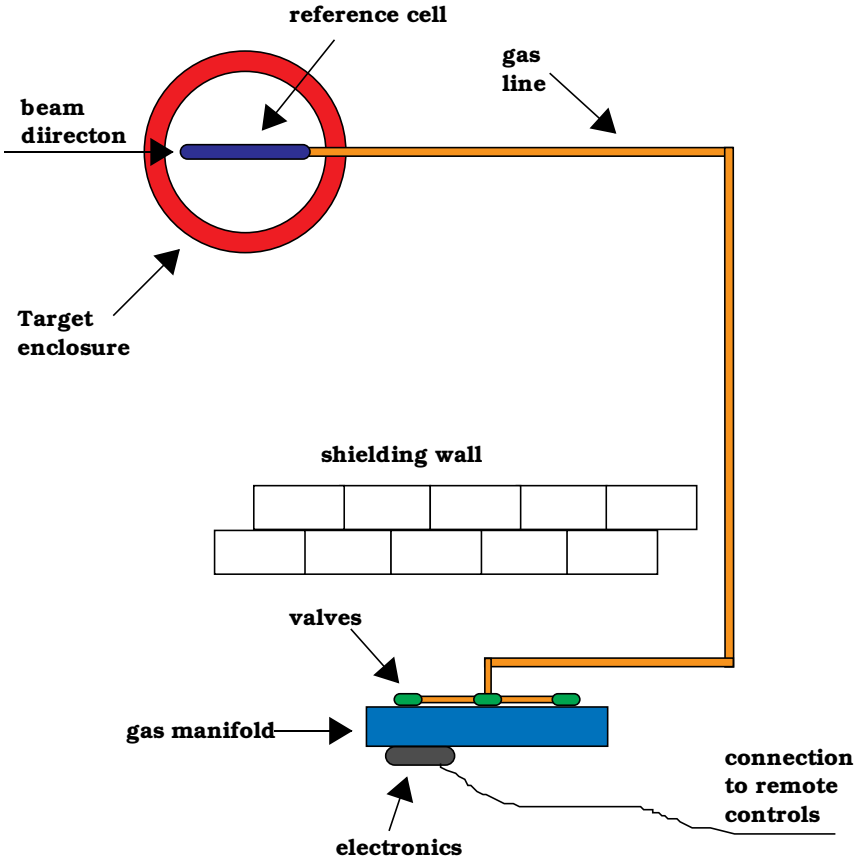

Figure D.1: Schematic of reference cell system

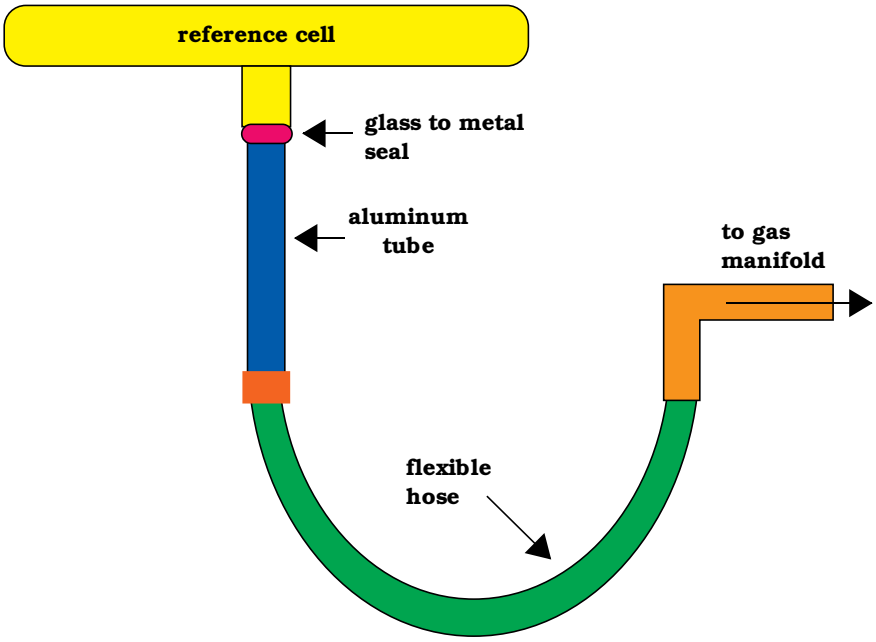

Figure D.2: Reference cell subsystem

glass shreds in the event of a cell explosion, one should not neglect the danger of being whipped by the flexible hose should the glass-to-metal seal fail while one is accessing the target enclosure.

The principal hazards associated with the local valve system are economic—loss of valuable material and damage to MIT property. The local valve system should not be activated except to relieve an emergency situation that threatens injury or serious property damage.

D.5 Hazard Mitigation

After testing the reference cell system between 210 to 240 psi and to protect the cell from rupturing during normal operation, the relief valves PRV1 and PRV2 (see Fig. D.1) have been set to 190-200 psi.

All personnel shall wear hearing protection when accessing the platform area while the cell is under high pressure and no windows are on the target enclosure. The valves and fittings on the gas manifold face the shielding wall; in order to retain the safety advantages of this configuration, personnel shall not insert themselves between the manifold and the wall, nor should they rotate the manifold away from the wall except to perform emergency repairs. Whenever doing so, they shall wear facial shielding, and torso padding.

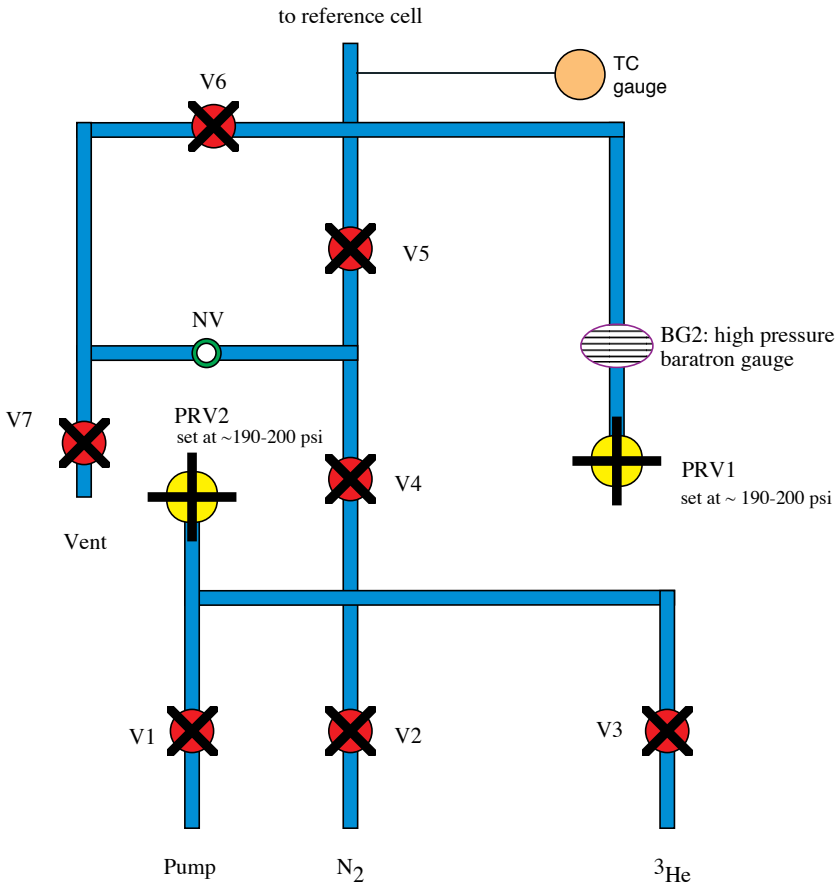

Figure D.3: Reference cell gas manifold

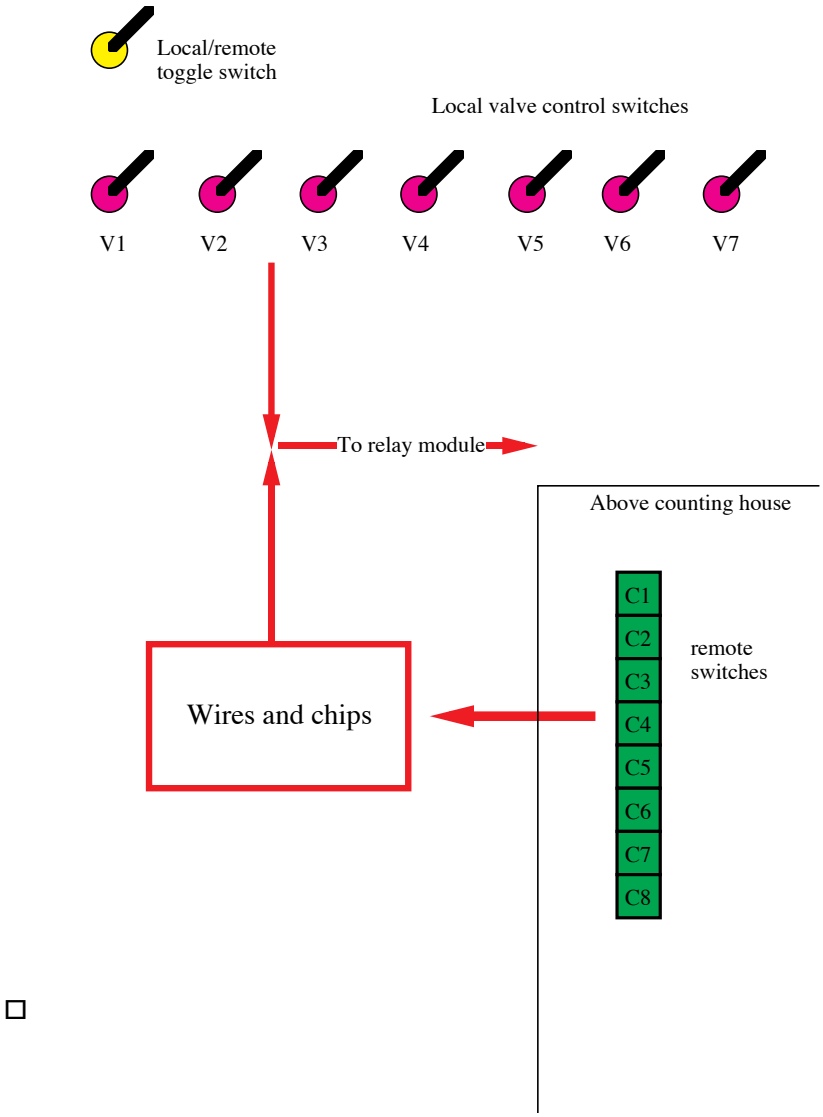

Figure D.4: Schematic of reference cell electronics

Special care must be taken when accessing the region inside the target enclosure. Full face shielding and body padding should be worn under these conditions. Before working in the vicinity of any of the reference cell components, personnel shall check the pressure in the manifold from the baratron readout in the remote control area.

D.6 Authorization

All personnel who will be working in the target enclosure area will be informed of the potential hazards, will read this OSP, and will receive training in the operation of the various reference cell subsystems.

Appendix E

Target Cell Heater and Controls

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The target pumping cell must be kept at a temperature of about 170°C (340°F) for optical pumping of Rb to be effective. This is accomplished by flowing hot air through a special temperature-resistant enclosure around the pumping cell (the "oven") and regulating the temperature of the air using a process controller. The system is described in detail in the following.

E.1 Design

Figure E.1 shows a schematic diagram of the heater system and the associated controls. Pressurized dry and filtered air at room temperature is provided by a dedicated compressor in the Hall. The air enters the system through a shut-off valve and a pressure regulator, which is typically set to an output pressure of 15 psi. The flow rate is measured with a gas velocity sensor (Omega model FMA-905) connected to a display unit (Omega DP41-E-S2R) that provides an alarm to indicate insufficient flow. The air then passes through a resistive heater element (120 VAC, 700 W) and continues through special temperature-resistant tubing (G-10) into the target oven. The oven material is Torlon and Vespel plastic which can withstand a temperature of at least 260°C continuously. The air finally exits the system through a several meters long exhaust pipe where it can cool down.

A 100Ω Pt RTD (Omega model F3105) measures the temperature inside the oven. A process controller (Omega CN77540-C2) operating in PID mode drives the heater via a solid-state relay (SSR) regulating the heater power dependent on the temperature detected by the RTD. The SSR (Omega model SSR240DC10) accepts a low-voltage (3-32 VDC) control signal of about 30 mA. A mechanical

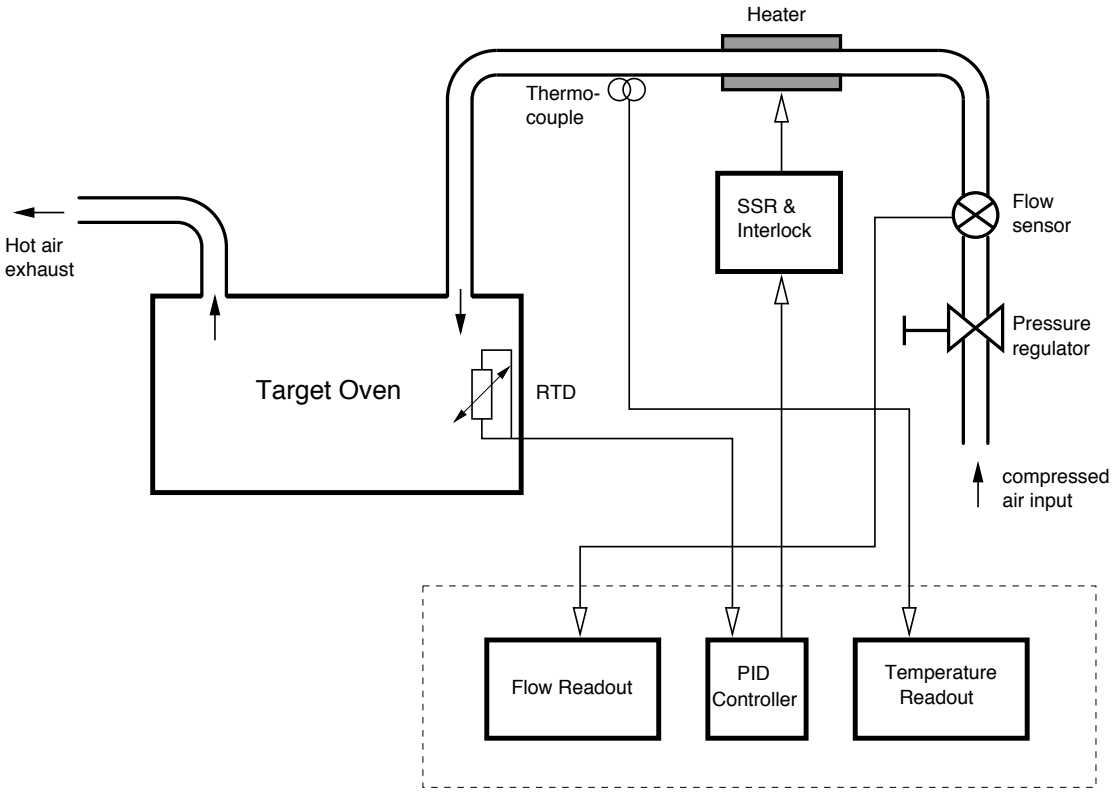

Figure E.1: Schematic diagram of the target cell oven control system. The instruments in the dashed box are located upstairs, while the remaining components are located in the Hall in the vicinity of the target. For clarity, the interlock circuitry is not shown (see Figure E.2).

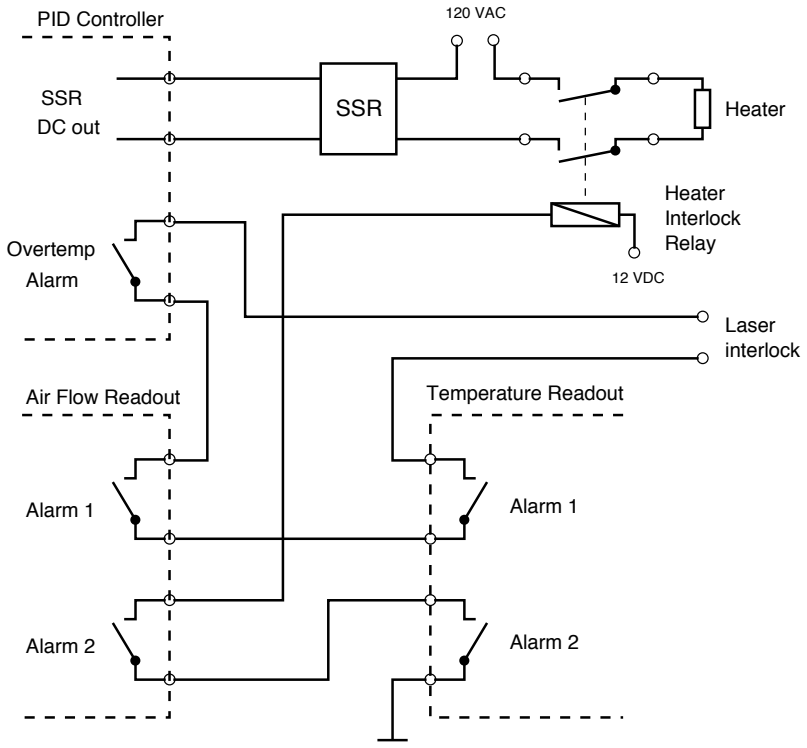

Figure E.2: Schematic diagram of the oven heater interlock system. The switches represent relays. In normal operation, the relays are energized (contacts closed). An alarm condition (or instrument power failure) will de-energize (open) the corresponding relays, interrupting the interlock circuit. The instruments are programmed such that their dual alarm outputs operate simultaneously.

relay between the SSR and the heater allows interruption of the 120 VAC heater power in case of a malfunction (see section E.2).

A thermocouple (Omega 5SC-GG-K-30-36) is mounted on the tubing right after the heater to allow monitoring of the temperature of the air exiting the heater. Another display unit (Omega DP41-TC-S2R) reads the thermocouple and generates an alarm if the temperature exceeds a preset threshold.

The PID controller as well as the two display units are installed in a 19" chassis in the electronics racks on the second floor of the counting house where they can be manually operated if necessary. All other components are located in the Hall in the vicinity of the target. The instruments can be monitored and programmed remotely via serial RS-232 communications, which allows convenient control via an EPICS/MEDM graphical user interface (GUI) in the counting house.

E.2 Safety Considerations

The heater system represents a significant fire hazard and therefore requires good failsafe protection. Possible failure modes include:

1. Insufficient air flow. Possible causes: Compressor failure; obstruction in filter; operator error. Possible harzards: Overheating of heater element, resulting in equipment damage and/or fire. Protection: Air flow is monitored; insufficient flow disables heater (and laser) via hardware interlock.

2. Heater overtemperature. Possible causes: Insufficient airflow; temperature controller failure; RTD failure; operator error. Possible hazards: Damage to heater element and/or tubing; fire. Protection: Heater temperature is monitored; excessive temperature disables heater (and laser) via hardware interlock.

3. Oven overtemperature. Possible causes: Temperature controller failure; RTD failure; insufficient air flow; excessive laser power; operator error. Possible hazards: Explosion of target cell; damage to oven enclosure and/or optical elements; fire. Protection: Temperature controller will generate alarm if RTD indicates excessive temperature, disabling heater via internal logic and and laser via hardware interlock.

A schematic diagram of the interlock system is shown in Figure E.2. The instruments are programmed such that their dual alarm relays operate simultaneously if a value is out of range. An interlock condition disables the heater as well as puts the lasers in standby mode. Interlocking the lasers is important as the laser light contributes significantly to the heating of the target oven.

E.3 Operation

The oven can be controlled from a GUI running on one of the Hall A counting house computers, or manually using the front panel controls. The GUI is not yet finalized, so we only give a brief description of the manual operating procedure here at this time:

1. The oven controller and temperature and flow displays are located in a 19" chassis in one of the racks upstairs. Make sure power to this chassis is on. The green light on the front panel should be lit.

2. Verify the alarm set points for the flow meter and temperature indicator. Press the `SETPTS` button until the display shows `SP3`. After about 1 second, the setpoint value appears. It should be 250 for the air flow display and 220 for the temperature display. Press `SETPTS` again and check setpoint `SP4`. It should be identical to `SP3`.

   To change any of the values use the `MIN` and `MAX` buttons. The `MIN` button selects the digit to be changed whereas the `MAX` button changes the value of the currently selected digit. Press `SETPTS` again to store the new value. When finished, press `SETPTS` until `RUN` appears in the display.

3. Verify the current temperature of the oven. It is shown in the upper (red) display of the temperature controller and is labeled `PV` for "Process Value". The units are °C. The value should be reasonable, *e.g.* around room temperature if the oven has been off for several hours or more. If the value does not make sense, either the controller is misconfigured (see below) or the RTD in the oven is broken or incorrectly connected. Do not proceed before you have a sensible reading.

4. (Optional) Verify the correct configuration of the controller. Use the `MENU` button on the controller to scroll through the various configuration menus. To inspect parameters within a menu, press `ENTER` followed by `MENU` again. The suggested default parameters are listed in Tables E.1 and E.2. This step is time-consuming and can be skipped if you are relatively certain that the configuration is ok. A detailed description of the controller parameters is given in the controller manual.

5. Verify that air is flowing. The air flow readout should indicate a value of 350–450. These are arbitrary units. As long as the heater is off, the reading should not fluctuate by more than about ±10 units.

6. Verify the current temperature of the heater. It should be close to room temperature. If the value is unreasonable, either the readout is misconfigured or the thermocouple is broken. Do not proceed before the problem is corrected.

7. Verify that alarms are reset. Underneath the main display there are four LEDs, one for each alarm 1–4. If either LED `3` or `4` is on on either instrument, it indicates that an alarm has

been triggered and that the system is interlocked. You must reset the alarms before you can continue. To do so, first correct the problem (*e.g.* turn the air flow on) then press *RESET* once on the affected instrument(s). If the LEDs stay on despite correct setpoints and readings, the instrument is probably misconfigured.

8. Begin heating. To avoid damage to the oven, the temperature must be increased to the final value slowly. A good final operating temperature is 170°C, and a good ramping rate is 60°C/h, *i.e.* heating of the oven will take about three hours to complete.

   In manual mode, you must enter a new temperature setpoint by hand at fixed time intervals. ("Ramp and Soak" does not seem to work reliably with this controller.) You should increase the value by 10°C every 10 minutes. For example, if the current oven temperature is 35°C, start with a setpoint of 45°C and increase this value by 10°C in approximately 10 minute intervals.

   To enter a new setpoint, do the following

   (a) Press `MENU` on the temperature controller. A little green light marked `SP1` in the upper left corner of the display will start to blink. Also, the first digit of the green numerical display, labeled `SV` for "Setpoint Value", will blink.

   (b) Use `MIN` to select the digit you wish to change and `MAX` to modify the value.

   (c) When done, press `ENTER`. The display will briefly show `run` when the controller enters normal operating mode. This starts the heating process.

9. Check correct operation of the controller. A little green light marked `SP1` in the upper left corner of the temperature controller display indicates that the heater is active. This light should blink slowly, being mostly on while the oven is heating up and being mostly off (or even completely off for periods of up to a few minutes) when the oven temperature has reached the setpoint.

   The heater temperature should increase proportionally to the fraction of time that the `SP1` indicator is on. Note that the temperature reading is *not* directly related to the oven temperature. In particular, the heater may become significantly hotter than the oven, and its temperature might fluctuate from almost room temperature to high values over short periods of time as the heater power is automatically cycled on and off by the controller. As long as the temperature stays below the alarm threshold (220°C) there is no reason for concern.

10. Check stability of the final temperature. The temperature might overshoot slightly. If the overshoot is less than about 5°C then this is normal. If the stability is poor it is probably due to incorrectly set PID parameters in the controller. Changing these parameters is best done by an expert since this requires in-depth understanding of the system.

    The laser contributes significantly to the heating of the oven. Therefore, you will notice sudden temperature instabilities when the laser is turned off or on. It will take several minutes for the

controller to compensate for such changes.

11. The air flow rate is slightly dependent on the heater power applied (conductance varies with temperature). Therefore, the flow rate will fluctuate by some 10-20%. This is normal.

12. At any time you can place the controller in standby mode by pressing `ENTER` twice. The display will show a blinking text `STBY`. This will turn the heater off completely and can be used when the system appears to malfunction. However, exercise some caution if the oven is at an elevated temperature since it will quickly cool down if heater power is disabled and you will lose time bringing it back up to operating temperature.

13. In an emergency, simply turn the power to the chassis off completely. This will open the interlock loops, thereby cutting power to the heater and placing the laser in standby mode.

Menu	Submenu	Setting
Output Redirection		S1.o1
Input Type		RTD
	RTD Type	385.3
	RTD Value	100_
RDG Configuration	Decimal Point	FFF.F
	Temperature Units	°C
	Filter Constant	0004
Alarm 1		Enabled
	Type	Absolute
	Latched	Latched
	Contact	n.c.
	Setup	Above
	Power On	Enabled
	Low Value	(anything)
	Hi Value	210.0
Alarm 2		Not Installed
Loop Break		Disabled
Output 1	Self	Disabled
	% Low	0000
	% High	0095
	Control Type	PID
	Action Type	Reverse
	Auto PID	Disabled
	Adaptive Control	Disabled
	Anti Integral	Enabled
	Start PID	Disabled
	Proportional Band	0038
	Reset Setup	0050
	Rate Setup	0000
	Cycle Time	0001
	Damping Factor	0001
Output 2	(any)	(anything)

Table E.1: Suggested default parameters for the temperature controller.

Menu	Submenu	Setting
Ramp & Soak	Ramp	Disabled
	Soak	Disabled
Analog Output		Not installed
Communication Option	Baud	9600
	Parity	Odd
	Data Bits	7bit
	Stop Bits	1bit
Bus Format	Checksum	no
	Line Feed	no
	Echo	no
	Standard	232C
	Mode	Command
	Separator	Space
Data Format	Status	yes
	Reading	yes
	Peak	no
	Valley	no
	Unit	yes
	ID	no
Address Setup	(any)	(anything)
Transmit Time	(any)	(anything)
Remote Setpoint		Not installed

Table E.2: Suggested default parameters for the temperature controller (continued).

Appendix F

Laser Operation and Safety Procedure

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F.1 List of Authorized Polarized ^{3}He Target Operators

Timothy Black	MIT
Gordon Cates	Princeton
Jian-Ping Chen	Jefferson Lab (Laser safety Supervisor)
Alexandre Deur	Jefferson Lab
Pibero Djawotho	College of William and Mary
Haiyan Gao	MIT
Ole Hansen	Jefferson Lab
Emlyn Hughes	Caltech
Sebastien Incerti	Temple University
Steffen Jensen	Caltech
Gary Jones	University of Kentucky
Wolfgang Korsch	University of Kentucky
Ioannis Kominis	Princeton
Meihua Liang	Jefferson Lab
Zein-eddine Meziani	Temple University
Dave Pripstein	Caltech
Dave Prout	Kent State University
Yves Roblin	University of Clermont-Ferrand
Karl Slifer	Temple University
Wang Xu	MIT

F.2 List of Authorized People to Change Target Cells

Alexandre Deur	Jefferson Lab
Pibero Djawotho	College of William and Mary
Ioannis Kominis	Princeton
Karl Slifer	Temple University

F.3 List of Laser Trained Personnel

Timothy Black	MIT
Gordon Cates	Princeton
Jian-Ping Chen	Jefferson Lab (Laser safety Supervisor)
Alexandre Deur	Jefferson Lab
Pibero Djawotho	College of William and Mary
Xiong Feng	MIT
Haiyan Gao	MIT
Emma Goldberg	Caltech
Ole Hansen	Jefferson Lab
Sebastien Incerti	Temple University
Steffen Jensen	Caltech
Gary Jones	University of Kentucky
Wolfgang Korsch	University of Kentucky
Enkeleida Lakuriqi	Temple University
Meihua Liang	Jefferson Lab
Zein-eddine Meziani	Temple University
Dave Pripstein	Caltech
Dave Prout	Kent State University
Yves Roblin	University of Clermont-Ferrand
Karl Slifer	Temple University
Wang Xu	MIT

F.4 List of Authorized People to Perform Laser Alignment

Steffen Jensen	Caltech
Dave Pripstein	Caltech
Jian-Ping Chen	Jefferson Lab

F.5 List of Authorized People to Work on the Reference Cell System

Timothy Black	MIT

Persons can be added to the above lists after proper training and authorized by Jian-ping Chen, pager 849-7413, phone 7413 and email:jpchen@jlab.org.