PRIMER: THE LABORATORY NOTEBOOK

WHAT IS THE PURPOSE OF A LAB NOTEBOOK?

Record keeping is an essential part of the scientific process. The laboratory notebook is the primary medium for keeping these records -- facilitating the recording of a range of different activities, crucial to doing effective science. First and foremost, **it serves as a record of precisely what one did (both successfully and unsuccessfully) during the course of one's experiment.** Furthermore, information in the notebook is essential to corroborating anything that ultimately ends up being published. **Effective record keeping practice is a skill that requires substantial time to cultivate to a point where your records will be suitable for a research lab, so it's important to start developing this skill early.**

WHAT TYPES OF INFORMATION ARE IMPORTANT TO RECORD?

There are a variety of different types of information that researcher's use a lab notebook to keep track of during daily lab activities. This information goes beyond simply recording parameter values and data points. The majority of the information falls under one of the four following categories:

- **Objective information:** This consists of the parameters, settings, and data that result from measurement, alignment, or any other concrete actions taken by the researcher. This type of information is what you may commonly think of as being present in scientific records. One might describe the objective information found in the notebook as the "facts" of the experiment.
- **Subjective information:** This usually manifests as the researcher's interpretation or evaluation of the events in lab and commonly accompanies the objective information from the experiment. Just because this information contains the opinion of the researcher does not mean that it is "unscientific". For example, researchers spend a great deal of time troubleshooting and redesigning their experimental apparatus in an attempt to improve their measurements – by including subjective interpretation of various measurements (*e.g.* "these data looked unusual" or "it seems like the alignment is bad") the researcher can better recall their impression of prior measurements, and thus are better able to put these in the context of their current understanding of the experiment.
- **Analysis information:** It is common for analysis to be performed on raw data throughout the entire experimental process. Often, this is done in order to directly compare experimental results to theoretical models/predictions. Examples include short calculations and plots with accompanying fits to models. The information from this kind of analysis is often recorded in the notebook alongside the experimental details about the data, which aids the reader in interpreting the results.

- **Planning information:** This consists of future plans or directions for the research. This information can entail both short term/incremental plans (*e.g.* taking more data, similar to previous measurements but with slightly different parameters) as well as long term/substantial plans (*e.g.* complete redesigns of experimental apparatus). Researchers are constantly reflecting on and re-conceptualizing the day-to-day outcomes of their experiments; therefore it can be difficult to keep track of new ideas and experimental directions unless they are written alongside other pertinent experimental information.

WHAT'S IMPORTANT TO CONSIDER WHEN RECORDING INFORMATION?

- **Context:** Understanding the context of a lab notebook entry means understanding the "what" and the "why" of each experimental decision – in other words, "what was it that I measured and why did I measure it?" **It means understanding each entry in the broader picture of the entire experiment.** So, when recording information in your notebook consider if you are able to understand how what you're writing pertains to the experiment as a whole. If you are simply writing down the numbers for each parameter and listing the different data that you've recorded without explaining the reasoning behind the measurements, it is likely you will be unable to make sense of what you've written later on.

- **Audience:** You are the primary audience of your notebook, but authentic research is done collaboratively, therefore the lab records of an experiment must be available to all the researchers involved. This may include peers in the same research group, one's advisor, or researchers from collaborating research groups. Thus, when writing in your notebook try to imagine how your writing may be interpreted by others. Keep in mind what things you infer or assume, without writing down, and ask yourself whether or not others may be able to make sense of the context of your entry without this information. **In the case of your lab class, your audience will also likely include your lab partner and your instructor.**

- **Timescale:** You will find that you may need to reference various pieces of information recorded in your notebook in a week, a month, or in the case of authentic research potentially more than a year from when it was recorded. Of the information you write down, you will never know what you will need and when you will need it, but through experience you will find that some of the information maybe be of more short term importance (*e.g.* equipment parameters that will be updated in the subsequent few days) whereas other information you may keep coming back to over the course of weeks or months (*e.g.* a commonly reproduced alignment procedure). It is important to be mindful of this when writing each entry – it is good practice to ask yourself "When might I need this?" whenever writing down new information. **The farther in the future that may be, the more detail you should include.**

- **Time investment:** The process of keeping lab records is a fine balance between writing enough detail so that your records will be useful in the future and doing so in a time efficient way that does not slow the progress of your experiment. Record keeping is a time intensive part of the experimental process – many researchers express that they feel they should be taking more time to write additional information in the lab records that they keep. Very few of them feel that they spend too much time adding detail to these records. **Do not look at record keeping as an afterthought to the actual experimental process, but rather as an integral part that will require substantial amounts of your lab time to get right.**

LAB NOTEBOOK EXAMPLES

Here we present some examples of notebook records taken from a physics research lab here at CU. The various entries are recorded by several different researchers who are working collaboratively on the project. You will notice that each researcher has a different style and format to their entry, but much of the same information and thought process can be seen in each entry. These excerpts are meant as examples of authentic scientific record keeping and **do not represent a definitive illustration** for how you should maintain your records.

Annotations:

Provides context by referencing the measurements made in the previous day. This helps to motivate this day's work.

Compares new measurement to previous measurement and provides interpretation of comparison.

Provides subjective interpretation of plotted results.

Plot is well labeled with axes, units, and legend.

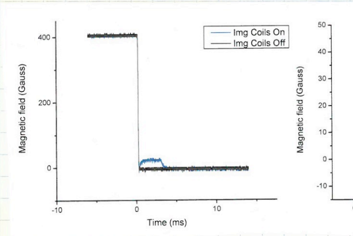
Clearly states all objective information pertinent to the measurements.

Preliminary analysis of results, synthesized in well labeled plot and accompanied by evaluation of fitting.

10/5/12

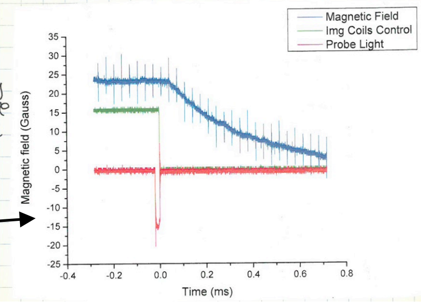
Yesterdays measurements were taken in the MOT load position. When the coils are in that position the λ/4 waveplate for the verticle MOT beams is right above the Top coil. This was causing an eddy current That made the magnetic field turn off much slower.

After repeating this measurement at the absorption imaging location the magnetic field turn off was ~~much more~~ quicker. so it looks like the imaging coils are not the problem. Also the measured field is pretty close to the calculated field (24 G)



Next looked at probe light timing and img coils timing to make sure they are happening at the same time.

Looks fine →



60s MOT load $N = 1.21 \times 10^9$ $\tau = 20.28$

decide to try a smaller magnetic field for imaging coils and try to tune probe to that.

control voltage: 4V B=12 Gauss $\Delta\nu$ = 17.8 MHz

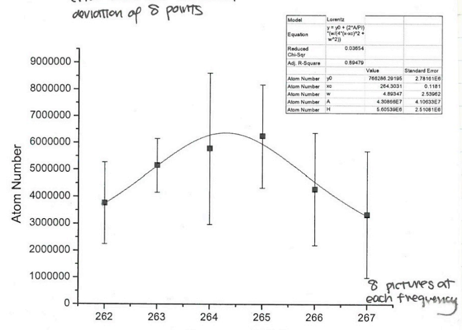
set AOM1 → 267.8 MHz and AOM2 → 250 MHz

Finally saw atoms in absorption imaging with imaging coils on!

Started tracing out a beam profile with ~$\Delta\nu$ = 17.8 MHz detuning however after 3 different frequencies the probe beam stopped locking above 269 MHz. At this point I also noticed that the lenses and mirror for focusing the image on the Andor camera were tilted and the beam was not centered on the lenses. Fixed this and decided to move on to imaging with a 24 Gauss field (8V control on img coils).

coil control voltage: 8V $B_{calculated}$ = 24 Gauss $\Delta\nu_{calculated}$ = 33.6 MHz
AOM2 = 233.0 MHz (held constant)
AOM1 was varied
MOT load to [0.5V] though this could have been higher since the fitted # of Atoms never reached 10^7

error bars are standard deviation of 8 points



Initially it looked like the image would saturate so I made the MOT load smaller but this turned out to be too small because the wings of the Lorentzian were not accessible because there its mostly noise and the program cannot fit to it.
This should probably be repeated with either a larger MOT load or once other parameters have been optimized

In this second example of a research notebook, the entry comes after a number of days of attempting to troubleshoot and understand a particular piece of equipment. The researcher has tried a number of different approaches to characterize the behavior of the piece of equipment over this time period. This entry was written at the conclusion of this process.

8/25/2009

Still looking at Uzi valve stability : Valve = 2.0×10^{-5} torr (10 Hz) 940 μs detect time.

The 0.1 Hz histogram from yesterday showed a slow decrease in signal over the run, could have been deuteration issues.

run histogram_5Hz.txt
histogram_10Hz.txt

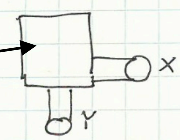
- did many histograms with various parameter values to try and improve stability, no effect.

- optimized valve XY position, Saturation! Turned MCP down to 2900V.
Vast improvement in signal size, no effect on stability
(x~2.5)

Specifies files where results of measurements and analysis can be located.

Describes interpretation of results.

new valve position [black #5]
~~X: 13.80mm~~
Y: 15.65mm



run 10Hz_after_valve_optimization_mcp3000_5utorr.txt

CONCLUSIONS ABOUT UZI VALVE FROM LITTLE BOY

(1) The PZT valve is more stable shot to shot, by a factor of ~2 to 3
[5% stdev vs. 10-15% stdev]
(2) The uzi valve loses less signal as repetition rate is decreased.
[only 25% drop from 10 Hz → 0.1 Hz for uzi, 50% drop for PZT]
(3) Free flight signals are comparable, with the uzi valve possibly being slightly better. The uzi valve also appears to have a more narrow velocity spread.

The researcher then synthesizes the results of the previous several days of characterization. This concise description makes the full picture clearer than if one had to read back over all previous entries.

With these conclusions in mind, we put the uzi valve on Kelvinator to try bunching/slowing/trapping. A significant difference made itself apparent, in that the uzi free flight signal was significantly smaller than the PZT free flight signal. This persisted for both bunching and slowing as well. The main chamber differences are

(a) Kelvinator has a much larger front chamber (~ a factor of 10), and much higher pumping speed there (~ another factor of 10).
(b) The flight distance from valve to detection is about twice as far in Kelvinator.

The researcher then goes on to describe the future direction for the experiment.

June 7, 2011

This concise description shows consideration for a broader audience.

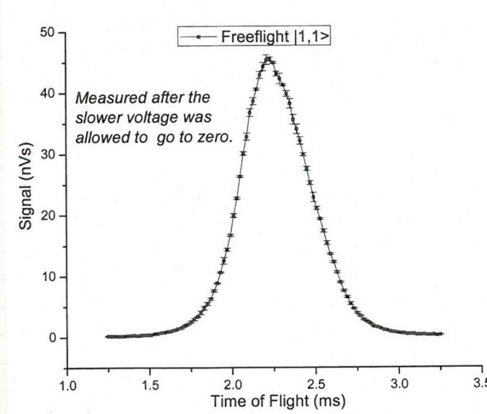
Started by checking signal on the first peak of slowing for A=1, detecting |1,1⟩. This peak was down to about 32 nVs from 38 nVs yesterday. Switched to slow and detect |1,1⟩ with the new timings and were down to ≈ 32 nVs from ≈ ~~44~~ 42 two days ago. Remixed gas and got 10% back, up to ≈ 38 nVs. Tried picomotor scan, found max at exact same location as yesterday (+2.65 mm).

Thorough description of process performed during the day and makes clear the comparison with previous day's results.

* Switched to freeflight of |1,1⟩ and found signal was enormous (>200 nVs). This was being caused by residual charge on the slower acting as a DC guide. If the slower is not allowed to discharge fully, it can hold charge long enough to give erroneous signal values for an entire freeflight scan. This may be the cause of the discrepancy between slowed and freeflight signal levels where freeflight has been substantially larger. With as little as 100V on the slower, the signal was ≈ 20% higher. After allowing the slower to completely discharge, freeflight was about 50 nVs, compared to ≈ 47 nVs for slowing, which is much more reasonable.

Speculation about potential cause of observed discrepancy.

Thoroughly labeled plot with all potentially relevant information.



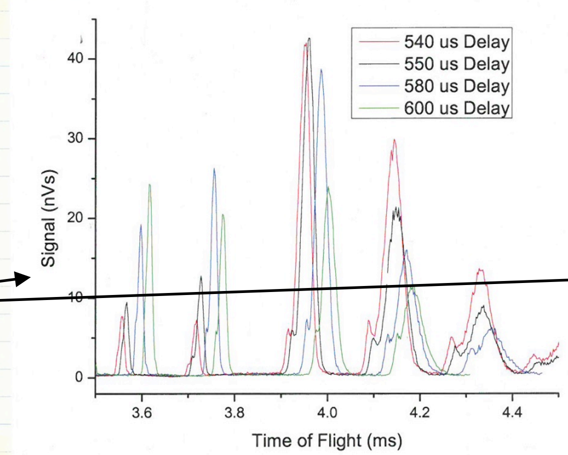
Freeflight |1,1>

Gas	ND_3
MCP (V)	-4000
Valve (V)	-461
Valve Temp (°C)	184
Pressure (10^{-5} Torr)	1.1
TOFMS (V)	1000
Phase Angle (deg.)	
Sirah λ (cm^{-1})	31511.5
Wavemeter λ (cm^{-1})	15755.51
Laser Power (mJ)	11.9 (Sirah)
Final Velocity (m/s)	
Detect Time (ms)	2.23
Step Size (μ s)	20
Scope Averages	56
Labview Averages	3
Date	6/7/2011

Explicitly states the intended test to determine the cause of the discrepancy.

To test if the initial delay was a possible source of disagreement between experiment and simulation, the delay was varied and TOF spectra were measured.

Well labeled plot with interpretation.



Varying the delay did not improve agreement!

TESTS

The concise synthesis of all tests performed allows for other

The small powermeter was used to check losses at mirrors, with little change found from Sirah output to the last mirror.

The MCP power supply was changed to check stability, with no change in signal.

After re-optimizing the Sirah, freeflight of |1,1⟩ was down to ≈ 36 from ≈ 50 earlier today. And slow/detect |1,1⟩ was down to ≈ 30 nVs from 38 earlier today.

researchers to quickly understand results.

Researcher connects the current day's work with previous results so that reader may easily reference and understand the background to the current work ("synthesize again")

Researcher makes it clear that they obtained a null result.

Makes thorough list of hypotheses about the cause of the null result. This list may serve to motivate subsequent days' measurements.

After testing all of their hypothesis the researcher then provides motivation for the direction of the subsequent day's work.

2/16/11

Synthesize again, see pg 2/16/11 in synthesis notebook.

make 178 torr of $HNCO$ (gauge)
mix with 83 psi of Argon for 3.5 %
(don't want to go too much lower than this because of large argon pressures).

power in excimer = 15 mJ/pulse
Sirah = 13 mJ

MCP - start at 3500
chamber pressure = $5 \cdot 10^{-5}$
valve backing pressure = 5 psi

we see a big fat nothing

see nothing at largest voltages

possible reasons

- wrong wavelength
  - * scanned from ~ 35080 – 35125 and saw nothing at all. there should be something there.
- bad synthesis
  - * made 178 torr this time; gas evolved immediately upon warming from vacuum trap. No reason to think it went badly.
- bad mixture?
  - we are at 3.5 %, a little on the high side...

try - mixing a smaller percentage
- measuring wavelength
  - Sirah position??? (valve position optimized)
  - lens position???
  - timings

Other brilliant suggestions go here.

quick checks at O_2 lines
- excimer position - DC charge?
- between right set of TOFMS plates?
  - TOFMS peak dependence

~~TOFMS peak~~
- Sirah was in between the right TOFMS plates
- at O_2 line 110 excimer position shows a peak

Excimer not on DC charge

Put in Ammonia and DCM dye - we see signal immediately without changing valve position. Optimize Sirah position.

we do have to change this every time we switch mirrors, but it shouldn't be that sensitive.

At their most broadened, how far off from a peak can we be and still see signal? i.e. what is broadened peakwidth?