

# PHY 451 Advanced Lab

## Lecture 01

### Logbooks: Writing is Thinking (TWO Logbooks)

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January 12, 2022

PHY 451 – Spring 2022

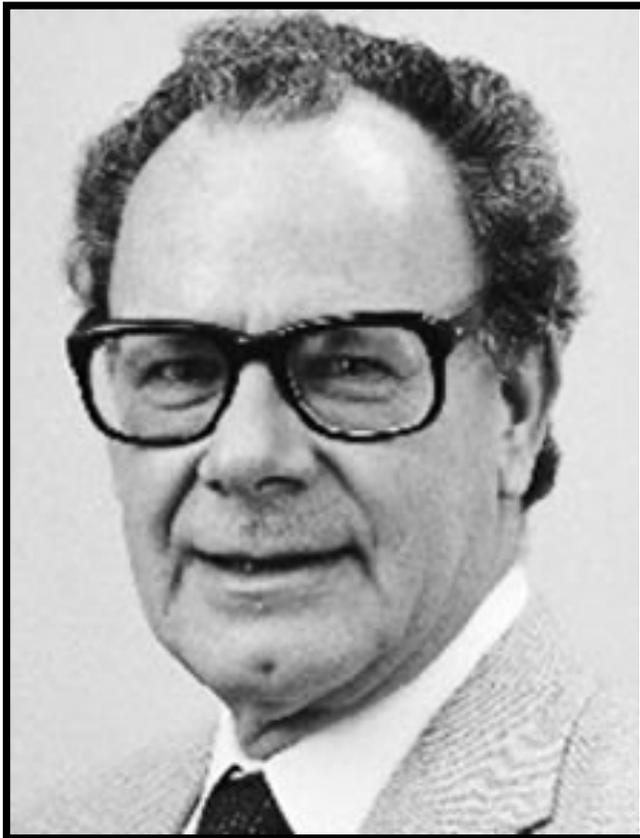


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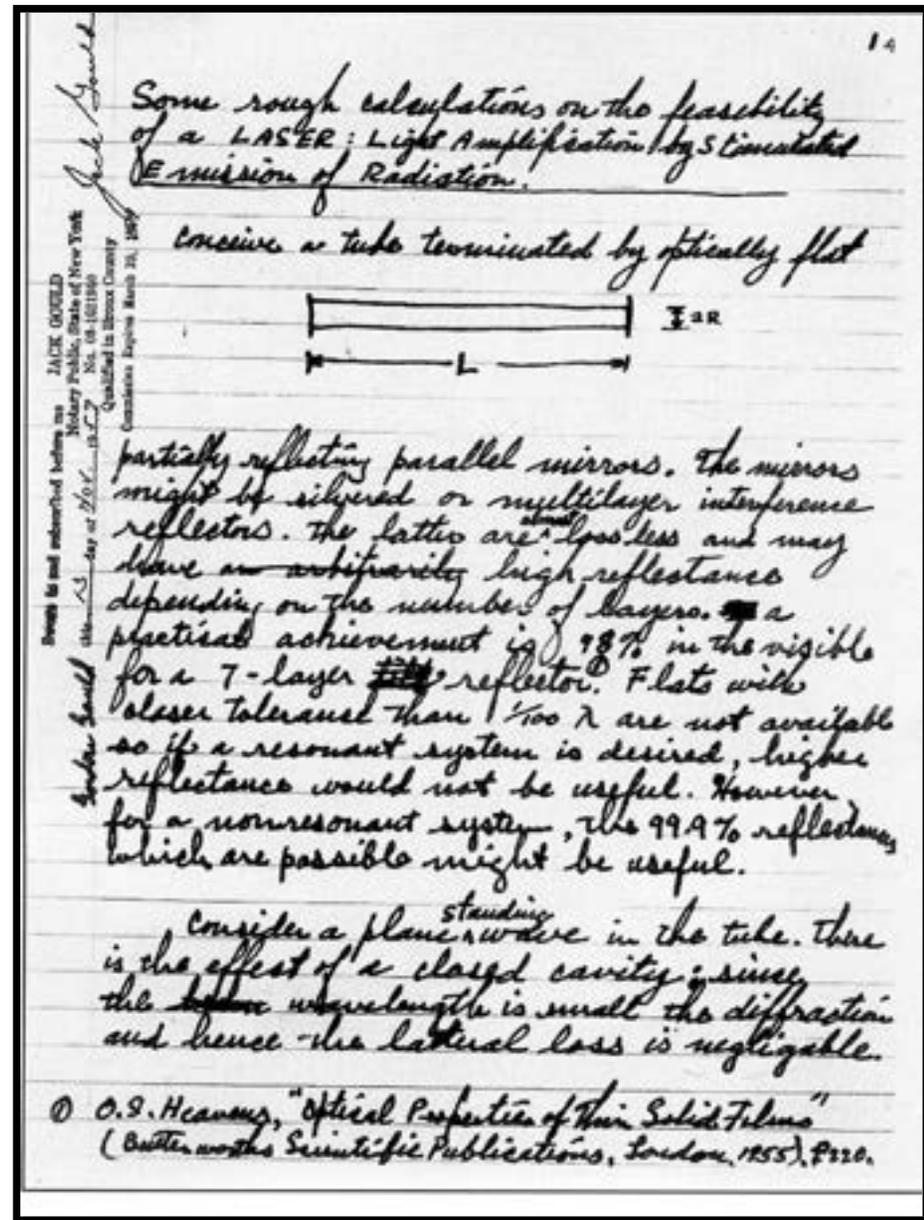


# The Importance of Documenting your Work

## Gordon Gould and Lasers

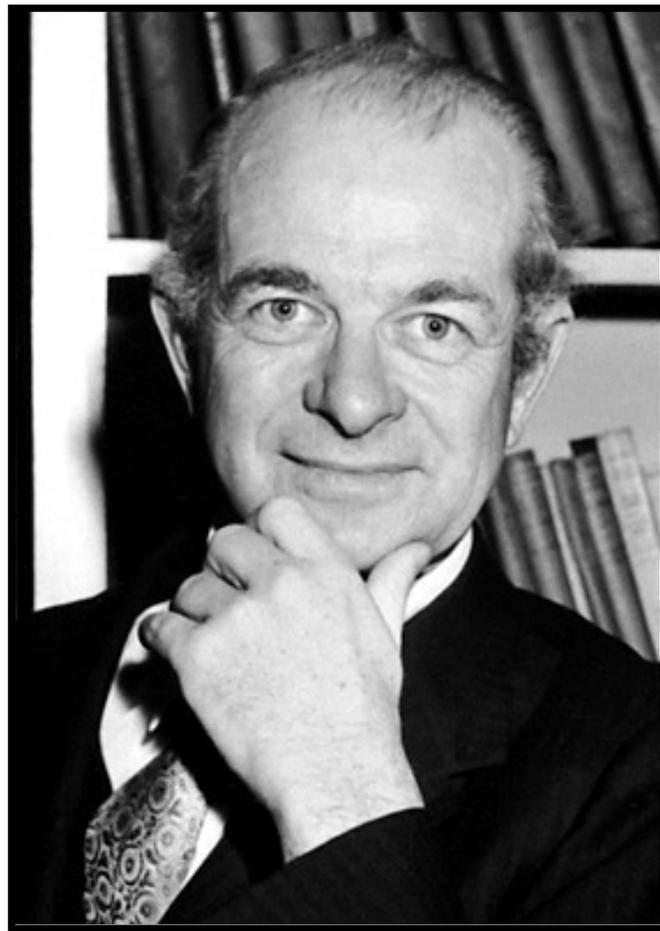


<http://www.nndb.com/people/658/000104346/>



[https://en.wikipedia.org/wiki/File:Gould\\_notebook\\_001.jpg](https://en.wikipedia.org/wiki/File:Gould_notebook_001.jpg)

# Linus Pauling



[https://www.nobelprize.org/nobel\\_prizes/chemistry/laureates/1954/pauling-facts.html](https://www.nobelprize.org/nobel_prizes/chemistry/laureates/1954/pauling-facts.html)

<http://scarc.library.oregonstate.edu/coll/pauling/rnb/index.html>



# Dates/Legibility/Comments

Oct. 1922 2K<sub>2</sub>SO<sub>4</sub> K<sub>2</sub>SO<sub>4</sub> Oct 25, 1922

Preparation by fusion. Crystal faces (111), (100) - Book 1, Page 26.  
Density by pycnometer 2.322 " " " 31.

Spectral measurement of (110) face compared with CaCO<sub>3</sub> (100). Film # 190.  
Re. Third reflection from CaCO<sub>3</sub> coincided with the fifth " from 2K<sub>2</sub>SO<sub>4</sub> K<sub>2</sub>SO<sub>4</sub>.  
 $n_1 \lambda_1 \sin \theta_1 = n_2 \lambda_2 \sin \theta_2$ ,  $\lambda = 5055 \text{ \AA}$ ,  $d = 2009 \text{ \AA}$ ,  $\therefore \sin \theta = .27013$  from CaCO<sub>3</sub>  
 $n_1 \lambda_1 \sin \theta_1 = n_2 \lambda_2 \sin \theta_2$ ,  $\sin \theta' = \frac{27013 \times 5055}{2009} = .67403$ ,  $\lambda = 4221 \text{ \AA}$ ,  $M = 48274$   
 $\frac{n^2}{\lambda} = \left( \frac{2.322 \times 10^4}{\lambda \sqrt{1 + \frac{2.322^2}{\lambda^2}}} \right)^2 \frac{M}{M_p}$ ,  $\frac{n^2}{\lambda} = .25453$   
 $\therefore$  There are 4 molecules in a unit cube,  $n_1 \lambda_1 \sin \theta_1 = n_2 \lambda_2 \sin \theta_2$ ,  $n = 2$ . The first is assumed correct

$d_{111} = \frac{a}{\sqrt{3}} = 5663 \text{ \AA}$ ,  $d_{100} = 5663 \times \sqrt{3} = 9.809 \text{ \AA}$  side of unit cube  
Density from X-rays = 2.325

Law made Oct. 31, 1922.

Plate III	2K <sub>2</sub> SO <sub>4</sub> K <sub>2</sub> SO <sub>4</sub> (10)
307	345
309	341
311	345
313	345
315	341
317	345
319	341
321	345
323	341
325	345
327	341
329	345
331	341
333	345
335	341
337	345
339	341
341	345
343	341
345	345

Plate without planes of symmetry, hence it can be only T with.  
As 112, with 2 odd one axis and one odd one present in first order, and not with 2 even and 1 odd, and odd with 2 odd both odd are also present in the first order, the only groups permissible are  $T$ ,  $T_h$ ,  $T_d$

$T_h$  has (100) absent in odd orders.

Nov. 1922 NaCl<sub>2</sub> Sup. 130. About 5 Nov. 1922

For references and preparation see Book 1, page 29.

Reflection from (10) face, with CaCO<sub>3</sub> (100) for reference. Film #  
The third NaCl<sub>2</sub> line (7th " ) was .260 cm farther in than the second CaCO<sub>3</sub>. In 1st 1/2

CaCO<sub>3</sub> (100)  $d = 2009 \text{ \AA}$ ,  $\sin \theta = \frac{27013}{2009} = .67403$ ,  $\theta = 42.293^\circ$ ,  $\tan 2\theta = 4.309$   
 $\times 2 = 4.309 \text{ cm}$   
 NaCl<sub>2</sub> (10)  $\lambda = 4.309 - .260 = 4.049$ ,  $\tan 2\theta = 4.049$ ,  $\theta = 41.63^\circ$ ,  $\sin \theta = .6712$   
 $d = \frac{\lambda}{\sin \theta} = \frac{4.049}{.6712} = 6.032 \text{ \AA}$ , assuming  $n=3$   
 $\therefore d_{10} = 3.330 \text{ \AA}$ , assuming  $n=1$  for first line (small molecular unit)

$\frac{n^2}{\lambda} = \left( \frac{2.322 \times 10^4}{\lambda \sqrt{1 + \frac{2.322^2}{\lambda^2}}} \right)^2 \frac{M}{M_p}$ ,  $M = 2415$ ,  $p = 5669$ ,  $n = 6.032 \times 10^3$   
 $\frac{n^2}{\lambda} = \left( \frac{2.322 \times 10^4}{\lambda \sqrt{1 + \frac{2.322^2}{\lambda^2}}} \right)^2 \frac{2415}{646 \times 10^3} = 2.407$   
 $\therefore n = 3, n = 4$  or  $n = 6, n = 64$  etc.

Using  $n=3$ ,  $a = \frac{333}{2} \text{ \AA}$ ,  $2 \tan(11)$

Law photographic data - Plate #

341	2	345	345	345
343	2	341	341	341
345	2	337	337	337
347	2	333	333	333
349	2	329	329	329
351	2	325	325	325
353	2	321	321	321
355	2	317	317	317
357	2	313	313	313
359	2	309	309	309
361	2	305	305	305
363	2	301	301	301
365	2	297	297	297
367	2	293	293	293
369	2	289	289	289
371	2	285	285	285
373	2	281	281	281
375	2	277	277	277
377	2	273	273	273
379	2	269	269	269
381	2	265	265	265
383	2	261	261	261
385	2	257	257	257
387	2	253	253	253
389	2	249	249	249
391	2	245	245	245
393	2	241	241	241
395	2	237	237	237
397	2	233	233	233
399	2	229	229	229
401	2	225	225	225
403	2	221	221	221
405	2	217	217	217
407	2	213	213	213
409	2	209	209	209
411	2	205	205	205
413	2	201	201	201
415	2	197	197	197
417	2	193	193	193
419	2	189	189	189
421	2	185	185	185
423	2	181	181	181
425	2	177	177	177
427	2	173	173	173
429	2	169	169	169
431	2	165	165	165
433	2	161	161	161
435	2	157	157	157
437	2	153	153	153
439	2	149	149	149
441	2	145	145	145
443	2	141	141	141
445	2	137	137	137
447	2	133	133	133
449	2	129	129	129
451	2	125	125	125
453	2	121	121	121
455	2	117	117	117
457	2	113	113	113
459	2	109	109	109
461	2	105	105	105
463	2	101	101	101
465	2	97	97	97
467	2	93	93	93
469	2	89	89	89
471	2	85	85	85
473	2	81	81	81
475	2	77	77	77
477	2	73	73	73
479	2	69	69	69
481	2	65	65	65
483	2	61	61	61
485	2	57	57	57
487	2	53	53	53
489	2	49	49	49
491	2	45	45	45
493	2	41	41	41
495	2	37	37	37
497	2	33	33	33
499	2	29	29	29
501	2	25	25	25
503	2	21	21	21
505	2	17	17	17
507	2	13	13	13
509	2	9	9	9
511	2	5	5	5

This small wave length is impossible.  
 $\therefore n = 64$ . Double all  $n$  values.  
This makes  $h a I$  of  $11.976$

# Plots/Commentary

for 23.28 Å unit.

hkl	I	x	2θ	2θ	d	h
205	1	137	185	110	1	
205	1	133	191	112		
220	3	137	193	117		
254	5	141	207	113		
455	3	146	255	207		
455	3	140	259	205		
511	2	240	162	241		
511	3	244	163	236		
711	2	313	226	340		
871	1	295	195	324		
774	1	250	226	257		
715	1	246	207	295		
471	1	240	221	215		
511	0	246	207	216		
511	0	230	204	210		
771	1	241	162	241		
757	2	312	173	267		
117	3	213	177	241		
715	1	143	24	185		
103	1	214	205	192		
214	1	214	205	217		
214	1	157	150	1150		
559	55	131	235	1180		
431	75	97	195	215		named spots
251	68	51	267	158		

The planes with large indices might be caused by twinning. The transition equations for (100) planes are  
 $p' = -p + q + r$   
 $q' = 2p - q + r$   
 $r' = 3p + q - r$   
 This gives  $205 \rightarrow 247$ , with the same  $nd$ .

These intensities are not in accord with the expected ones. Dashes show intensities of ray, using  $\frac{1}{2}$  and  $-\frac{1}{2}$  using double unit cube-side.

Transition to twin gives (209) or 173, about. Then the intensity jump is between 21.215 and 0.48. This is good, since the cd edge is at 0.463 Å.

Low data (110, 200) Plate 191.  $E = 41000 \text{ v. (50000 peak)}$

hkl	I	x
101	4	176
104	5	239
107	27	143
204	4	196
111	1	528
101	2	180
102	5	247
103	15	398
103	2	725
103	13	307
103	3	245
103	4	24

see next page: data using larger unit.

hkl	x	2θ	2θ	d	h	Remarks
120	115	175	12	181	1616	Faint
120	121	174	12	181	1616	Absent
105	245	312	76	107	152	Faint
105	250	311	76	107	152	Very faint
105	242	314	76	107	152	Absent

These indices are on the basis of the small unit. Apparently the lower limit is 17 Å, which, on being doubled, gives 34, approximately correct. Hence we must take a unit which doubles the  $nd$ .

Doubling the axial length along a gives a unit with four molecules, 2 is halved; if L is odd, H and I are doubled;  $d_{001}$  is unchanged. So for planes with L odd on the small unit  $nd$  is unchanged.

Rotation thru  $30^\circ$  by calling the  $30^\circ$  spectrum a third order reflection, gives this relation:

$$H_2 = -H_1 - 2I_1 \quad d_{001} \text{ constant} \quad (L)_2 = \frac{1}{2}(L)_1$$

$$I_2 = 2H_1 + I_1$$

If  $H_1, I_1, L_1$  have no factor in common (1), (1), (1)  
 has common factor 2 (2), (2), (2)

Both planes above are in case (1), so that this transformation is not of use in this case. Plane 103,  $d_{001}$  has  $nd = 181$ . This is of class (2), so that there is no need of rotating the axes.

Not, 84thk this is wrong. See page

# Mistakes/Summary

REL	I	F <sub>10</sub>	h	k	l	h	k	l
110	222	5	345			1147	415	
130	216	5	302				477	
140	210	5	300				480	
150	204	5	270				540	
160	198	5	240				600	
170	192	5	210				660	
180	186	5	180				720	
190	180	5	150				780	
200	174	5	120				840	
210	168	5	90				900	
220	162	5	60				960	
230	156	5	30				1020	
240	150	5	0				1080	
250	144	5	-30				1140	
260	138	5	-60				1200	
270	132	5	-90				1260	
280	126	5	-120				1320	
290	120	5	-150				1380	
300	114	5	-180				1440	
310	108	5	-210				1500	
320	102	5	-240				1560	
330	96	5	-270				1620	
340	90	5	-300				1680	
350	84	5	-330				1740	
360	78	5	-360				1800	
370	72	5	-390				1860	
380	66	5	-420				1920	
390	60	5	-450				1980	
400	54	5	-480				2040	
410	48	5	-510				2100	
420	42	5	-540				2160	
430	36	5	-570				2220	
440	30	5	-600				2280	
450	24	5	-630				2340	
460	18	5	-660				2400	
470	12	5	-690				2460	
480	6	5	-720				2520	
490	0	5	-750				2580	
500	-6	5	-780				2640	
510	-12	5	-810				2700	
520	-18	5	-840				2760	
530	-24	5	-870				2820	
540	-30	5	-900				2880	
550	-36	5	-930				2940	
560	-42	5	-960				3000	
570	-48	5	-990				3060	
580	-54	5	-1020				3120	
590	-60	5	-1050				3180	
600	-66	5	-1080				3240	
610	-72	5	-1110				3300	
620	-78	5	-1140				3360	
630	-84	5	-1170				3420	
640	-90	5	-1200				3480	
650	-96	5	-1230				3540	
660	-102	5	-1260				3600	
670	-108	5	-1290				3660	
680	-114	5	-1320				3720	
690	-120	5	-1350				3780	
700	-126	5	-1380				3840	
710	-132	5	-1410				3900	
720	-138	5	-1440				3960	
730	-144	5	-1470				4020	
740	-150	5	-1500				4080	
750	-156	5	-1530				4140	
760	-162	5	-1560				4200	
770	-168	5	-1590				4260	
780	-174	5	-1620				4320	
790	-180	5	-1650				4380	
800	-186	5	-1680				4440	
810	-192	5	-1710				4500	
820	-198	5	-1740				4560	
830	-204	5	-1770				4620	
840	-210	5	-1800				4680	
850	-216	5	-1830				4740	
860	-222	5	-1860				4800	
870	-228	5	-1890				4860	
880	-234	5	-1920				4920	
890	-240	5	-1950				4980	
900	-246	5	-1980				5040	
910	-252	5	-2010				5100	
920	-258	5	-2040				5160	
930	-264	5	-2070				5220	
940	-270	5	-2100				5280	
950	-276	5	-2130				5340	
960	-282	5	-2160				5400	
970	-288	5	-2190				5460	
980	-294	5	-2220				5520	
990	-300	5	-2250				5580	
1000	-306	5	-2280				5640	
1010	-312	5	-2310				5700	
1020	-318	5	-2340				5760	
1030	-324	5	-2370				5820	
1040	-330	5	-2400				5880	
1050	-336	5	-2430				5940	
1060	-342	5	-2460				6000	
1070	-348	5	-2490				6060	
1080	-354	5	-2520				6120	
1090	-360	5	-2550				6180	
1100	-366	5	-2580				6240	
1110	-372	5	-2610				6300	
1120	-378	5	-2640				6360	
1130	-384	5	-2670				6420	
1140	-390	5	-2700				6480	
1150	-396	5	-2730				6540	
1160	-402	5	-2760				6600	
1170	-408	5	-2790				6660	
1180	-414	5	-2820				6720	
1190	-420	5	-2850				6780	
1200	-426	5	-2880				6840	
1210	-432	5	-2910				6900	
1220	-438	5	-2940				6960	
1230	-444	5	-2970				7020	
1240	-450	5	-3000				7080	
1250	-456	5	-3030				7140	
1260	-462	5	-3060				7200	
1270	-468	5	-3090				7260	
1280	-474	5	-3120				7320	
1290	-480	5	-3150				7380	
1300	-486	5	-3180				7440	
1310	-492	5	-3210				7500	
1320	-498	5	-3240				7560	
1330	-504	5	-3270				7620	
1340	-510	5	-3300				7680	
1350	-516	5	-3330				7740	
1360	-522	5	-3360				7800	
1370	-528	5	-3390				7860	
1380	-534	5	-3420				7920	
1390	-540	5	-3450				7980	
1400	-546	5	-3480				8040	
1410	-552	5	-3510				8100	
1420	-558	5	-3540				8160	
1430	-564	5	-3570				8220	
1440	-570	5	-3600				8280	
1450	-576	5	-3630				8340	
1460	-582	5	-3660				8400	
1470	-588	5	-3690				8460	
1480	-594	5	-3720				8520	
1490	-600	5	-3750				8580	
1500	-606	5	-3780				8640	
1510	-612	5	-3810				8700	
1520	-618	5	-3840				8760	
1530	-624	5	-3870				8820	
1540	-630	5	-3900				8880	
1550	-636	5	-3930				8940	
1560	-642	5	-3960				9000	
1570	-648	5	-3990				9060	
1580	-654	5	-4020				9120	
1590	-660	5	-4050				9180	
1600	-666	5	-4080				9240	
1610	-672	5	-4110				9300	
1620	-678	5	-4140				9360	
1630	-684	5	-4170				9420	
1640	-690	5	-4200				9480	
1650	-696	5	-4230				9540	
1660	-702	5	-4260				9600	
1670	-708	5	-4290				9660	
1680	-714	5	-4320				9720	
1690	-720	5	-4350				9780	
1700	-726	5	-4380				9840	
1710	-732	5	-4410				9900	
1720	-738	5	-4440				9960	
1730	-744	5	-4470				10020	
1740	-750	5	-4500				10080	
1750	-756	5	-4530				10140	
1760	-762	5	-4560				10200	
1770	-768	5	-4590				10260	
1780	-774	5	-4620				10320	
1790	-780	5	-4650				10380	
1800	-786	5	-4680				10440	
1810	-792	5	-4710				10500	
1820	-798	5	-4740				10560	
1830	-804	5	-4770				10620	
1840	-810	5	-4800				10680	
1850	-816	5	-4830				10740	
1860	-822	5	-4860				10800	
1870	-828	5	-4890				10860	
1880	-834	5	-4920				10920	
1890	-840	5	-4950				10980	
1900	-846	5	-4980				11040	
1910	-852	5	-5010				11100	
1920	-858	5	-5040				11160	
1930	-864	5	-5070				11220	
1940	-870	5	-5100				11280	
1950	-876	5	-5130				11340	
1960	-882	5	-5160				11400	
1970	-888	5	-5190				11460	
1980	-894	5	-5220				11520	
1990	-900	5	-5250				11580	
2000	-906	5	-5280				11640	
2010	-912	5	-5310				11700	
2020	-918	5	-5340				11760	
2030	-924	5	-5370				11820	
2040	-930	5	-5400				11880	
2050	-936	5	-5430				11940	
2060	-942	5	-5460				12000	
2070	-948	5	-5490				12060	
2080	-954	5	-5520				12120	
2090	-960	5	-5550				12180	
2100	-966	5	-5580				12240	
2110	-972	5	-56					

# What's Missing

- Times
- Prelab (preparation)
- Procedures
- Schematic of experimental setup (conceptual diagram)
- Part numbers & model numbers of essential equipment

# Failure is a gift.

- If you didn't write it down, then it never happened.
- Amateurs remember, professionals write it down.
- **Our only obligation as Scientists is to be honest. Write what you are doing and why in real time in your logbook.**
- Correlation is not causation.
- RTFM: Read The Fascinating Manual!
- <https://spinlab.me/2017/08/08/producing-scientific-diagrams-which-reveal-the-relevant-scale-edwardtufte/>

# General Contents of Logbooks

1. A record of experimental conditions and apparatus
2. A record of the experimenter's realtime observations, actions, and thought process
3. Notes from meetings and discussions
4. **Descriptive commentary - just the facts**
  - What happened?
  - When did it happen?
  - What did I do?
5. **Reflective commentary - an articulation of your thought process**
  - Why did it happen?
  - What did I do that?
  - What did I think will happen?
  - What went well?
  - What should be improved for next time?

# Specific Contents of Logbooks

1. Leave first couple of sheets blank for table of contents. Each line should be descriptive with date and page number. This helps you find info later.
2. For each logbook entry, write down both the date and time. This helps you figure out when things happened and how long they took.
3. Make schematic of your experimental apparatus (conceptual diagram).
4. Write at least three entries per hour in the Lab (on average).
5. Each page of your logbook should represent about an hour of work in the Lab (on average).
- 6. Write your pre-Labs in the logbook. (Scan & upload them for scoring.)**
7. At the end of the experiment, make a list of your main conclusions and a summary plot/table of your experimental results.

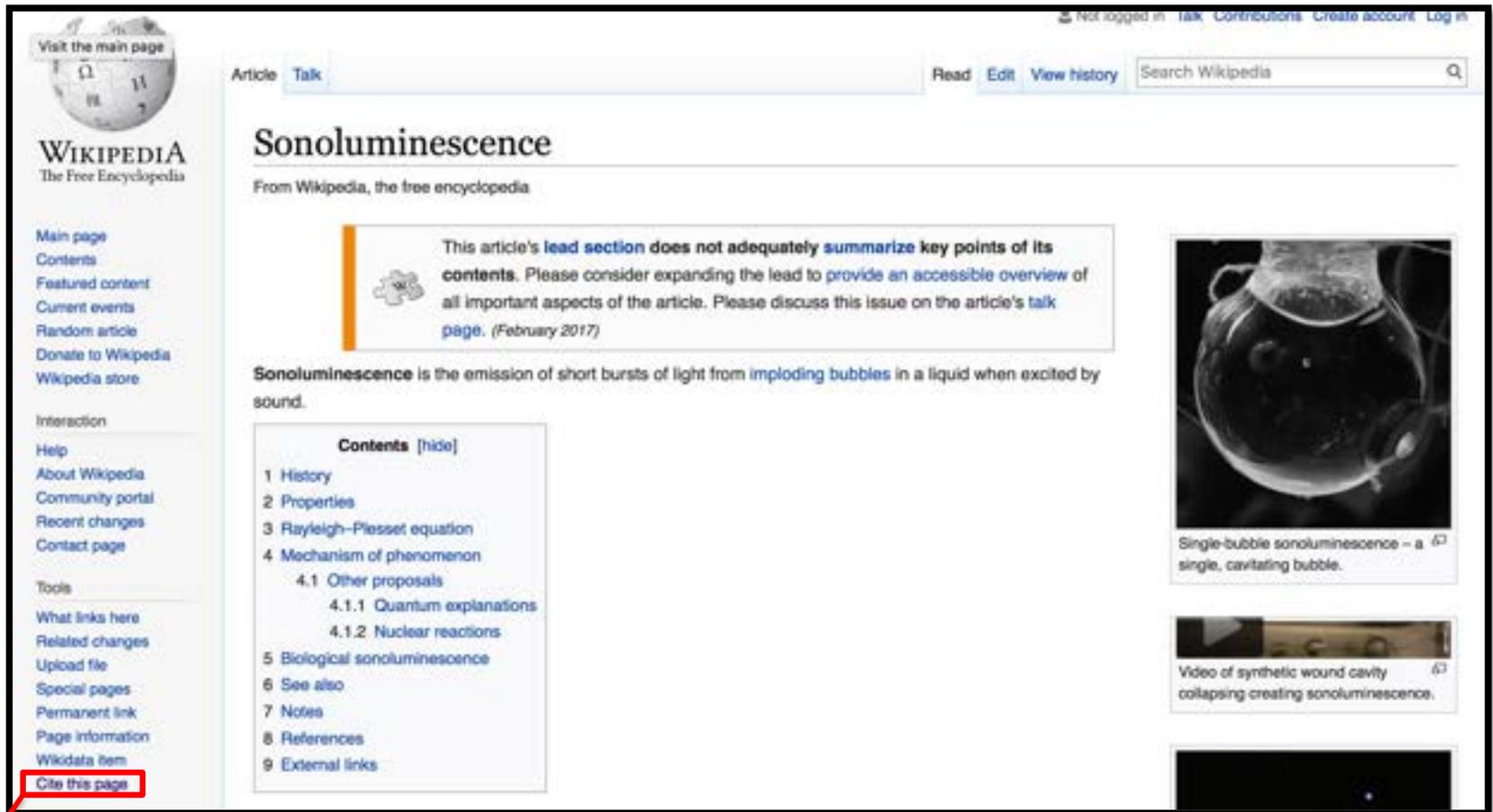
# General Hints

1. Read the “pre-Lab” documents *throughout* the experiment and *write summaries* of the important points in your logbook.
2. Review your logbook before every Lab session and *write down* a list of goals and a plan for achieving those goals.
3. Gives proper citations for works referenced:
  - articles: Giaver, I. Rev. Mod. Phys. 46, 245 (1974)
  - books: Taylor, J. R. An Introduction to Error Analysis. University Science Books, Sausalito, CA, USA. 2<sup>nd</sup> Edition. 1997.
  - websites: see next page for example and secret hint for Wikipedia

## Hints for pre-Lab (“Read & Take Notes”) and Reflective Commentary

1. initial model of physical system
2. initial model of measurement system
3. initial cartoon of experiment
4. what knob / needle curve to expect
  1. what is the knob and units and range of settings?
  2. what is the needle, units, and range of readings?
  3. what kind of feature am I looking for? (dip, peak, discontinuity, deviation)
  4. what knob setting allows me to see the feature?
  5. how big of a change in the needle reading am I expecting?
  6. how wide or sharp (range of knob setting) is the feature?
  7. how deep or tall (range of needle readings) is the feature?
5. what does success (presence of feature & how many) look like?
6. what does failure (absence of feature) look like?

# Citing The Internet, Example: Wikipedia



The screenshot shows the Wikipedia article for "Sonoluminescence". The page title is "Sonoluminescence" and it is from Wikipedia, the free encyclopedia. A notice at the top states: "This article's lead section does not adequately summarize key points of its contents. Please consider expanding the lead to provide an accessible overview of all important aspects of the article. Please discuss this issue on the article's talk page. (February 2017)". The main text defines sonoluminescence as "the emission of short bursts of light from imploding bubbles in a liquid when excited by sound." A table of contents is visible, listing sections from 1 History to 9 External links. On the right side, there are two images: a photograph of a single-bubble sonoluminescence experiment and a video of a synthetic wound cavity collapsing to create sonoluminescence. In the bottom left corner of the screenshot, the "Cite this page" link is highlighted with a red box, and a red arrow points from this box to the citation text below.

Wikipedia contributors. "Sonoluminescence." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 13 Sep. 2017. Web. 10 Oct. 2017.

# Perfect Table of Contents

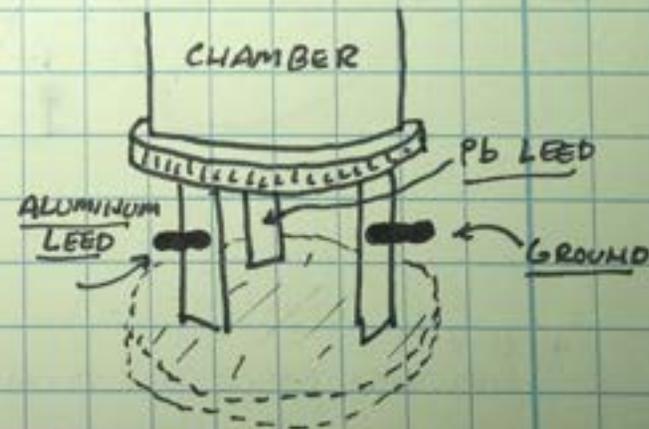
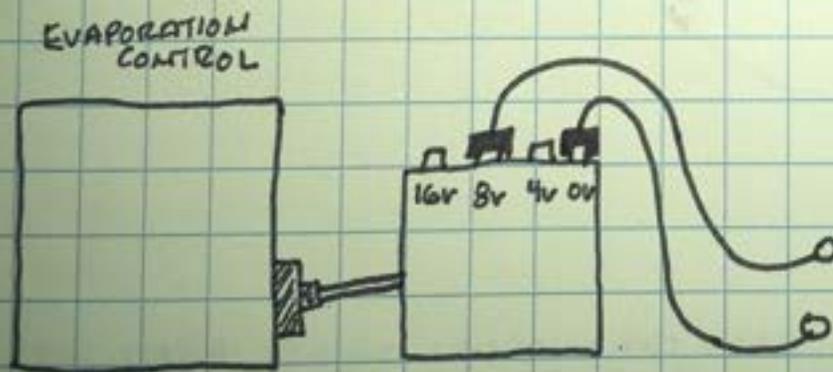
1. on the first page of logbook
2. says "Table of Contents"
3. Includes dates
4. Includes page numbers
5. Descriptive organization of the work

	Page
Table of Contents	3
Experiment I: Superconductivity	3
Background	5
Day I Checklist	5
Evaporation Steps	6
I-V measurement circuit	7
Procedure	9
"Pre Lab"	11
Apparatus Drawings	12
Finding difference between thickness monitor & junction thickness	12
"Day Session II 9/14/17"	
Fabricating SIN Junction	13
Coarse Pump reading calibration	14
Circuit arrangement	16
I-V curves (Theoretical)	17
First chip result	18
Fabricating SIN Junction Redux	19
Results	23
"Day III 9/26/17"	
Fabricating SIN Junction III	24
Chip attempt #3	24-25
"measurements & Data"	26
"Golden Pages"	27-30
Equipment Used	27
Experiment Model	28
Procedure	28
SIN Junction	29-30
Measuring Superconductivity	30
Results / Summary / Analysis	31-34

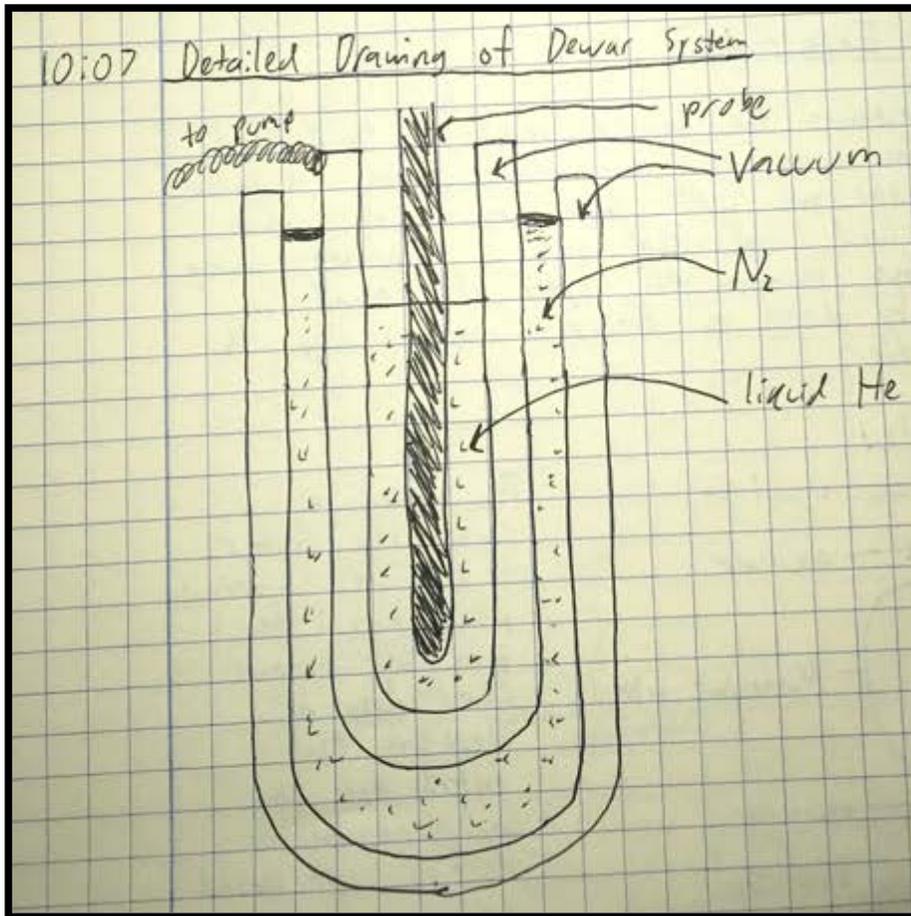
# Build Safety In At the Planning Stage

## 4) EVAPORATION

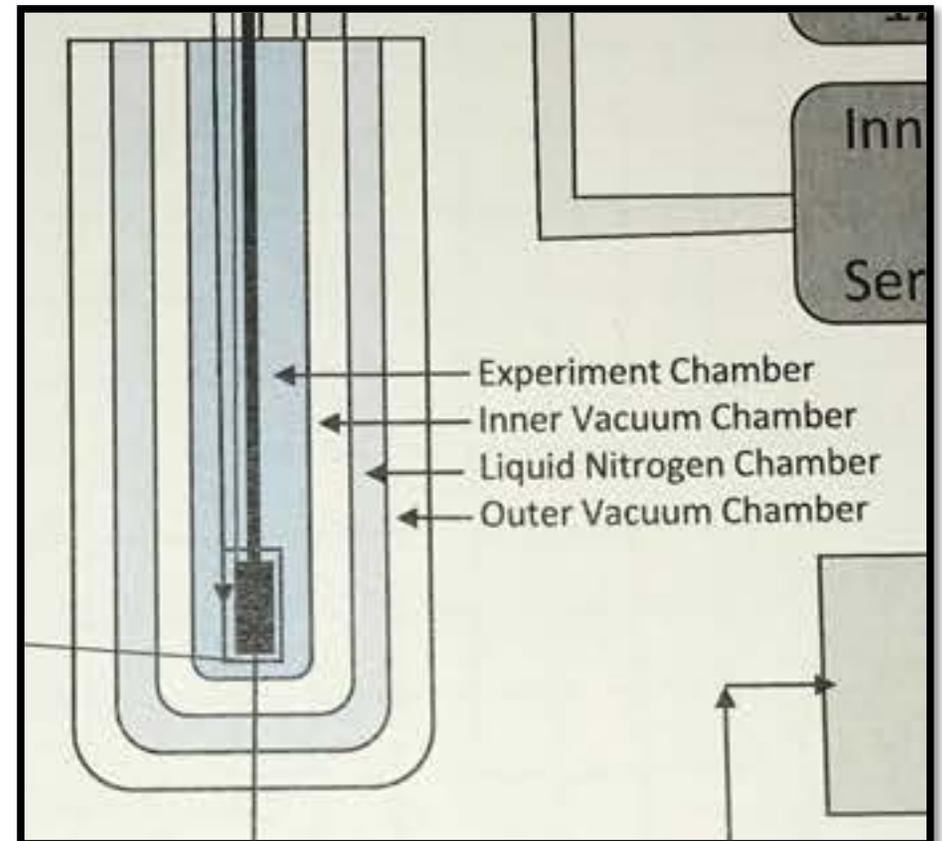
- ATTACH CONNECTORS TO THE ALUMINUM AND GROUND LEEDS. APPLY CURRENT TO THE BOAT SO THAT THE ALUMINUM BOILS AND EVAPORATES. THIS WILL TAKE TRIAL AND ERROR. BE SURE TO RECORD VOLTAGE, CURRENT, AND TIME. TURN THE SHIELD TO EXPOSE THE ALUMINUM. WAIT TIME. <sup>AND THICKNESS</sup> CLOSE SHIELD.
- TURN THE CURRENT OFF! TAKE THE ELECTRICAL LEED OFF OF THE ALUMINUM LEED, AND PLUG IT ON THE Pb LEED. ADJUST THE MASK SLIDE TO 46 mm (Pb PADS). TURN CURRENT ON, AND TURN THE SHIELD TO EXPOSE THE Pb. WAIT UNTIL DESIRED THICKNESS, THEN CLOSE THE SHIELD.
- TURN THE CURRENT OFF!



# Model of Measurement System

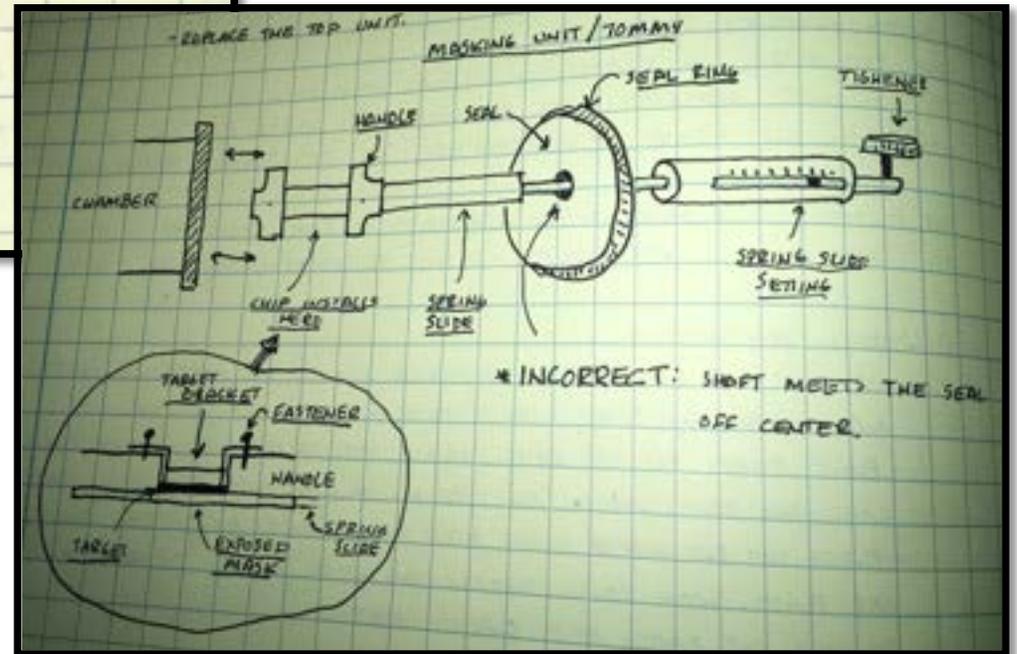
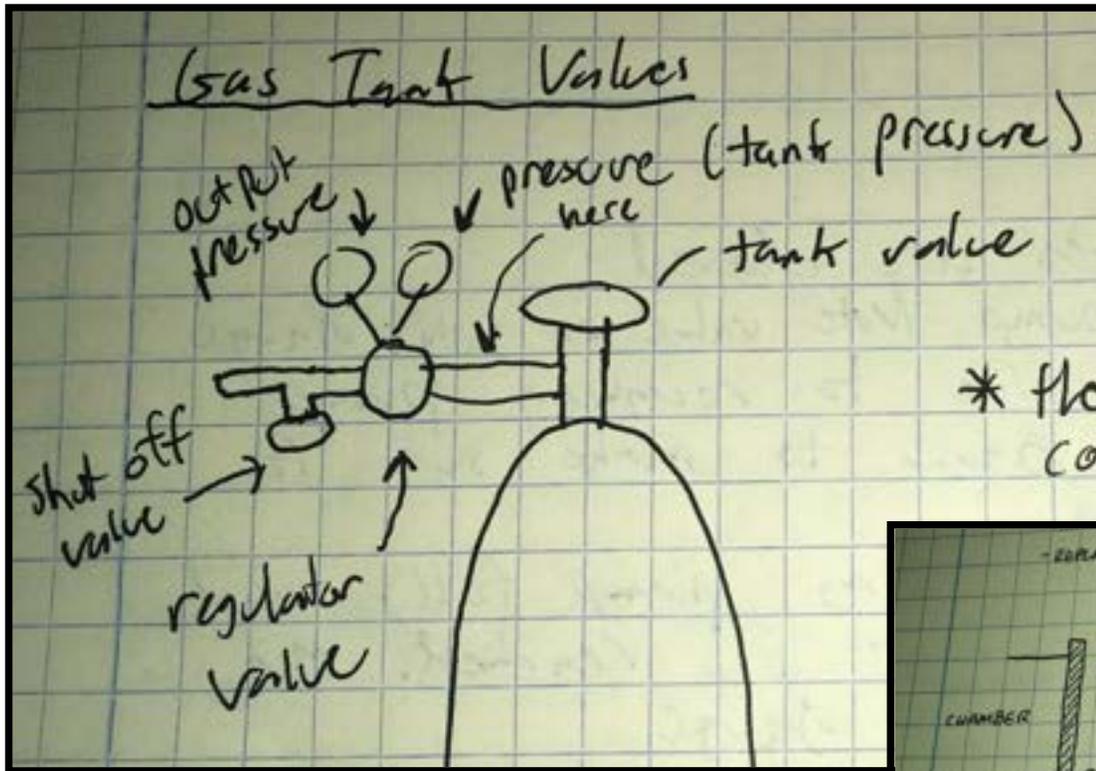


Great hand drawn schematics in logbook.



Great pre-publication quality schematic in logbook summary – perfect starting point for final version of diagram used for the presentation/papers.

# “Round Black Knob” is never a good name for a knob.



# Write Down Everything That Jaideep Says

Optical Pumping  
Zero Field transition Retry (cont.)

4:00 pm \* Jaideep recommended using the o-scope to get the data but ~~we were~~ we discussed and it doesn't record very good ~~scale~~ scaling. Instead, critical values will be taken and used to give the data the proper ~~scale~~ scale. For this case the min horizontal, max horizontal, and dip point horizontal will be used to properly ~~scale~~ scale the x-axis and the vertical voltage min and max will be used to scale the y-axis. From these the minimum of the dip can be used to calculate the earth's magnetic field in the x and y directions. Note that the estimates and suggestions made on ~~pg. 8~~ pg. 8, 11 are incorrect in estimating the scale on the Graph as well as the value of the field. I have made this mark  $\otimes$  with the date and time next to these lines to indicate they are incorrect.

# Realtime Descriptive Commentary

When?

What conditions?

What happened?

How long did it last?

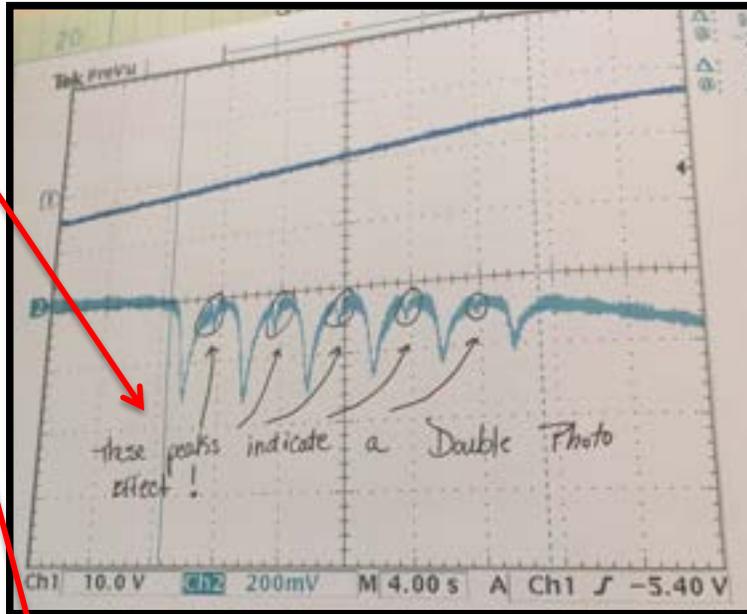
What next?

What is the name of the datafile?

tank  
8:33 Put new sample of cold degassed water in tank  
res. freq. 26187 Hz  
temp @ top: 5.9°C  
bottom: 4.9°C  
8:38 WE HAVE SUSPENDED BLUE GLOWING DOT THAT  
CAN BE SEEN w/o CURTAIN. not flashing  
bottom antinode, seen from above  
8:40 still there!  
8:46 still there  
8:50 glowing for 10 min.

19:47 We observed the phase transition!!!  
19:56 The first run (with the light on and vac  
off is done). The final data point was  
152,650.  
19:57 We are now cooling down to about 1.7 K  
again.  
20:03 We turned off the vacuum pump and are  
letting the temperature rise without the  
light. The first datapoint is 154400.

# Realtime Descriptive Commentary + Planning



8:34  $\Delta = 732$  ms (distance from outer peaks)  
Currently working with Johannes on the main field calibration  
Spacing between the peaks is changed by the frequency!

8:48 Goal for next session

- Get Data for Main field calibration
- Do Rabi Oscillation experiment ☺

9:32 PM will need to use efficient  
Since we didn't get anywhere need to do.

Checklist:

- optical rail elements
- control box
- Voltmeters
- oscilloscope
- optical rail alignment

# Knob Settings and Expected Needle Reading

9:32 We cooled the liquid helium to  $\sim 1.9$  K  
Speed of second sound is  $\sim 25$  m/s  
 $u = 2L \Delta f$   
 $25 \text{ m/s} = 2(0.04 \text{ m}) \Delta f$   
 $\Delta f = 312.5 \text{ Hz}$   
VI settings:  
Start Frequency: 100 Hz  
Stop Frequency: 10000 Hz  
Frequency Step: 5 Hz  
Time Interval: 1 s  
WFG Output: 10 V  
Bias Voltages: 67.5 V  
Temperature: 1.885 K

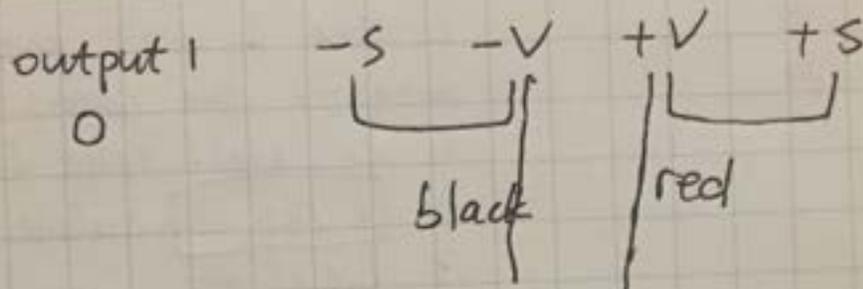
In order to see the physics, you need to have a starting guess as to where to look so that you set your knobs in a reasonable manner.

# Major Change in Equipment or Settings

Since the old machine is not stable. we got another new one.  
Before we exchange these two machines, I made a sketch

7:30 pm

The old philips programmable power supply  
sketch

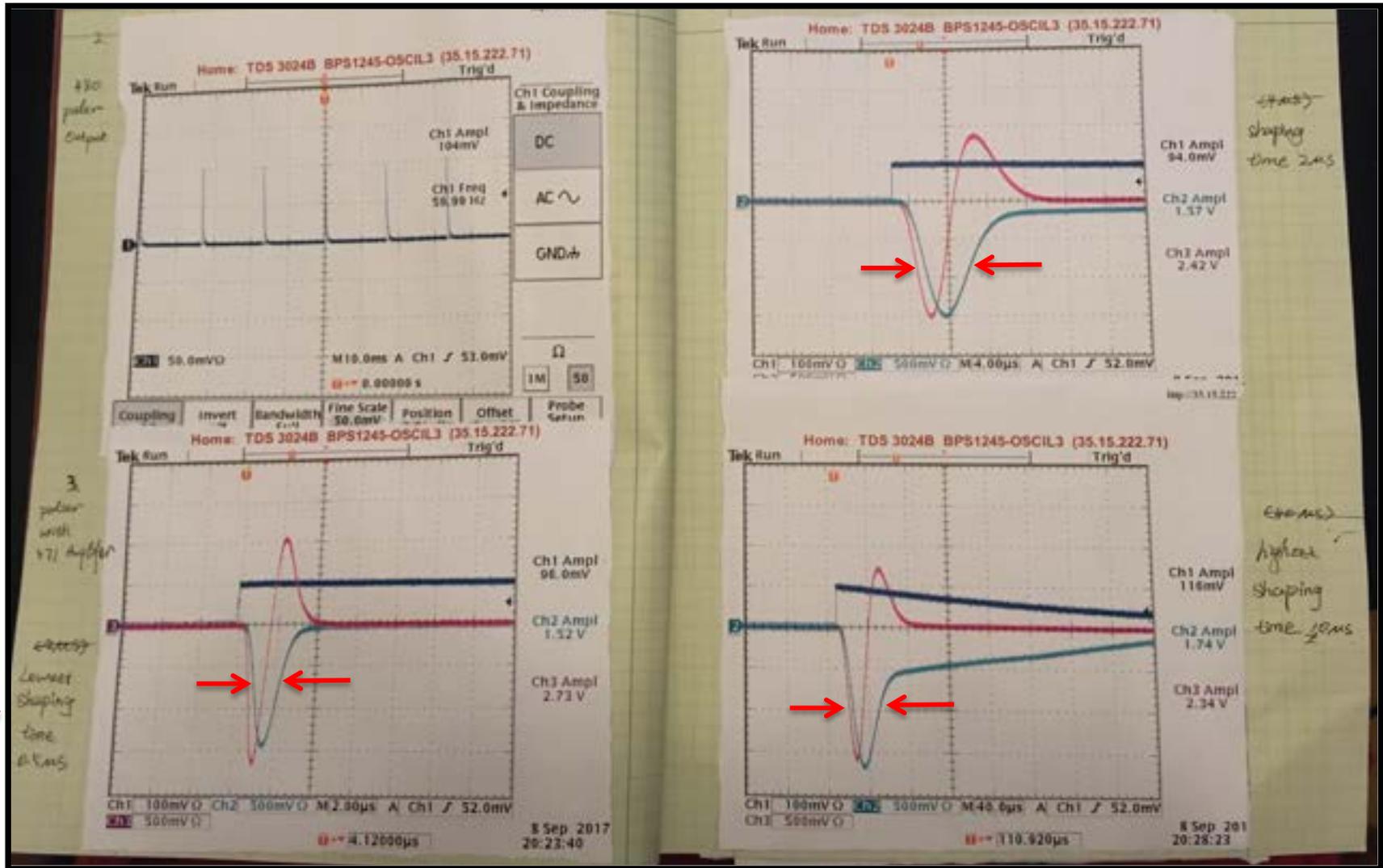


Replaced equipment: KEYSIGHT E3632A DC power supply

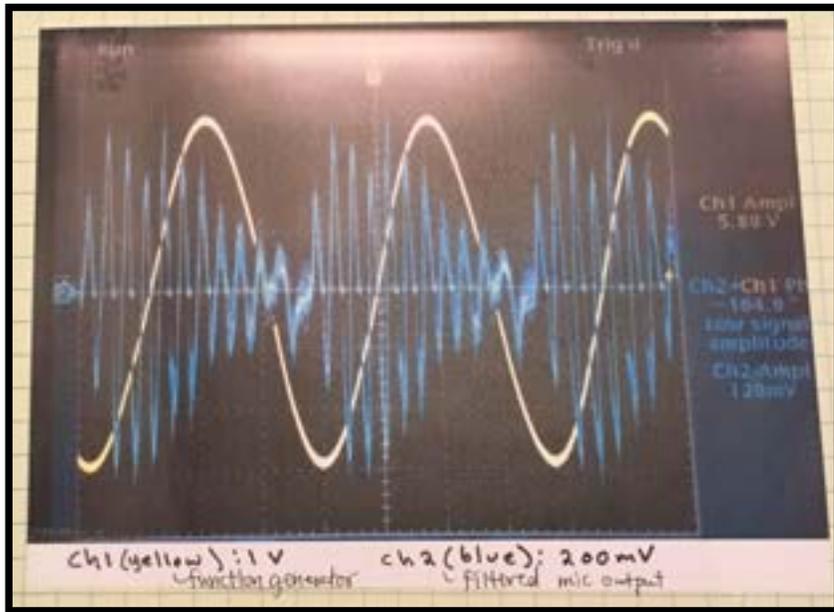
We connect as following:

+S + - -S  
red black

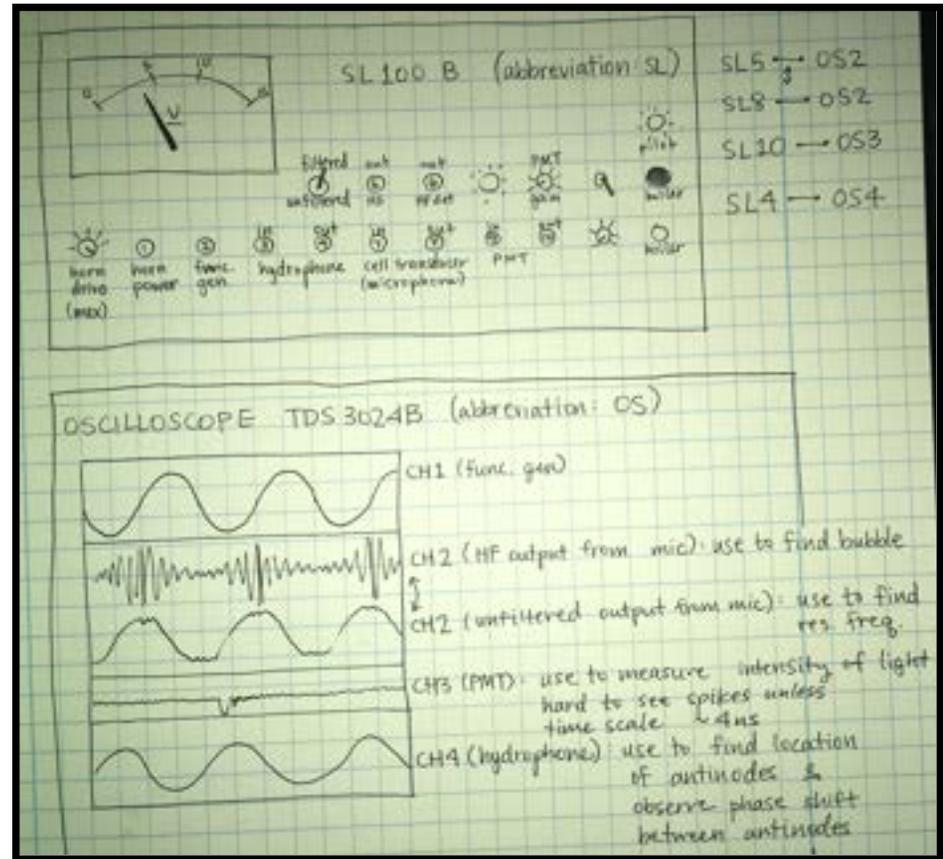
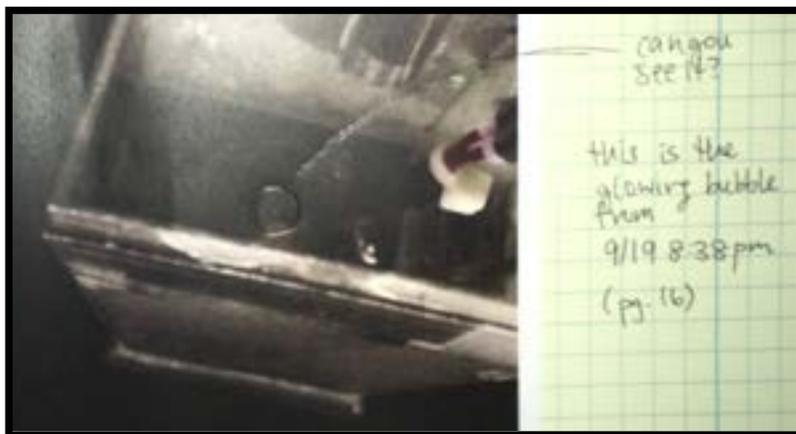
# What is the Relationship Between Knob Settings and Needle Readings?



# Realtime capture of good raw data+settings



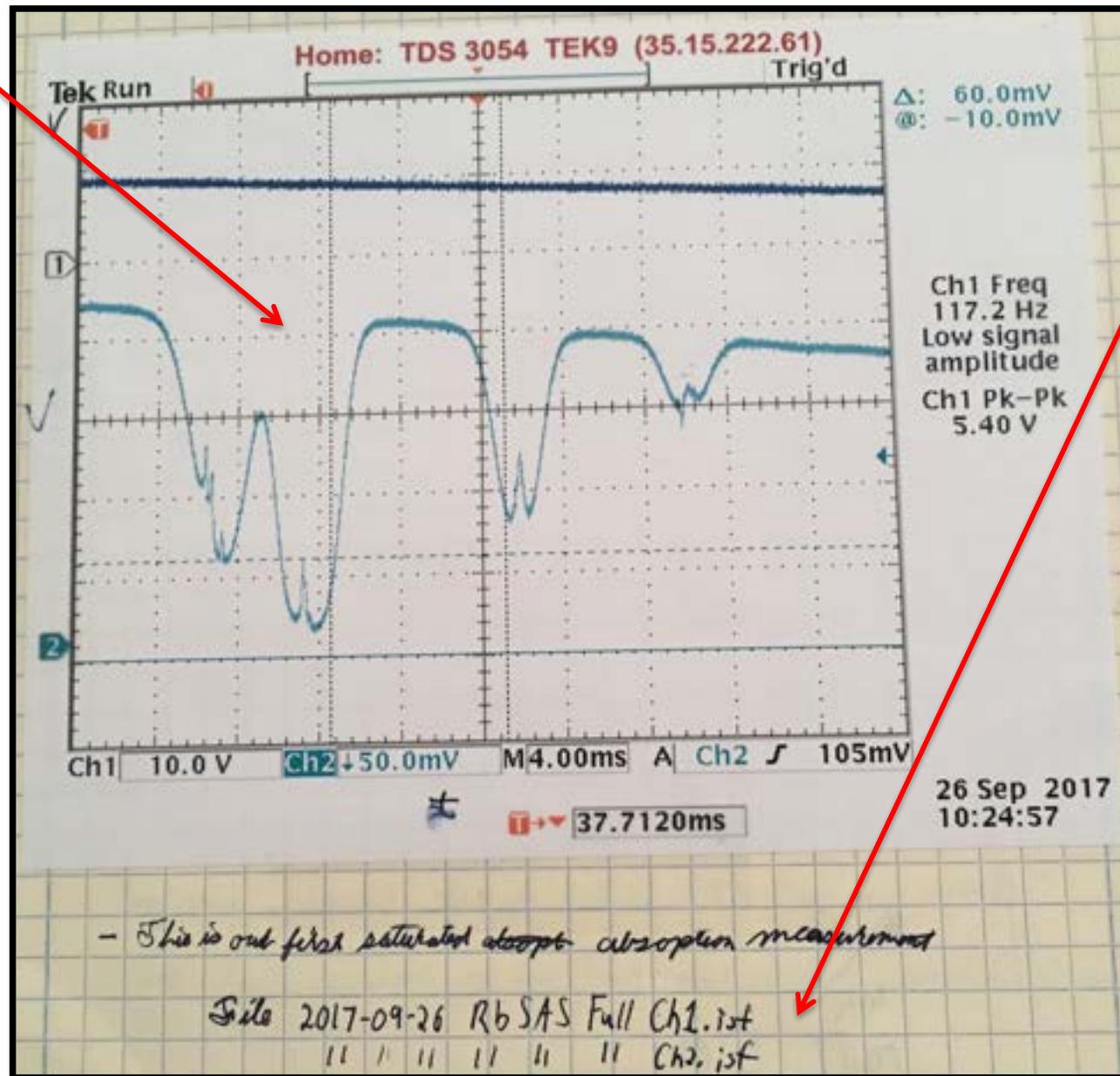
Each “needle” is labeled along with the appropriate scale and units.



How do we see each “needle”?

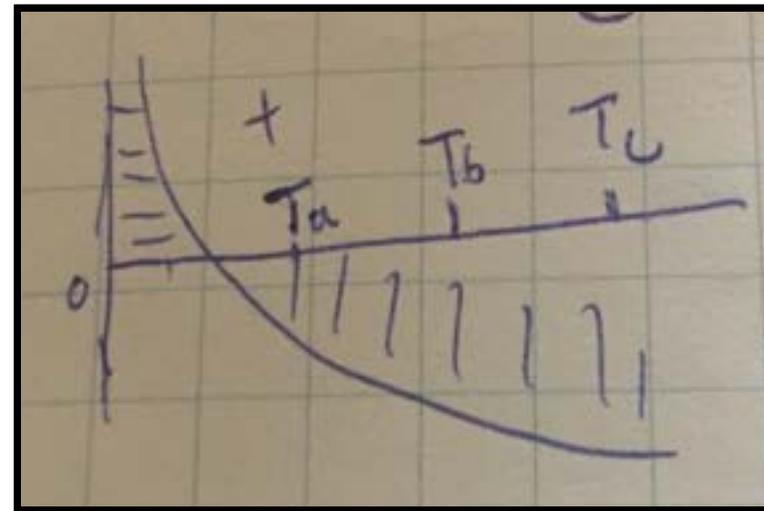
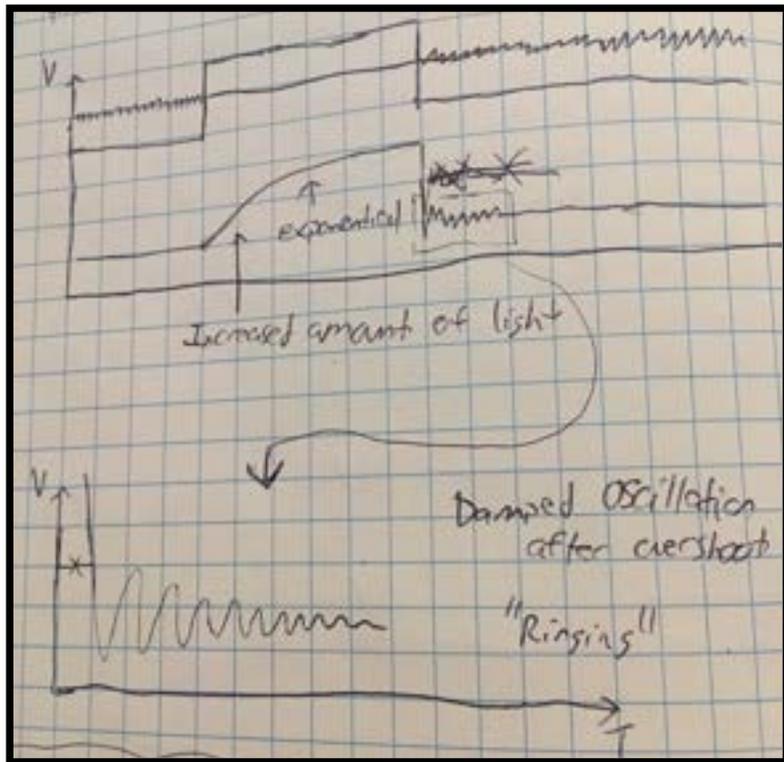
What is the “needle reading” when the experiment is working?

# Print Out Good Raw Data & Write Down Filename

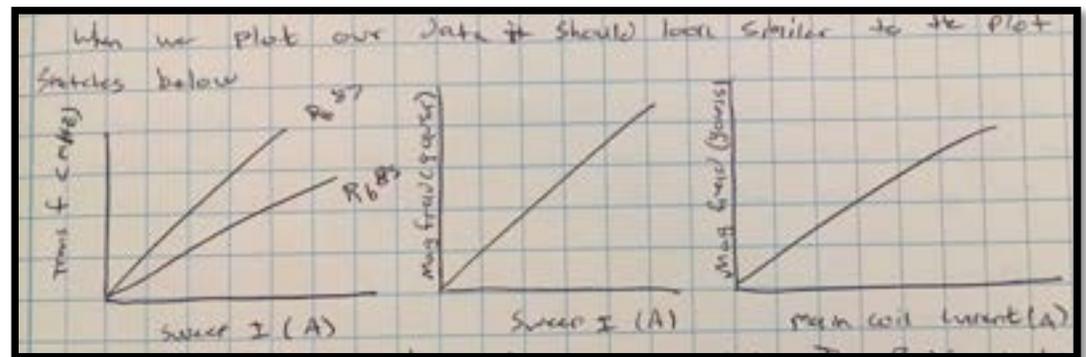


# Quick Sketch of What Success Looks Like

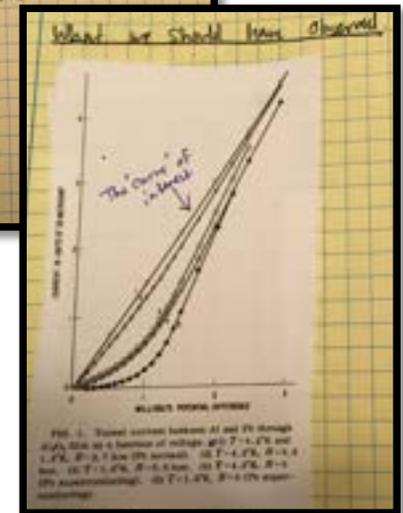
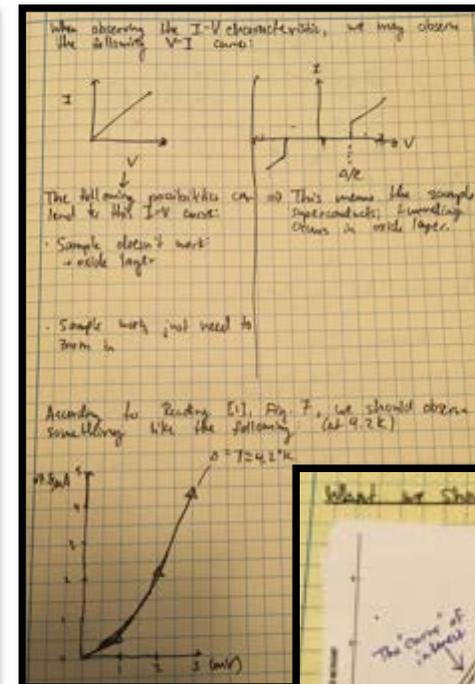
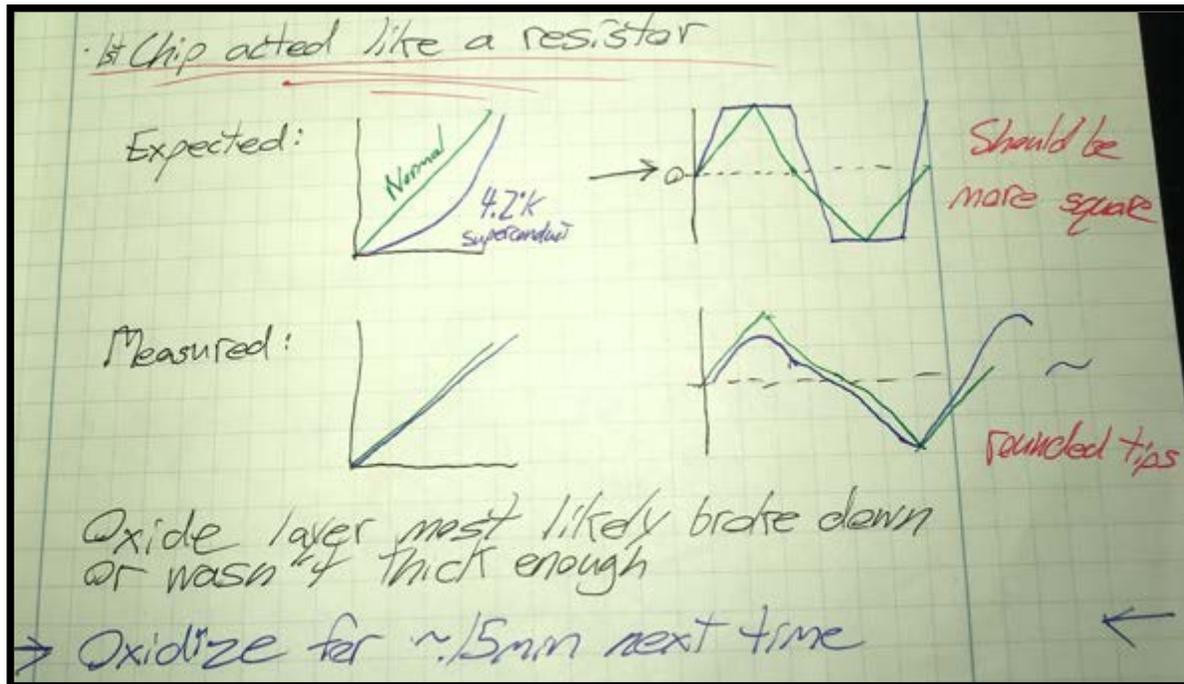
## Measured



## Expected

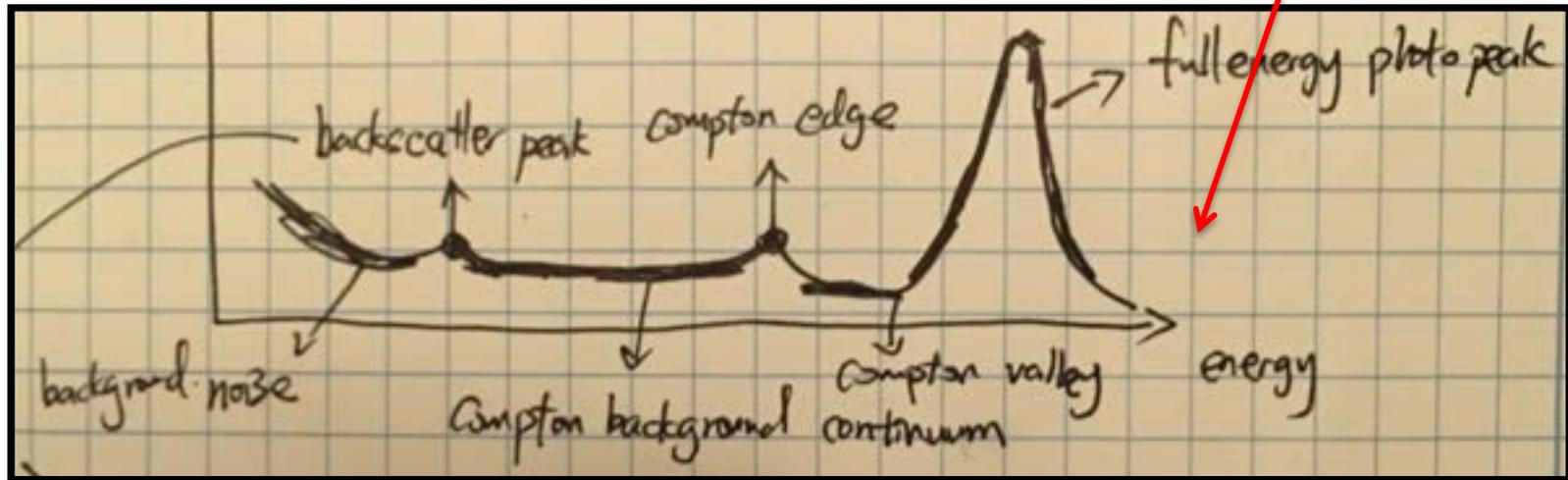
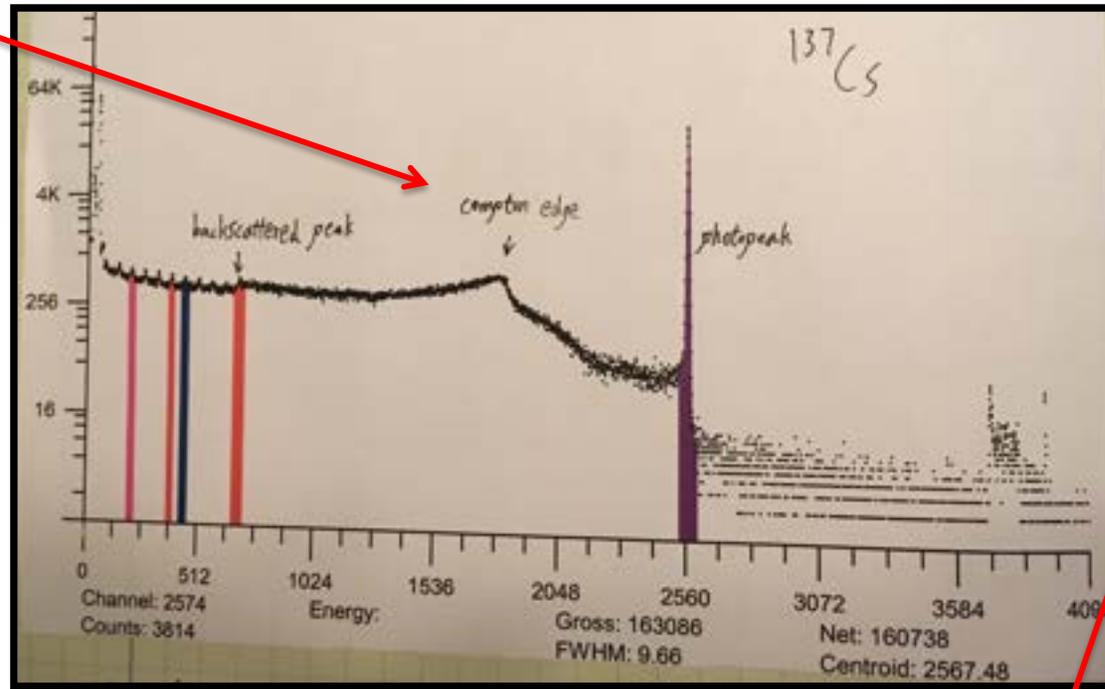


# Expectations & Comparisons

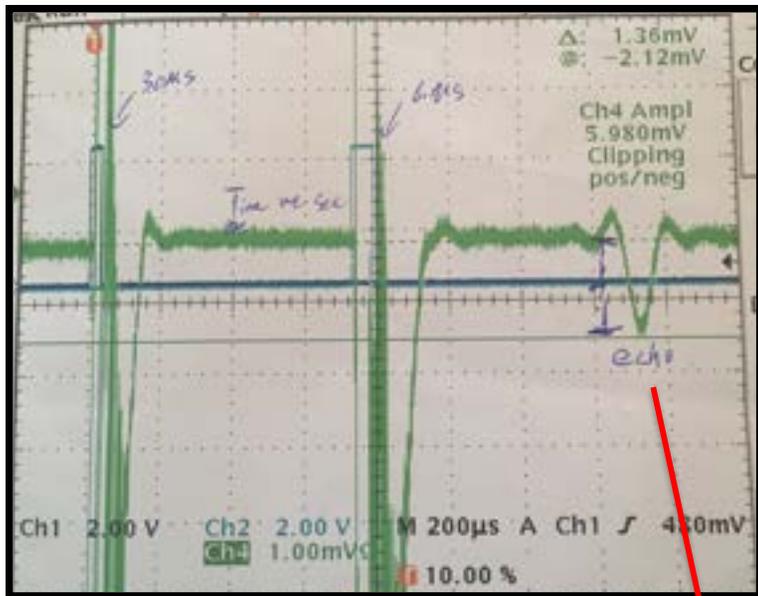


In order to see the physics, you need to have a starting guess as to where to look so that you set your knobs in a reasonable manner.

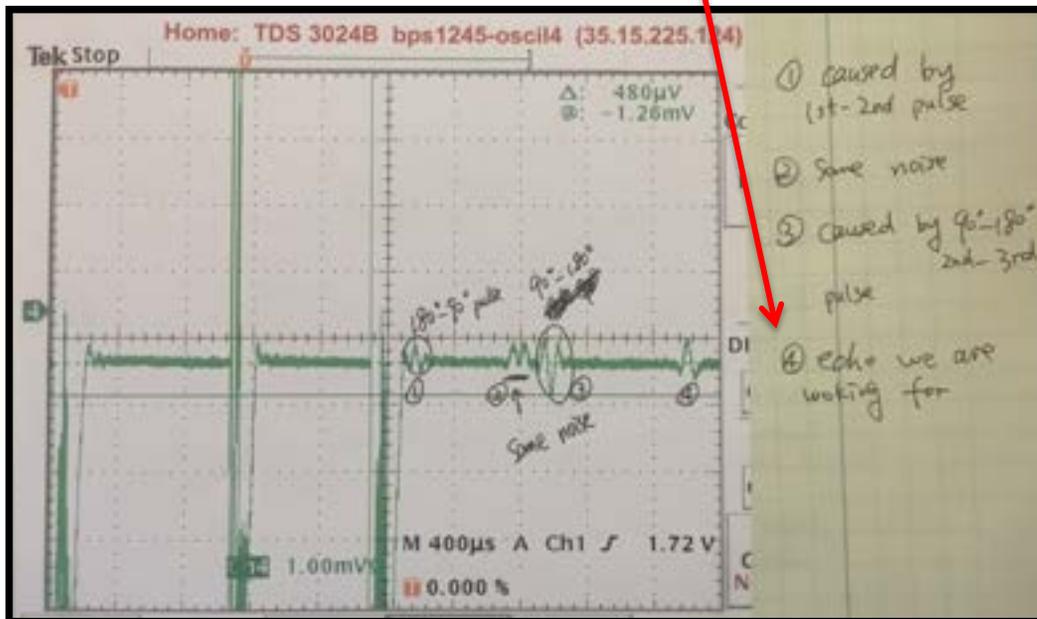
# Annotated Raw Data Compared to Expectations



# Quality Control: What is the Real Signal?



nearby best as we could  
 I watched tank with a little light peaking through curtain, and I saw yellow/orange light coming off the boiler itself. The extra yellow flash was relative to wire. I think yellow flashes from last week were from wire, not sonoluminescence.  
 spark came from here  
 Antonius fixed it by recoiling wire.



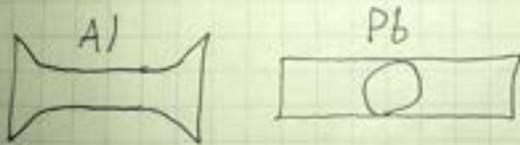
Prime Directive of the Knob-Turner:

The knob-turner must stare **at the correct needle when turning the knob.**

# Short useful notes written in Realtime

\* The trick appears to be to adjust the  $V$  amplitude while the bubbles are forming.

The correct usage of boats are important. Lead has a low surface tension and must be used in the boat with the bowl



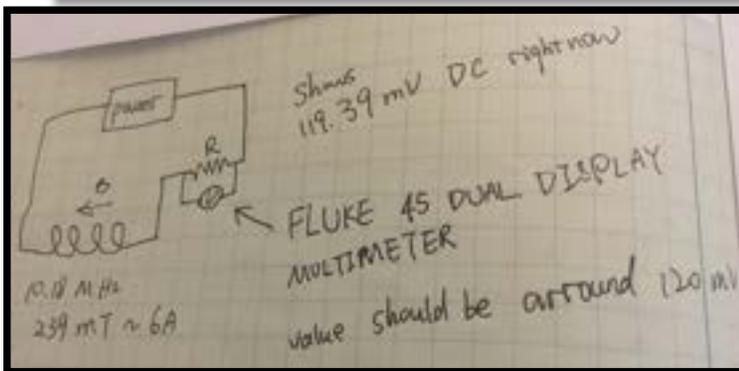
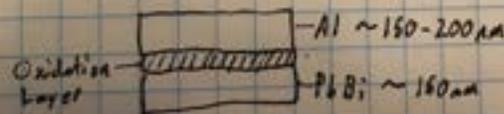
~1 or 2 pellets

~3 nuggets

\* the regulator valve can come off if too loose

SIN Junction thicknesses:

- 150-200 nm thick layer Al (N portion)
- 100 nm thick PbBi pads on Al
- Oxidation layer (variable thickness) time dependent
- ~150 nm thick layer PbBi



It took about ~~30~~ 30 mins to reach the desired temperature. The gauge fluctuates from 50.2°C to 49.8°C about every 5 minutes.

# Realtime Reflective Commentary

Assuming the gas is not self interacting,  
 $T \propto E = KE = \frac{1}{2} m \langle v \rangle^2 \rightarrow \langle v \rangle \propto \sqrt{\frac{2T}{m}}$

~~speed~~  $\langle v \rangle \propto$  speed of sound =  $u$

$\rightarrow \frac{u_1}{u_2} \propto \sqrt{\frac{m_2}{m_1}}$  if temp is the same, pressure too

$$\rho = \frac{m}{\epsilon} T$$

$$\left[ \frac{\text{J}}{\text{s}} \right] = \left[ \frac{\text{J}}{\text{kg} \cdot \text{K}} \right] \left[ \text{kg} \right] \left[ \frac{\text{K}}{\text{s}} \right]$$

Therefore, the units make sense!

# Our only obligation as Scientists is to be honest.

I was the person primarily responsible for data analysis of the speed measurements and Liam handled the lambda point analysis, we exchanged information on 10/6/2017.



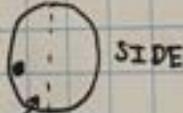
# Articulate & Check Your Assumptions

• There is a large protocol about aligning the laser by fine tuning the knobs in the laser housing. We are assuming that these controls do not need to be tuned. The equipment was calibrated at this time last year. We are assuming that no further calibration is needed. This could be a potential error in our results in the future. We will continue to keep this in mind as we move forward. We will adjust as needed.

34  
11:24 am  
9/19/17

~~NO HORIZONTAL ADJUSTMENT WAS NECESSARY! DON'T HAVE TO HARD TUNE THE LASER. Our earlier assumption that the laser itself does not need physical tuning stands. We will not be adjusting below laser housing.~~

JUST KIDDING!! THE LASER WAS NOT PROPERLY ADJUSTED HORIZONTALLY. We tuned the laser to a new horizontal position by turning the SIDE knob. The final position of the side knob is:

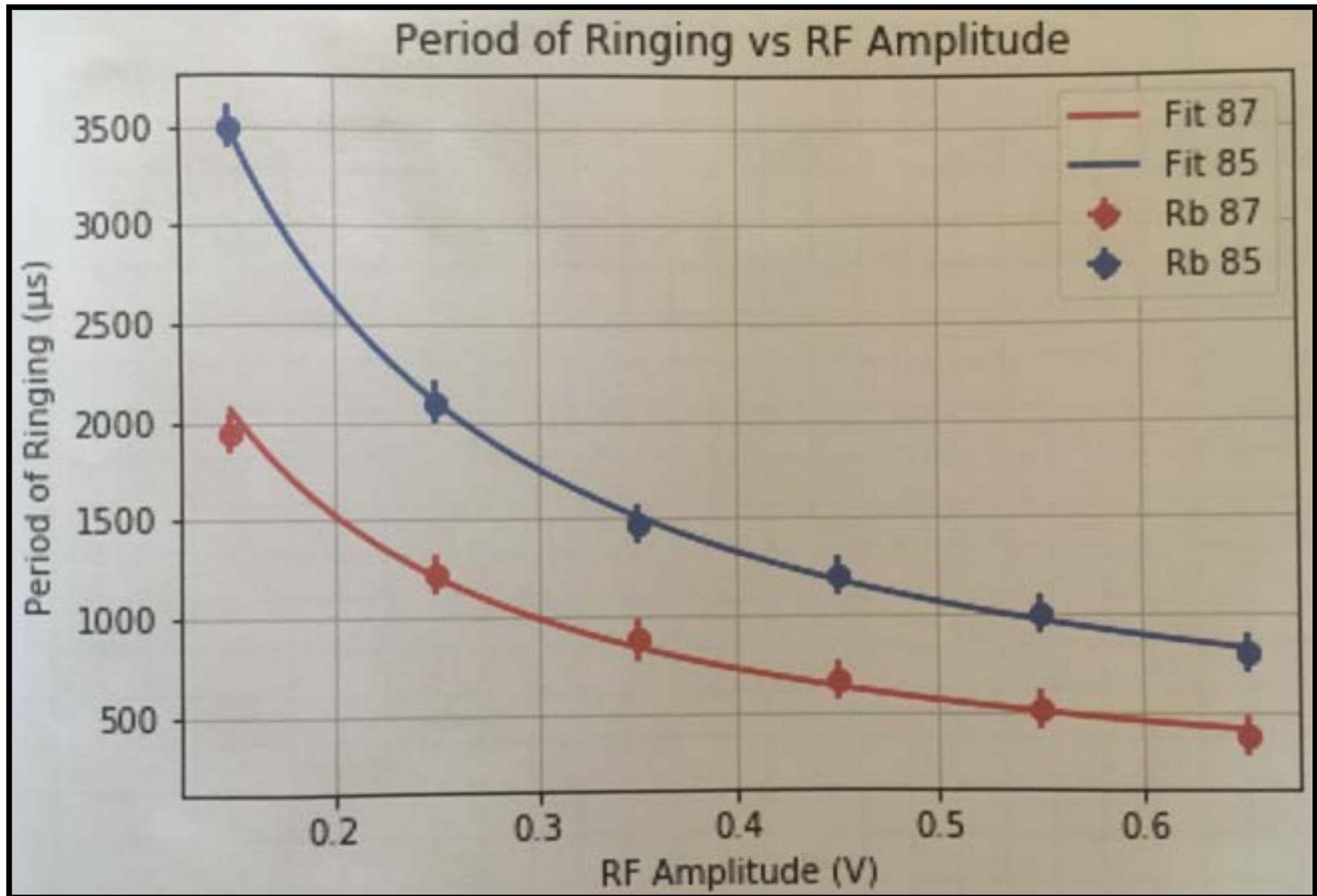


When this happened, we saw a lot of beam flashing on the TV. The beam was very present and flashing. This is the sign that we had properly tuned our laser. We were able to see the spectroscopy on the oscilloscope.

# Highly Observant Reflective Synthesis

i. In principle, horn drive can also be adjusted to change amplitude of sound waves. But we found it easier to keep the horn drive fixed and adjust amplitude on function generator only. In general, the amplitude needed to trap a bubble increases w/ temperature of the water. For degassed water at  $5-7^{\circ}\text{C}$ , an amplitude of  $\sim 3.5-5\text{V}$  was needed. For degassed water at  $15-20^{\circ}\text{C}$ ,  $\sim 8-9\text{V}$  was needed (and it was still hard to keep bubbles stable). Water above  $20^{\circ}\text{C}$  was completely useless.

# Summary of Results: Plots



# Summary of Results: Table w/ Reflective Commentary

Summary:

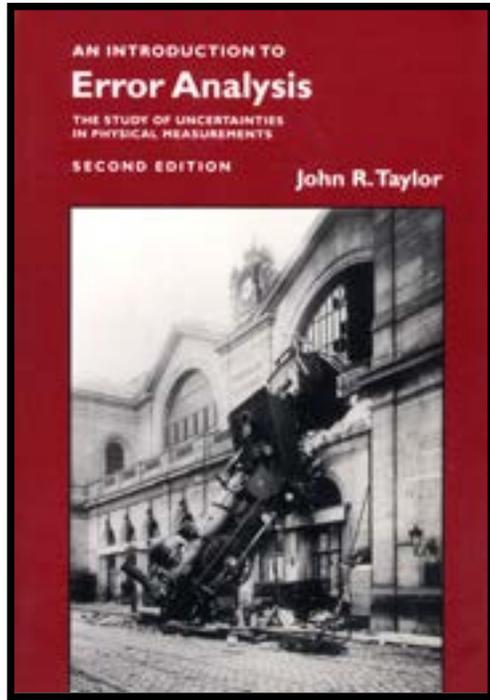
The accepted values for all the speeds were within the error bars of our data and we were able to measure the speed of sound in Helium II with great accuracy. The results are summarized in the following table.

Substance, Sound	Mean $\Delta$ Frequency (Hz)	$\Delta$ Frequency Error (Hz)	Speed (m/s)	Speed Error (m/s)	Actual Speed (m/s)	Within Error?	Percent Error
Air, 1 <sup>st</sup>	4275	243	342	21	343	Yes	0.29%
Nitrogen Gas, 1 <sup>st</sup>	4348	315	348	27	354	Yes	1.74%
Helium Gas, 1 <sup>st</sup>	11114	1034	889	86	972	Yes	8.53%
Liquid Helium, 2 <sup>nd</sup>	248	13.8	19.9	1.2	20.0	Yes	0.72%

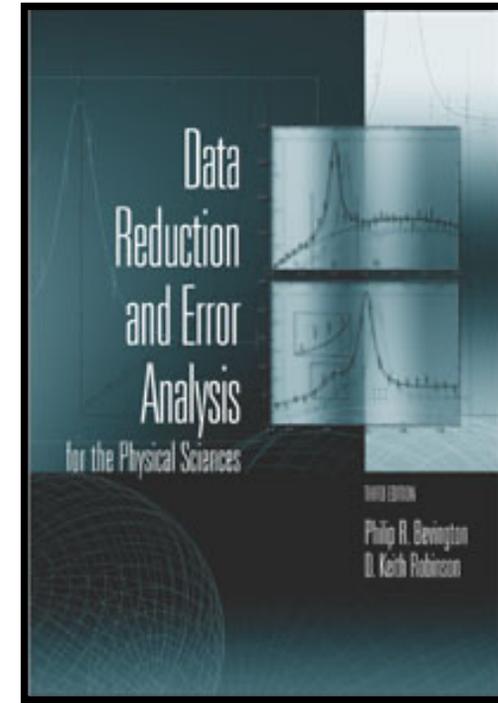
Trial	Al thick (nm)	Evap. Pres. (mbar)	Evap. time (min)	Jct thick (nm)	Pb thick (nm)	R Al (Ohm)	R Pb (Ohm)	Vacuum (mbar)	Result
1	150?	0.15	10	119	202	0*	0*	1.00E-05	Inconclusive. *Did not measure chip resistance beforehand
2	179	0.15	18	101	202	9.4	64	1.00E-05	No superconducting properties
3	154	0.3	20	119	202	6	460	1.00E-05	V vs. I looks like a resistor. See Data Analysis

Summary Table of Trials

# Good References



*An Introduction to Error Analysis, 2/e*  
**John R. Taylor**  
<http://www.uscibooks.com/taylornb.htm>



*Data Reduction and Error Analysis for the Physical Sciences, 3/e*  
**Philip R. Bevington  
& D. Keith Robinson**  
<http://highered.mheducation.com/sites/0072472278/index.html>