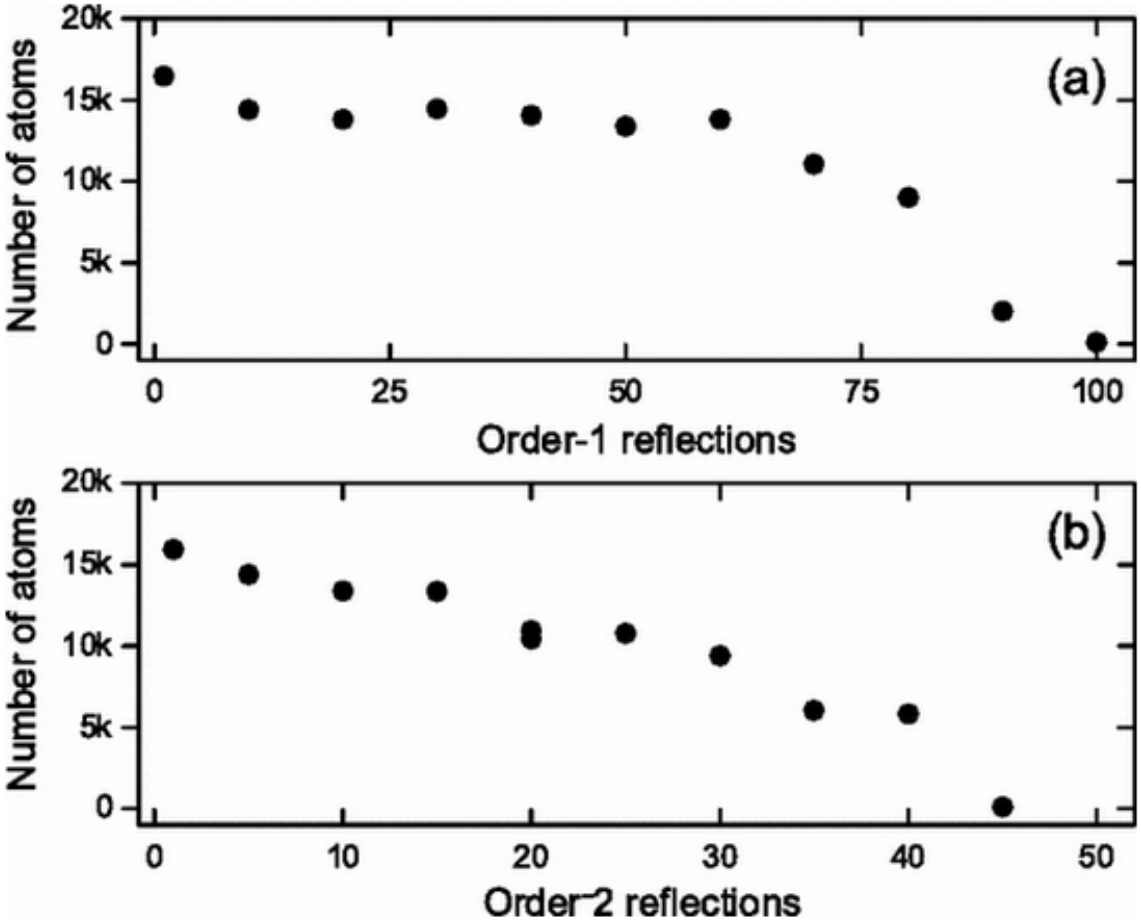
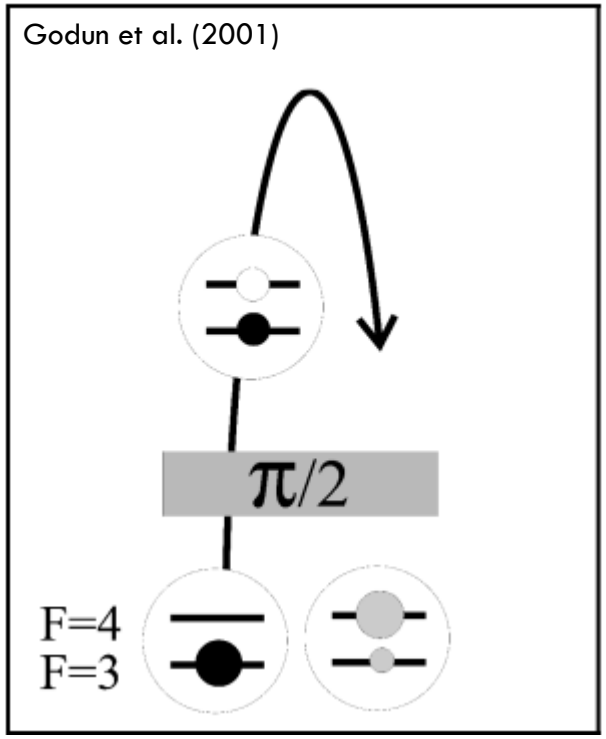
# A compact vapor cell for cold atom applications

Tanwa Arpornthip

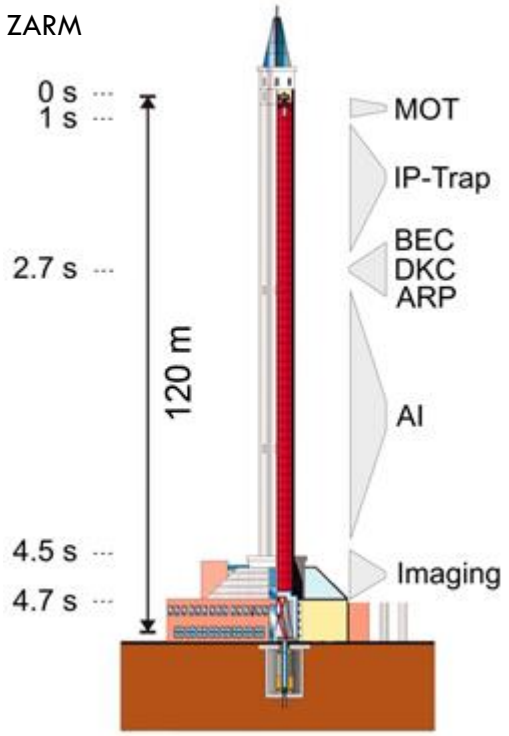
# Introduction

# Atom interferometry gravimetry



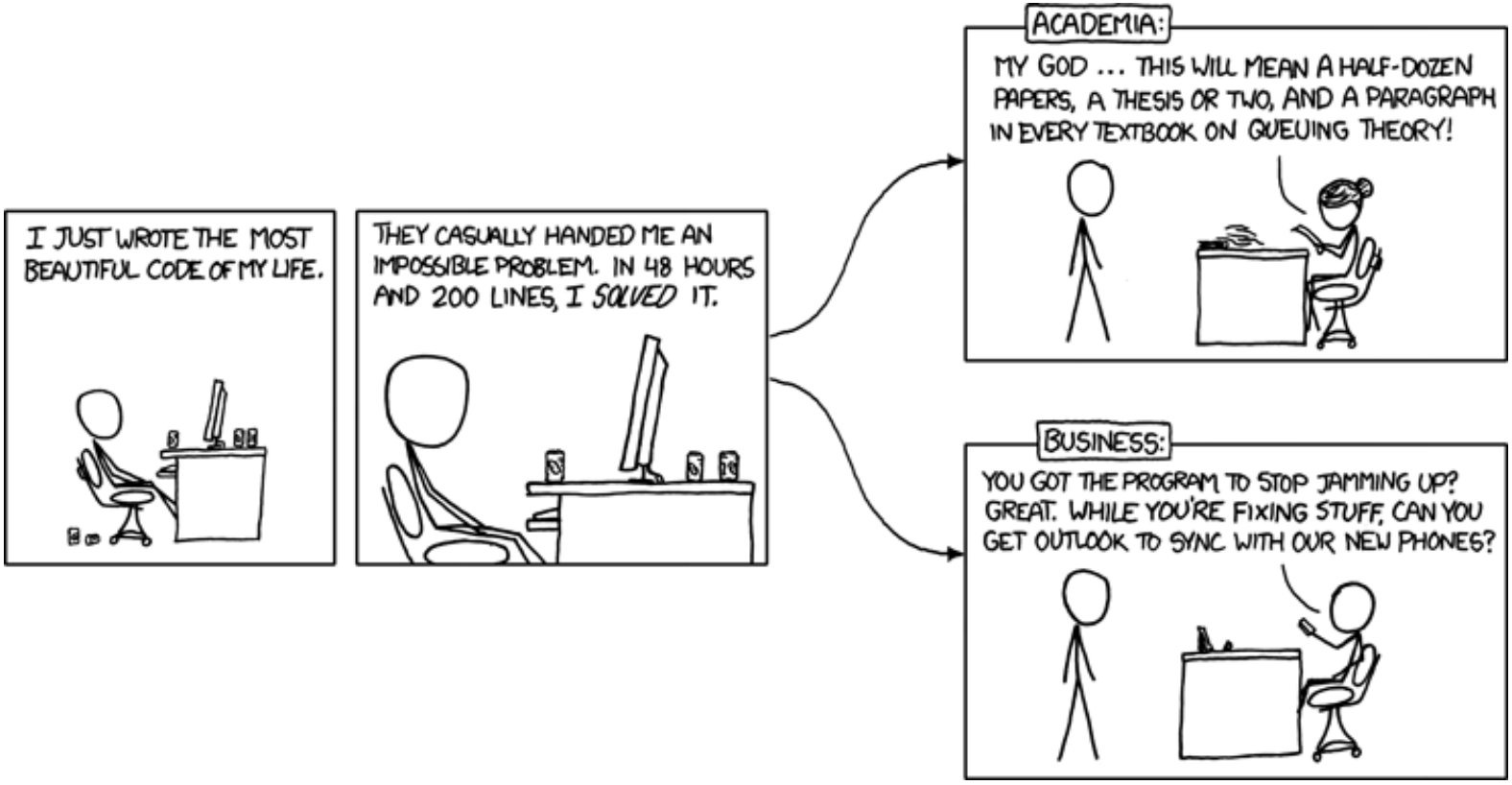



Atom fountain: Frequency standard, time standard

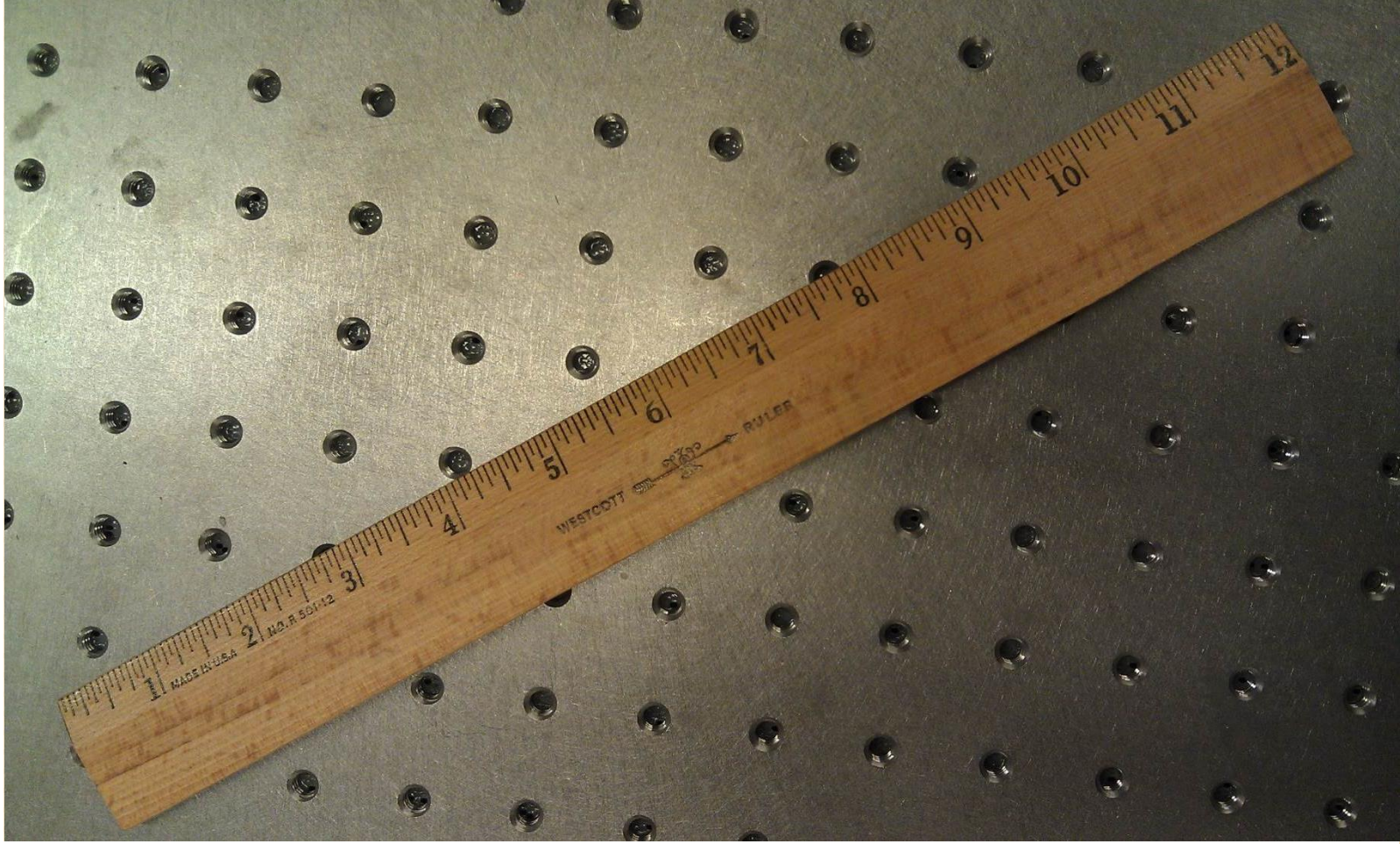



ZARM drop tower, Germany: Universality of free falling

Godun et al., "Prospects for atom interferometry," Contemporary Phys. 42, 2001, 77-95


I JUST WROTE THE MOST BEAUTIFUL CODE OF MY LIFE.
THEY CASUALLY HANDED ME AN IMPOSSIBLE PROBLEM. IN 48 HOURS AND 200 LINES, I SOLVED IT.
ACADEMIA:
MY GOD ... THIS WILL MEAN A HALF-DOZEN PAPERS, A THESIS OR TWO, AND A PARAGRAPH IN EVERY TEXTBOOK ON QUEUING THEORY!
BUSINESS:
YOU GOT THE PROGRAM TO STOP JAMMING UP? GREAT. WHILE YOU'RE FIXING STUFF, CAN YOU GET OUTLOOK TO SYNC WITH OUR NEW PHONES?

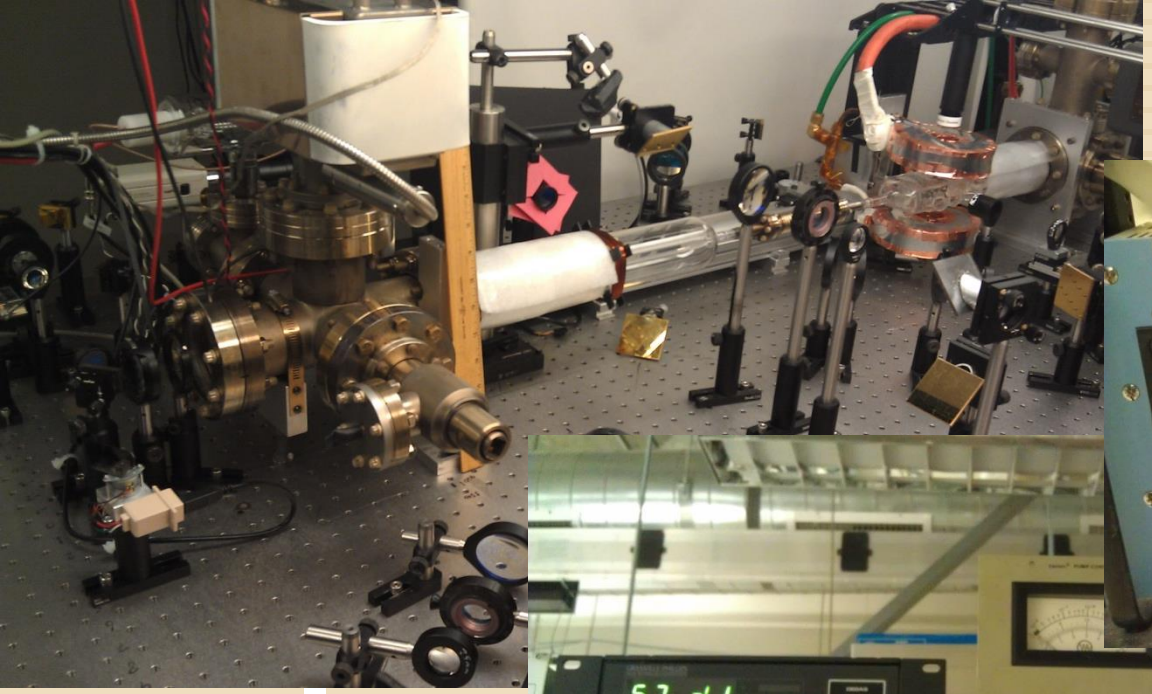
# The problem of size




# Good ol' trusty ruler

"The length of this document defends it well against the risk of its being read."

Winston Churchill



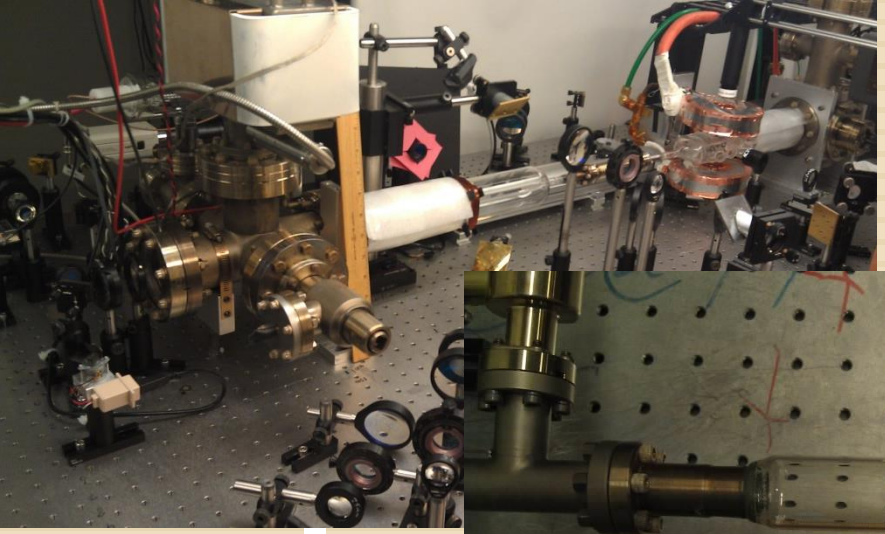

# Typical cold atom application size

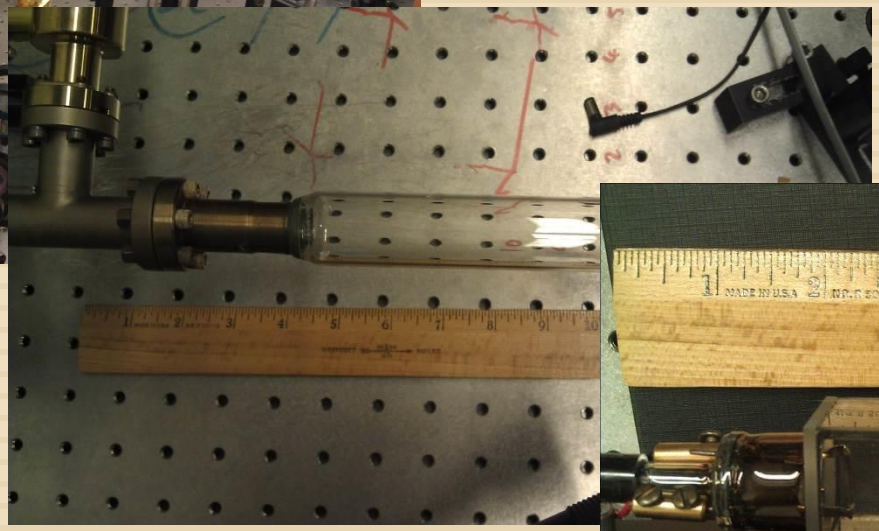
"When all else fails, complicate matters."

Aaron Allston

# Our goals

- Reduce the physical size of the cell
- Reduce the amount of connection needed
- Simplify the cell
- Provide long-term solutions (years)



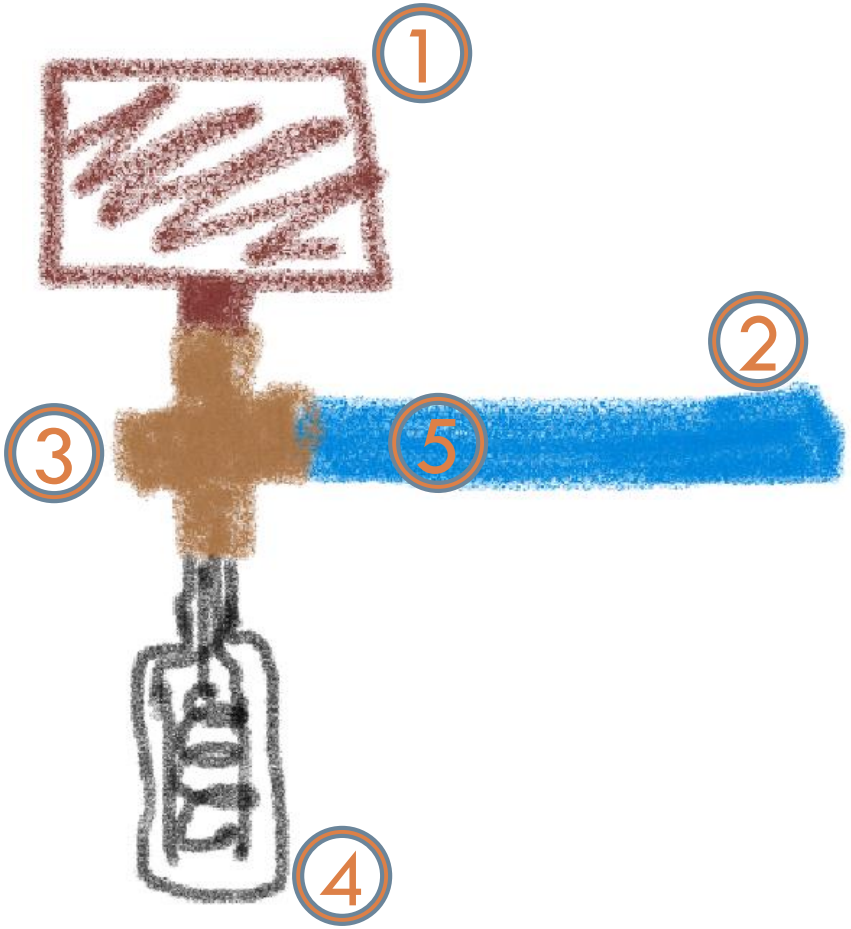



# Conclusion (cell evolution)

"A conclusion is the place where you got tired thinking."

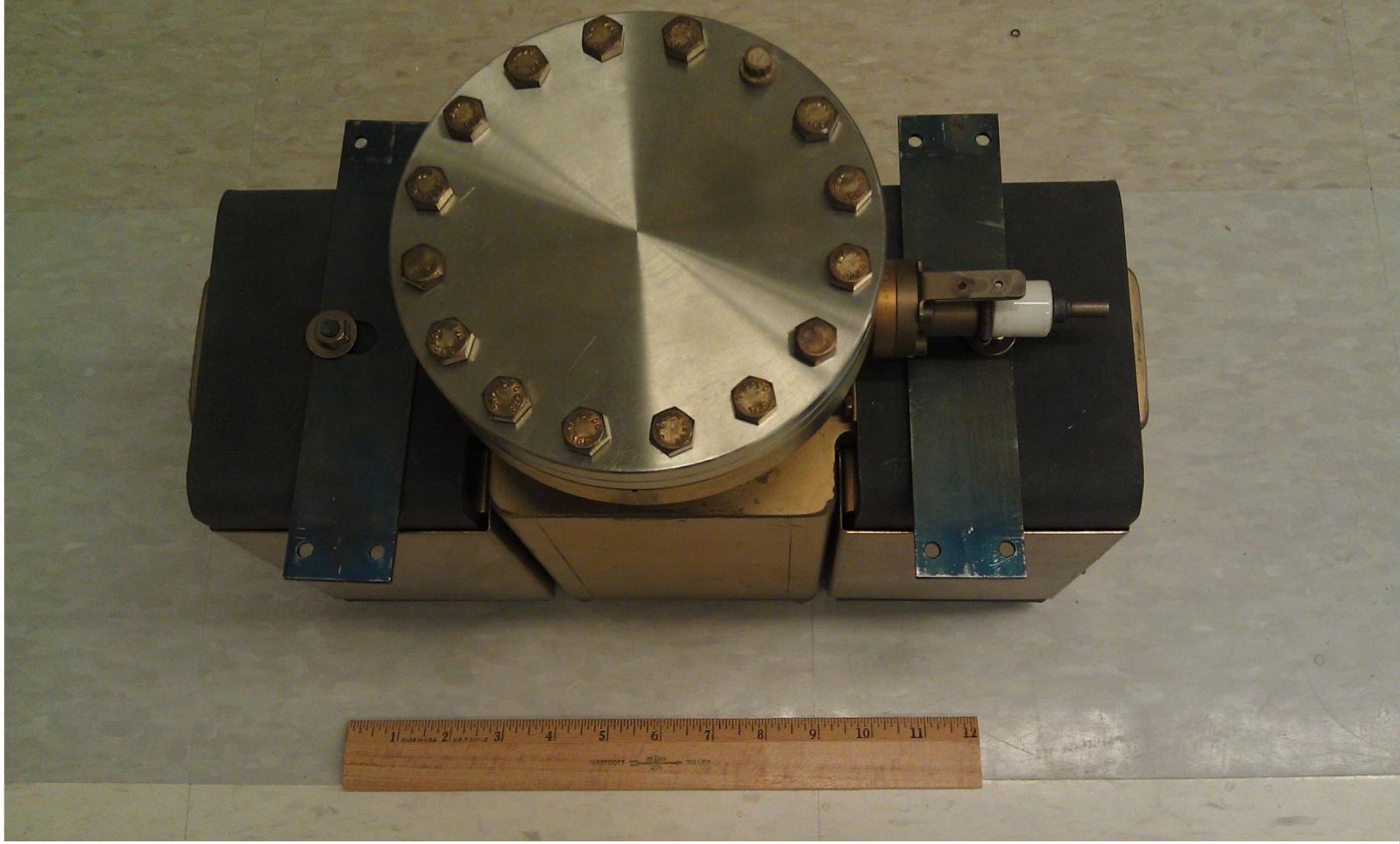
Martin H. Fischer

# Our approach




1. Replace ion pump with a passive pump
2. Use proprietary glass to achieve longer cell lifetime
3. Redesign bake-out connection
4. Remove ion gauge
5. Control the amount of interested atoms

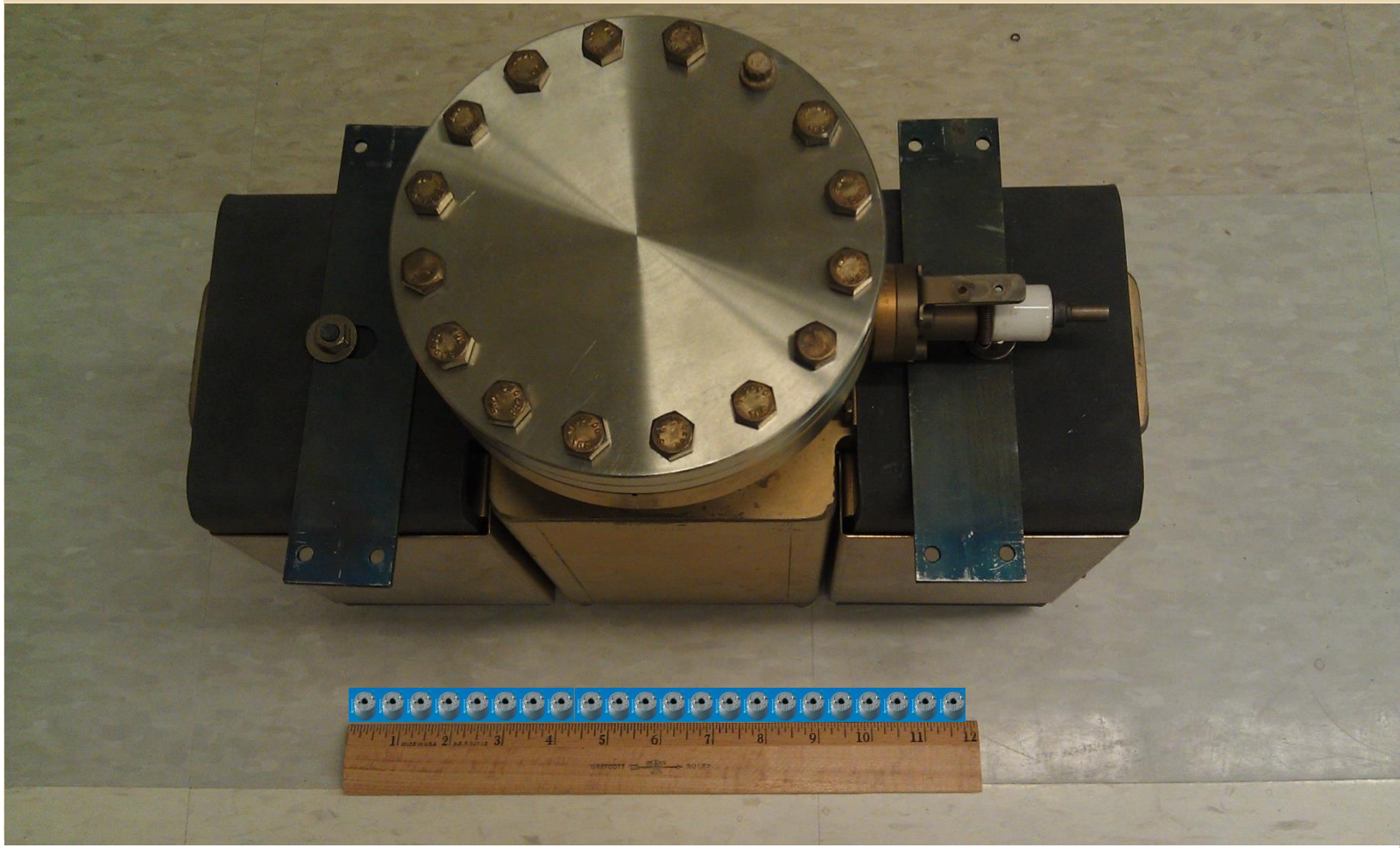
# 1. Replace ion pump



# Typical ion pump

"If cats were double the size they are now, they'd probably be illegal."

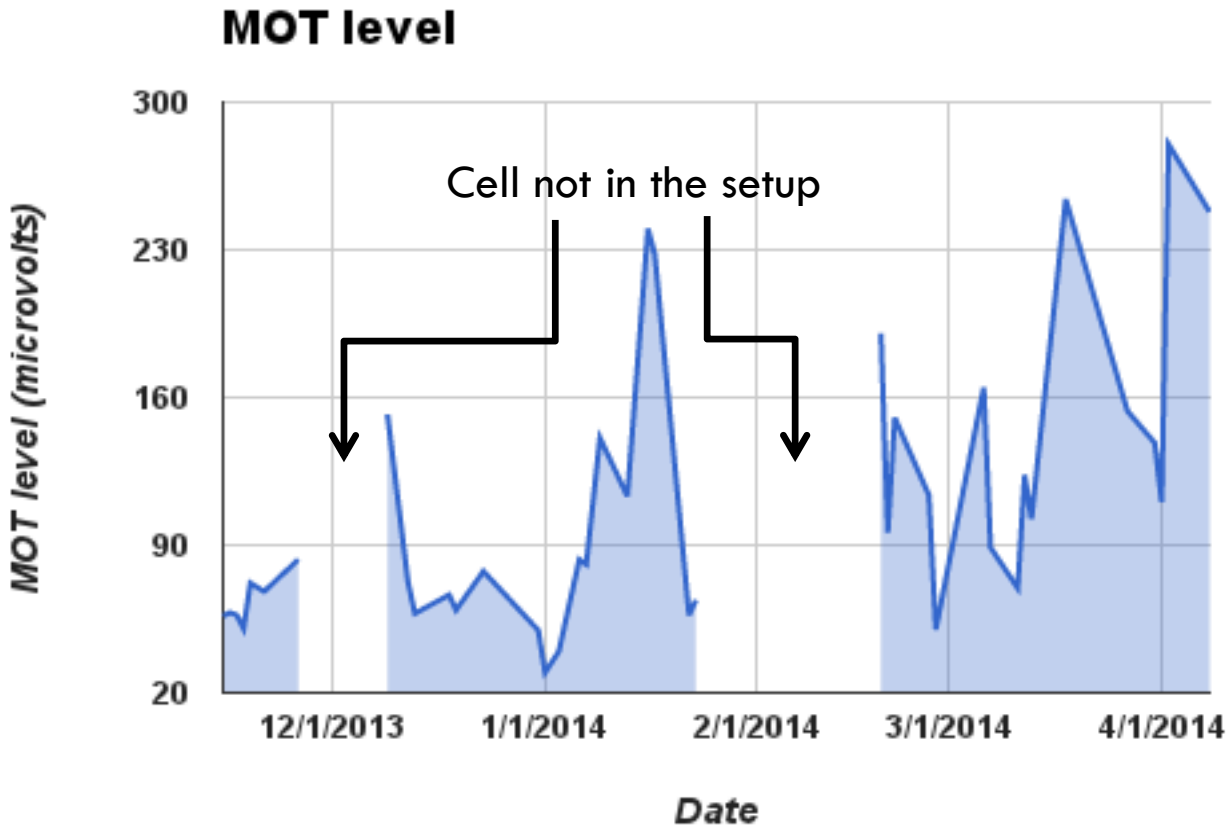
Douglas Coupland

# Non-evaporable getter (NEG)

"I went into a clothing store, and the lady asked me what size I was. I said, 'Actual.' I'm not to scale."

Demetri Martin

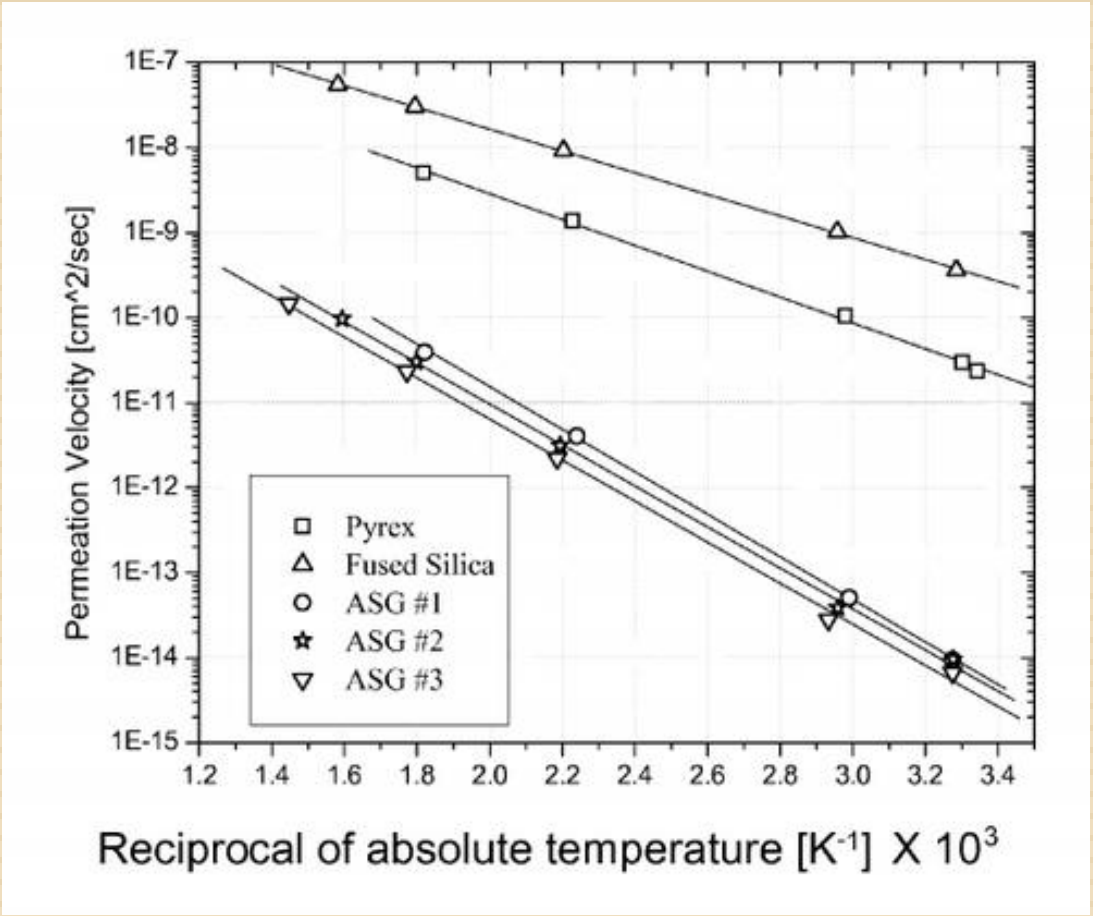



Atom trap (MOT) maintained in the cell with an NEG

# Nov 2013 - Present

# 2. Proprietary glass

Helium permeation problem

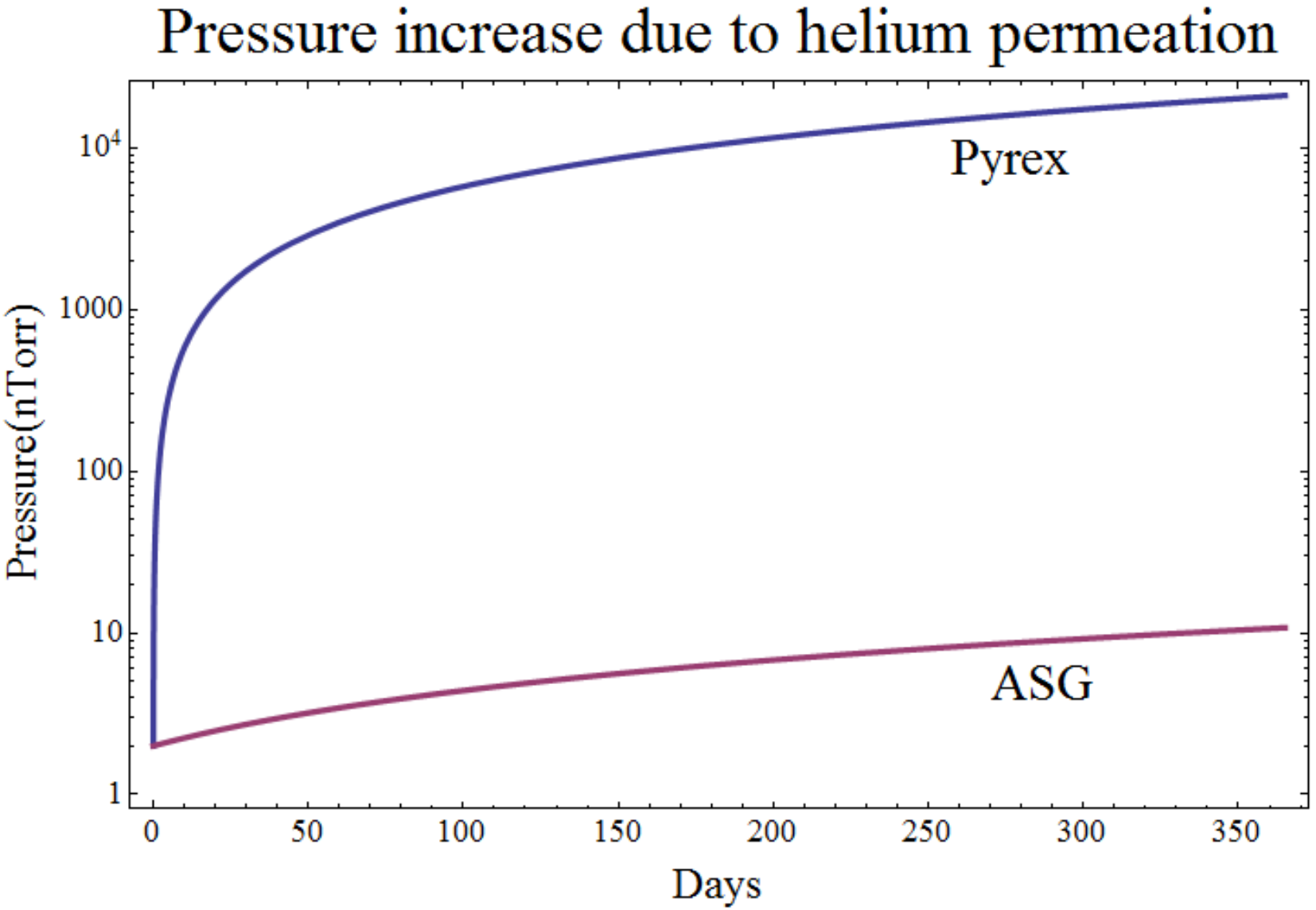


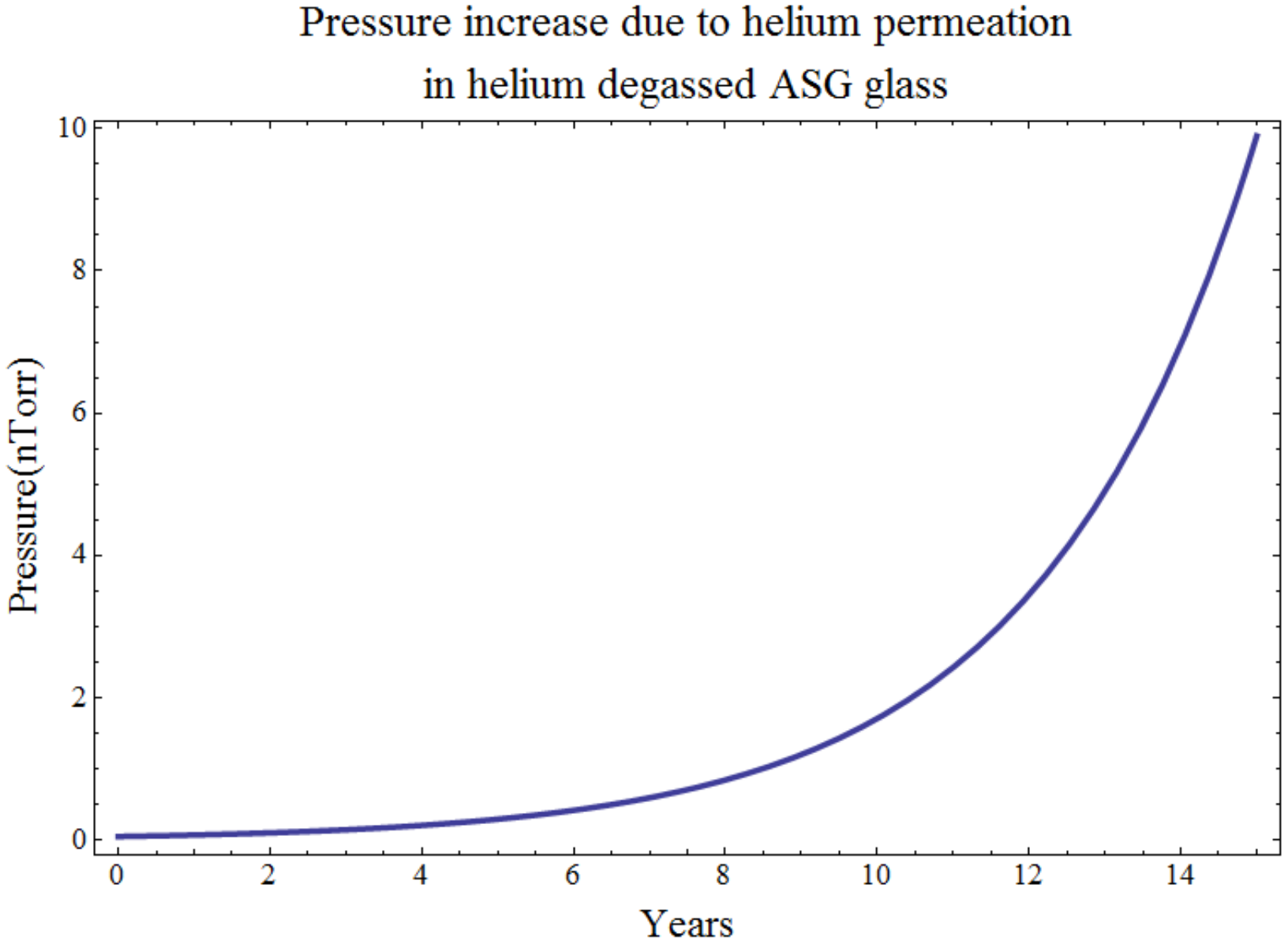

# Permeation of Helium through different glass

"When things get too heavy, just call me helium."

Jimi Hendrix

Hughes et al. "Helium barrier atom chamber." Patent 2012/0258022. 11 Oct 2012


Pressure increase due to helium permeation
Pyrex
ASG
Pressure(nTorr)
Days
10^4
1000
100
10
1
0
50
100
150
200
250
300
350


Pressure increase due to helium permeation
in helium degassed ASG glass
Pressure(nTorr)
0
2
4
6
8
10
0
2
4
6
8
10
12
14
Years

(19) **United States**

(12) **Patent Application Publication**

**Hughes et al.**

(10) **Pub. No.: US 2012/0258022 A1**

(43) **Pub. Date: Oct. 11, 2012**

(54) **HELIUM BARRIER ATOM CHAMBER**

(75) Inventors: **Kenneth Jeramiah Hughes**, Lafayette, CO (US); **Charles Ackley Sackett**, Charlottesville, VA (US); **Archie Theodore Brown**, Longmont, CO (US)

(73) Assignee: **TRIAL TECHNOLOGY, INC.**, Longmont, CO (US)

(21) Appl. No.: **13/441,466**

(22) Filed: **Apr. 6, 2012**

**Related U.S. Application Data**

(60) Provisional application No. 61/516,758, filed on Apr. 7, 2011.

**Publication Classification**

(51) **Int. Cl.**

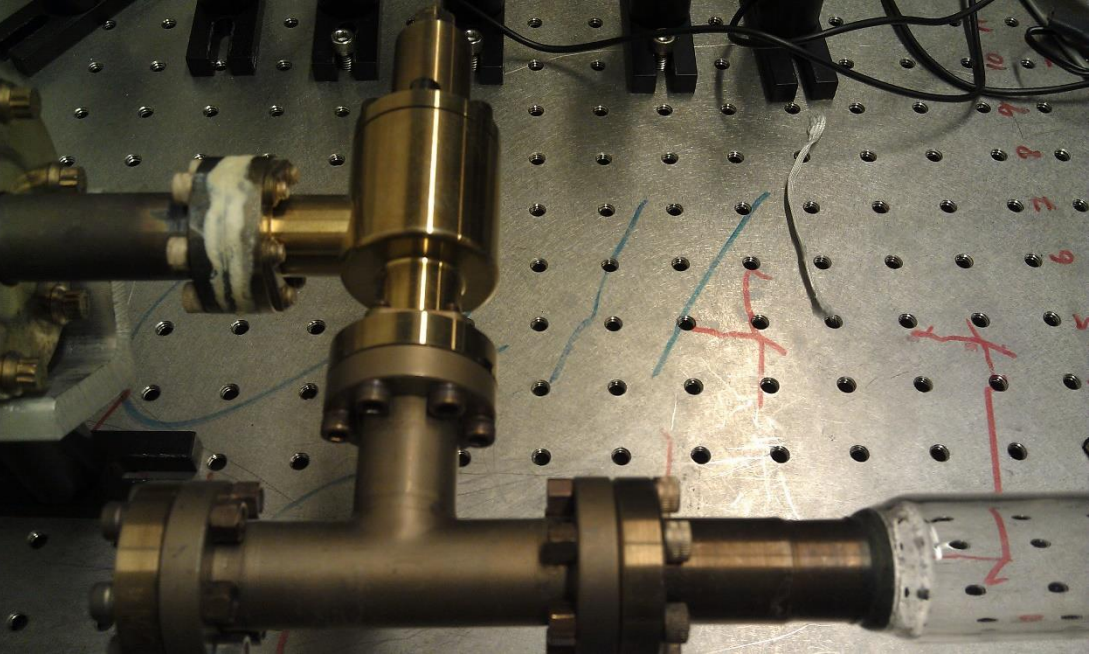
| | |
|---|---|
| ***B65D 25/54*** | (2006.01) |
| ***B01J 19/00*** | (2006.01) |
| ***C03B 32/00*** | (2006.01) |

(52) **U.S. Cl.** ..... **422/291**; 220/662; 65/111

(57) **ABSTRACT**

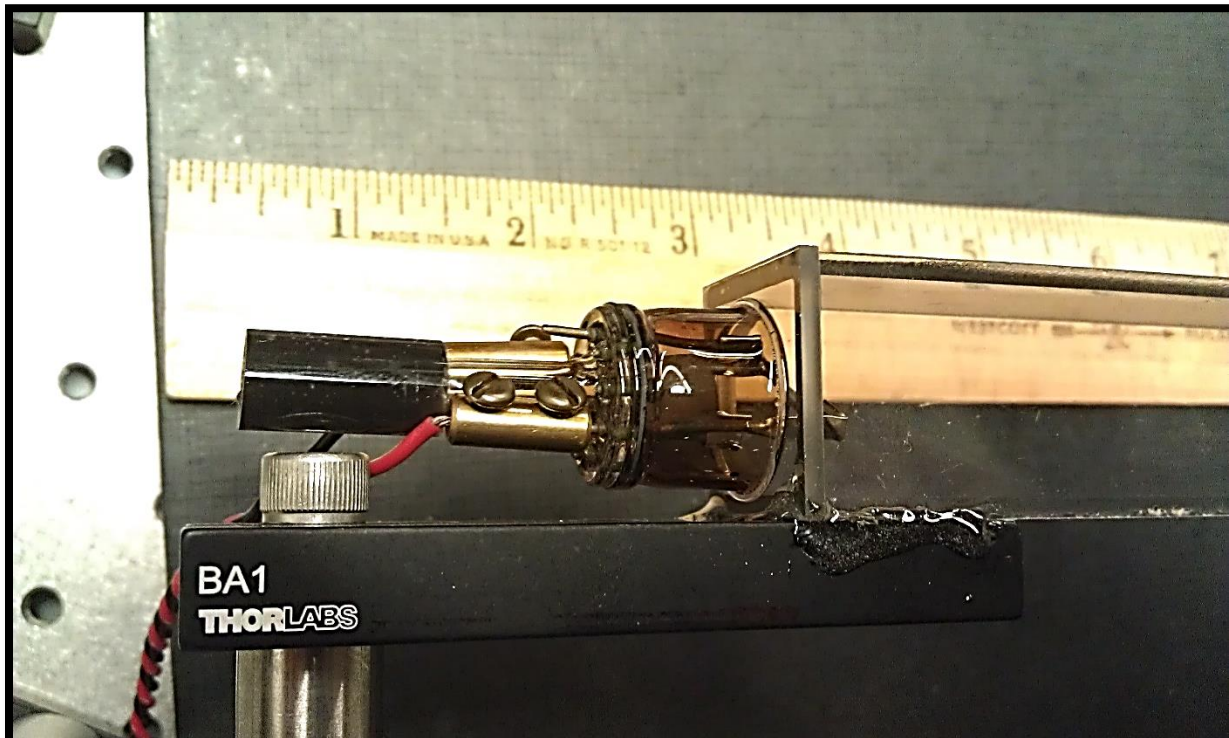
The present invention discloses a vacuum chamber having operating pressures in the ultra-high vacuum (UHV) range ($10^{-8}$ torr to $10^{-13}$ torr) and incorporating transparent windows, said windows constructed from transparent materials (preferably glass), and having low helium permeability velocity under operating and storage conditions. Embodiments may also contain surface coatings on windows to reduce helium permeation. Also disclosed herein is a method for vacuum processing said chamber by heating entire chamber and exposing the inside and outside of the chamber windows to helium free environments. Methods for final sealing said chamber are also discussed. The vacuum chamber is useful as a container for optically-cooled atoms for use in quantum information and atomic clocks and as a sensor for magnetic fields, gravitational fields, and inertial effects.

# 3. Redesign bake-out connection



Valve connection

Pinch off connection

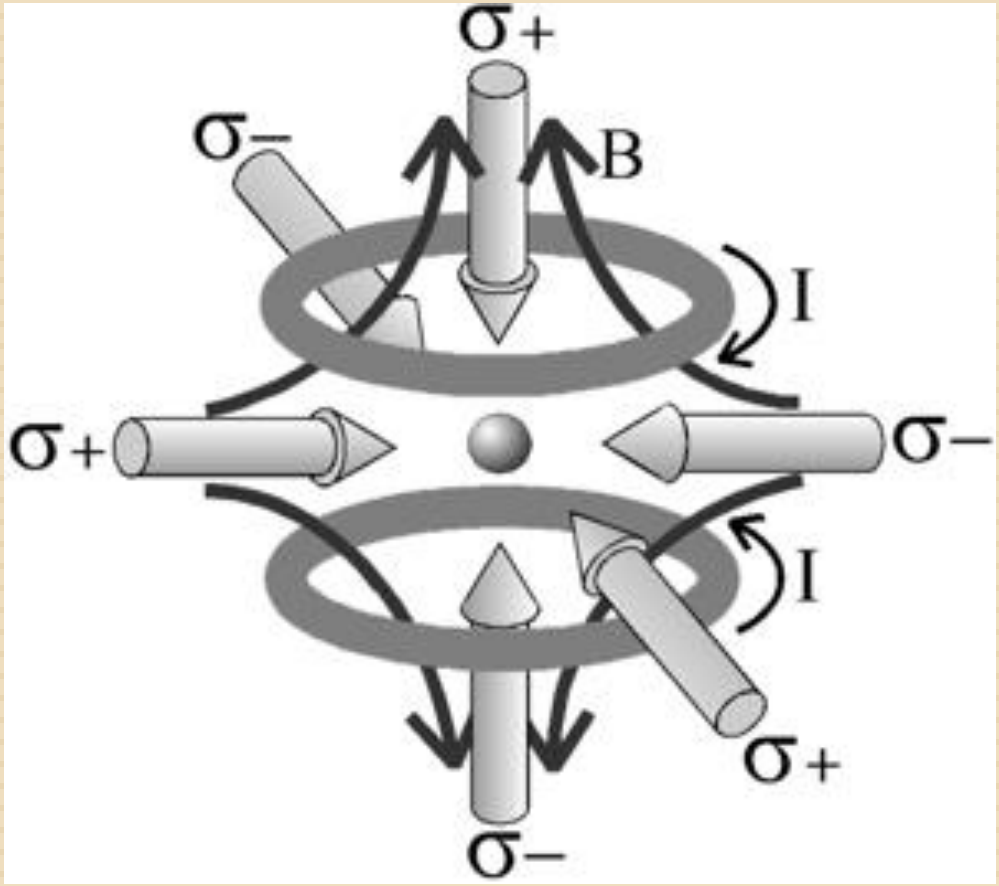


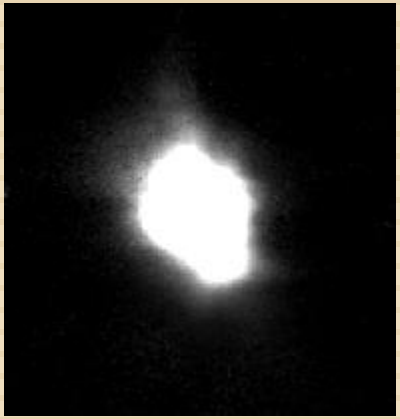
# 4. Remove ion gauge

But what are we going to use???!?!?!


# Ionization gauge

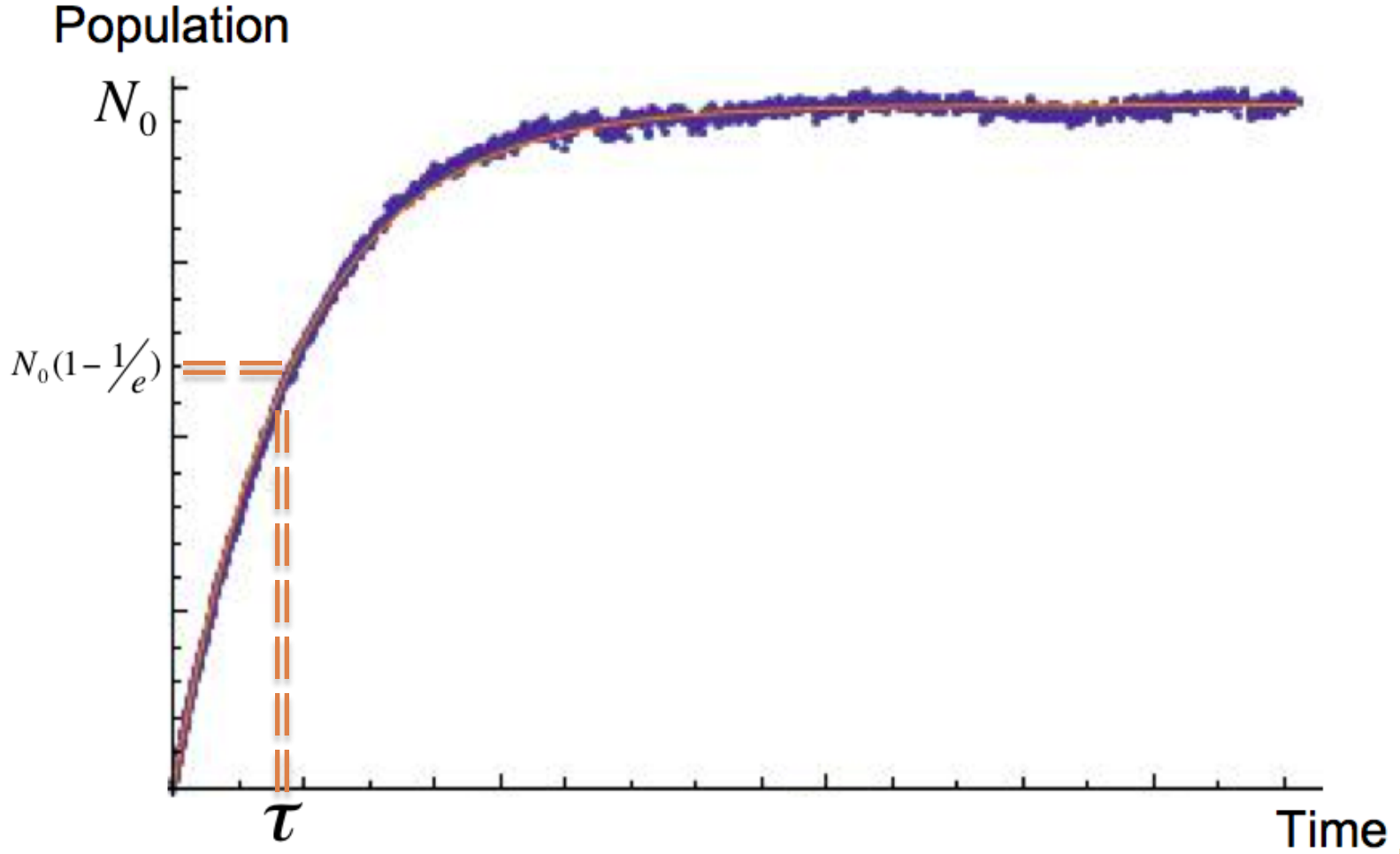
Did you seriously expect me to find funny quotes about an ionization gauge?



# Magneto-optical trap

Can we all please stop saying “laser focus”?




# MOT exponential loading curve

"The greatest shortcoming of the human race is our inability to understand the exponential function."

Albert A. Bartlett

# Error associated with the method

**Unknown background gas composition**

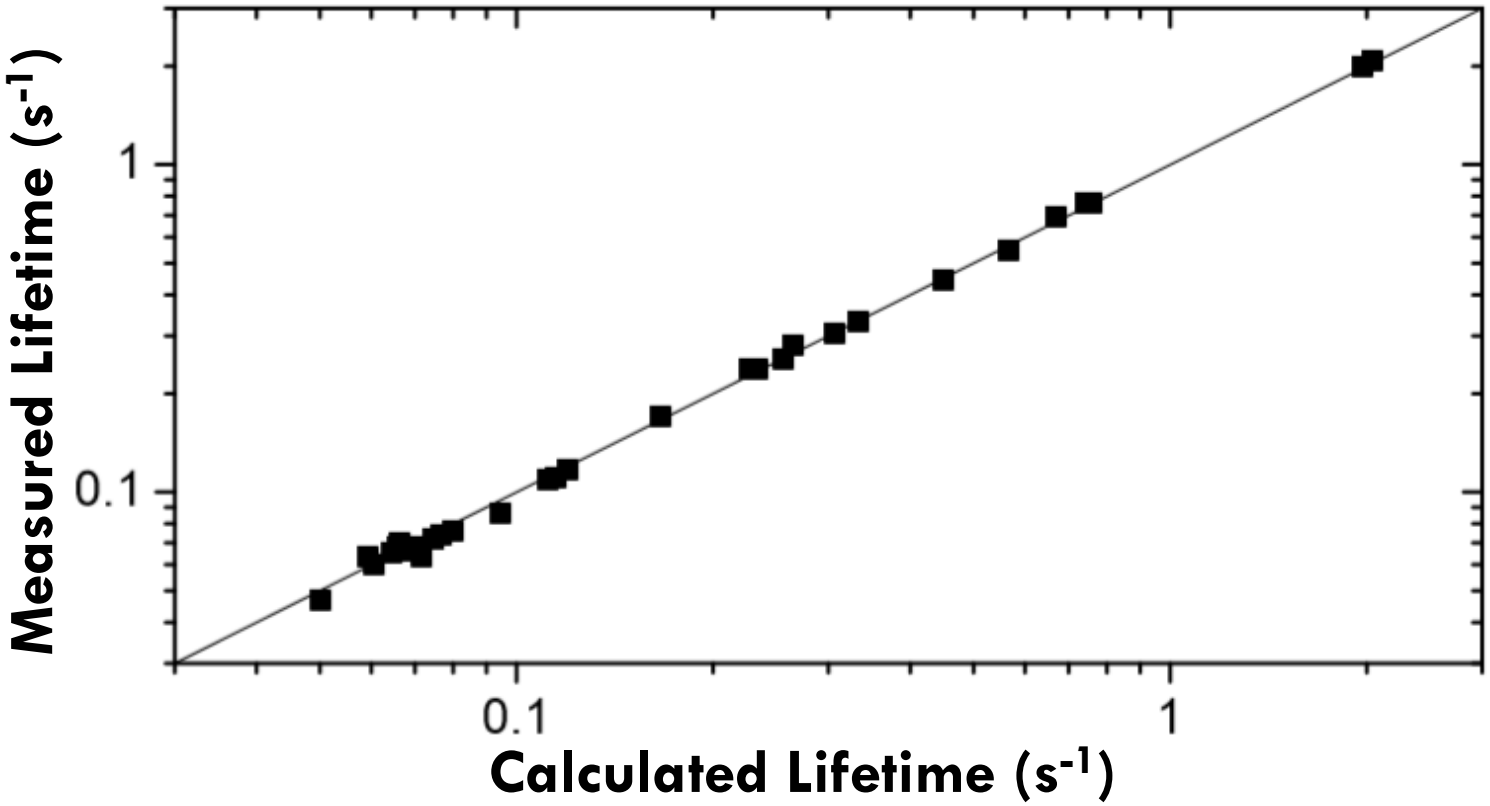
| Species | Van der Waals coef. (a.u.) | $\gamma_i/P$ (x $10^7$ $Torr^{-1}$ $s^{-1}$) |
|---|---|---|
| Hydrogen | 137 | 4.9 |
| Helium | 35 | 2.5 |
| Water | 241 | 2.8 |
| Nitrogen | 302 | 2.6 |
| Argon | 278 | 2.3 |
| $CO_2$ | 482 | 2.6 |
| Rb | 4400 | 4.4 |

**Different Trapped species**

| Species | Van der Waals coef. ($H_2$ bg) (a.u.) | $\gamma_i/P$ (x $10^7$ $Torr^{-1}$ $s^{-1}$) |
|---|---|---|
| Lithium | 82.5 | 6.4 |
| Sodium | 91 | 5.3 |
| Potassium | 130 | 5.4 |
| Rubidium | 140 | 4.9 |
| Cesium | 170 | 4.9 |

Arpornthip, T., C.A. Sackett, and K.J. Hughes, 2012, "Vacuum pressure measurement using a magneto-optical trap," Physical Review A 85, 033420.

$$P = \frac{20\ nTorr \cdot s}{\tau}$$

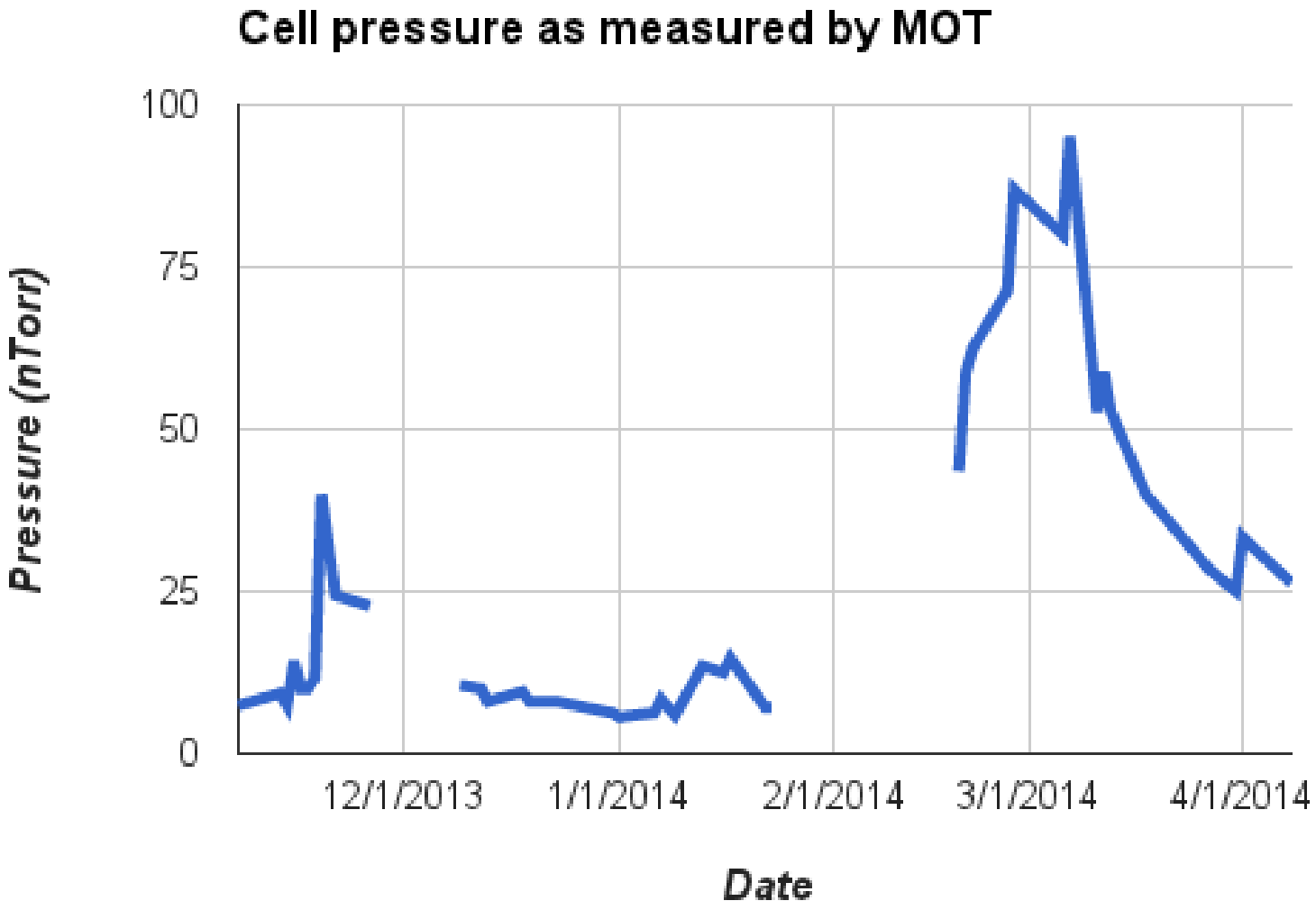



# Measurement accuracy of $P = (20\ nTorr \cdot s)/\tau$

"The way we perceive accuracy and what accuracy statistically is, are two different things."

Nate Silver

Arpornthip, T., C.A. Sackett, and K.J. Hughes, 2012, "Vacuum pressure measurement using a magneto-optical trap," Physical Review A 85, 033420.

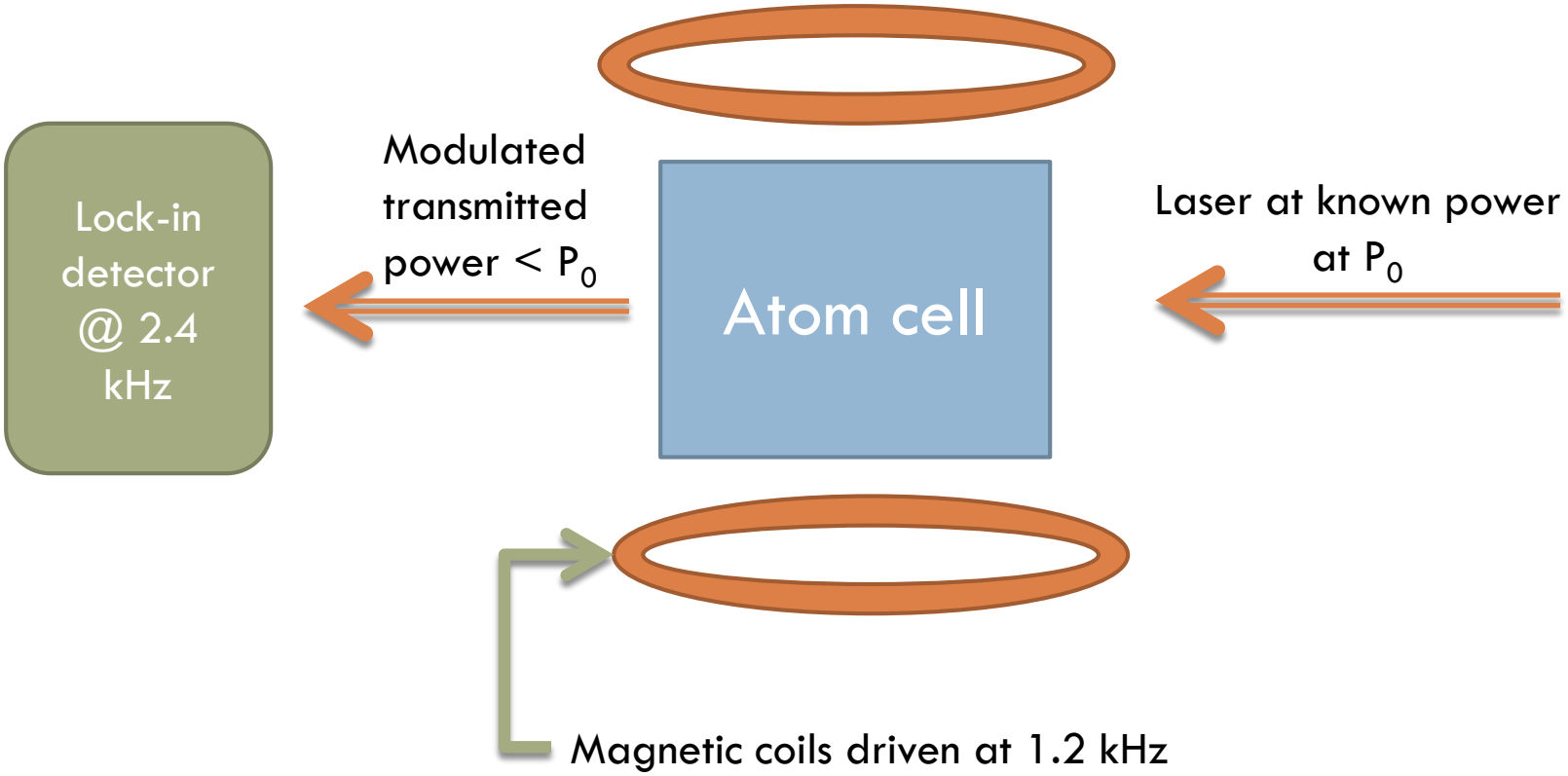

Cell pressure as measured by MOT
100
75
50
25
0
Pressure (nTorr)
12/1/2013
1/1/2014
2/1/2014
3/1/2014
4/1/2014
Date

# 5. Control the amount of Rb

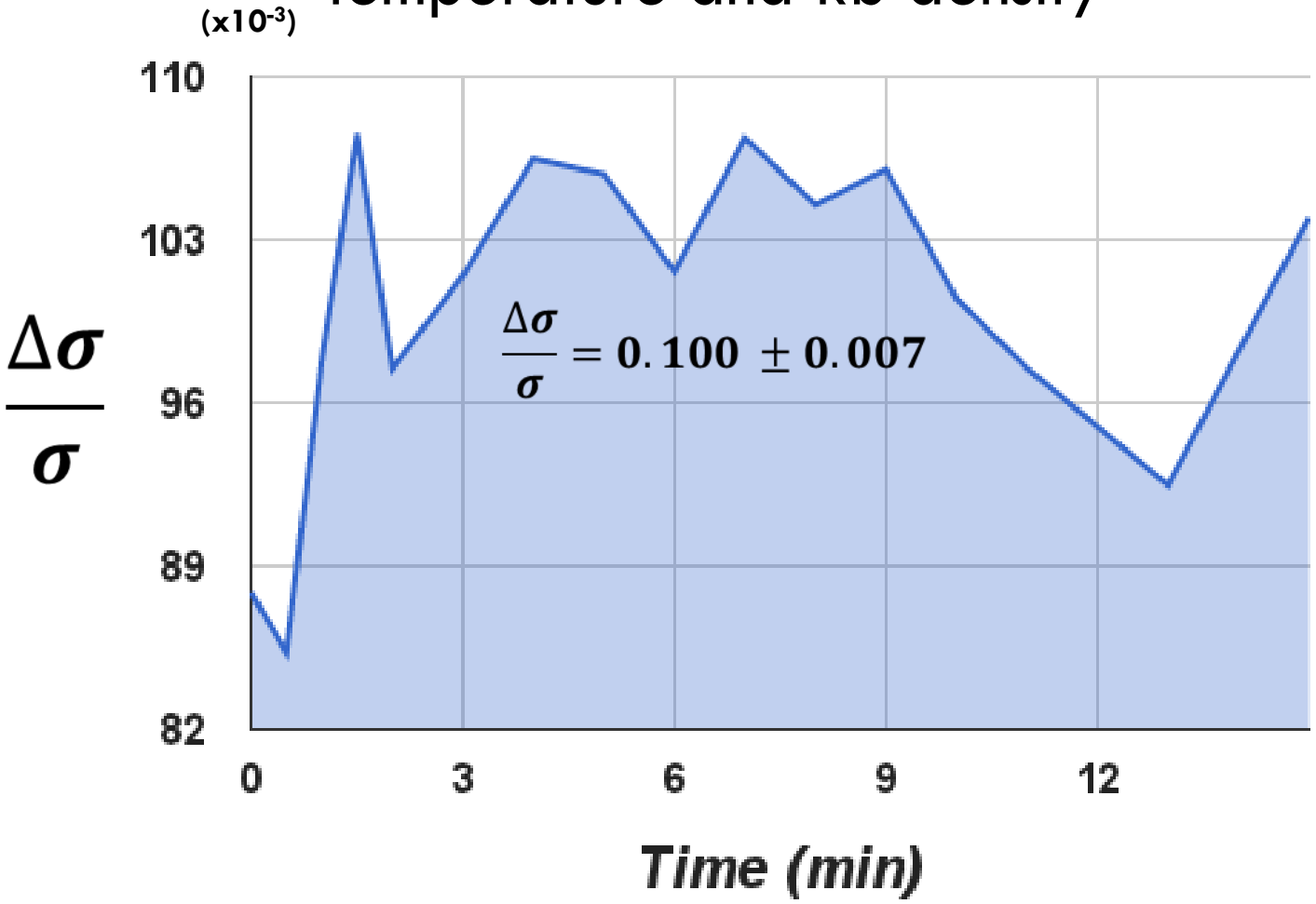
# Cell development questions

- Typical atom cells need atom supplies
- Means more power supplies, more wires
- If we can get just the right amount of atoms in the cell, no more power supplies
- Cell wall highly adsorbent to Rb
- Know the amount of Rb we want in the cell
- But how much do we need on the cell surface?
- What about in the NEG? How much surface area is in the NEG?

# Rb detection method

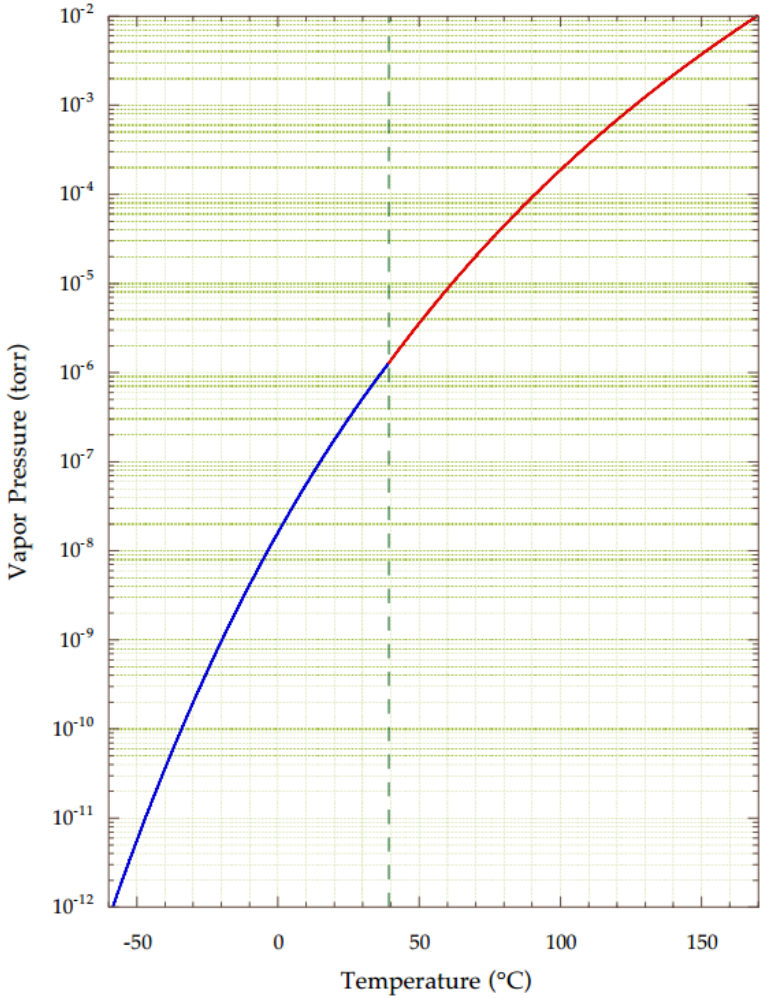


# Detection method works over a wide range of temperature and Rb density




Time change = Temperature change (3 °F → 72 °F)

# Rb bulk pressure at various temperature

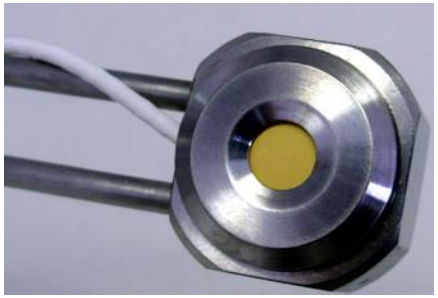



Steck, "Rubidium 87 D Line Data," Version 2.1.4, Theoretical Division (T-8), LANL, 2001

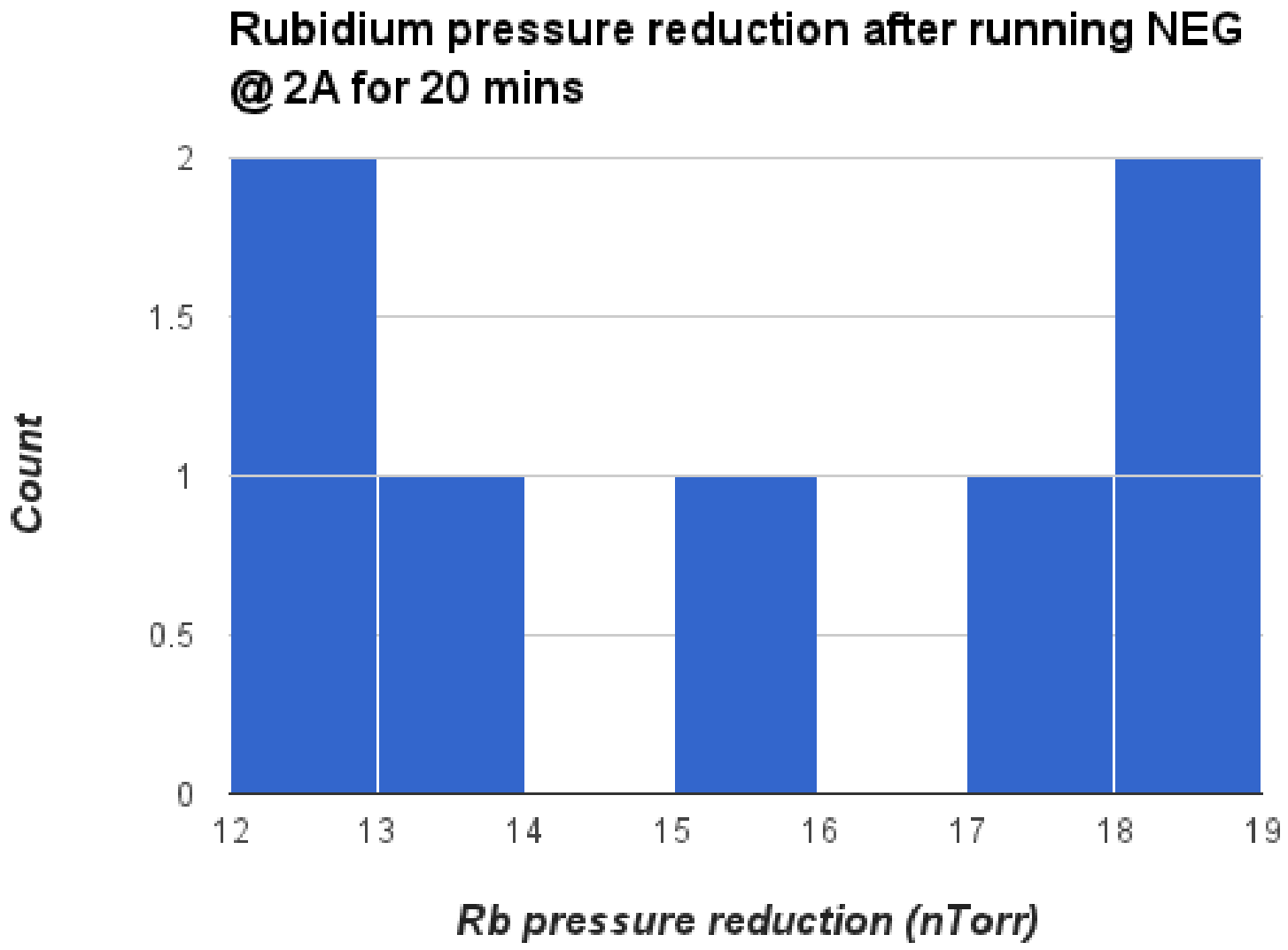
What if we just cover the cell partially?

# Rubidium level control

- Increasing
  - Rb dispenser
  - Dispensing rate
  - Trial and error initially
  - An effort in absorption measurement
  - Quartz thickness monitor in the work



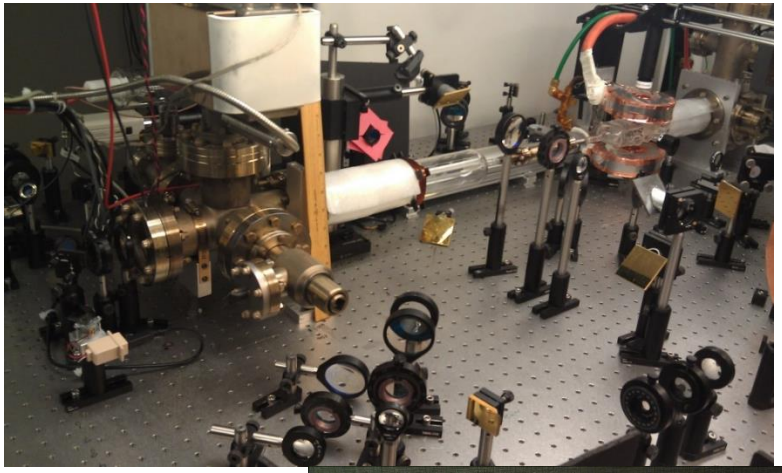
- Decreasing
  - Rb absorption by the NEG
  - Decreasing Rb possible
  - Full mechanics to be understood

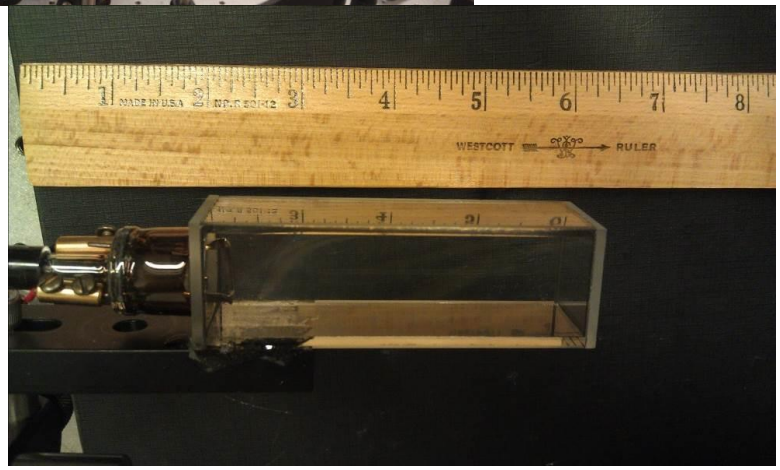

Rubidium pressure reduction after running NEG @ 2A for 20 mins
Count
2
1.5
1
0.5
0
12
13
14
15
16
17
18
19
Rb pressure reduction (nTorr)

# Conclusion

# A vapor cell suitable for cold atom applications

- Future work
- Measure Rb dispensing rate precisely
- Study Rb dispenser evolution
- Calibrate Rb pressure to deposition layers
- Complete control of the system!





# Acknowledgements


- Prof. Cass Sackett
- Labmates: Bob, Rob, Eun, Adam
- Prof. Gallagher and Hyunwook Park
- Triad Technology Inc.




# Question?

Comments? Concerns?