MAGIS-100 Laser Transport Vacuum Simulations and LED Atom Tracker

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Mentors: Linda Valerio, Jesse Batko, Beth Klein

Intern Poster Session

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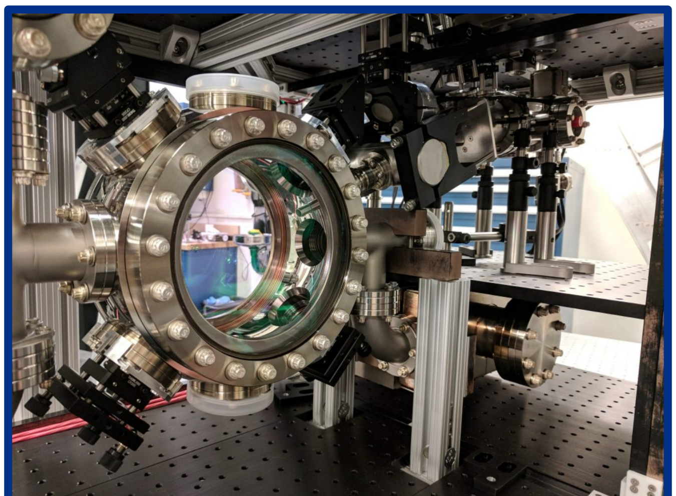
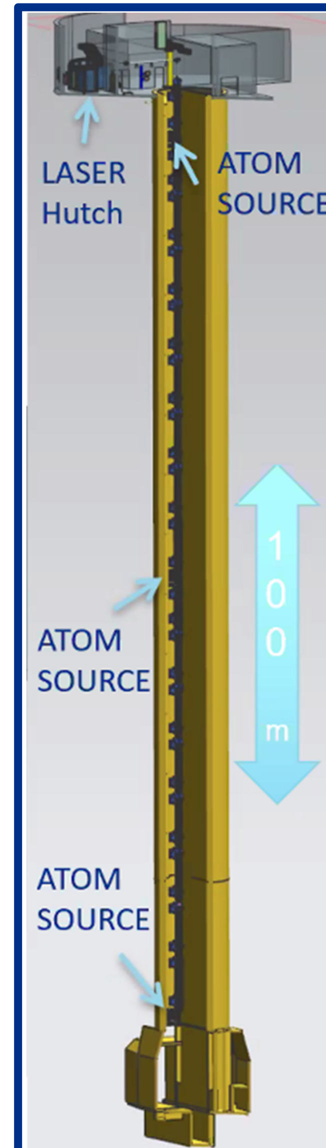
Background

- Matter-wave Atomic Gradiometer Interferometric Sensor
  - – Dark matter and new forces
  - – Advancing quantum science
  - – Gravitational wave detector development
- Atom interferometry



Atom Source Photo: Stanford University

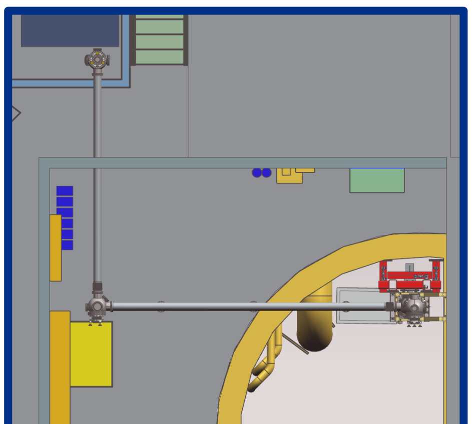


100m shaft Sr atoms will traverse

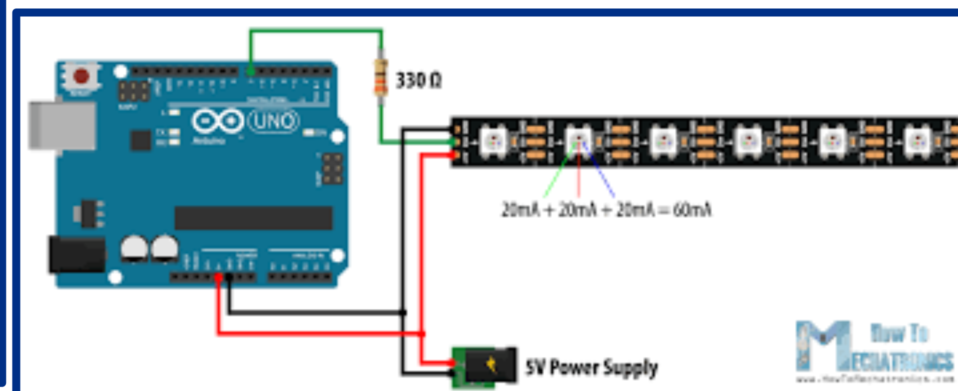
My Projects

- Vacuum Simulations for the Laser Transport System (LTS)
  - Compare low conductance designs of lens mounts
  - Characterize pressure profile of the LTS
- LED Atom Tracker
  - Propose materials to implement in the project
  - Design software for the different science modes

Ion Pump Photo: Ideal Vacuum Products



Laser Transport System



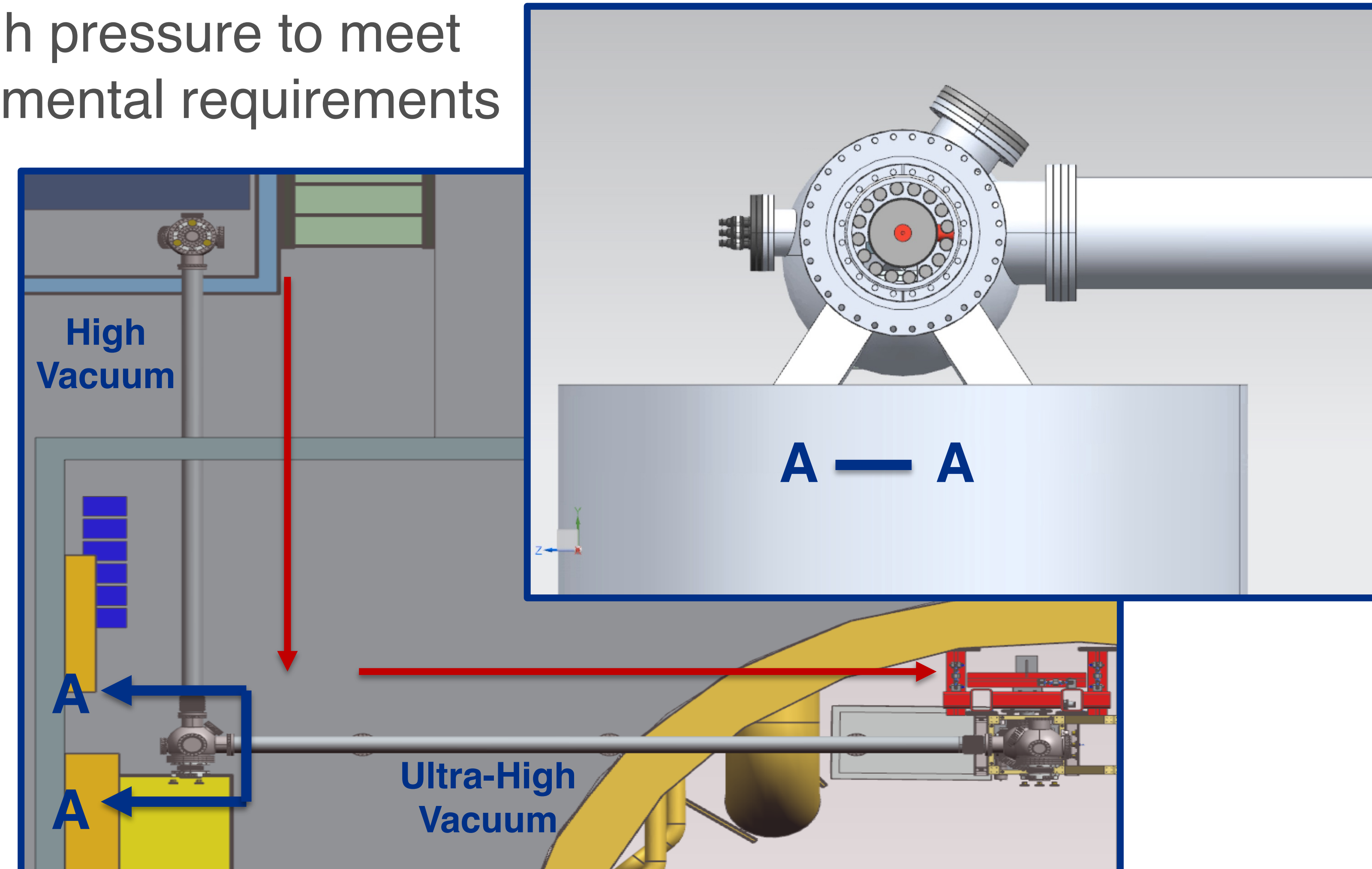
Arduino Uno and LED strip simulation Photo: How To Mechatronics

Vacuum Simulations for the Laser Transport System (LTS)-Purpose

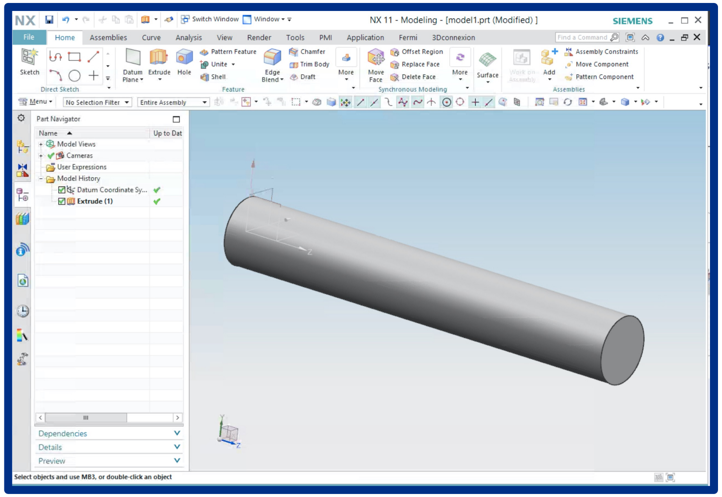
- Ensure vacuum system has low enough pressure to meet experimental requirements

Inside look at the LTS

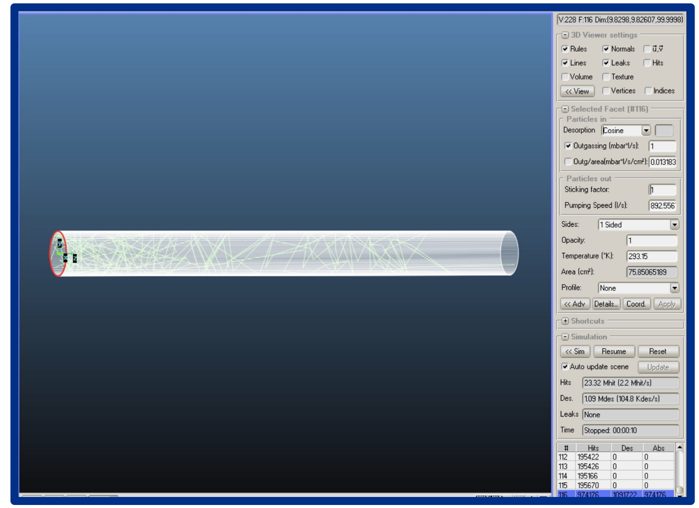
Laser goes through the LTS to the top of the shaft



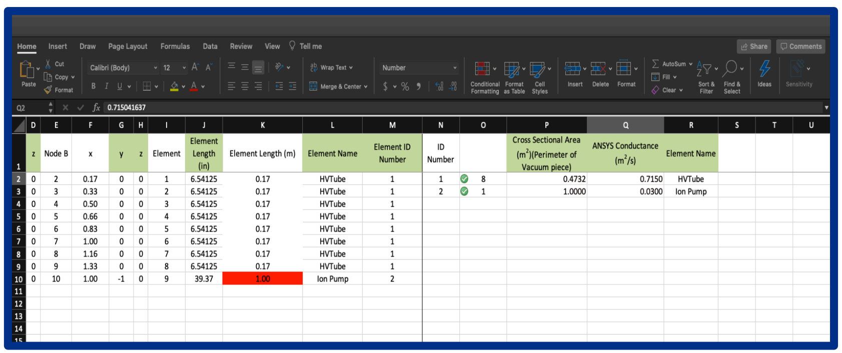
Vacuum Simulations for the Laser Transport System (LTS)-Procedure



1. Create vacuum tube in NX

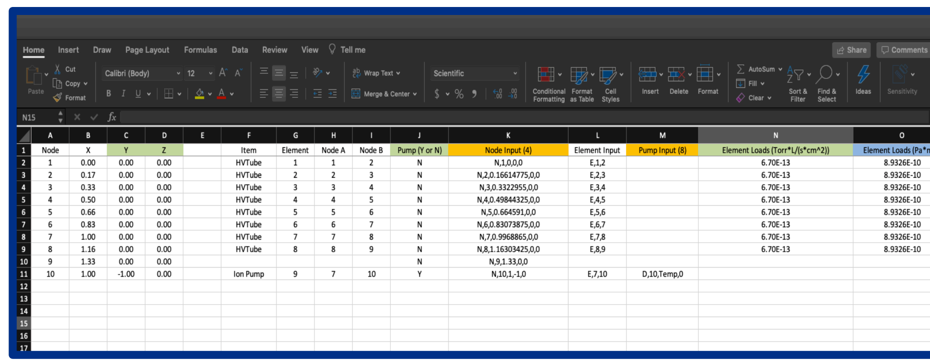


2. Find conductance in Molflow



	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	z	Node B	x	y	z	Element	Element Length (in)	Element Length (m)	Element Name	Element ID Number	ID Number		Cross Sectional Area (m^2)(Perimeter of Vacuum piece)	ANSYS Conductance (m^2/s)	Element Name
2	0	2	0.17	0	0	1	6.54125	0.17	HVTube	1	1	8	0.4732	0.7150	HVTube
3	0	3	0.33	0	0	2	6.54125	0.17	HVTube	1	2	1	1.0000	0.0300	Ion Pump
4	0	4	0.50	0	0	3	6.54125	0.17	HVTube	1					
5	0	5	0.66	0	0	4	6.54125	0.17	HVTube	1					
6	0	6	0.83	0	0	5	6.54125	0.17	HVTube	1					
7	0	7	1.00	0	0	6	6.54125	0.17	HVTube	1					
8	0	8	1.16	0	0	7	6.54125	0.17	HVTube	1					
9	0	9	1.33	0	0	8	6.54125	0.17	HVTube	1					
10	0	10	1.00	-1	0	9	39.37	1.00	Ion Pump	2					

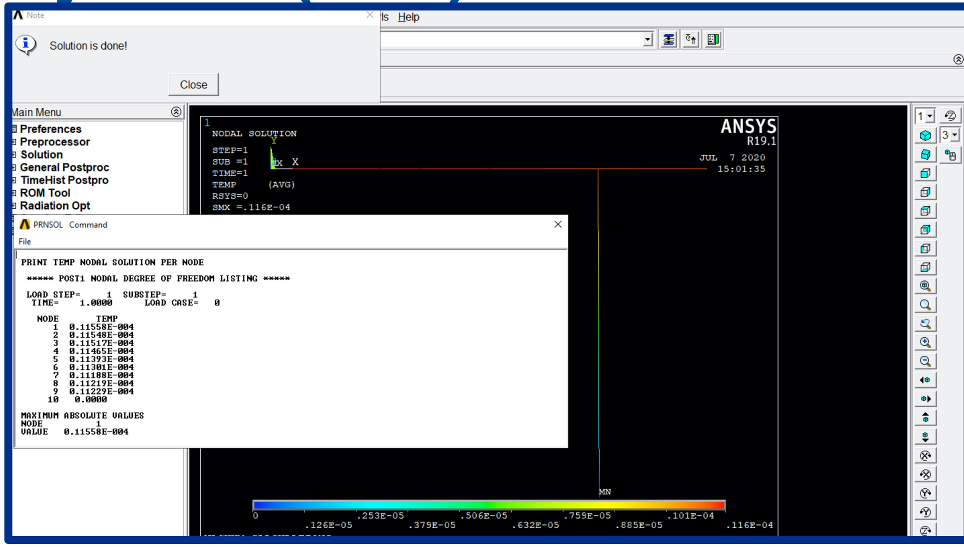
3. Complete spreadsheet with nodes and conductance data, spreadsheet format courtesy of Jesse Batko, Fermilab

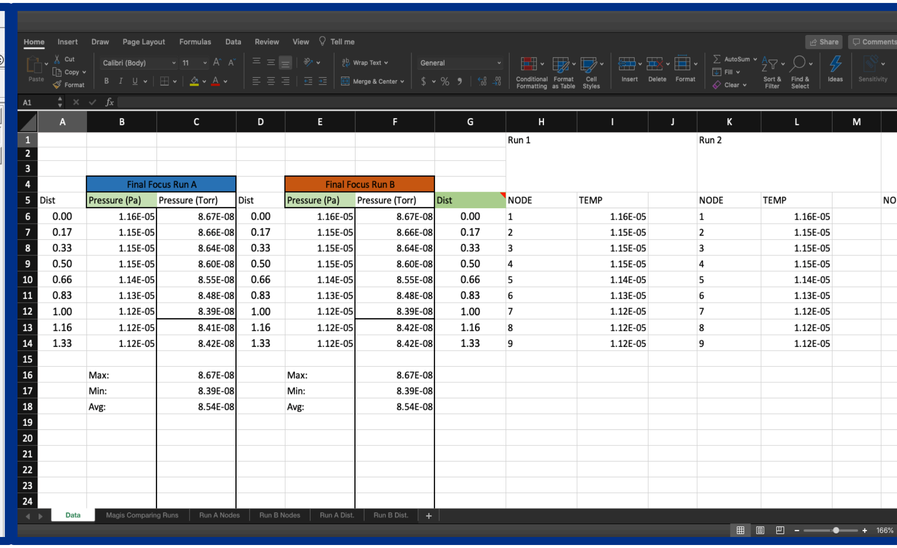


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Node	X	Y	Z		Item	Element	Node A	Node B	Pump (Y or N)	Node Input (4)	Element Input	Pump Input (8)	Element Loads (Torr*L/(s*cm^2))	Element Loads (Pa*m/s
2	1	0.00	0.00	0.00		HVTube	1	1	2	N	N,1,0,0,0	E,1,2		6.70E-13	8.9326E-10
3	2	0.17	0.00	0.00		HVTube	2	2	3	N	N,2,0.16614775,0,0	E,2,3		6.70E-13	8.9326E-10
4	3	0.33	0.00	0.00		HVTube	3	3	4	N	N,3,0.3322955,0,0	E,3,4		6.70E-13	8.9326E-10
5	4	0.50	0.00	0.00		HVTube	4	4	5	N	N,4,0.49844325,0,0	E,4,5		6.70E-13	8.9326E-10
6	5	0.66	0.00	0.00		HVTube	5	5	6	N	N,5,0.664591,0,0	E,5,6		6.70E-13	8.9326E-10
7	6	0.83	0.00	0.00		HVTube	6	6	7	N	N,6,0.83073875,0,0	E,6,7		6.70E-13	8.9326E-10
8	7	1.00	0.00	0.00		HVTube	7	7	8	N	N,7,0.9968865,0,0	E,7,8		6.70E-13	8.9326E-10
9	8	1.16	0.00	0.00		HVTube	8	8	9	N	N,8,1.16303425,0,0	E,8,9		6.70E-13	8.9326E-10
10	9	1.33	0.00	0.00						N	N,9,1.33,0,0				
11	10	1.00	-1.00	0.00		Ion Pump	9	7	10	Y	N,10,1,-1,0	E,7,10	D,10,Temp,0		

4. Convert vacuum units to thermal units and generate code

Vacuum Simulations for the Laser Transport System (LTS)-Procedure



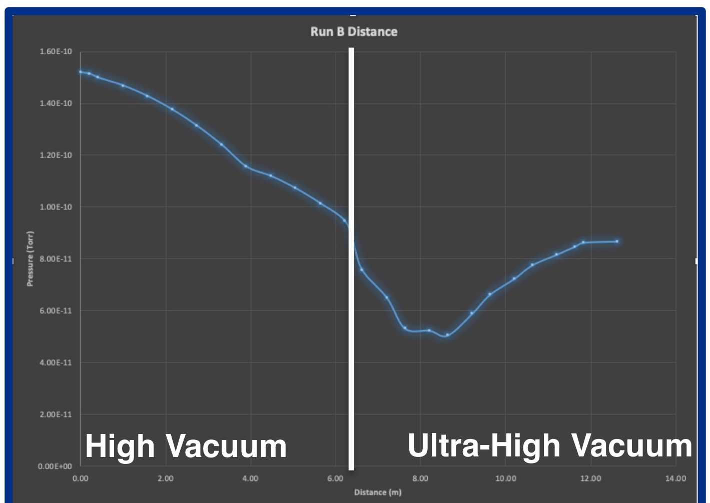


	Final Focus Run A			Final Focus Run B			Run 1		Run 2	
Dist	Pressure (Pa)	Pressure (Torr)	Dist	Pressure (Pa)	Pressure (Torr)	Dist	NODE	TEMP	NODE	TEMP
0.00	1.16E-05	8.67E-08	0.00	1.16E-05	8.67E-08	0.00	1	1.16E-05	1	1.16E-05
0.17	1.15E-05	8.66E-08	0.17	1.15E-05	8.66E-08	0.17	2	1.15E-05	2	1.15E-05
0.33	1.15E-05	8.64E-08	0.33	1.15E-05	8.64E-08	0.33	3	1.15E-05	3	1.15E-05
0.50	1.15E-05	8.60E-08	0.50	1.15E-05	8.60E-08	0.50	4	1.15E-05	4	1.15E-05
0.66	1.14E-05	8.55E-08	0.66	1.14E-05	8.55E-08	0.66	5	1.14E-05	5	1.14E-05
0.83	1.13E-05	8.48E-08	0.83	1.13E-05	8.48E-08	0.83	6	1.13E-05	6	1.13E-05
1.00	1.12E-05	8.39E-08	1.00	1.12E-05	8.39E-08	1.00	7	1.12E-05	7	1.12E-05
1.16	1.12E-05	8.41E-08	1.16	1.12E-05	8.42E-08	1.16	8	1.12E-05	8	1.12E-05
1.33	1.12E-05	8.42E-08	1.33	1.12E-05	8.42E-08	1.33	9	1.12E-05	9	1.12E-05
	Max:	8.67E-08		Max:	8.67E-08					
	Min:	8.39E-08		Min:	8.39E-08					
	Avg:	8.54E-08		Avg:	8.54E-08					

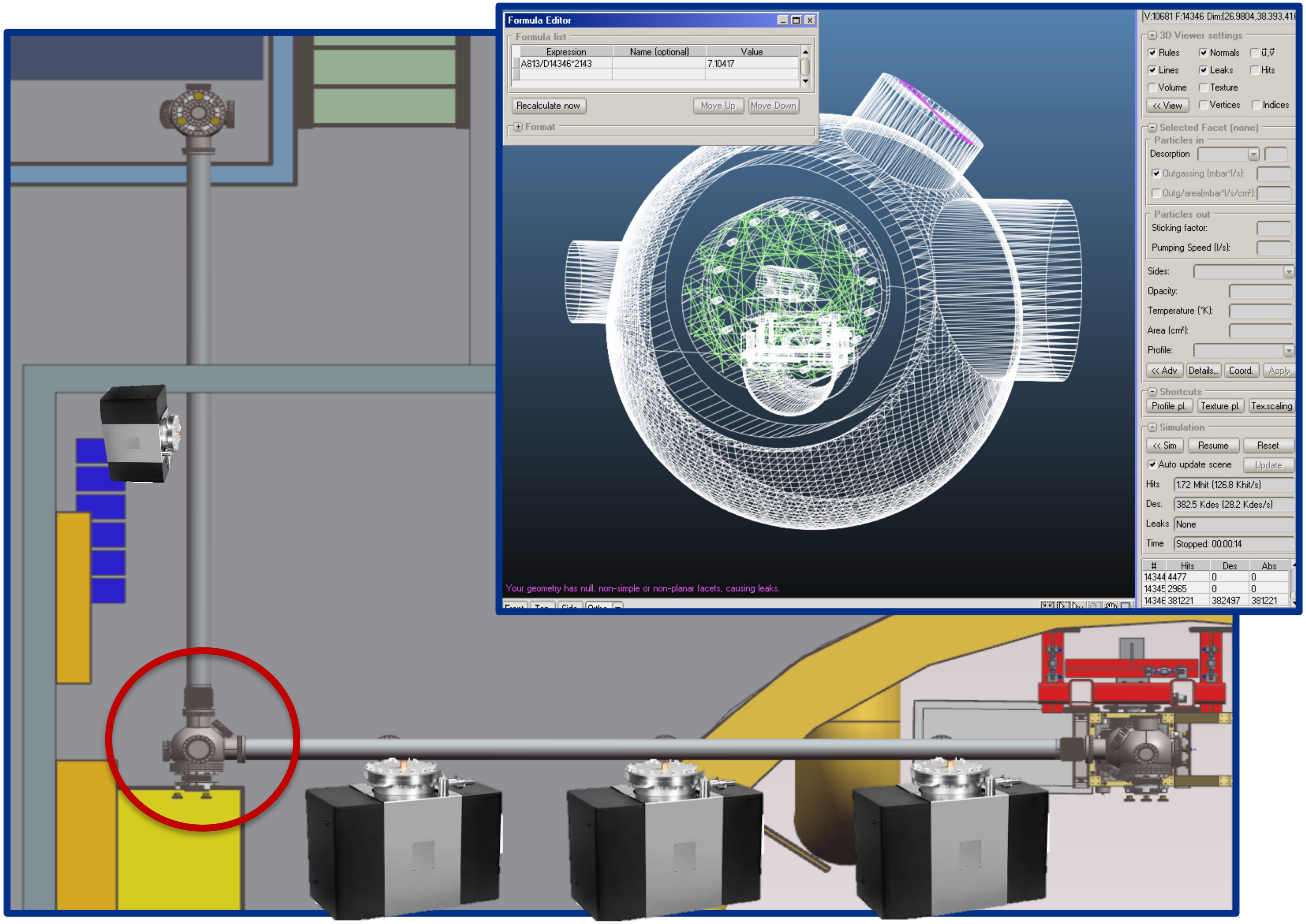
5. Run thermal simulation in ANSYS

6. Convert data back to vacuum

7. Plot pressure distribution



Vacuum Simulations for the Laser Transport System (LTS)-Variables



Middle mirror box's orifice

Ion pump speed and placement

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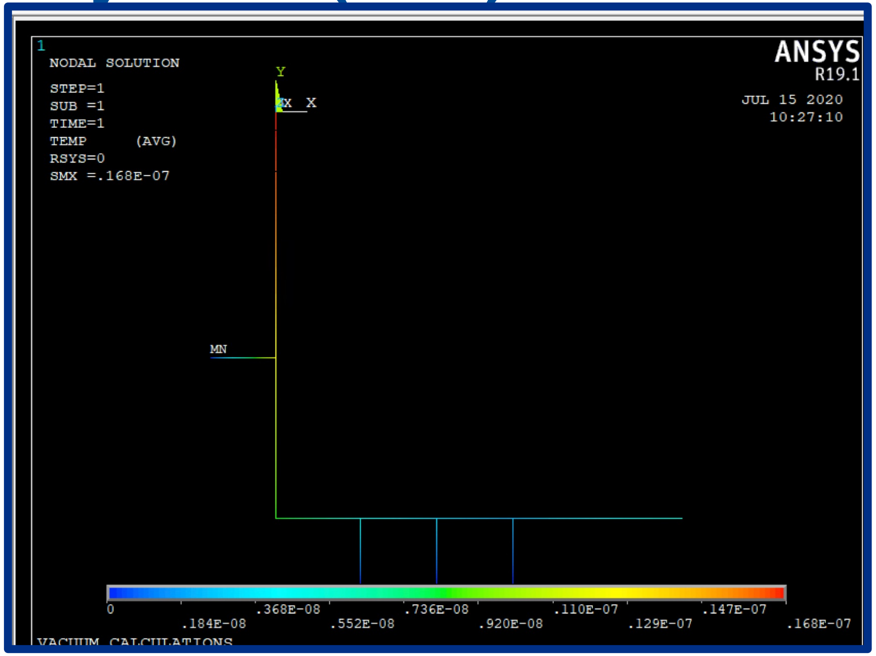
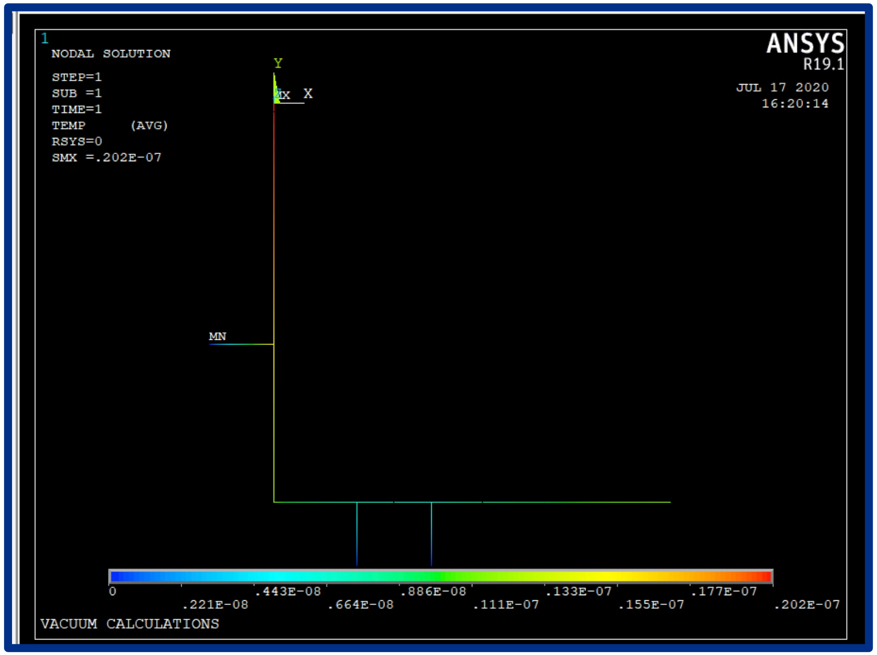
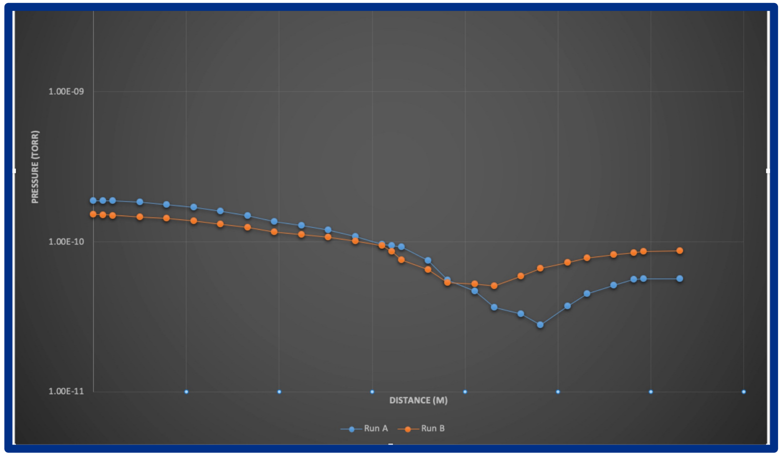
Vacuum Simulations for the Laser Transport System (LTS)-Results





Initial design:
4 ion pumps
0.8” orifice holes



Final design: adjusted orifice size to remove an ion pump

Final proposed design- meets experimental requirement at 8.67E-11 torr

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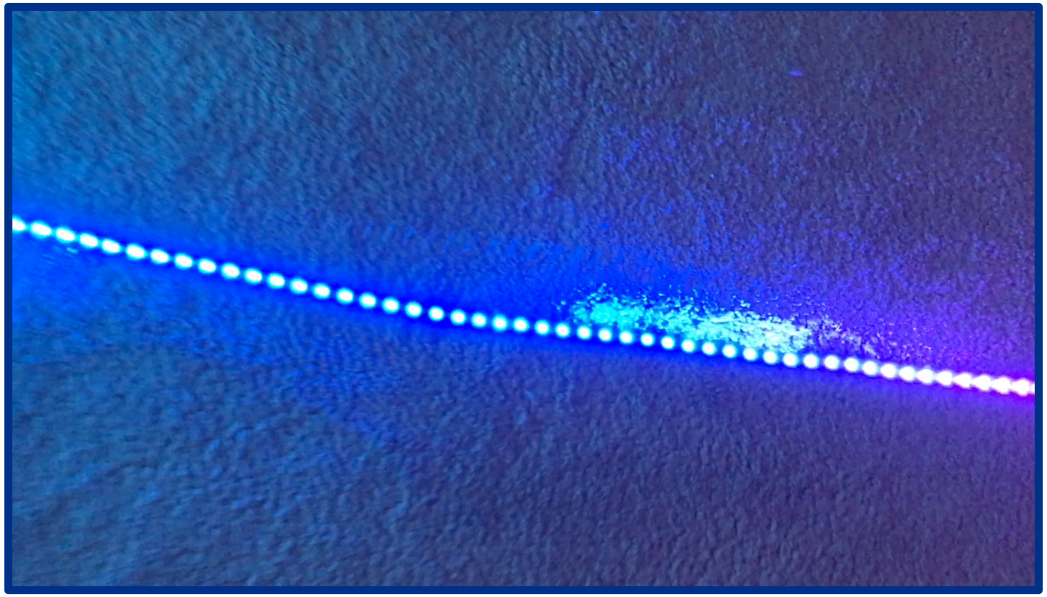
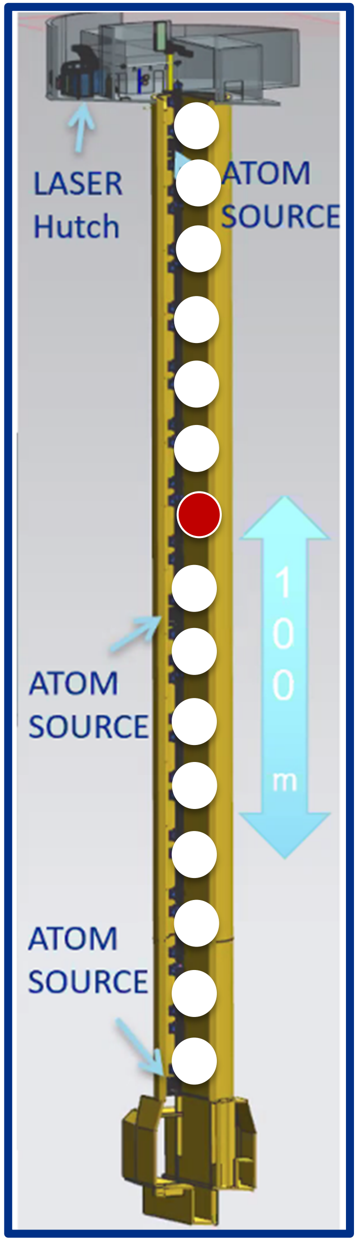
LED Atom Tracker-Purpose

- Allow spectators to see where the Sr atoms are while the experiment is running
- Public outreach

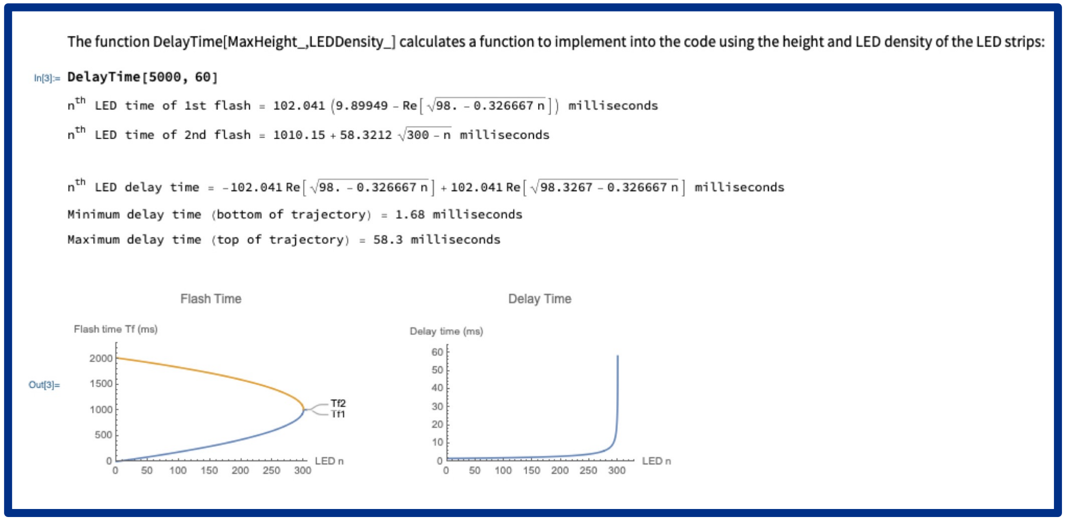


Programmable LEDs in action

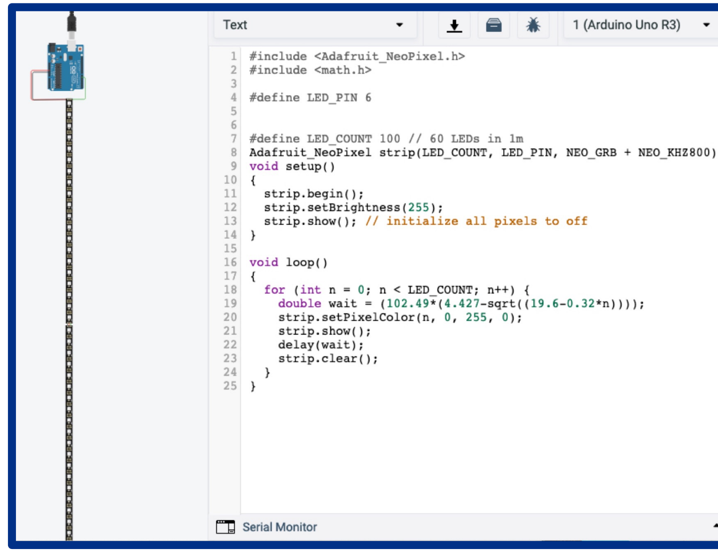
Where is the Sr?



LED Atom Tracker-Procedure



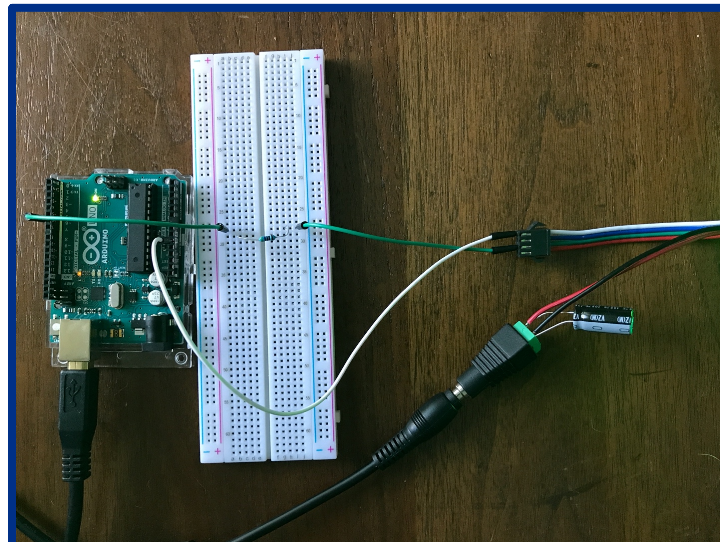
1. Calculate atoms’ trajectory, Mathematica Notebook courtesy of Sam Carman, Stanford



2. Design in TinkerCAD

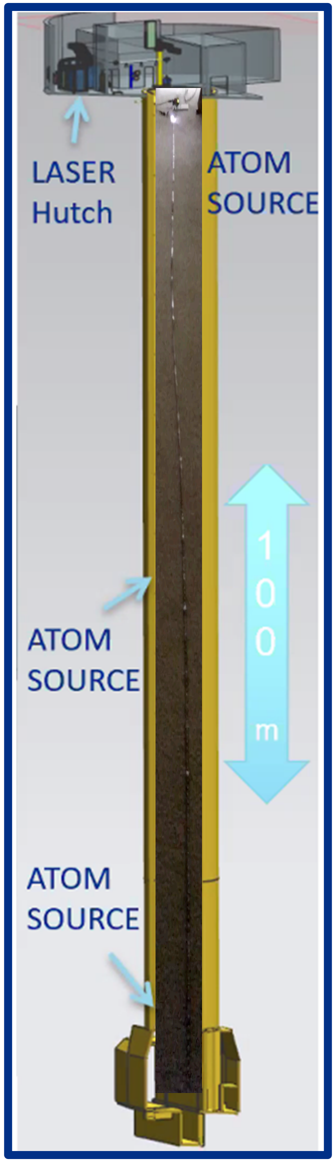
3. Create program in Arduino Integrated Development Environment (IDE)

4. Connect Arduino to LED strip



LED Atom Tracker- Procedure

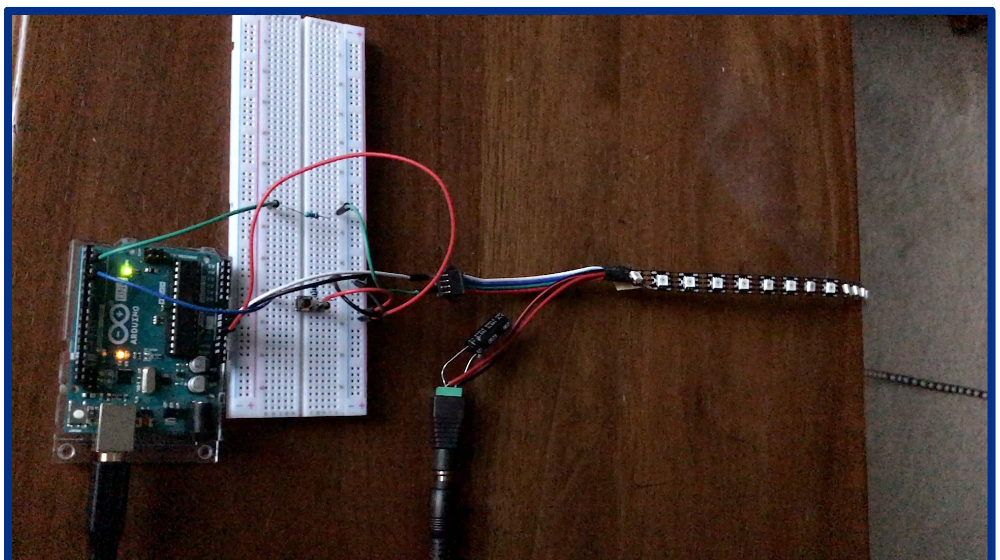
5. Run the Circuit



LED Atom Tracker- Results

- 5m segment complete
  - Software programs
  - Stable Connections
  - Start on button press
- Power requirements
- Recommendations on how to scale

Connection for power injection



Circuit starting
on button press

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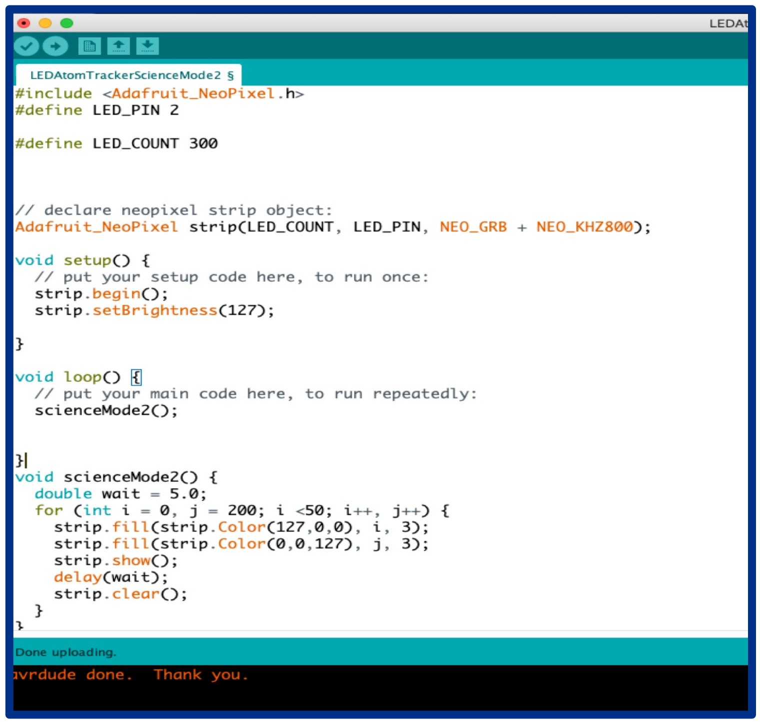
LED Atom Tracker- Future

- Scale up to 100m
  - Power injection
- Safety specifications
- Software for all science modes



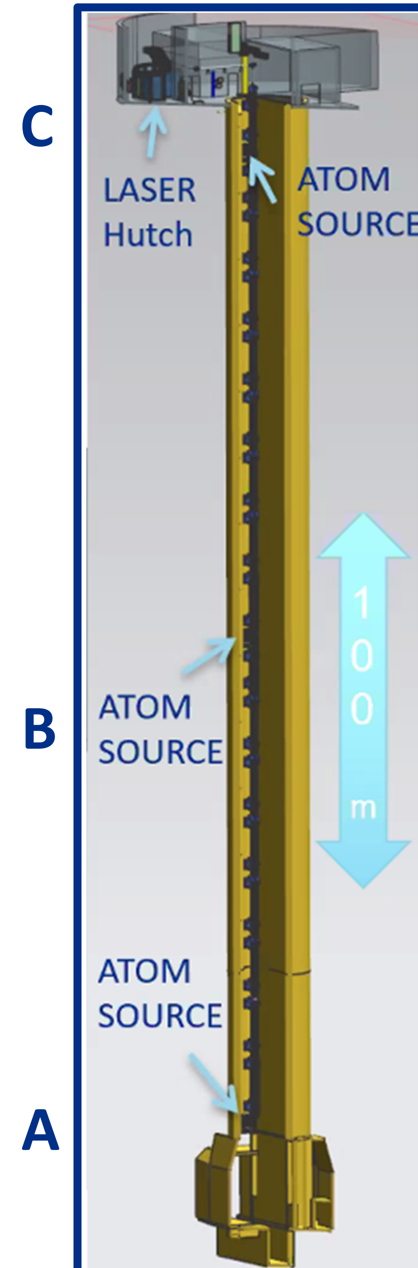
LEDAtomTrackerScienceMode2 §

```
#include <Adafruit_NeoPixel.h>
#define LED_PIN 2

#define LED_COUNT 300



// declare neopixel strip object:
Adafruit_NeoPixel strip(LED_COUNT, LED_PIN, NEO_GRB + NEO_KHZ800);

void setup() {
  // put your setup code here, to run once:
  strip.begin();
  strip.setBrightness(127);

}

void loop() {
  // put your main code here, to run repeatedly:
  scienceMode2();


}
void scienceMode2() {
  double wait = 5.0;
  for (int i = 0, j = 200; i <50; i++, j++) {
    strip.fill(strip.Color(127,0,0), i, 3);
    strip.fill(strip.Color(0,0,127), j, 3);
    strip.show();
    delay(wait);
    strip.clear();
  }
}
```

Done uploading.

avrdude done. Thank you.

Science mode 2 program



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