To Predict ▶ To Design ▶ To Perform

College of Engineering
Department of Mechanical & Industrial Engineering

ME, ECE, BE Capstone Design Programs

Electrostatic Levitator

Team #31: Justin Cotten, Matthew Guidry, David Jordan, and Jared McDuffey

LSU Louisiana State University | College of Engineering | Department of Mechanical & Industrial Engineering

Objective:

To design an electrostatic levitation device to stably levitate a small metal sphere within a vacuum chamber for the study of material properties.

Background:

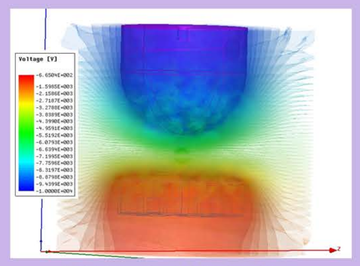
Governing Equations:

Laplace Equation in Cylindrical Coordinates:

$$\nabla^2 V = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right) + \frac{\partial^2 V}{\partial z^2} + \frac{1}{r^2}\frac{\partial^2 V}{\partial \theta^2} = 0$$

Laplace Equation in Spherical Coordinates:

$$\nabla^2 V = \frac{\partial^2 V}{\partial r^2} + \frac{2}{r}\frac{\partial V}{\partial r} + \frac{1}{r^2 \sin^2\theta}\frac{\partial V}{\partial \varphi} + \frac{cot\theta}{r^2}\frac{\partial V}{\partial \theta} = 0$$



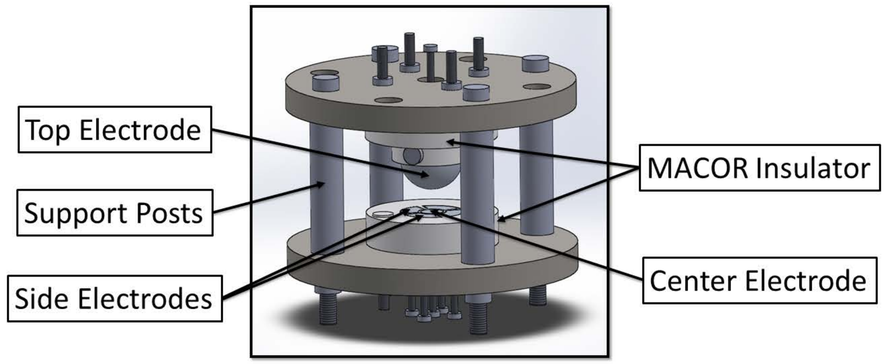
Voltage simulation based on design

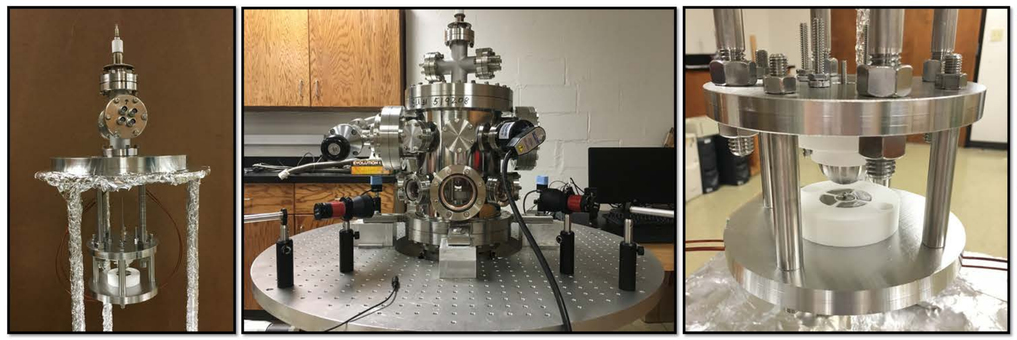
Engineering Specifications:

- Vacuum Pressure: 10^{-6} – 10^{-7} Torr
- Power Supply: 10kV Vertical, 3kV Horizontal
- ± 100µm Vertical Stability
- ± 45µm Horizontal Stability
- Chamber/Electrode Material: 304 Stainless Steel
- Insulating Material: MACOR
- Test Sphere Materials:
  - Aluminum, Nickel, Titanium
  - 1 – 4 mm diameter spheres

Safety:

- Meets IEEE Standards for High-Voltage lab setting
- Congruent with LSU Lab Testing Policies
- High-Voltage training necessary for operation
- Ultra-High Vacuum training necessary for operation



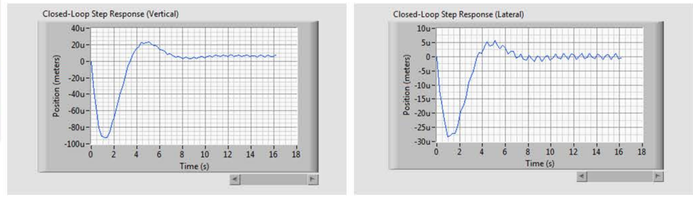


Testing:

- Vacuum Chamber Pressurization
  - Leak Testing
  - Pressurization via Turbo & Ion Pumps
- Positioning Equipment Calibration
- Control System
  - Computer Simulation
  - Oscilloscope Testing
  - Empirical Testing
- Full System Test – Sphere Levitation, Vertical/Horizontal control

Testing Results

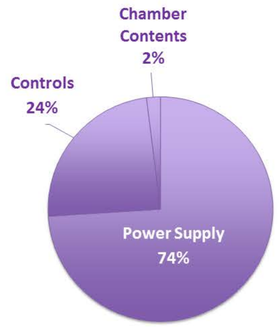
Chamber Pressure	1.50 x 10^{-5} Torr
Positioning Equipment Calibration	3V max output
Control System Simulations	Vertical: K_p=170, K_i=-6
	Lateral: K_p=15



Simulation results for vertical and lateral controls.

Budget

Chamber Contents	$971.07
Controls	$12,166.90
Power Supply	$37,100.00
TOTAL	$50,237.97



Conclusions & Recommendations:

- Fully functioning prototype designed and constructed
- Achieved PID constants with a sufficiently fast rise time with minimal noise, meeting Engineering Specifications of ±100µm, ±45µm for stability
- More full system testing necessary to refine control system

October	November	December	January	February	March	April	May
• Begin Concept Generation	• Begin Design • Complete Drawings, Simulations	• Complete Design Phase	• Order Materials/ Equipment	• Begin Construction • Complete Ordering	• Continue Construction • Begin Testing	• Complete Construction • Complete Sub-system Testing	• Functioning Prototype • Continue Full System Tests

Sponsors: Wenjin Meng, Dimitris Nikitopoulos, and Phil Sprunger **Advisor: Dorel Moldovan**