SCHOOL OF ENGINEERING

Increasing Bandwidth of Kinetic Meso-Scale Energy Harvesters using Parachute-Based Proof Mass

Material Testing and Evaluation

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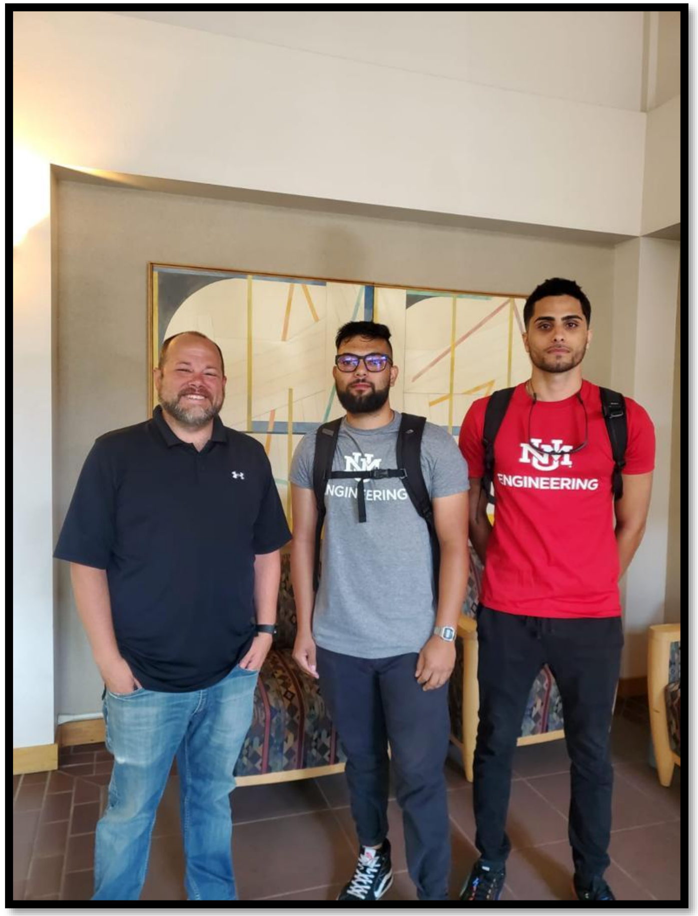
Collaboration: Gregory J. Vega

CHRES CONSORTIUM OF HYBRID RESILIENT ENERGY SYSTEMS

DE-NA0003982

About Me



Academic:

- Electrical Engineering undergraduate at UAGM
- Senior Status currently starting 5th year
- First internship experience

Hobbies:

- Surfing
- Building circuits (small projects) at home
- Reading books

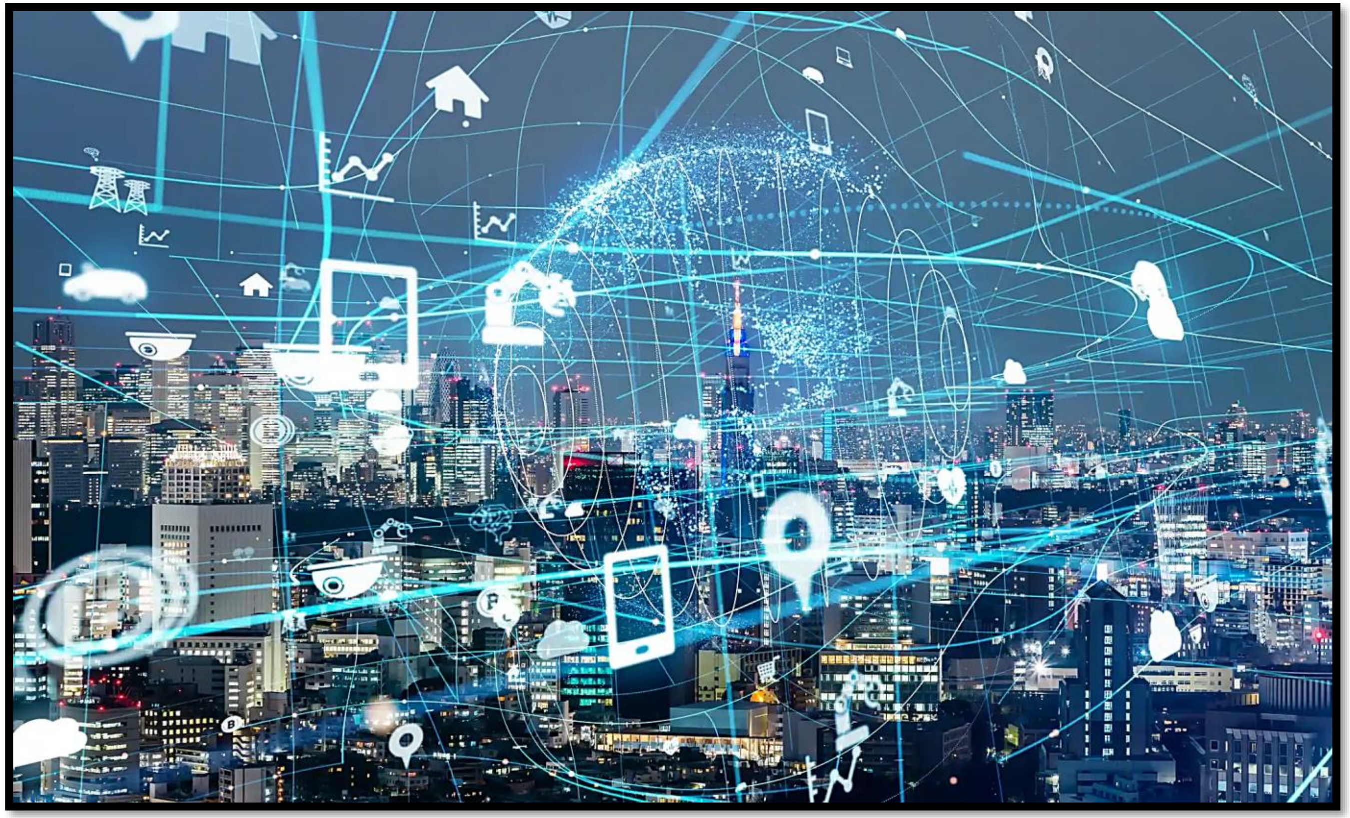
Abstract:

Our research focused on working with a macro scale piezoelectric energy harvesting device that converts mechanical energy in the form of vibrations to electrical energy. Normally, these devices suffer from a very limited bandwidth that ranges from 1-3 Hz. This limits their applications drastically. Consequently, a parachute-based proof mass was developed with the intention to increase its bandwidth. Different materials and parachute sizes were tested through a variety of frequencies and accelerations.

Objective:

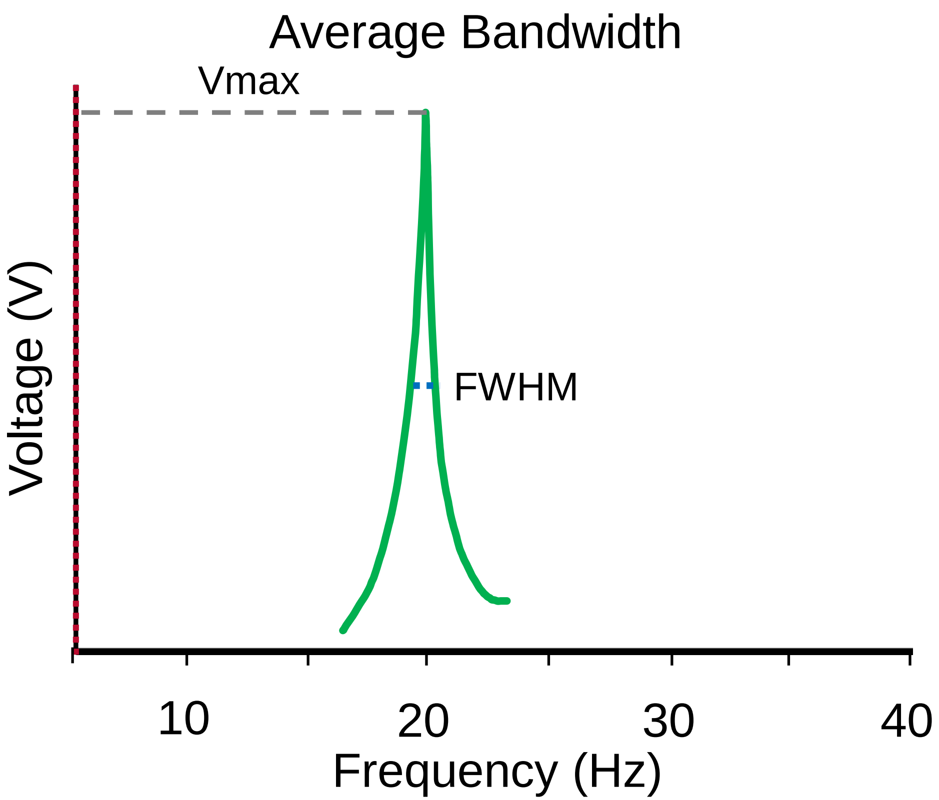
This research intends to find an optimal material, shape, and size for the parachute attached to the proof mass in order to increase the bandwidth of the piezoelectric energy harvesting device.

Why Micro-Energy Harvesting

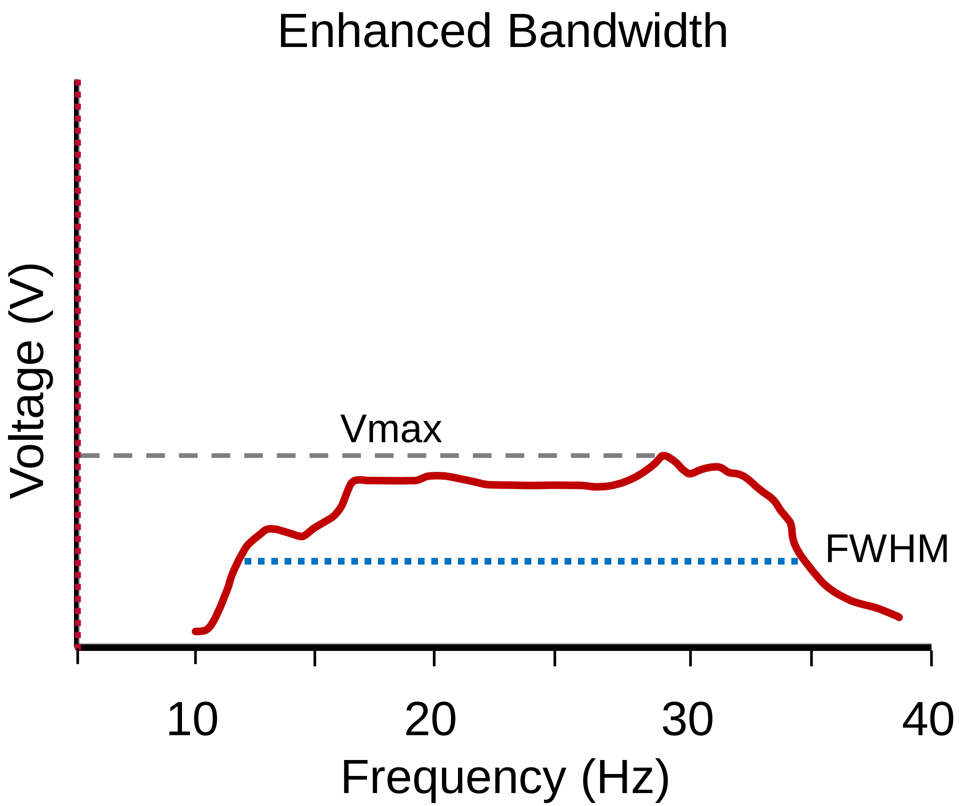


- Harness energy from the environment
- Self-sustaining wireless sensor networks (IoT)
- Superior operating lifetime

Benefits of Increasing Bandwidth



Graph 1: Average bandwidth example frequency vs voltage



Graph 2: Enhanced bandwidth example frequency vs voltage

Initial Testing

- 1mm, 5mm, and 10mm thickness
- 1.42mm parylene parachute
- Tested across 0.1, 0.2, and 0.3 g's of acceleration

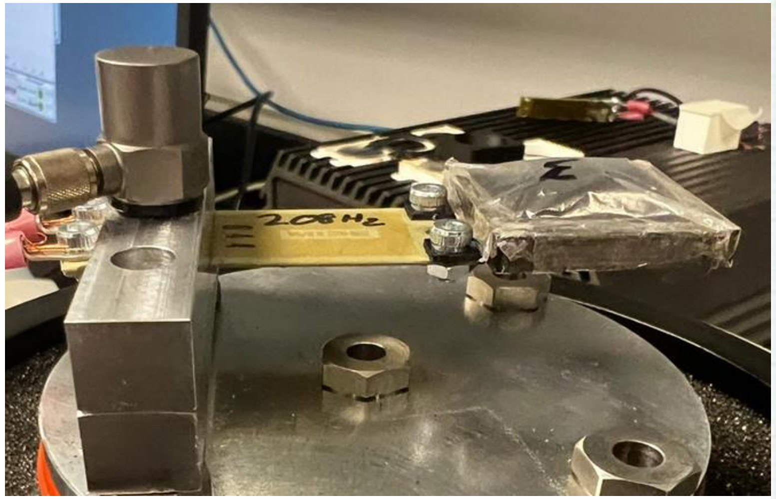
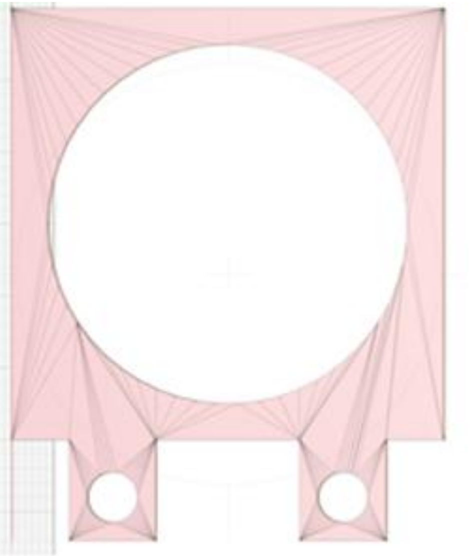
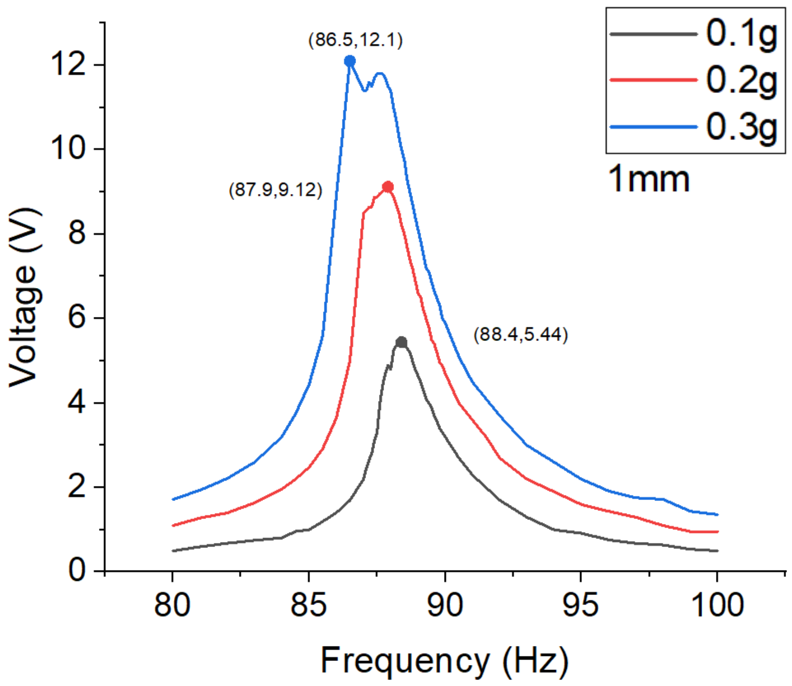


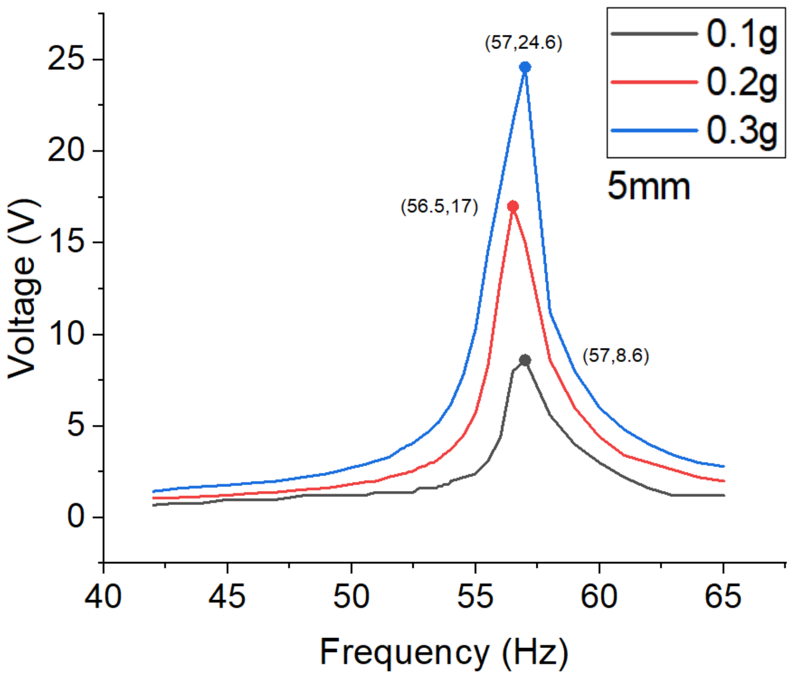
Figure 1 : Initial Proof Mass by Dr. Nathan Jackson



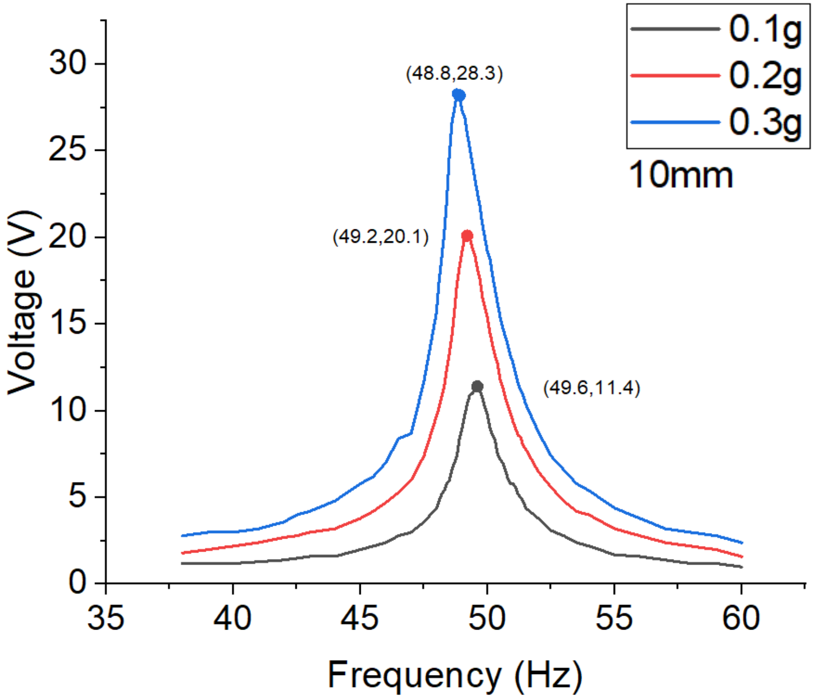
Initial Testing



Graph 3: Initial Proof Mass 1mm voltage vs frequency

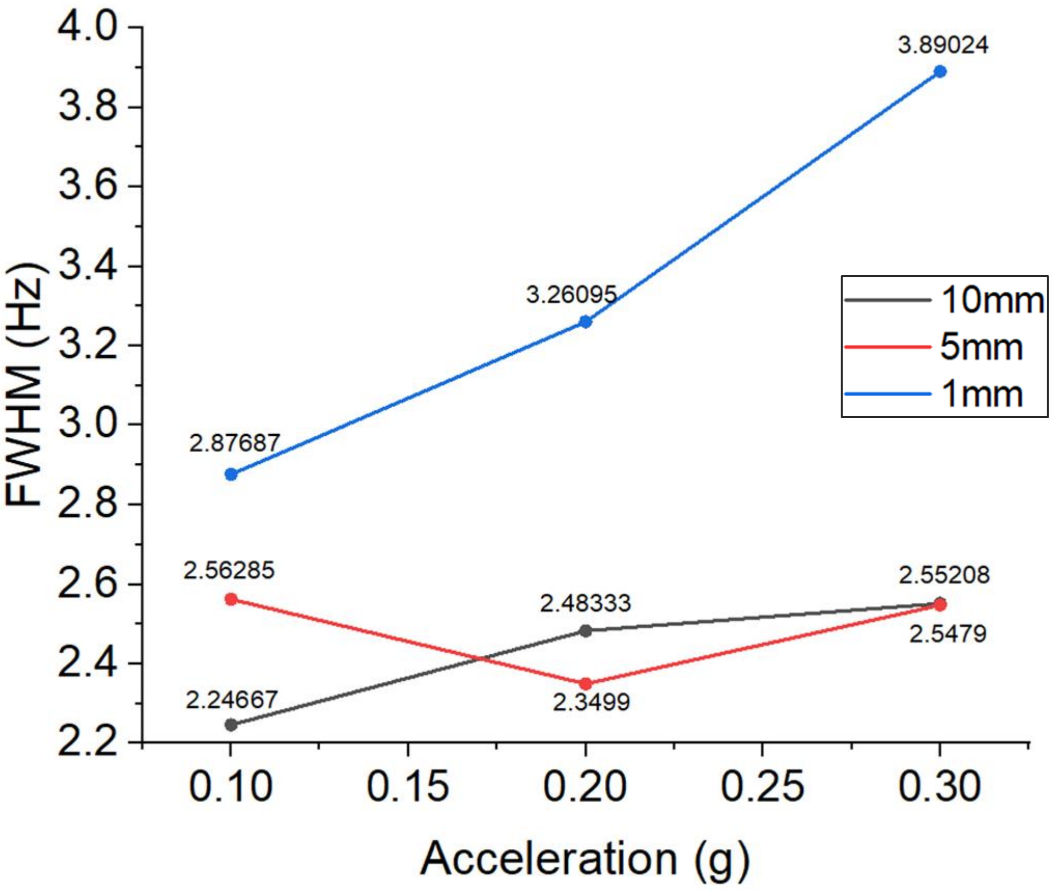


Graph 4: Initial Proof Mass 5mm voltage vs frequency



Graph 5: Initial Proof Mass 10mm voltage vs frequency

Initial Testing Results



Graph 6: Initial Proof Mass acceleration vs FWHM

- Low displacement
- Difficulty attaching material
- Material limitation

Material Testing

- Parylene
- Party balloon latex
- Nitrile
- Plastic Grocery Bag
- Natural rubber latex

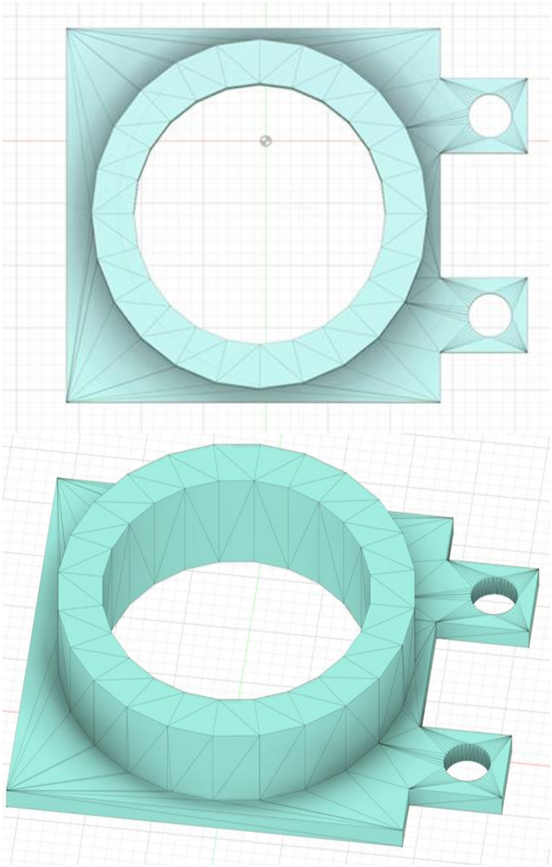
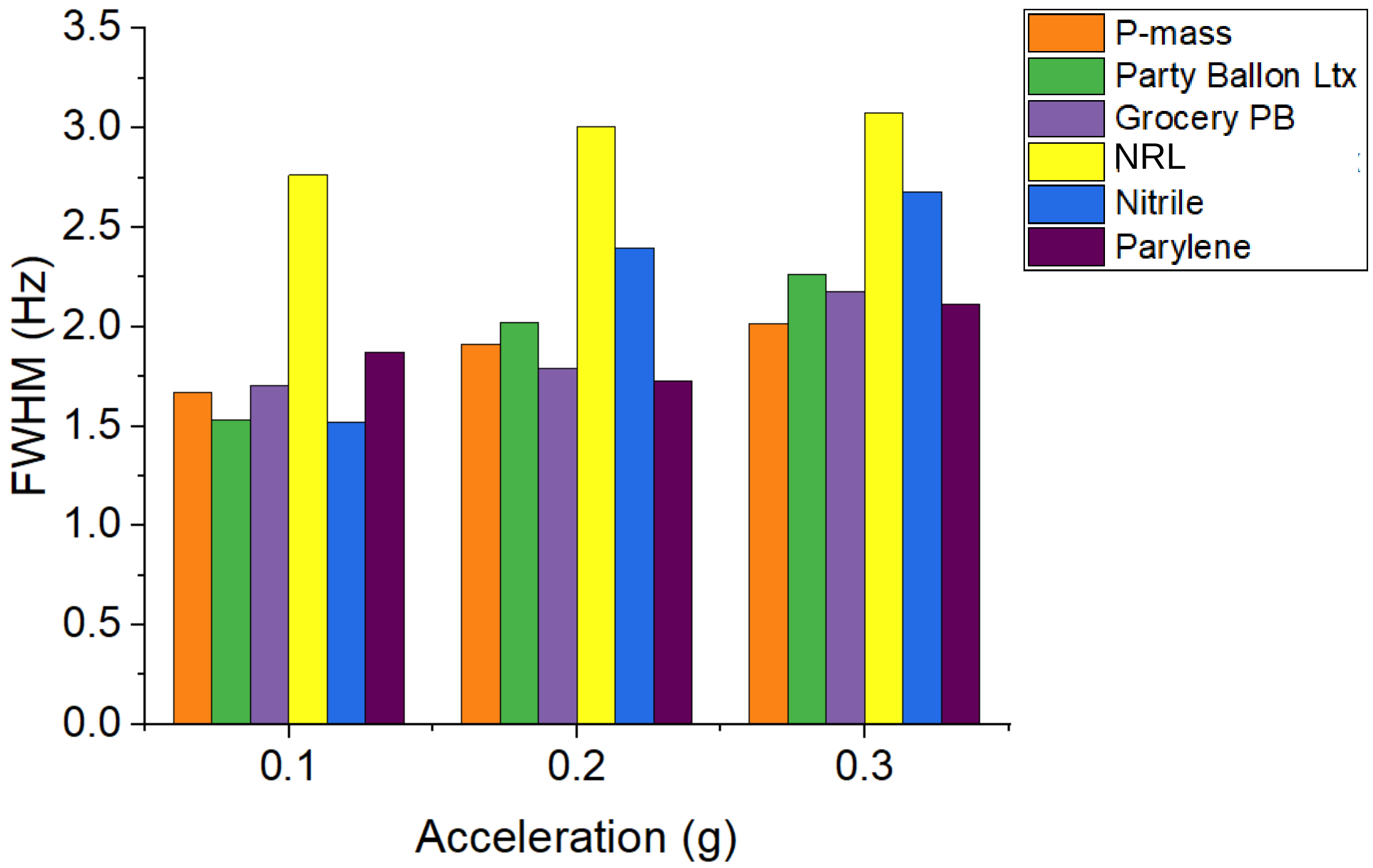


Figure 2: Cylindrical proof mass

Material Testing Results



Graph 7: Material Testing FWHM vs acceleration

- Stable performance
- Superior FWHM
- Flexible, light weight material

Optimal Material and Parachute Size Testing

- 5mm and 10mm thickness
- 1.42mm(MP) and 2mm(LP) size parachutes
- Tested across five accelerations 0.1 , 0.2 , 0.3, 0.4, and 0.5 g’s.

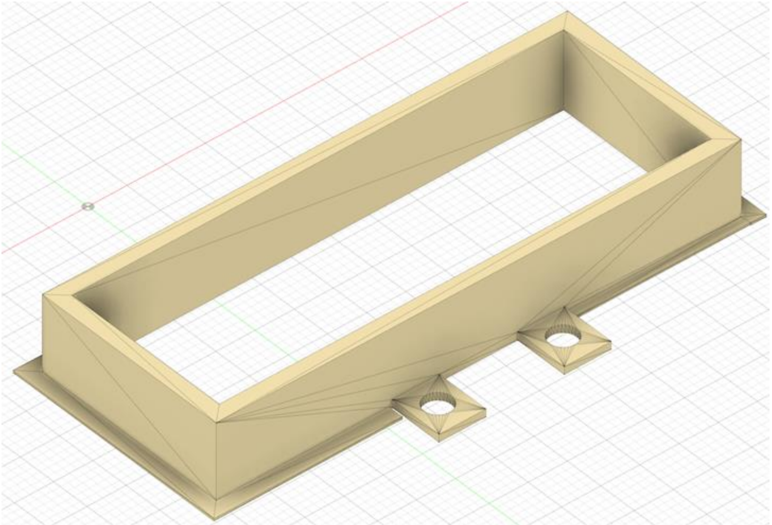
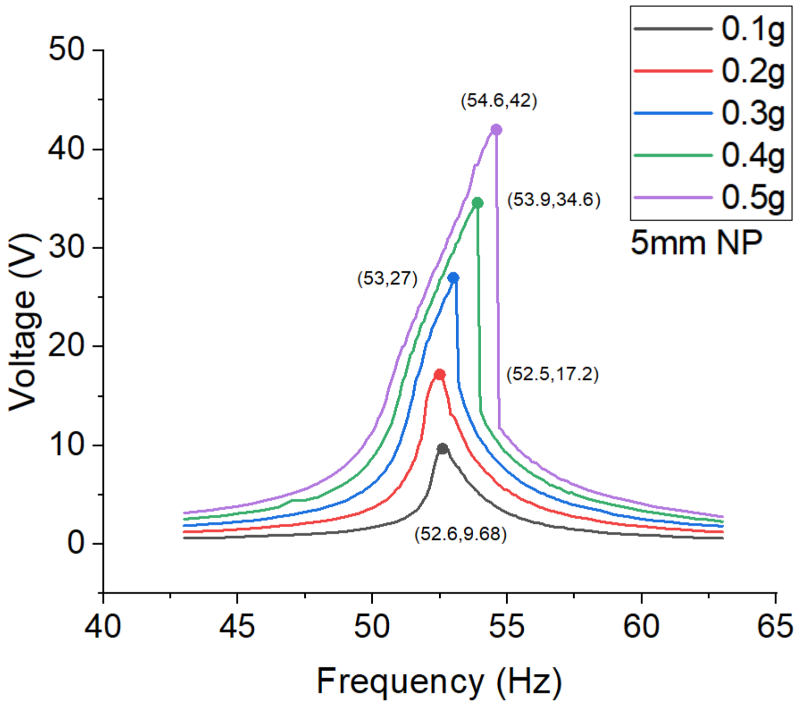
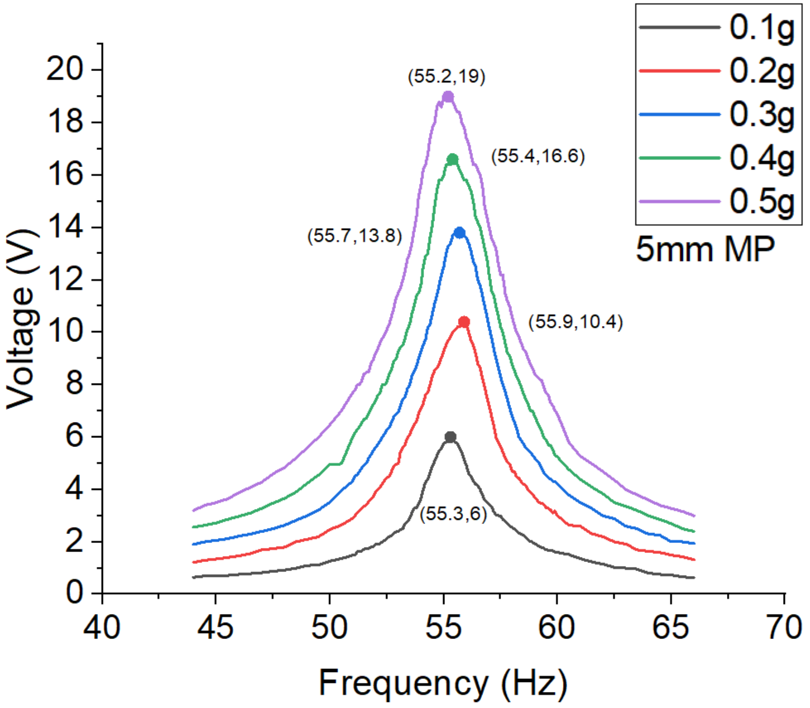


Figure 3: Wide proof mass

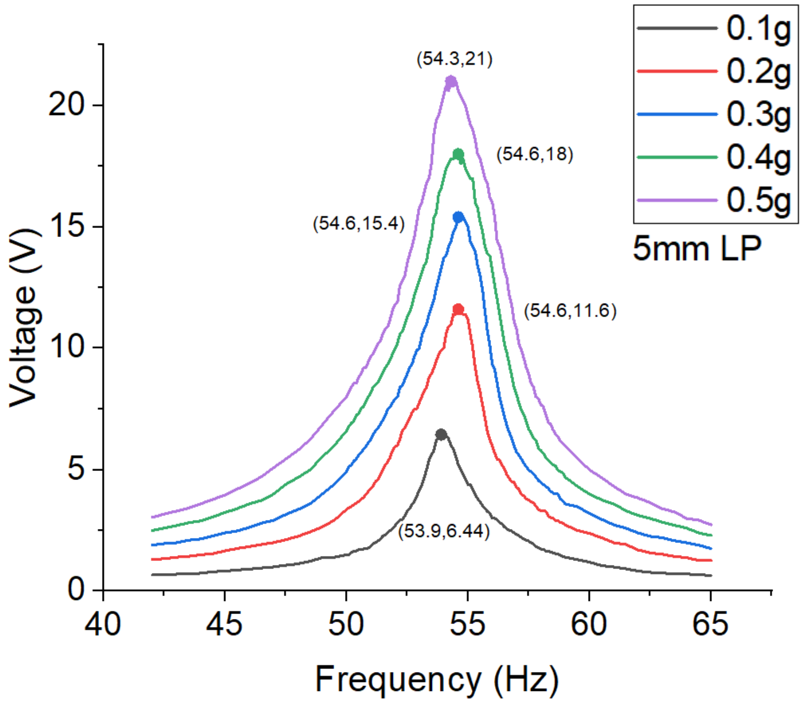
Optimal Material and Parachute Size Testing



Graph 8: 5mm NP voltage vs frequency

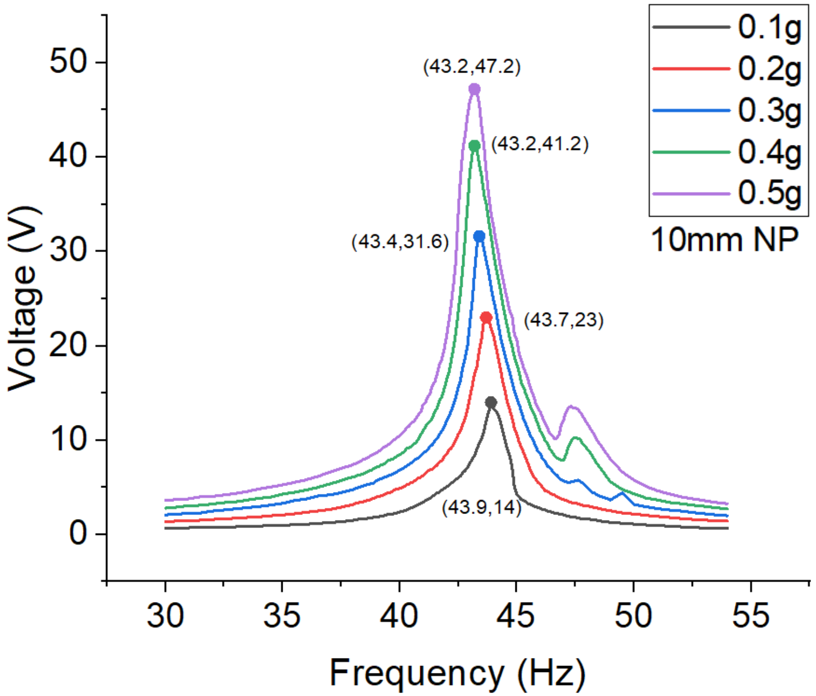


Graph 9: 5mm MP voltage vs frequency

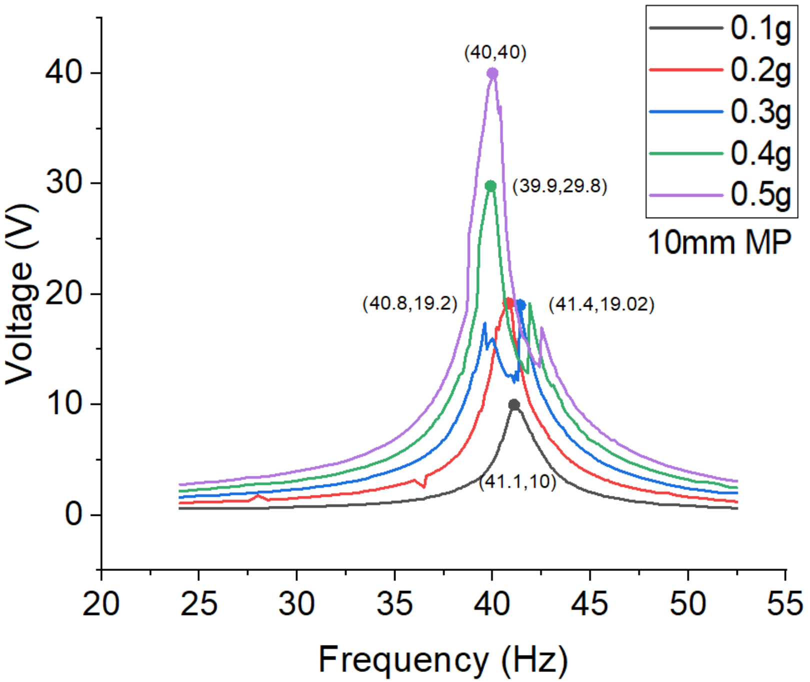


Graph 10: 5mm LP voltage vs frequency

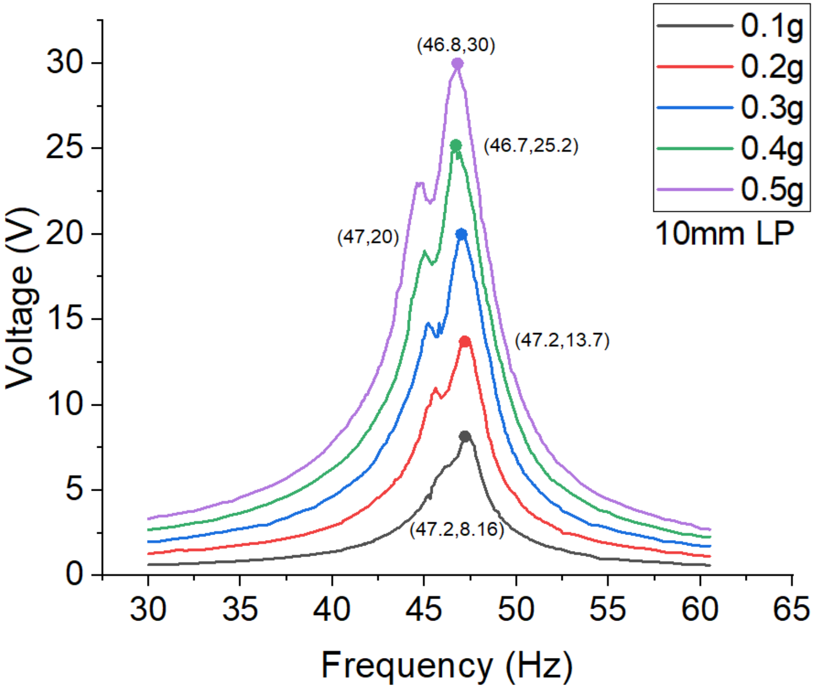
Optimal Material and Parachute Size Testing



Graph 11: 10mm NP voltage vs frequency

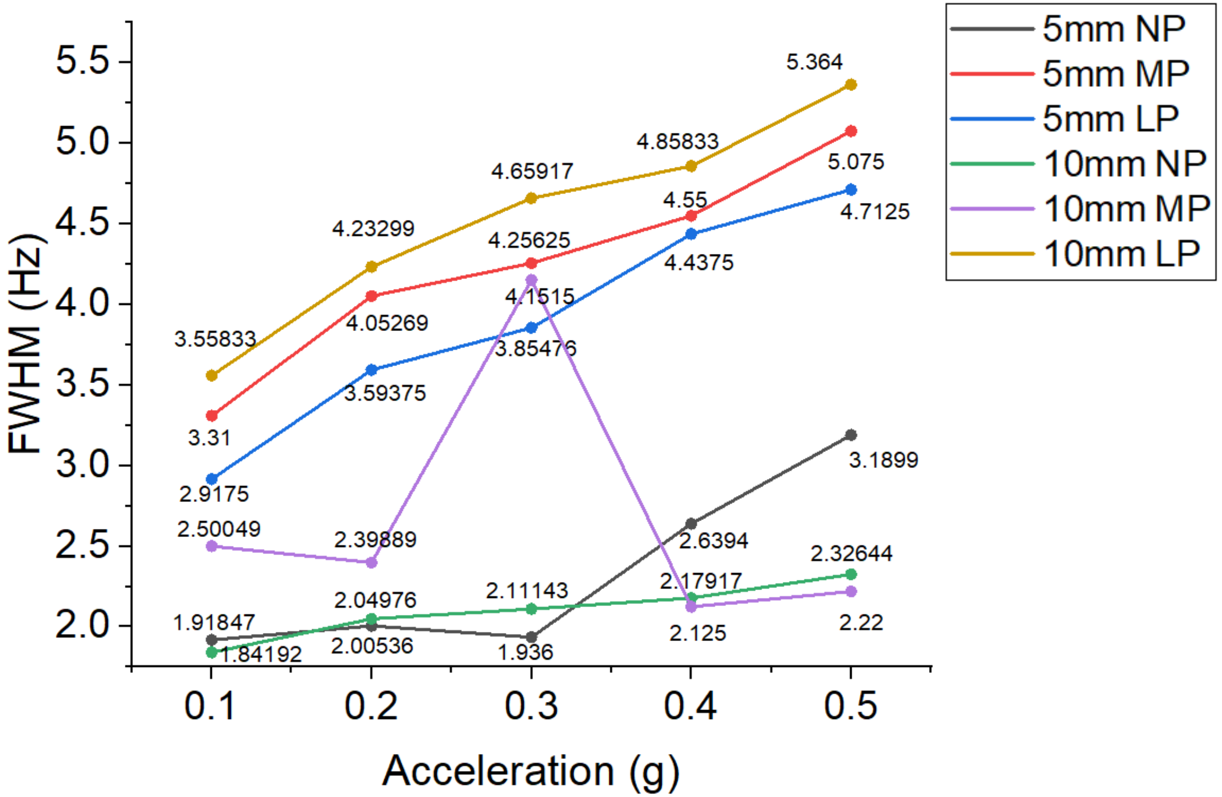


Graph 12: 10mm MP voltage vs frequency



Graph 13: 10mm LP voltage vs frequency

Optimal Material and Parachute Size Testing Results



Graph 12: 5mm and 10mm FWHM vs acceleration

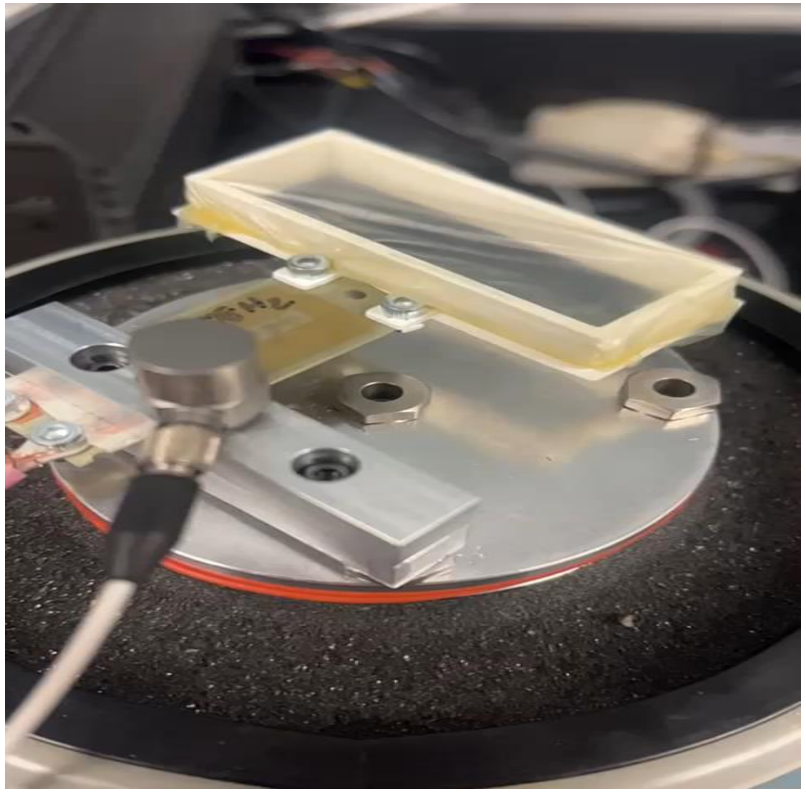
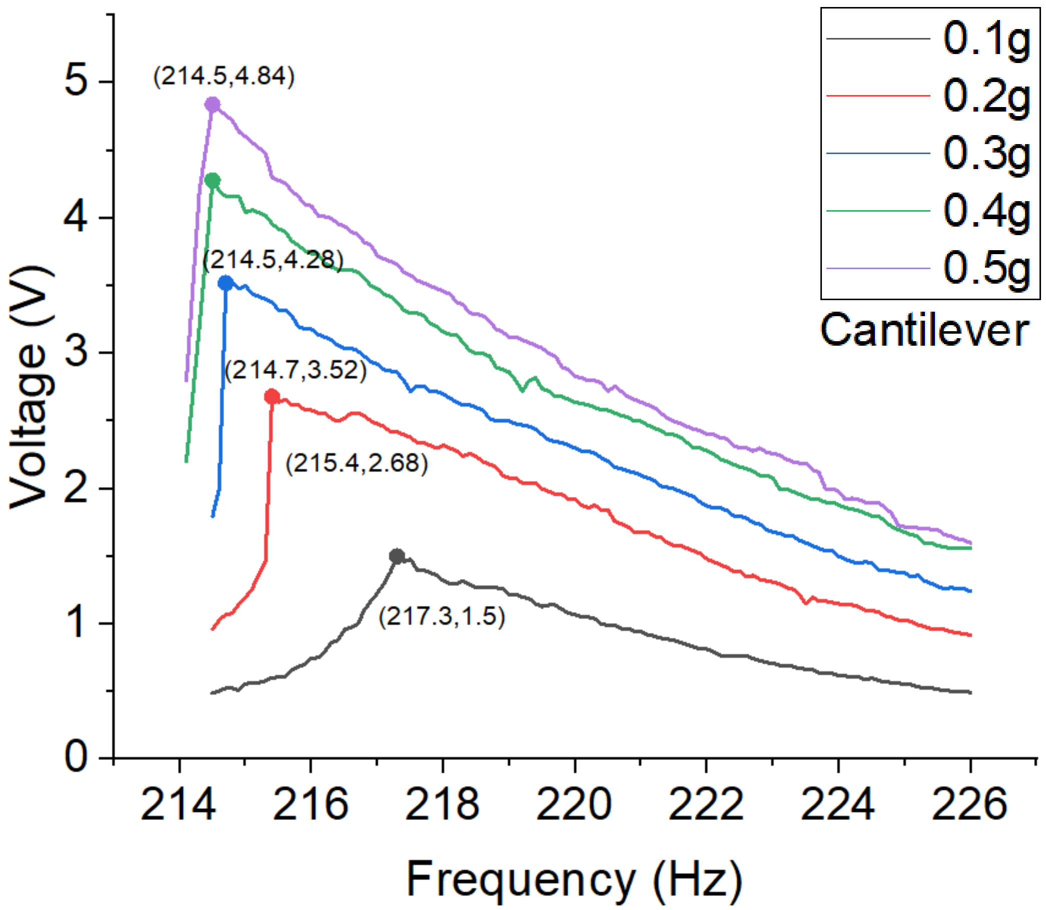
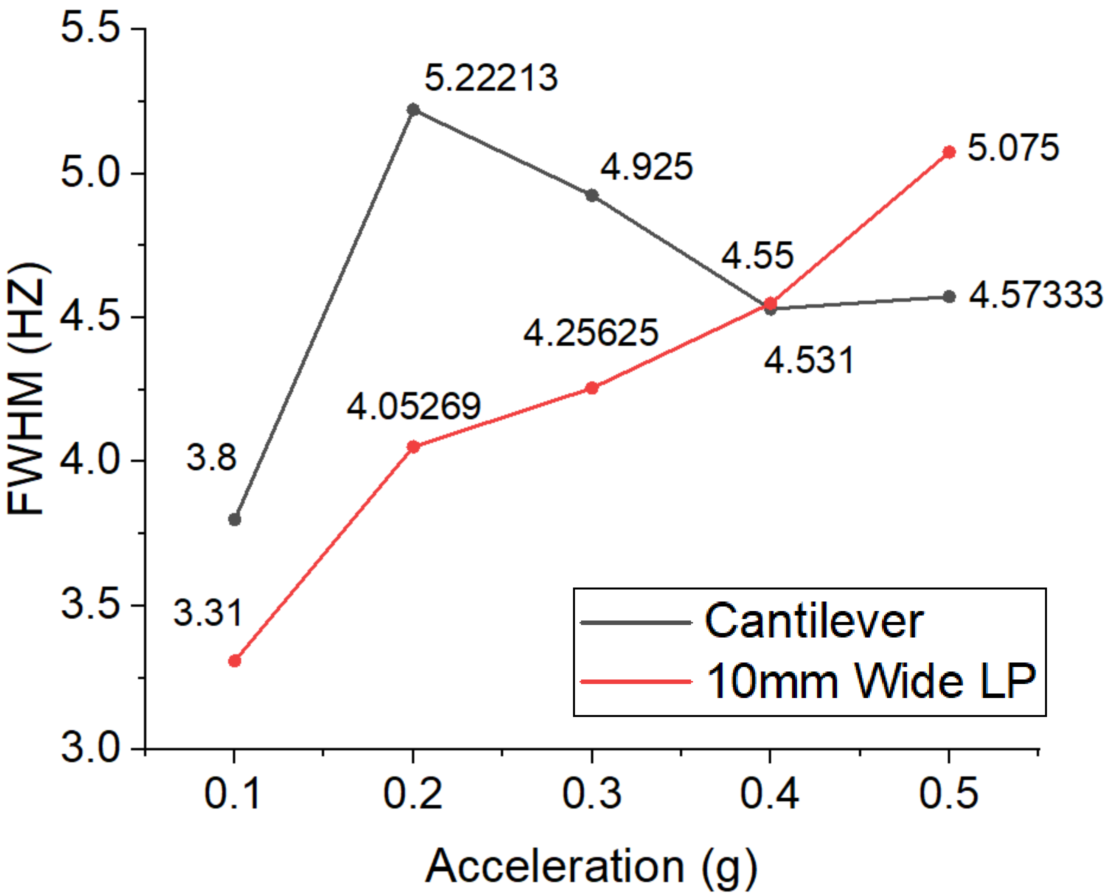


Figure 3: 10mm proof mass LP slow motion

Final Results



Graph 13: 5mm and 10mm FWHM vs acceleration



Graph 14: 5mm and 10mm FWHM vs acceleration

Conclusion

- Positive results at higher accelerations

  10.97% FWHM increase at 0.5g's

- Lack of displayment limits parachute performance

- Proof mass heavily lowers operating frequency to about 40 – 45 Hz

Further research to be done:

- Test different lightweight and elastic materials for the parachute
- Apply higher acceleration on latest models
- Try different parachute sizes

References

[1] R. Adhikari and N. Jackson, "Passive Frequency Tuning of Piezoelectric Energy Harvester using Embedded Masses," 2021 IEEE 20th International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications (PowerMEMS), Exeter, United Kingdom, 2021, pp. 176-179, doi: 10.1109/PowerMEMS54003.2021.9658377.

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[3] N. Jackson, F. Stam, O. Z. Olszewski, H. Doyle, A. Quinn, and A. Mathewson, "Widening the bandwidth of vibration energy harvesters using a liquid-based non-uniform load distribution," Sensors and Actuators A: Physical, vol. 246, pp. 170-179, 2016. [Online]. Available: https://doi.org/10.1016/j.sna.2016.04.063.

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[5] H. Liang, G. Hao y O. Z. Olszewski, "A review on vibration-based piezoelectric energy harvesting from the aspect of compliant mechanisms," in Sensors and Actuators A: Physical, vol. 331, no. 112743, 2021. [Online]. Disponible en: https://doi.org/10.1016/j.sna.2021.112743.

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Thank you!

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