



Imperial College
London



European
Commission



Performance Analysis of APA for Energy Harvesting

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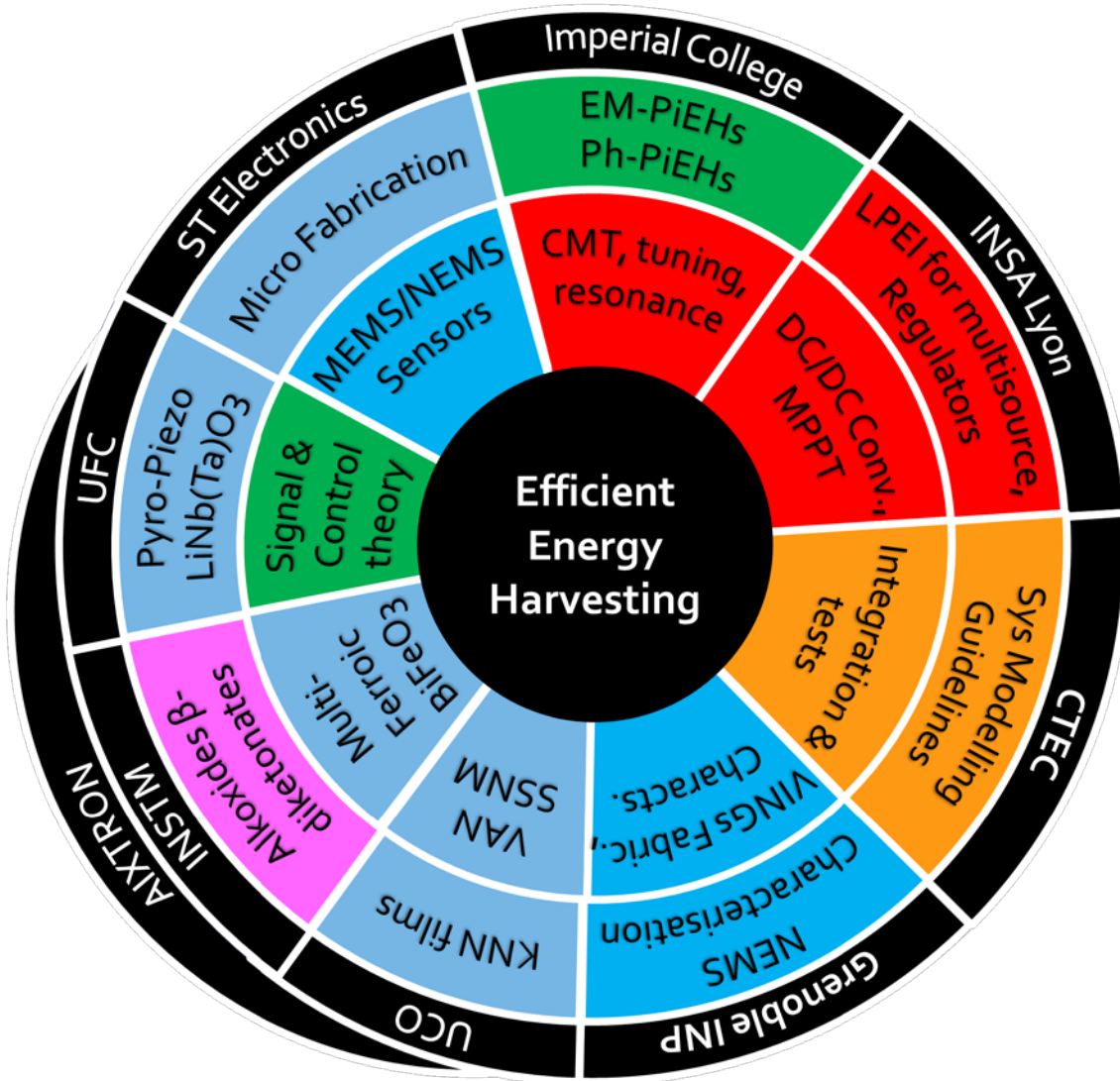
HAILING FU

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Agenda

- ENHANCE Project
- Piezoelectric Energy Harvesting
- What are Amplified Piezoelectric Amplifiers?
- Force – Charge Simulation
- Conclusion
- Future Work

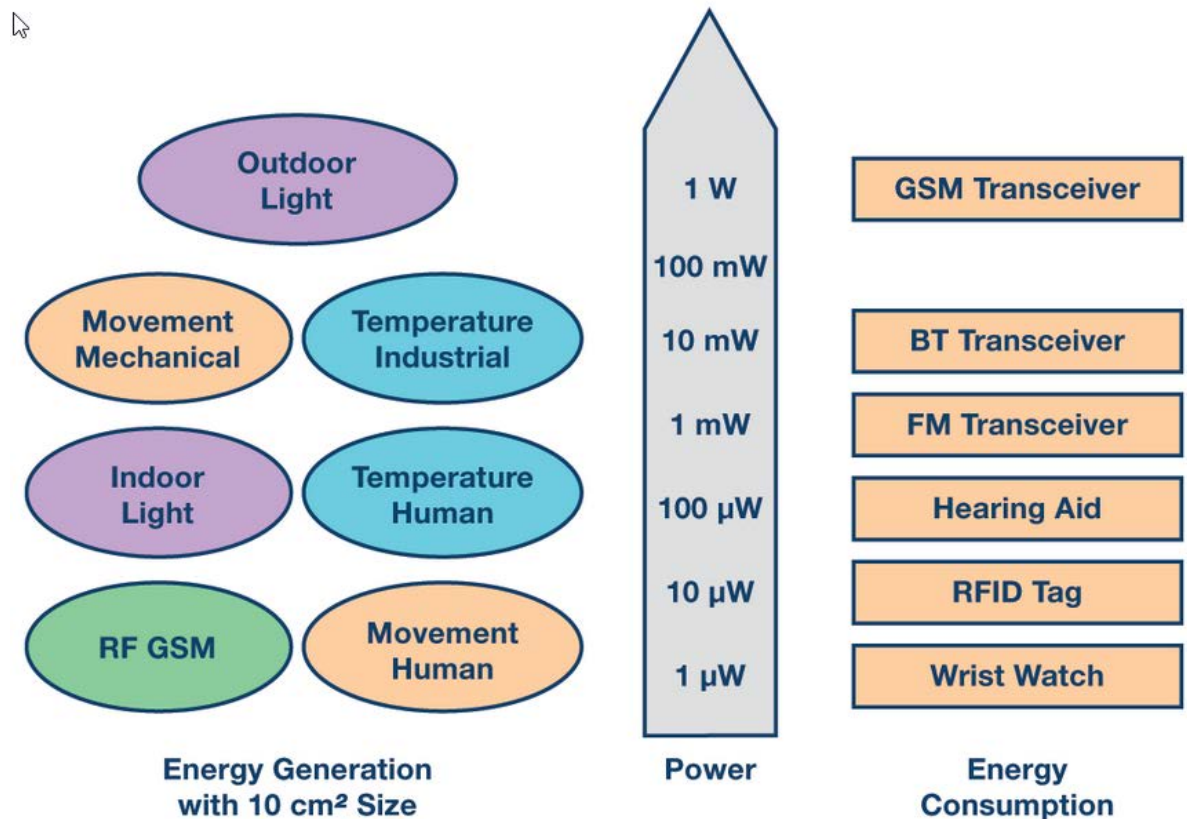


ENHANCE Project

- H2020 Internal Training Network – Marie Curie Scholarship Funded
- Interdisciplinary scientific network
- Lead – free piezoelectric materials (Lithium Niobate, KNN)
- System optimised, automobile application oriented solutions
- Coherent power management circuit

Piezoelectric Energy Harvesting (PiEH)

- Eliminate the need for battery maintenance where possible
- Harvesting locally available stray energy to feed nearby consumer system
- Piezoelectric EH
 - Miniaturisation (MEMs Applications)
 - High voltage output
 - Coupling thin films
 - Quick frequency response



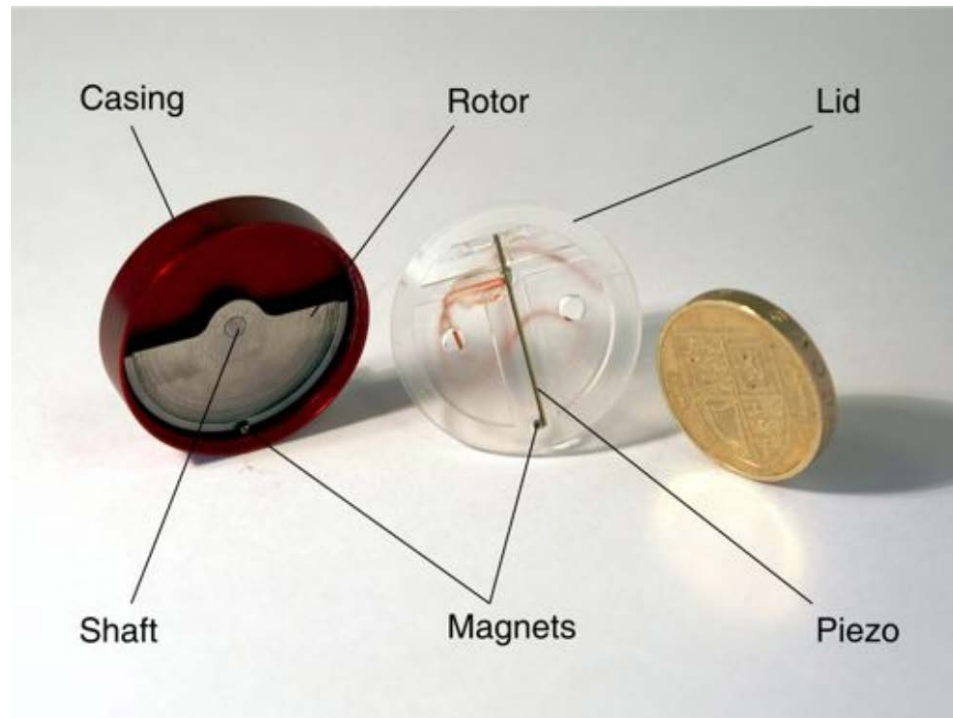
Picture Source: 'New advances in Energy Harvesting Power Conversion' Article: Analog Dialogue. [Online]

Rotational PiEH

- To overcome displacement limit
- Increase the operating frequency of the energy harvester
- Adaptable for both rotational and linear excitation (Based on design)

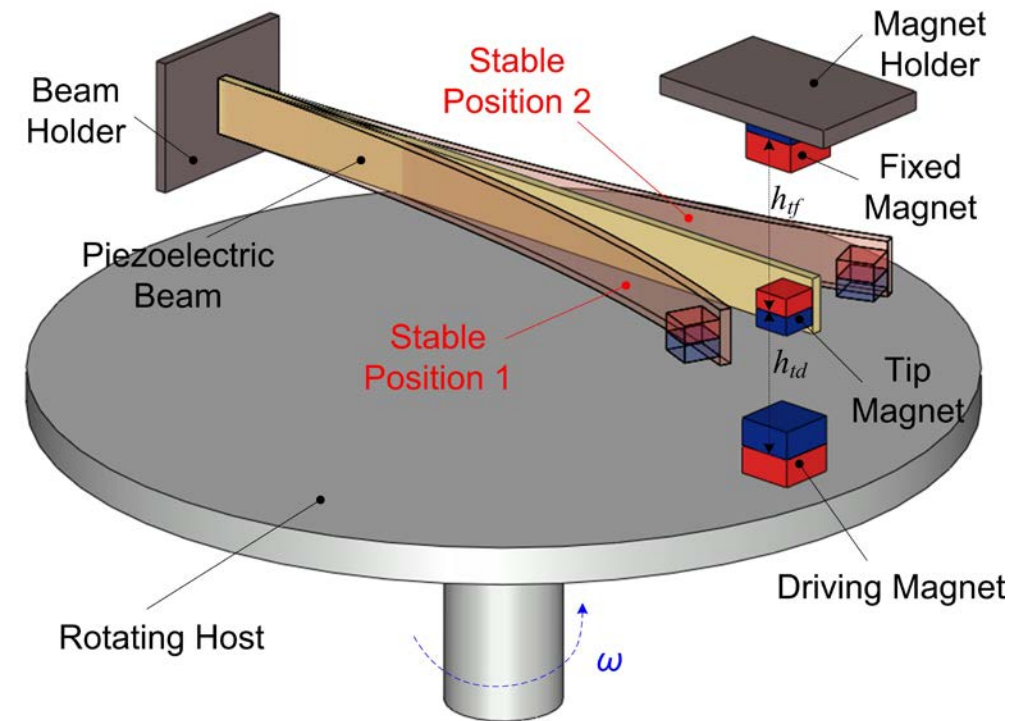
Frequency Up Conversion

MONOSTABLE HARVESTERS



P. Pillatsch, E.M. Yeatman, and A.S. Holmes, 'Real World Testing of a Piezoelectric Rotational Energy Harvester for Human Motion', PowerMEMS 2013, London 2013.

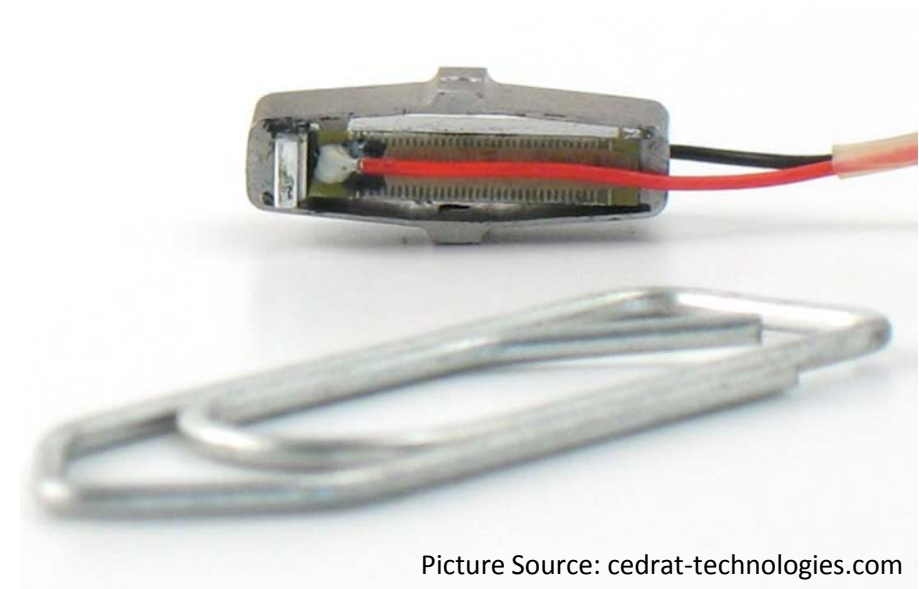
BISTABLE HARVESTERS



H.Fu and E.M. Yeatman, Mechanical Systems and Signal Processing, 2018.

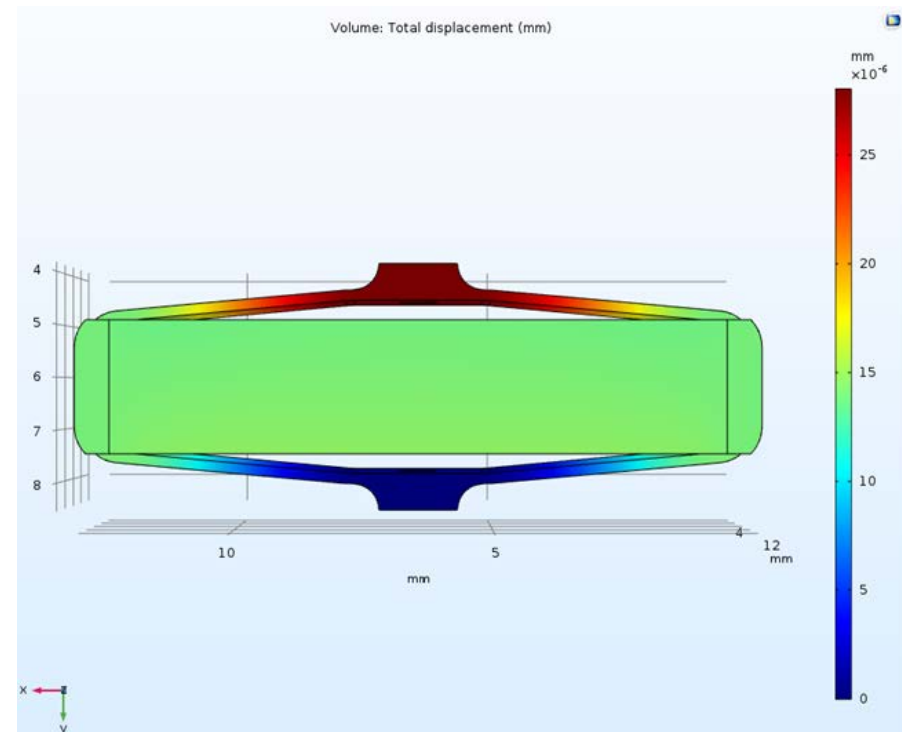
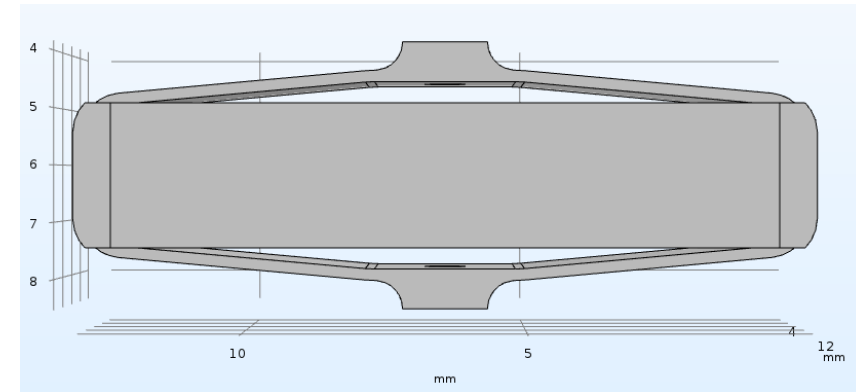
Amplified Piezoelectric Amplifiers[®]

- Stainless Steel elliptical shell
- Multi-layered ceramics (MLA) which is preloaded
- High stiffness
- Testing Amplified Piezoelectric Actuators as Energy Harvesters
 - Simulation
 - Delta Test
 - Impedance Matching



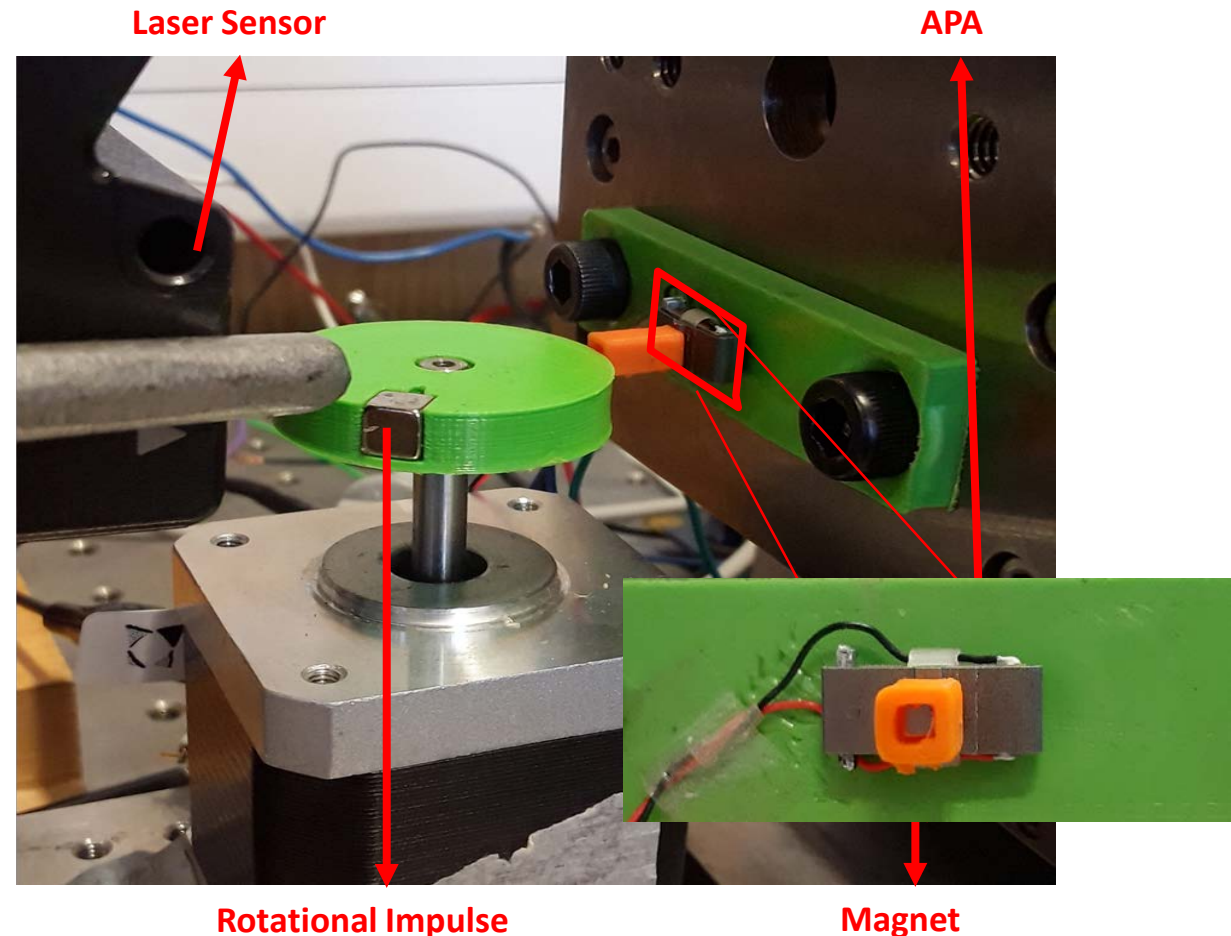
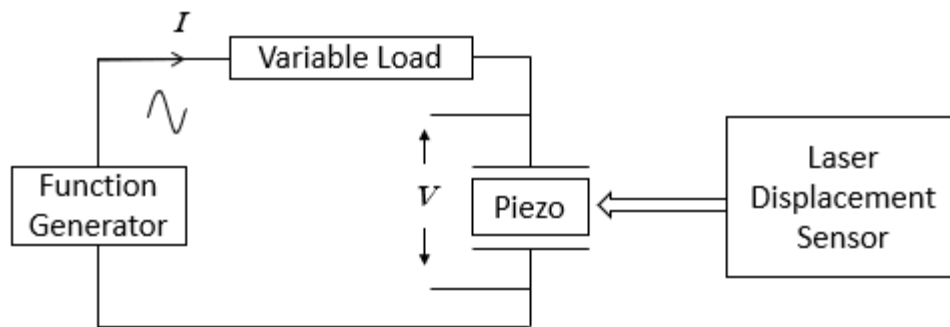
Structural Analysis

- Charge - Force simulation
- Blocked – Free mode
- Force Amplification factor = 2



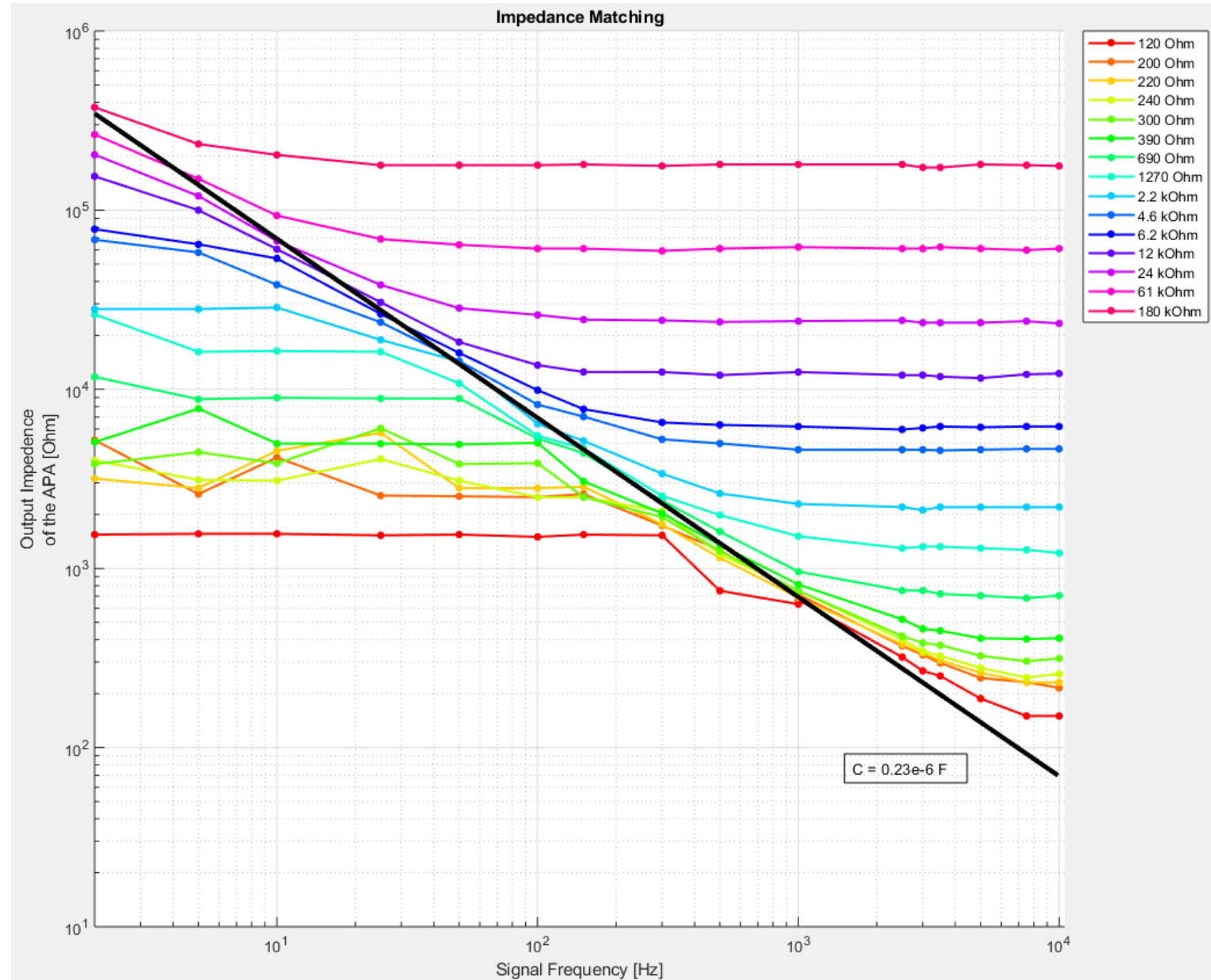
Experimental Setup

- Design the output impedance of the APA
- Study the performance of the APA on varying proof mass (Magnet)
- Study the Force – Charge relationship with laser displacement sensor



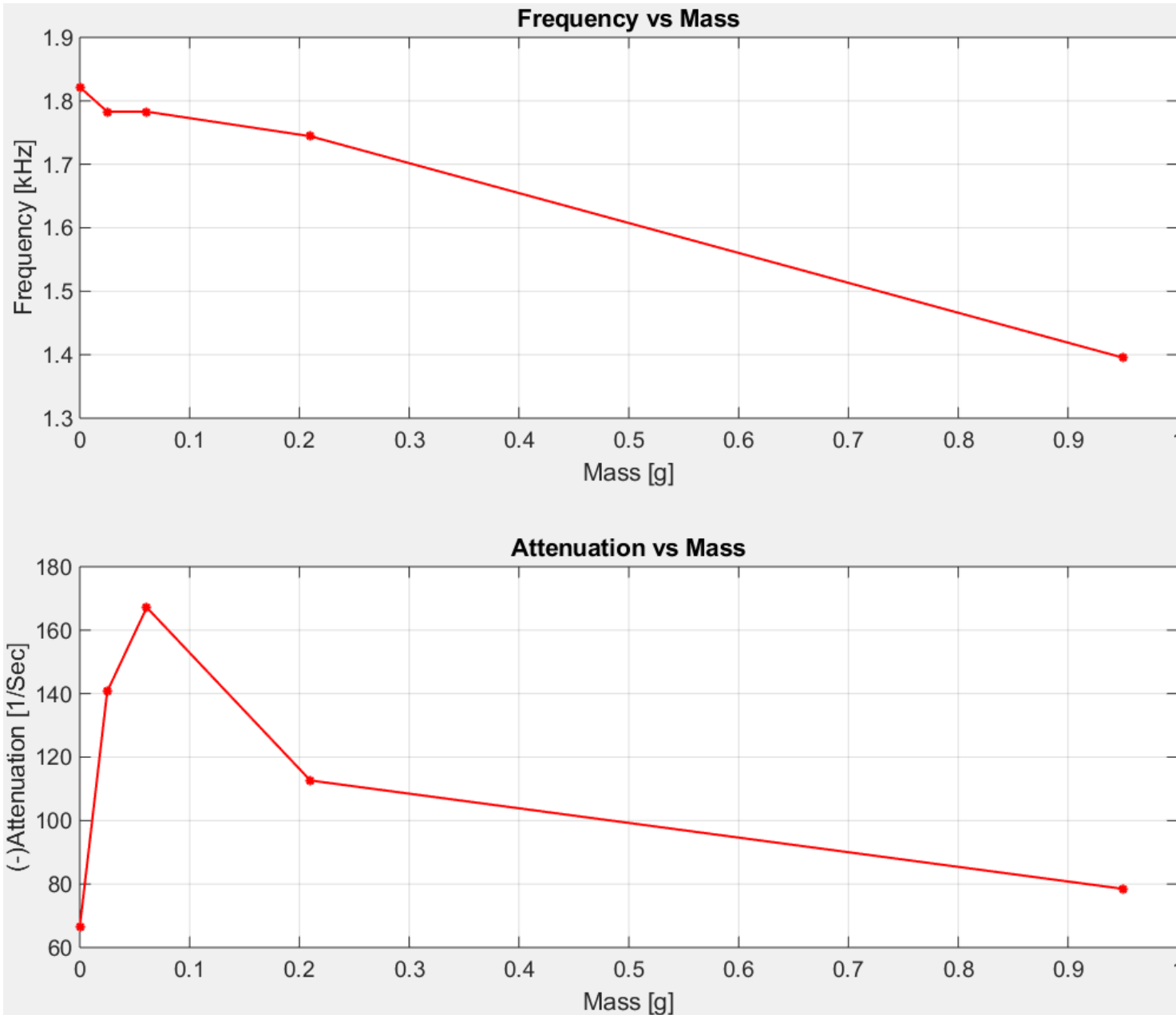
Impedance Matching

- Charge - Force simulation
- Blocked – Free mode
- Force Amplification factor = 6



Parameter Analysis

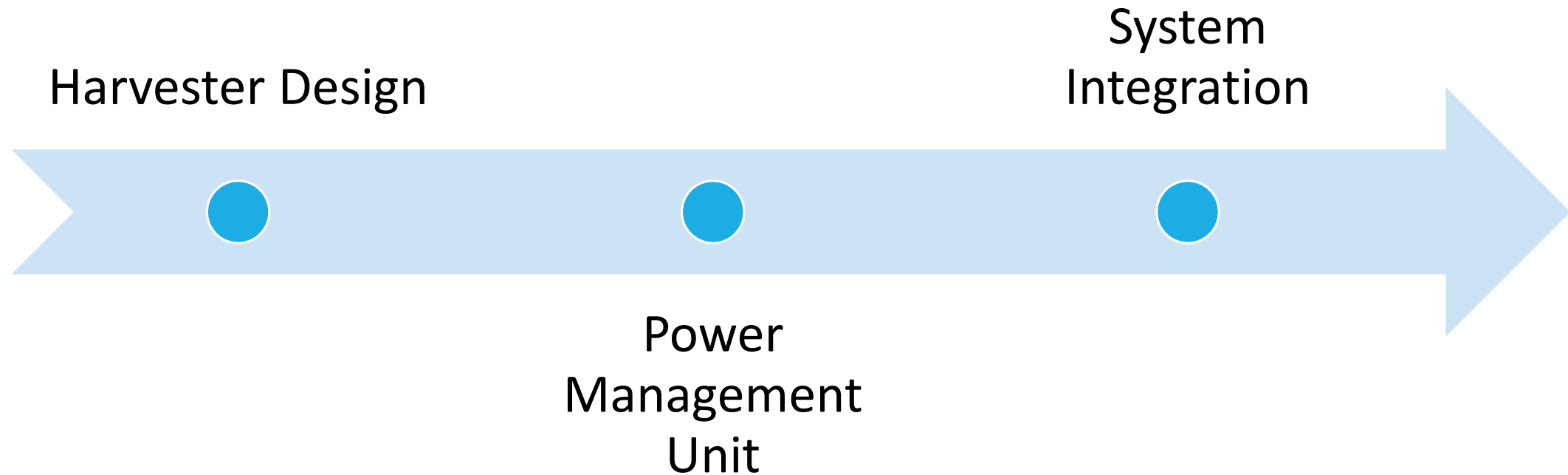
- Analysing the trend of the APA natural frequency and attenuation with changing proof mass
- Blocked – Free mode
- Excited with a mechanical impulse
- Open loop Voltage measured
- Experiment to get the trend for Q-factor of the device



Conclusions

- Application in direct impact application Eg. Suspension spring
- Possible adaptation of the APA in bistable / tristable architecture to improve power output
- Inverse APA design to get more output for less displacement (lever structure)

Future Work





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Any Questions?

