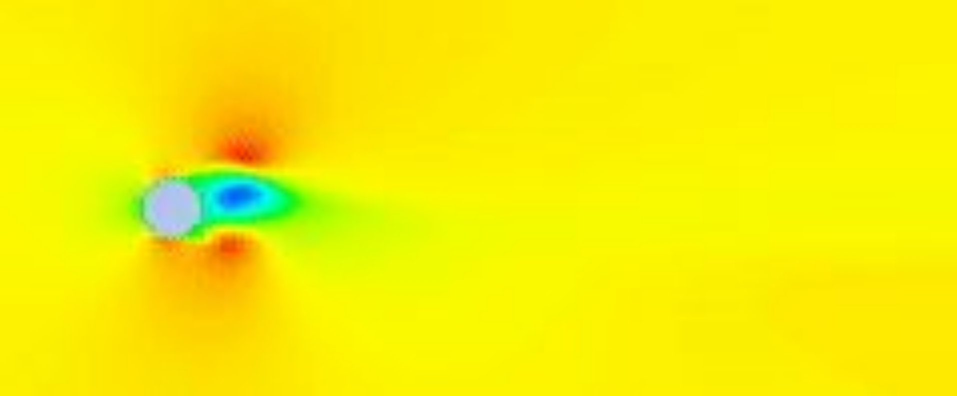
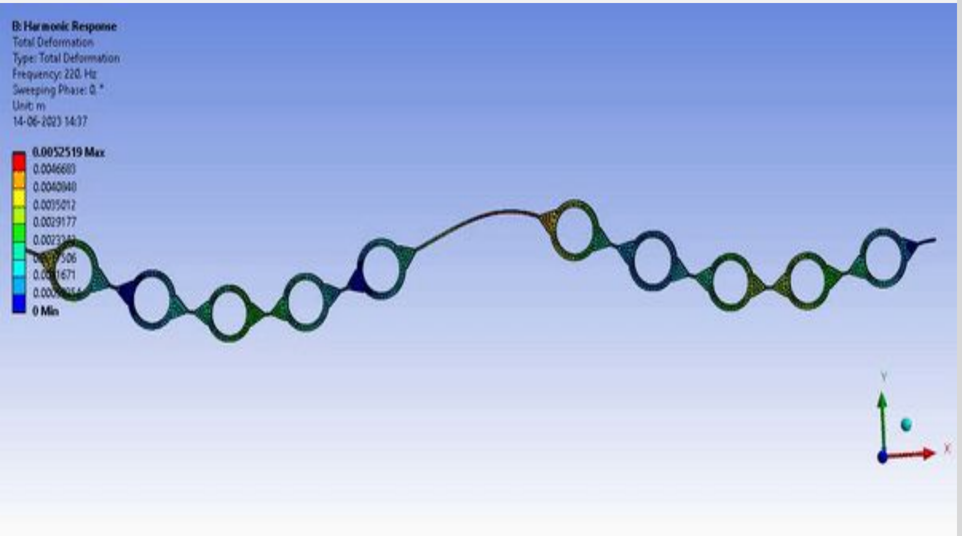




Meta Fluidic Vortex Induced Vibration Energy Harvester

By:

Shivansh Pandey

for the fulfilment of requirement of
Summer Internship 2023

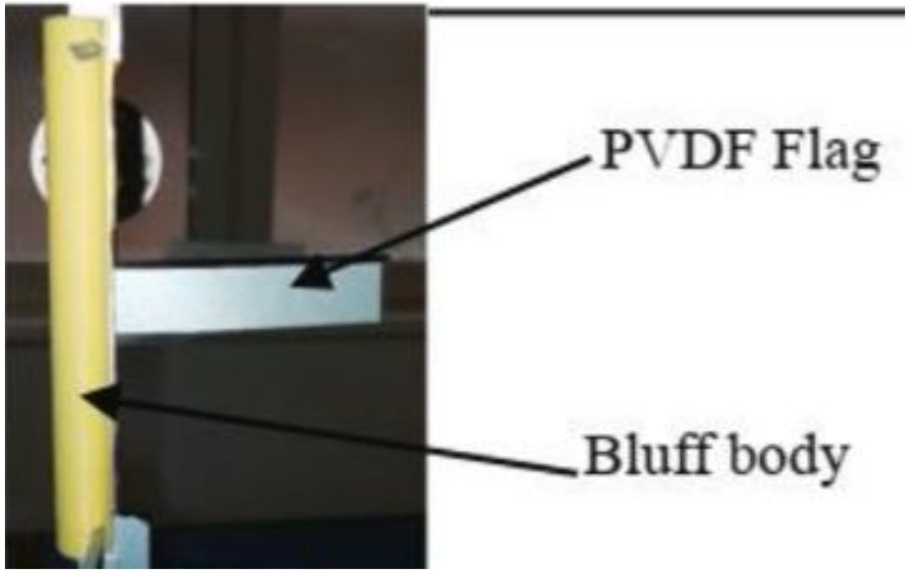
Principal Investigator:
Dr. Bishakh Bhattacharya
HAL Chair Professor, ME-IITK

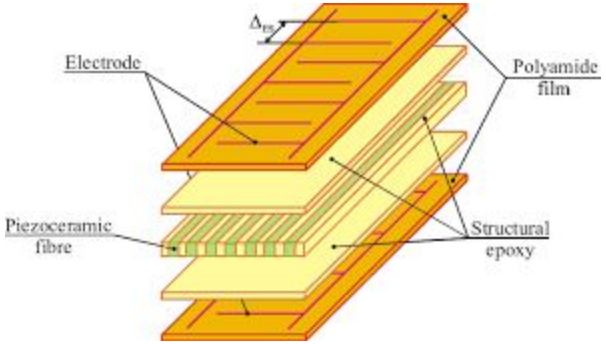
Mentors:
Dr. Manas Ranjan Behera
Vivek Gupta
Ashish Shukla

Smart Materials, Structures and Systems (SMSS) Laboratory
Department of Mechanical Engineering, IIT Kanpur
https://www.iitk.ac.in/smss/

Date: 20 June 2023

Introduction





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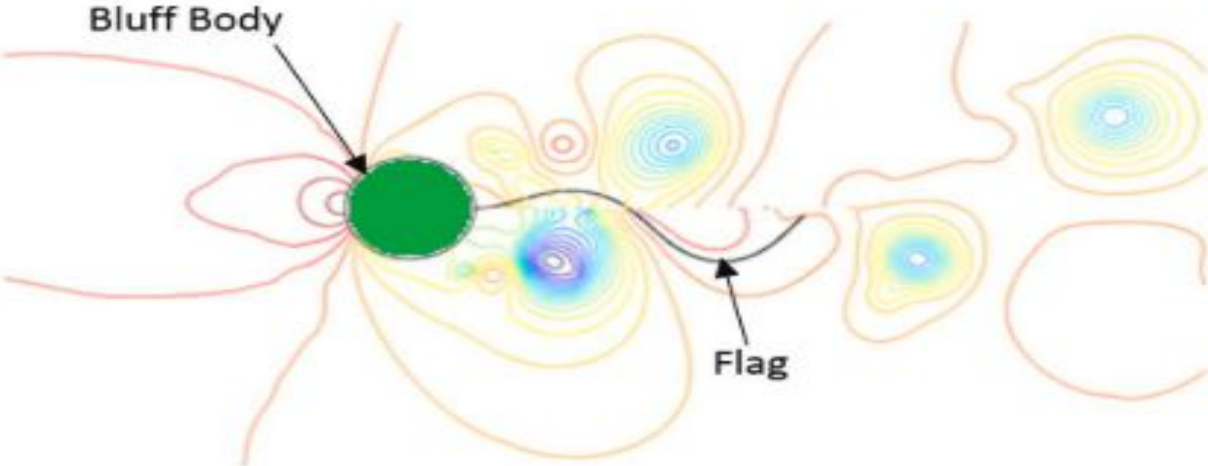
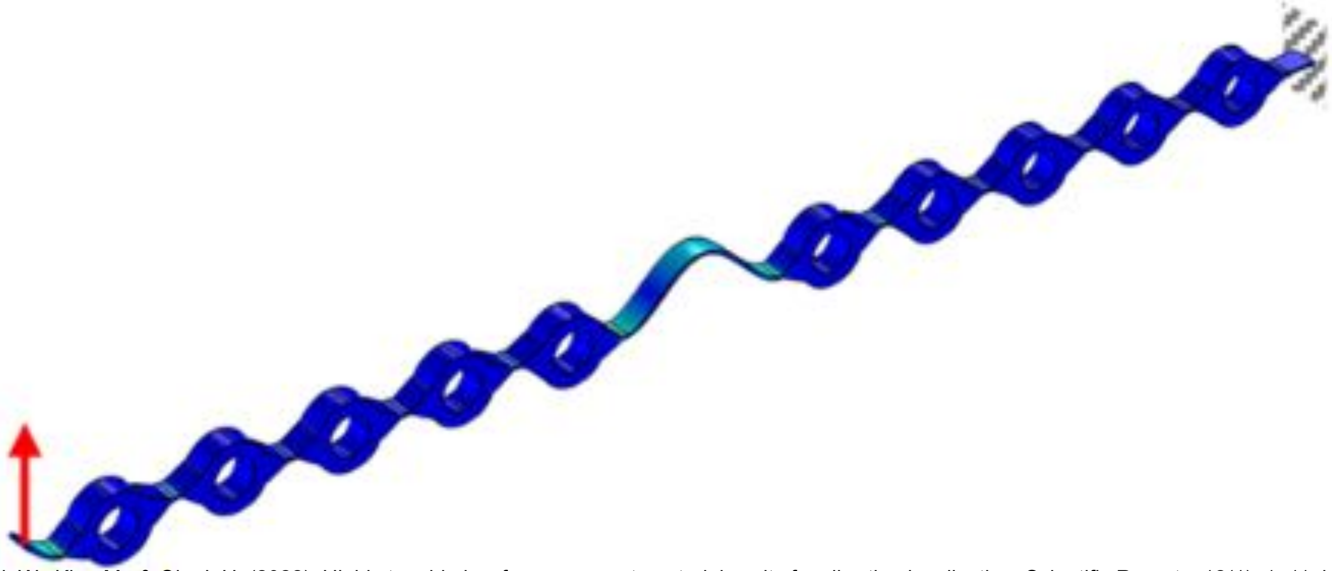


Kovalovs, A., Barkanov, E., & Gluhihs, S. (2007). Active control of structures using macro-fiber composite (MFC). Journal of Physics: Conference Series, 93(1). https://doi.org/10.1088/1742-6596/93/1/012034
Mehdipour, I., Madaro, F., Rizzi, F., & De Vittorio, M. (2022). Comprehensive experimental study on bluff body shapes for vortex-induced vibration piezoelectric energy harvesting mechanisms. Energy Conversion and Management: X, 13. https://doi.org/10.1016/j.ecmx.2021.100174
Park, H. W., Seung, H. M., Choi, W., Kim, M., & Oh, J. H. (2022). Highly tunable low frequency metamaterial cavity for vibration localization. Scientific Reports, 12(1), 1–11. https://doi.org/10.1038/s41598-022-13453-1

Objective

- To examine the effect of the design and properties of the meta-beam, which is connected to the bluff body, on the oscillation amplitude of a flow-induced vibration system.
- To match interface mode frequency with the shedding frequency of the vortices to get **lock in phenomena** .



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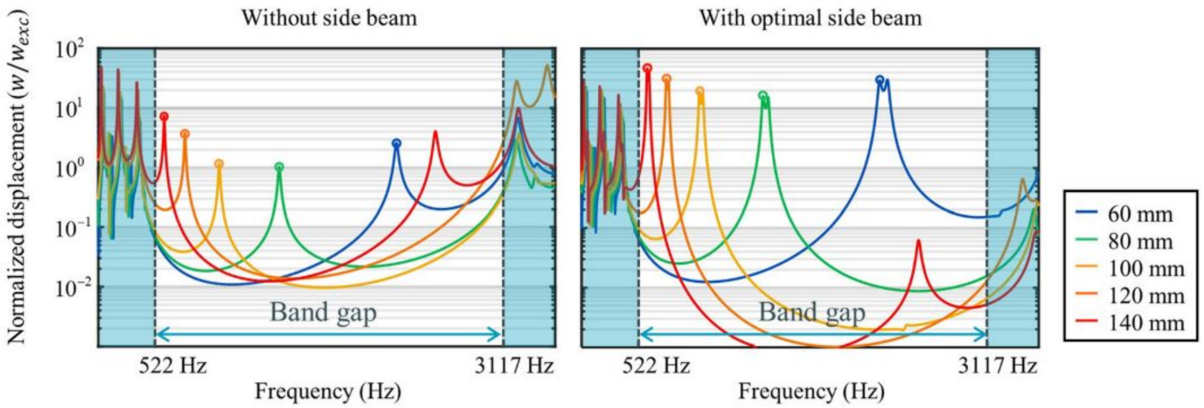
Park, H. W., Seung, H. M., Choi, W., Kim, M., & Oh, J. H. (2022). Highly tunable low frequency metamaterial cavity for vibration localization. Scientific Reports, 12(1), 1–11. https://doi.org/10.1038/s41598-022-13453-1

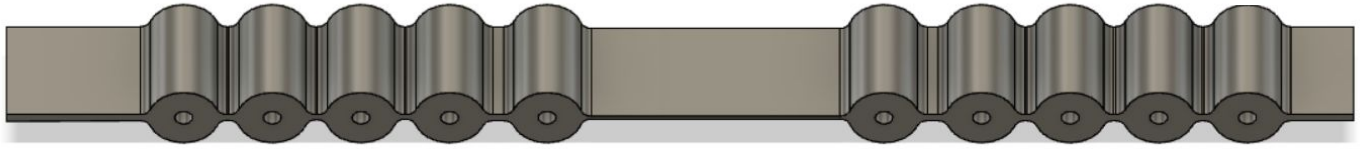
Meta–Beam Designs

Park et. (2022) [1]



$$\omega_{opening} = 2\sqrt{\beta/I}, \omega_{closing} = 2\sqrt{\alpha/m}.$$

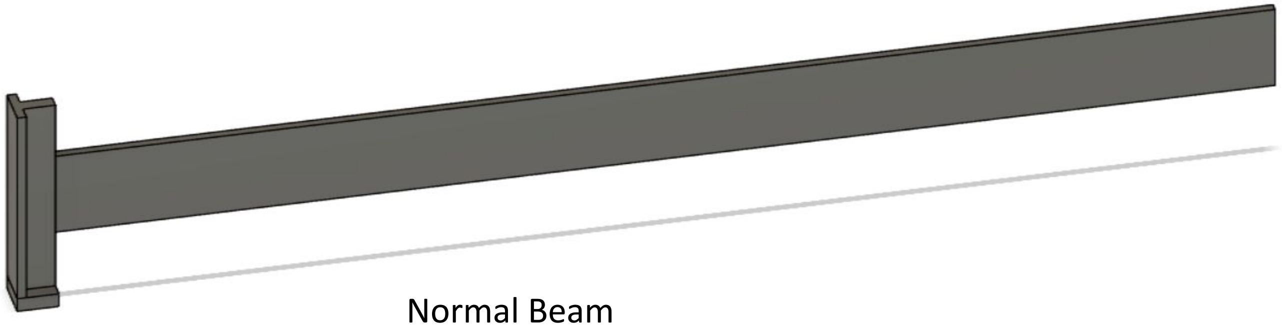
rotational inertia I *mass m*
bending stiffness β *shear stiffness α*



Meta-material beam
Length: 200mm Thickness: 1mm

Different variations-

- Inserts of stainless steel
- Increasing cavity length
- Increasing cavity thickness



Normal Beam
Length: 200mm, Thickness: 1.5mm

Compared with normal beam

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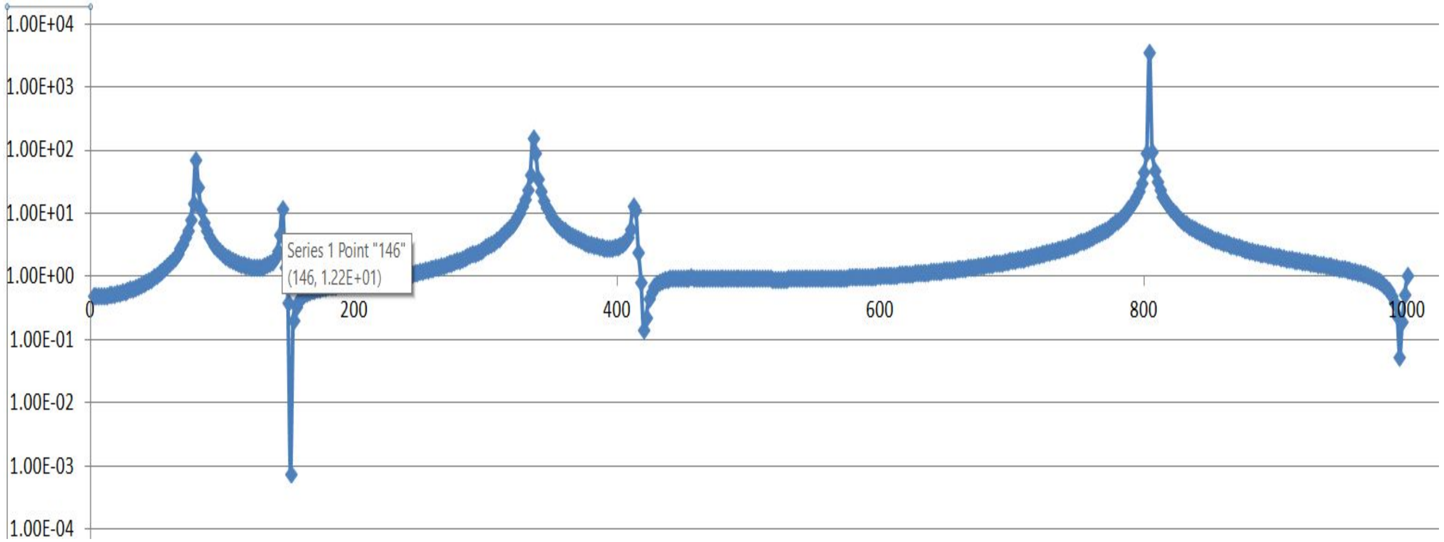
Park, H. W., Seung, H. M., Choi, W., Kim, M., & Oh, J. H. (2022). Highly tunable low frequency metamaterial cavity for vibration localization. Scientific Reports, 12(1), 1–11. https://doi.org/10.1038/s41598-022-13453-1

Meta-Beam with inserts

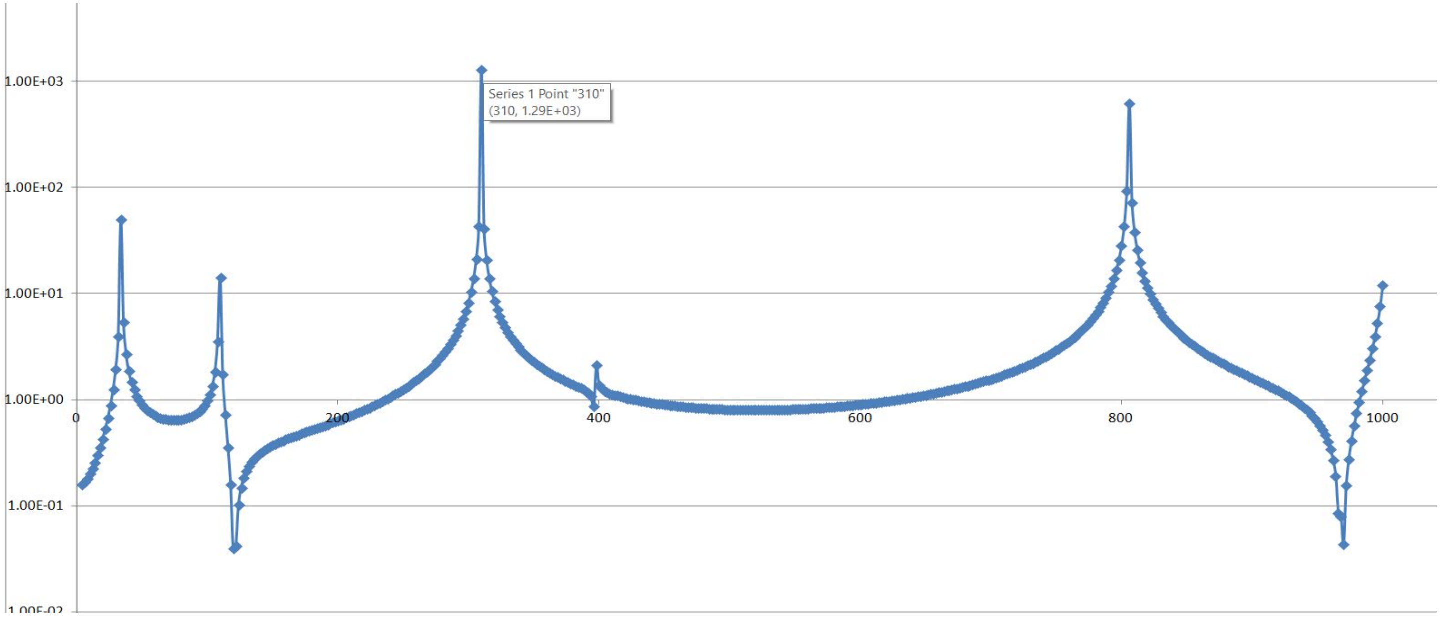
With 0 inserts-

Frequency (hz)	Amplitude ratio
80	74
146 - 152	12.2 - 0.0008
336	163
412 - 420	13.7 - 0.15
804	3640
994	0.056



With 2 inserts-

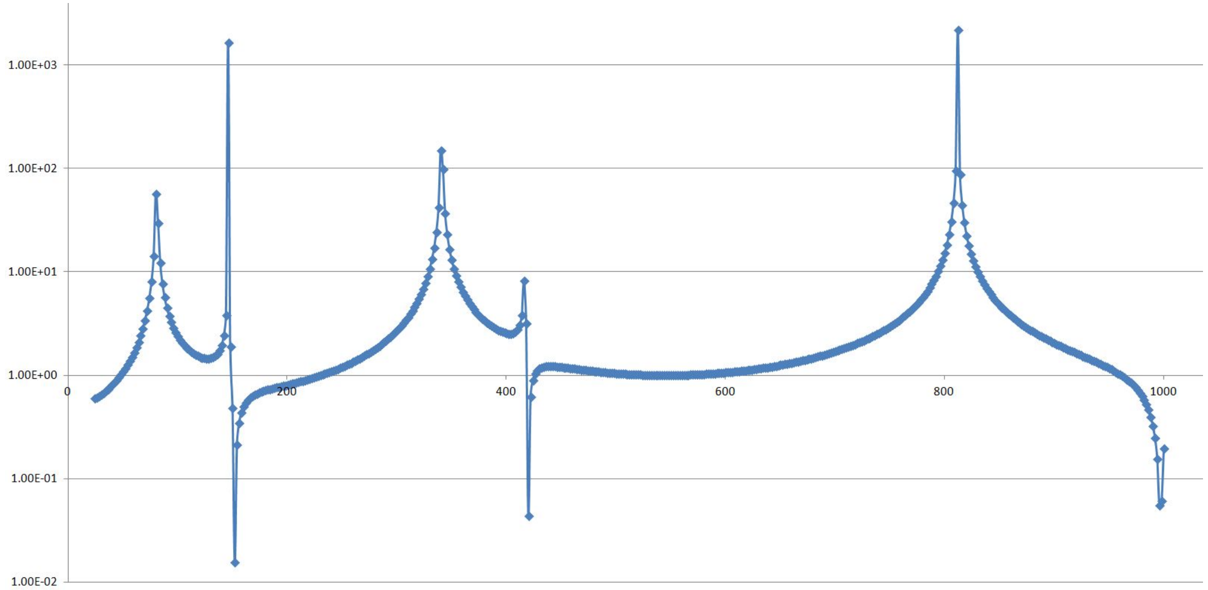
Frequency (hz)	Amplitude ratio
34	49.8
110 - 120	14.1 - 0.04
310	1290
396 - 398	0.87 - 2.1
806	621
970	0.0435



Meta-Beam with inserts

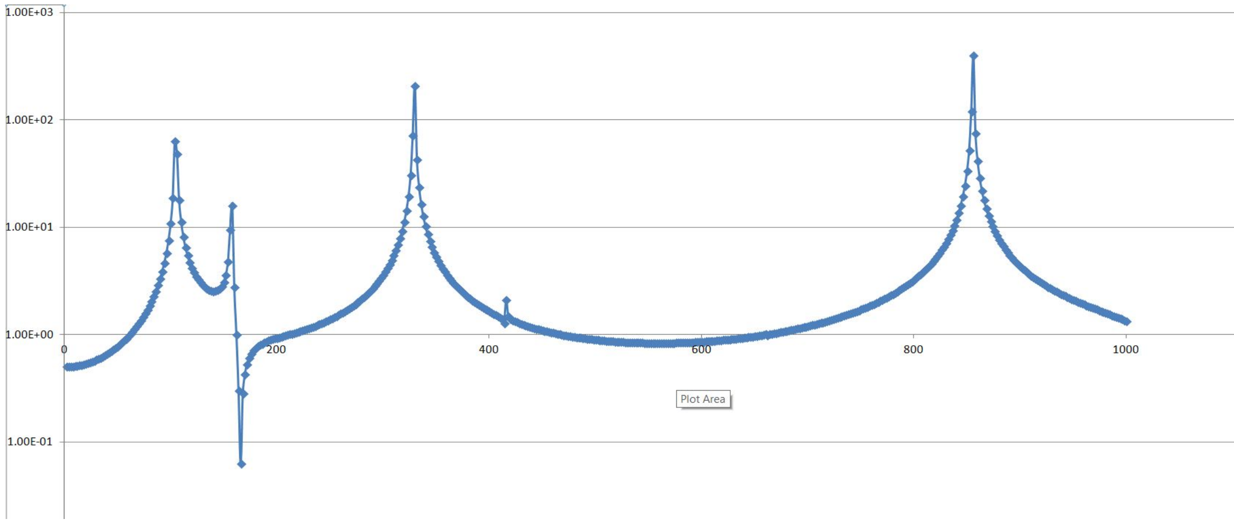
With 4 inserts-

Frequency (hz)	Amplitude ratio
80	57
146 - 152	1650 - 0.016
340	149
416 - 420	8.26 - 0.044
812	2190
996	0.055



With 6 inserts-

Frequency (hz)	Amplitude ratio
104	63.6
158 - 166	16 - 0.063
330	210
412 - 416	1.28 - 2.11
856	401



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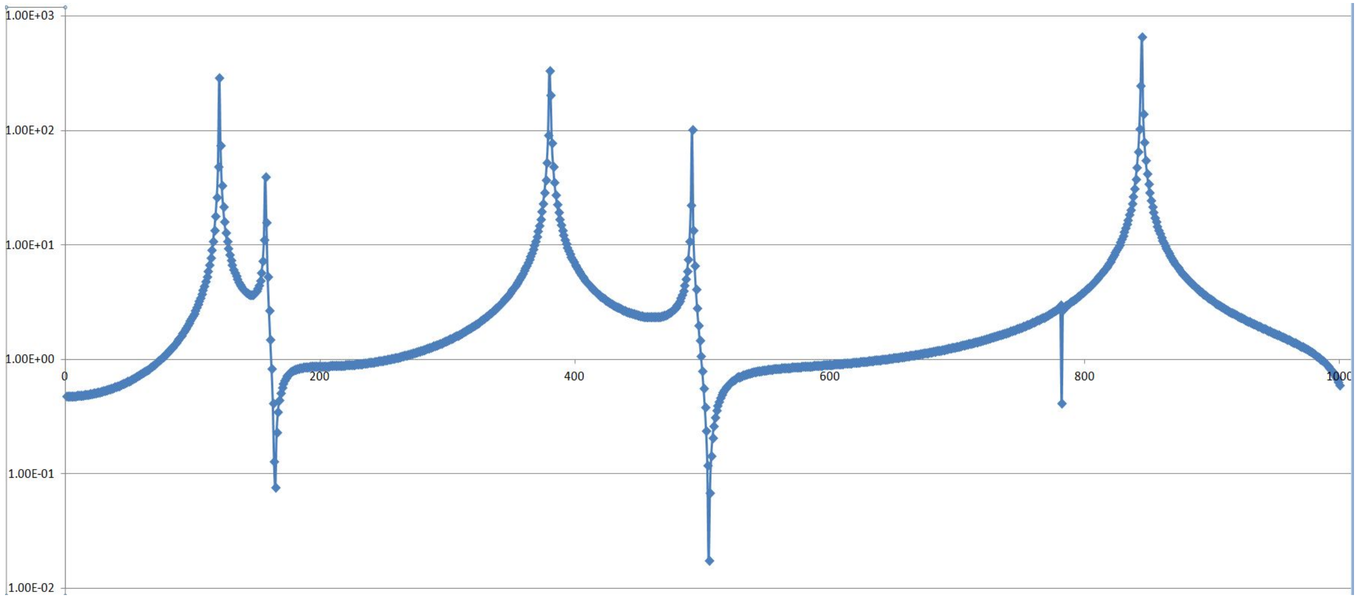
Meta-Beam with inserts

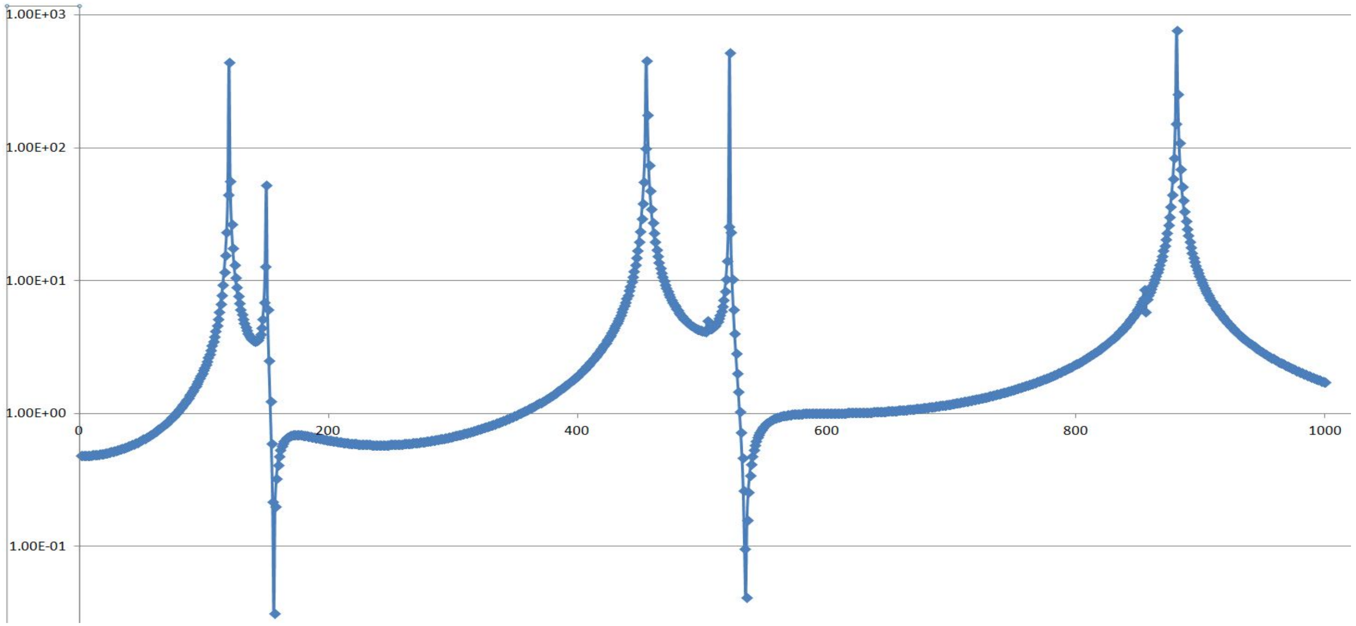
With 8 inserts

Frequency (hz)	Amplitude ratio
121	290
157 - 165	39.6 - 0.078
380	331
492 - 505	102 - 0.017
845	658



With 10 inserts

Frequency	Amplitude ratio
120	442
150 - 156	52.9 - 0.032
455	457
522 - 535	519 - 0.042
881	769



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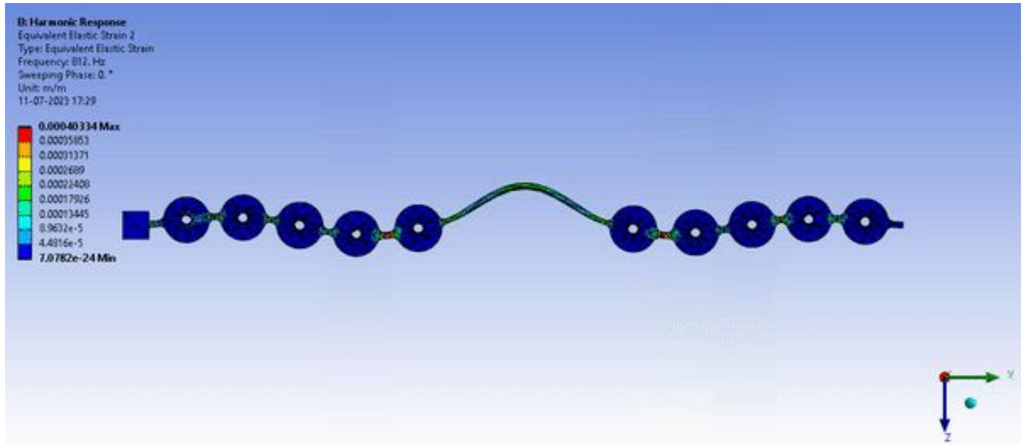
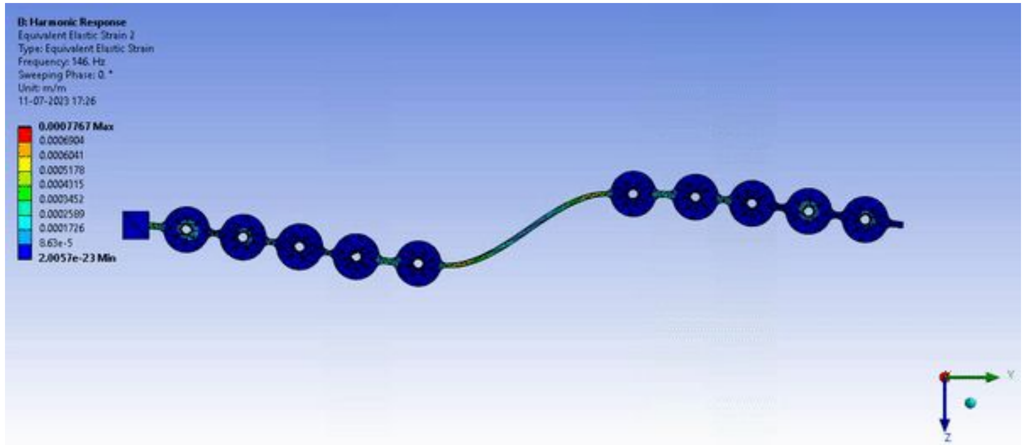
Results from Simulations

Meta-beam with	First mode (hz)	Antisymmetric mode (hz)	Interface mode (hz)	Amplitude ratio for Antisymmetric mode
0 inserts	80	146	804	12.2
2 inserts	34	110	806	14.1
4 inserts	**80**	**146**	**812**	**1650**
6 inserts	104	158	856	16
8 inserts	121	157	845	39.6
10 inserts	120	150	881	52.9
30% increased cavity length	**47**	**140**	**727**	**55.6**





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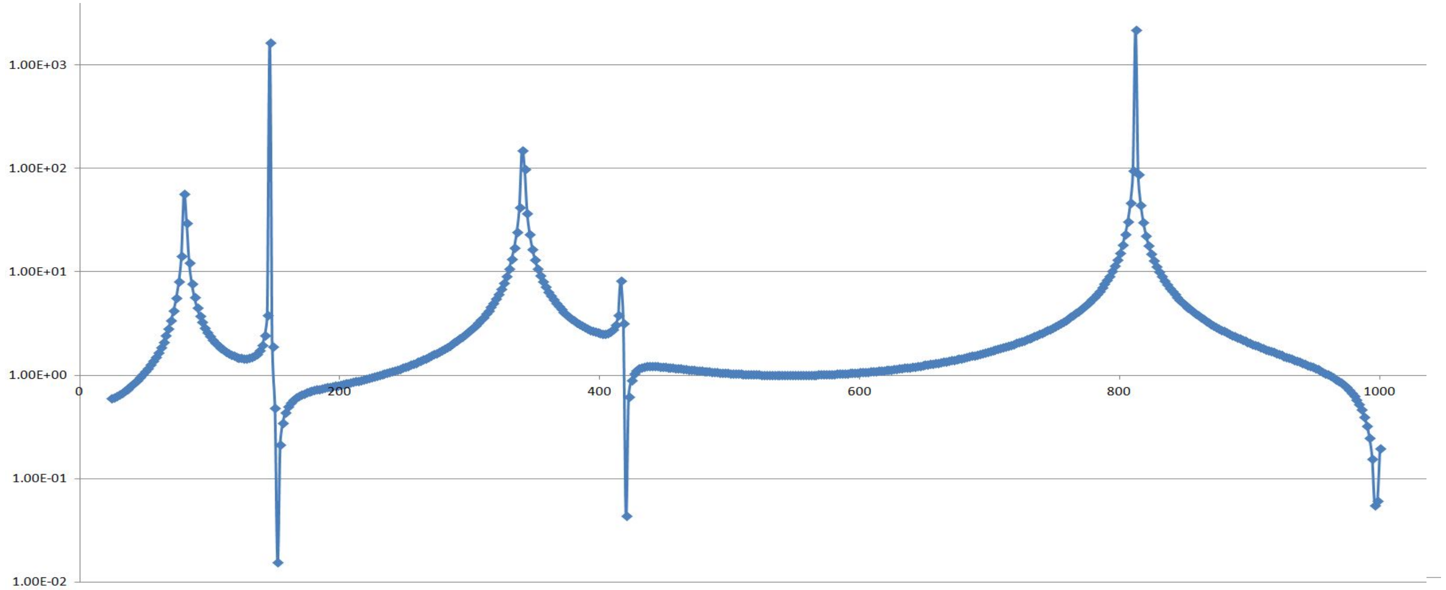
Increasing cavity length of Meta-Beam

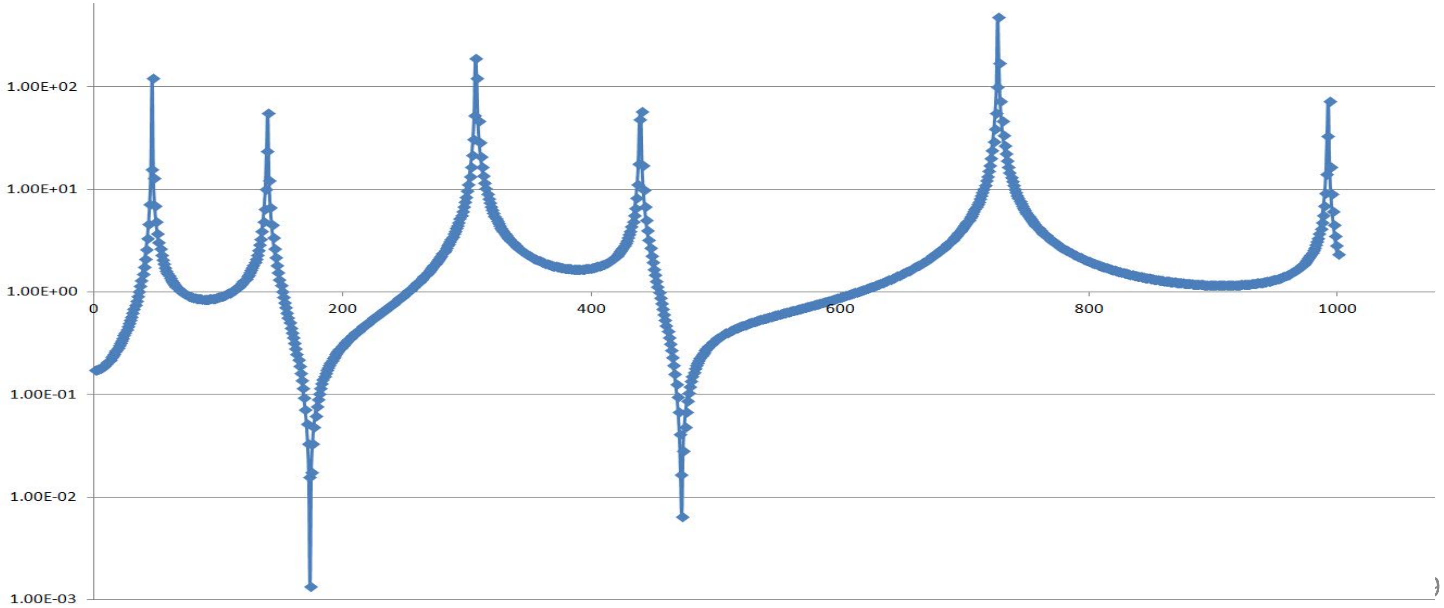
Meta-material beam with 4 inserts
Cavity length: 42mm

Frequency (hz)	Amplitude ratio
80	57
146 - 152	1650 - 0.016
340	149
416 - 420	8.26 - 0.044
812	2190
996	0.055



Meta-material beam with 4 inserts
Cavity length: 54.6mm
i.e.
30% increase

Frequency (hz)	Amplitude ratio
47	123
140 - 174	55.6 - 0.032
307	192
459 - 473	58 - 0.006
727	484
993	73



Experimental Set-up

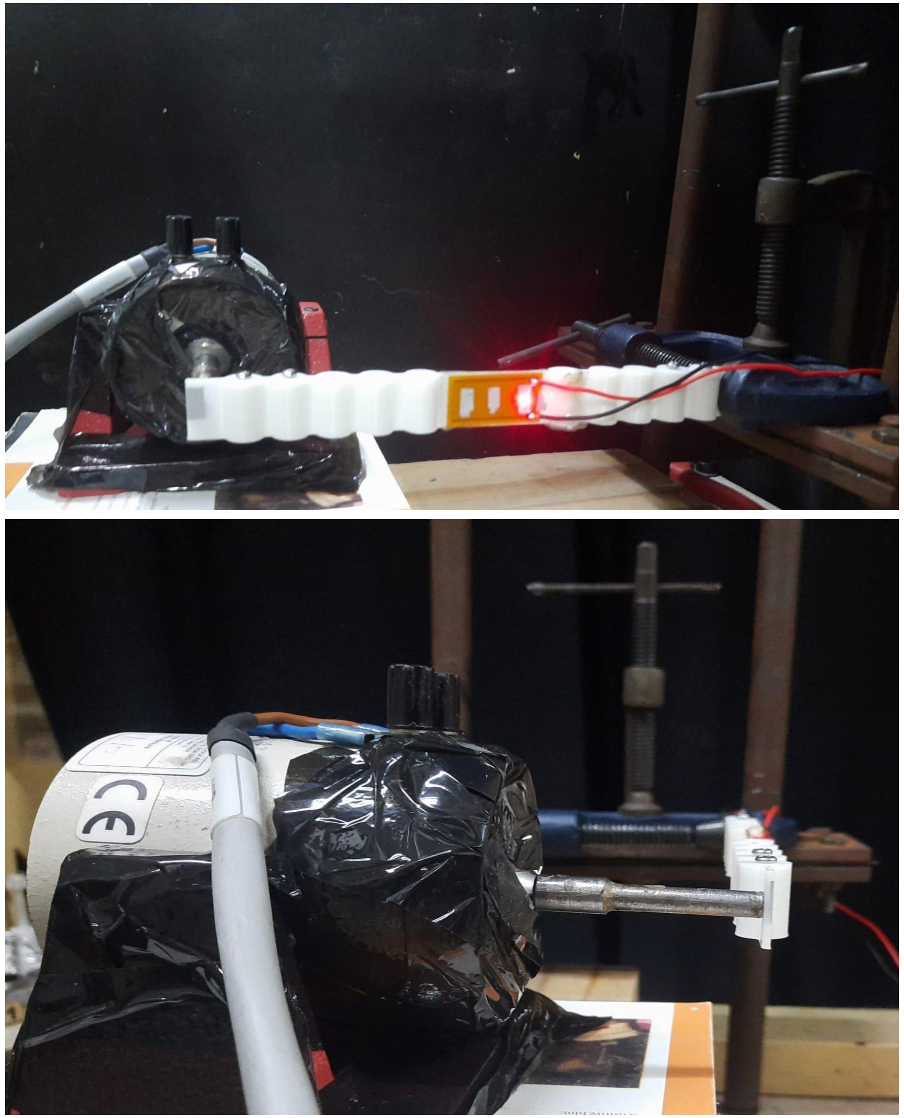


Fig: Experiment full set-up

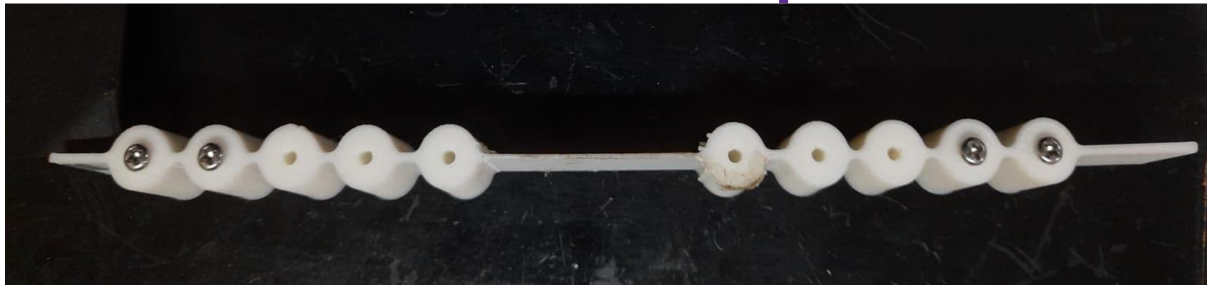


Fig: Meta-material beam

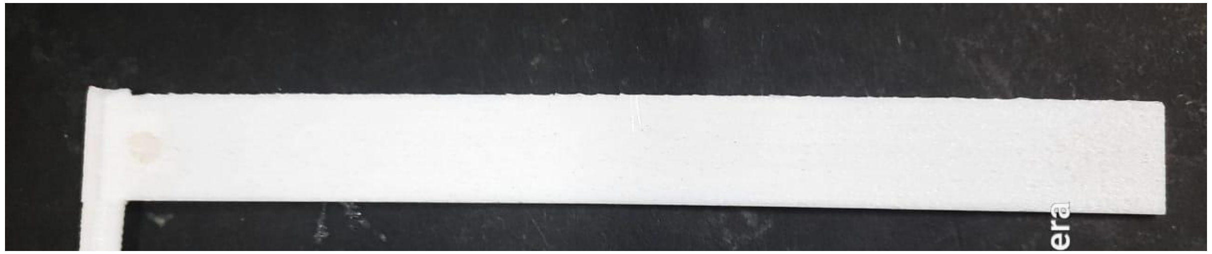


Fig: Normal beam

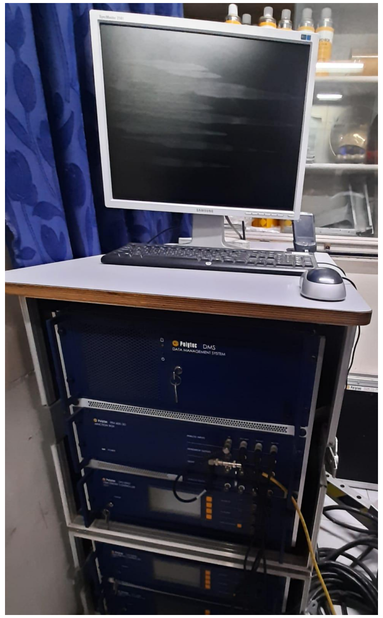


Fig: System

Fig: Clamp

Fig: Shaker

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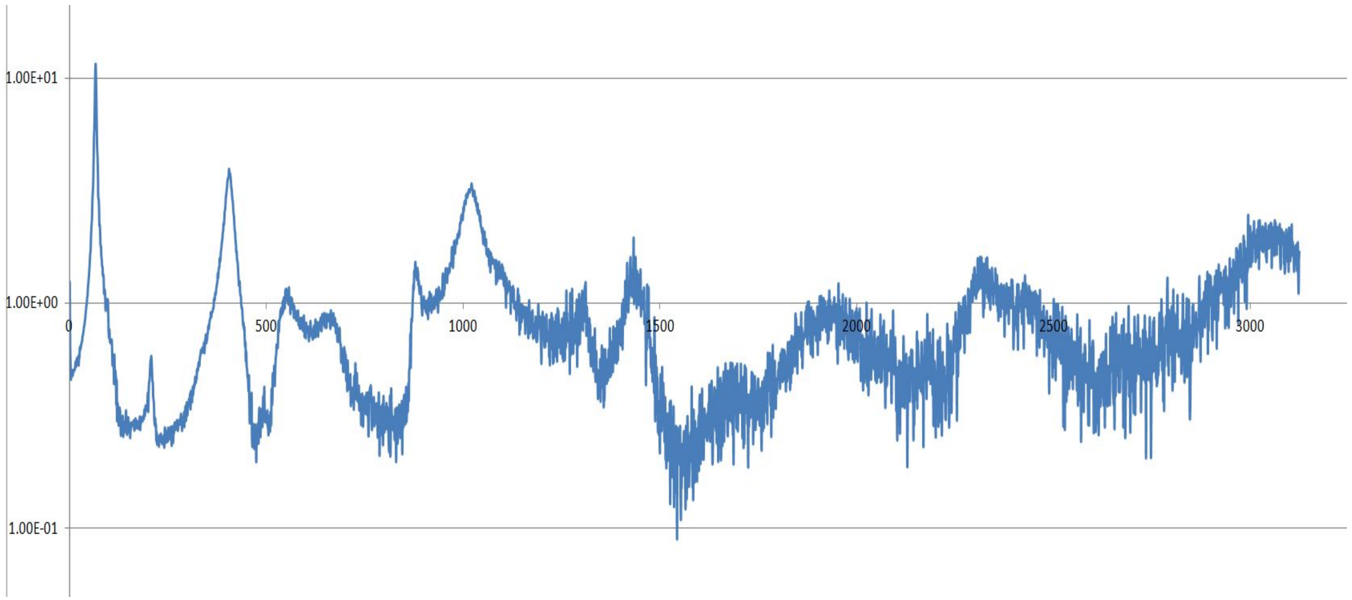
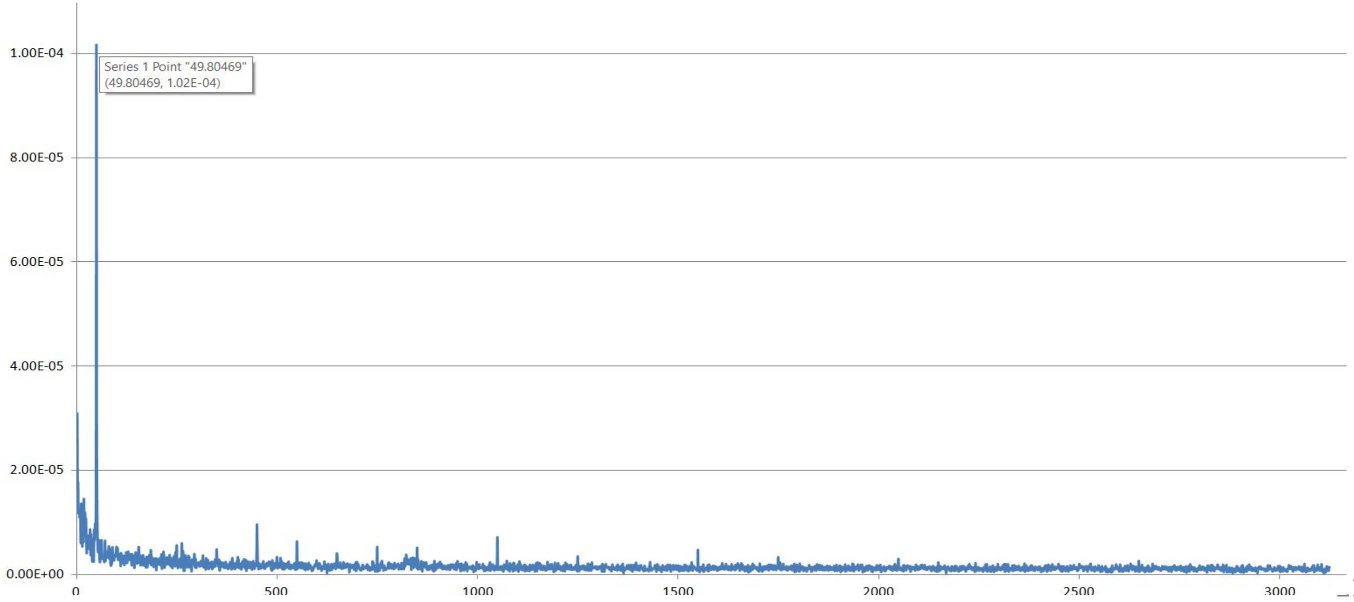
Experiment Results

NORMAL BEAM
Length: 200 mm,
Thickness: 1.8 mm

Frequency (hz)	Amplitude ratio
66.406	11.5
405.27	3.92
1021	3.38
1423	1.94

Frequency (hz)	Voltage (micro-V)	Amplitude ratio
49.805	102	1.35



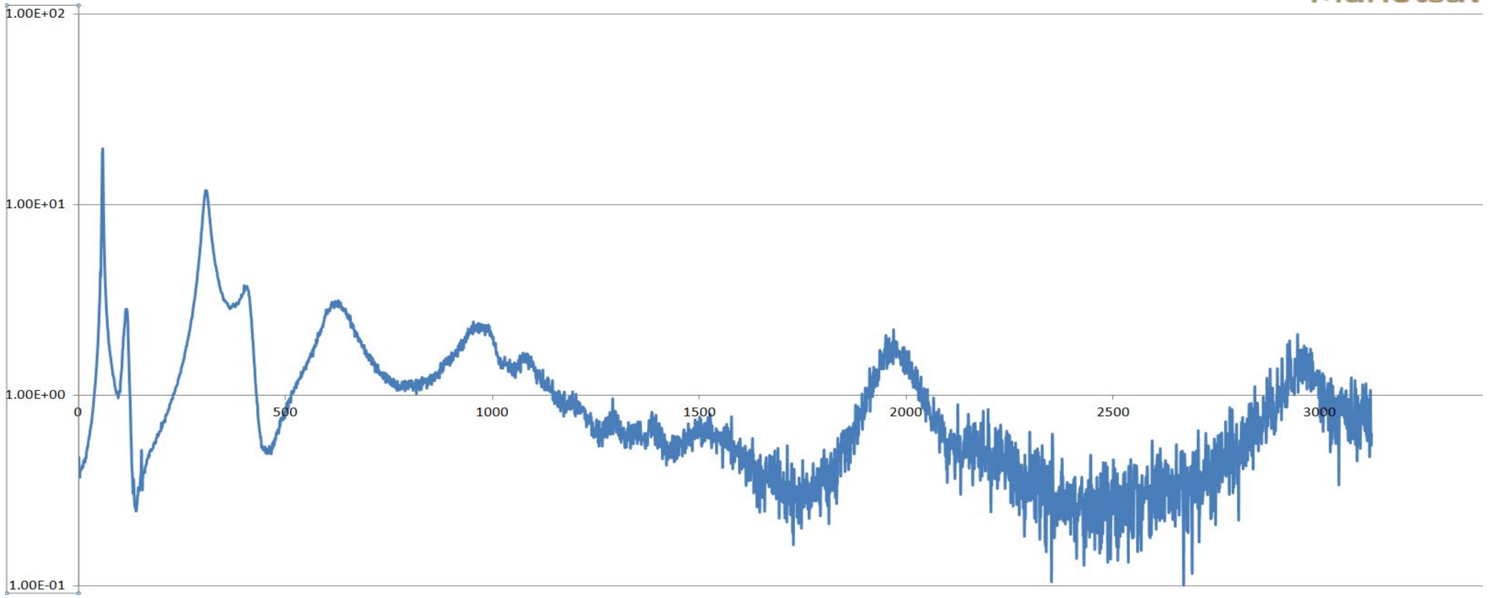


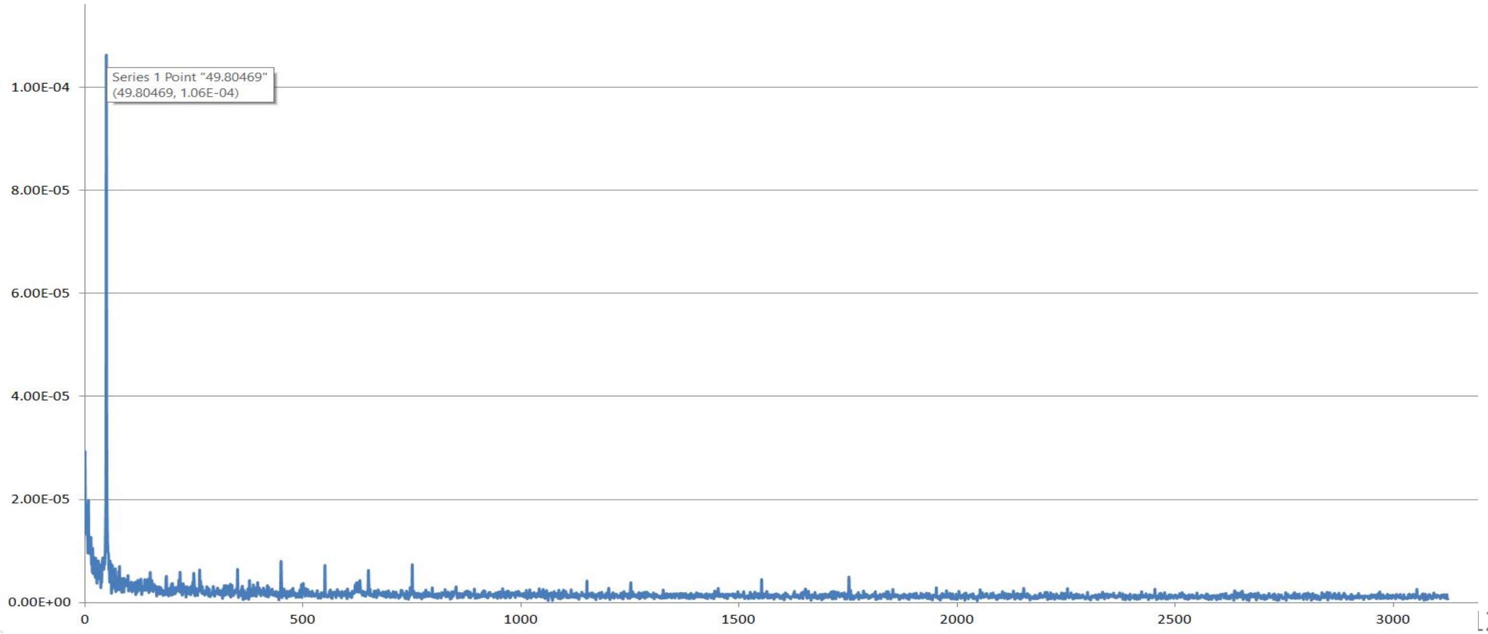
Experiment Results

META-MATERIAL BEAM
Length: 200 mm, Thickness: 1 mm

S. no.	Frequency (hz)	Amplitude ratio
1	58.6	19.7
2	116.2	2.85
3	309.6	11.9
4	400.4	3.79
5	627	3.15
6	957	2.23
7	1969	2.22
8	2964	1.64

Frequency (hz)	Voltage peak (micro-V)	Amplitude ratio
49.805	102	1.35



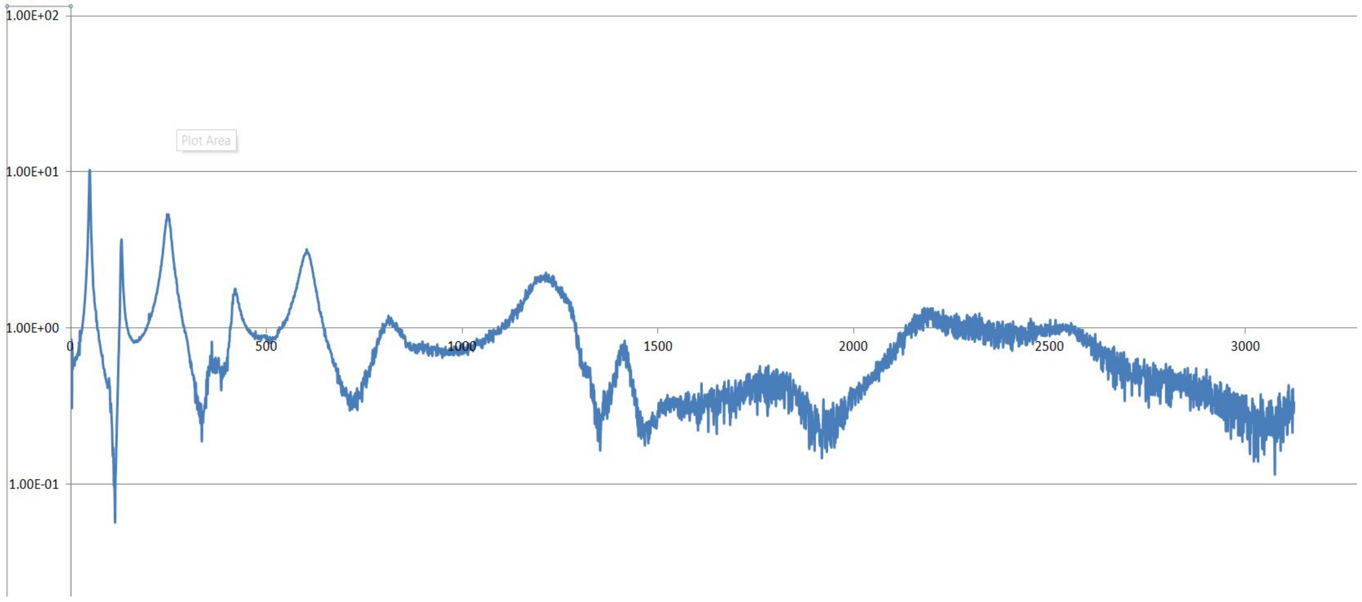


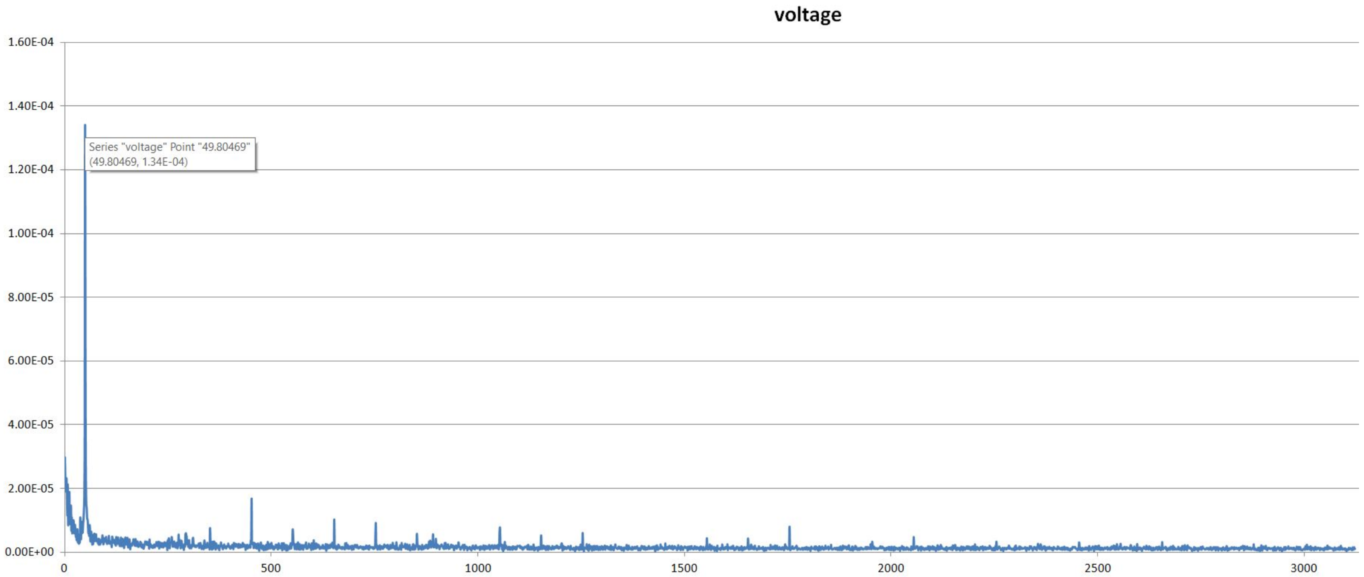
Experiment Results

META-MATERIAL BEAM
Length: 200 mm, Thickness: 2 mm

S. no.	Frequency (hz)	Amplitude ratio
1	48.8	10.3
2	127.9	3.12
3	245.1	4.87
4	417.9	1.64
5	596.7	2.96
6	810	1.11
7	1213	2.28

Frequency (hz)	Voltage peak (micro-V)	Amplitude ratio
49.805	134	10.3





Experiment Results Comparison

Beam Configuration	Thickness (mm)	Frequency (hz)	Voltage (micro-V)
Normal Beam	1.8	49.805	102
Meta-Beam	1	49.805	106
Meta-Beam	2	49.805	134

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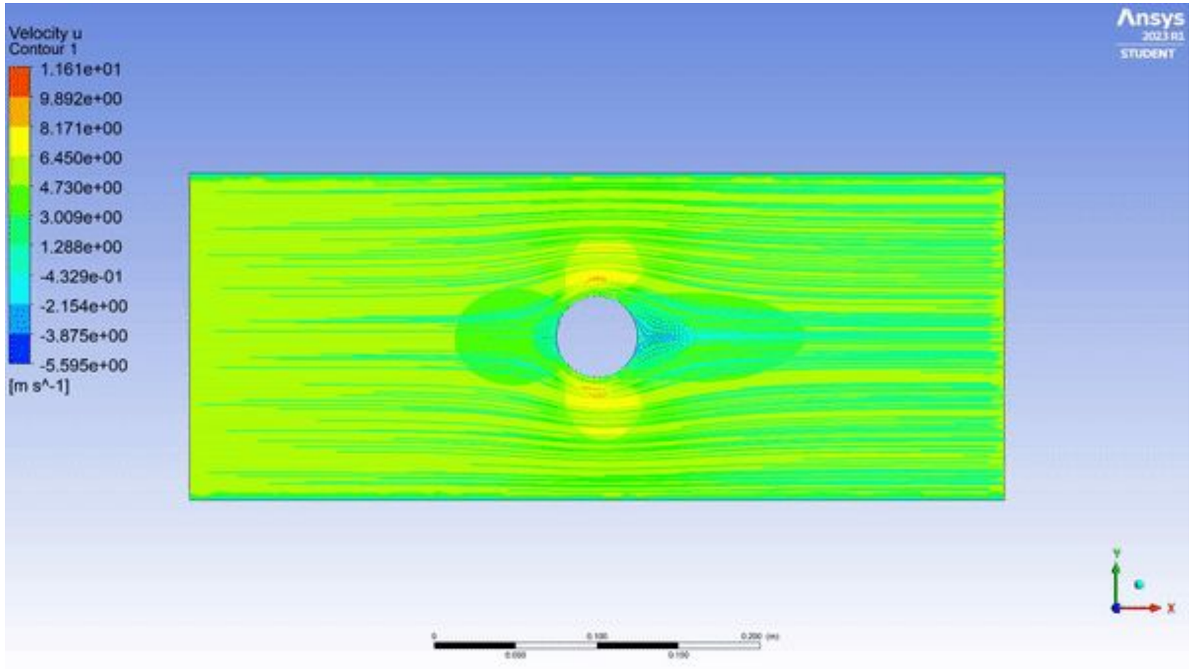
Future Goals



Ansys Fluent:

Different sizes of cylinder were simulated to determine optimum shedding frequency.

The simulation data had inconsistencies in determining shedding frequency, hence are avoided for this PPT.

Once the validation of method of finding shedding frequency is done, all the stored data can be used to get shedding frequency.

References

1. Park, H. W., Seung, H. M., Choi, W., Kim, M., & Oh, J. H. (2022). Highly tunable low frequency metamaterial cavity for vibration localization. Scientific Reports, 12(1), 1–11. https://doi.org/10.1038/s41598-022-13453-1
2. Mehdipour, I., Madaro, F., Rizzi, F., & De Vittorio, M. (2022). Comprehensive experimental study on bluff body shapes for vortex-induced vibration piezoelectric energy harvesting mechanisms. Energy Conversion and Management: X, 13. https://doi.org/10.1016/j.ecmx.2021.100174
3. Wang, J., Sun, S., Tang, L., Hu, G., & Liang, J. (2021). On the use of metasurface for Vortex-Induced vibration suppression or energy harvesting. In Energy Conversion and Management (Vol. 235). https://doi.org/10.1016/j.enconman.2021.113991
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5. Wang, J., Sun, S., Tang, L., Hu, G., & Liang, J. (2021). On the use of metasurface for Vortex-Induced vibration suppression or energy harvesting. In Energy Conversion and Management (Vol. 235). https://doi.org/10.1016/j.enconman.2021.113991

Thank You!

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Azadi Ka Amrit Mahotsav

Prof. Bishakh Bhattacharya
bishakh@iitk.ac.in