MA_P_45

Design and Analysis of Broadband Vibrational Energy Harvester Based on Switchable Dynamical System Using Electropermanent Magnet

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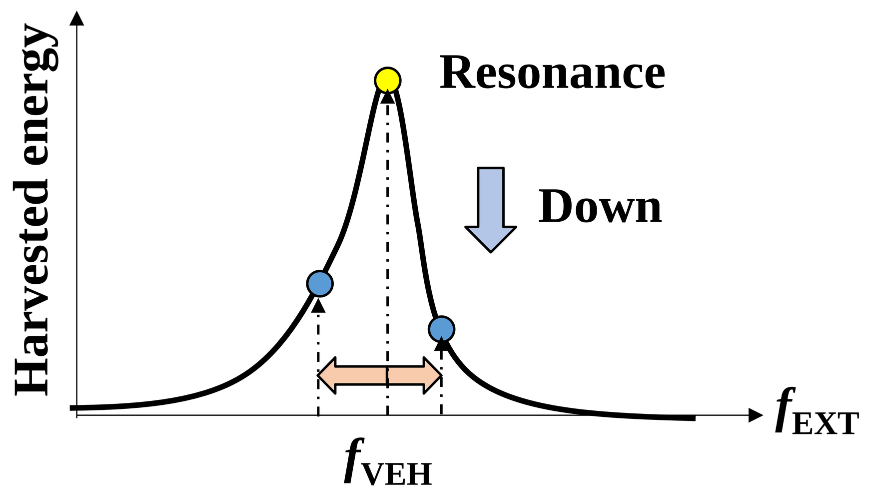
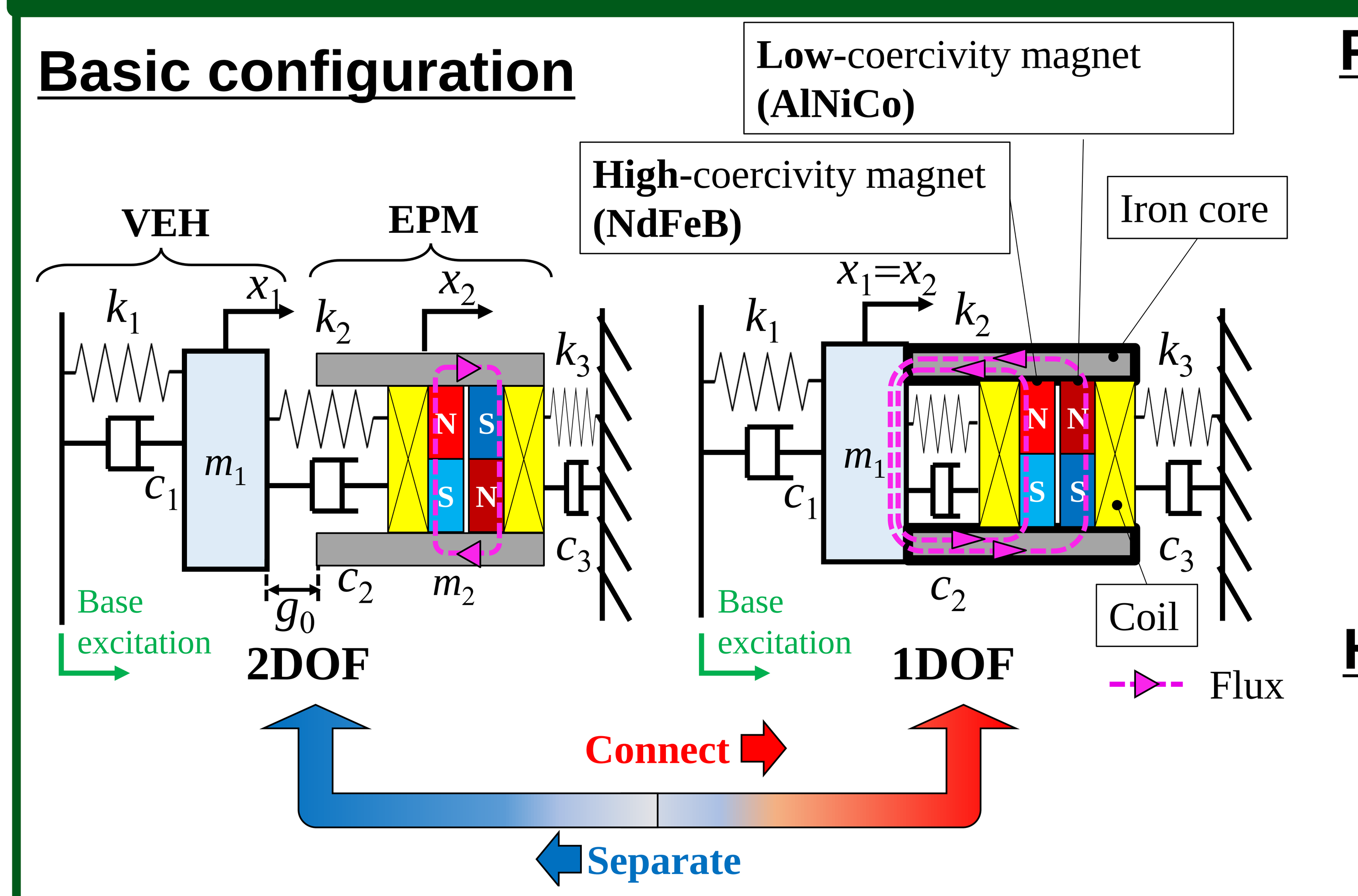
Introduction

- <u>Vibrational energy harvesting</u> converts kinetic energy in ambient vibration into electrical energy, and is gaining attention for application in <u>self-powered IoT device</u>.
- A vibrational energy harvester (VEH) generally maximizes the amount of harvestable power by matching f_{EXT} with f_{VEH}
- This paper proposes a new broadband VEH based on switchable dynamical systems using an <u>electropermanent magnet (EPM).</u>
- The proposed VEH actively switches its DOF (2- and 1-DOF) by connecting and releasing the EPM. The connection and separation of the EPM are actively controlled by applying a short-time pulsed current to a coil of the EPM.



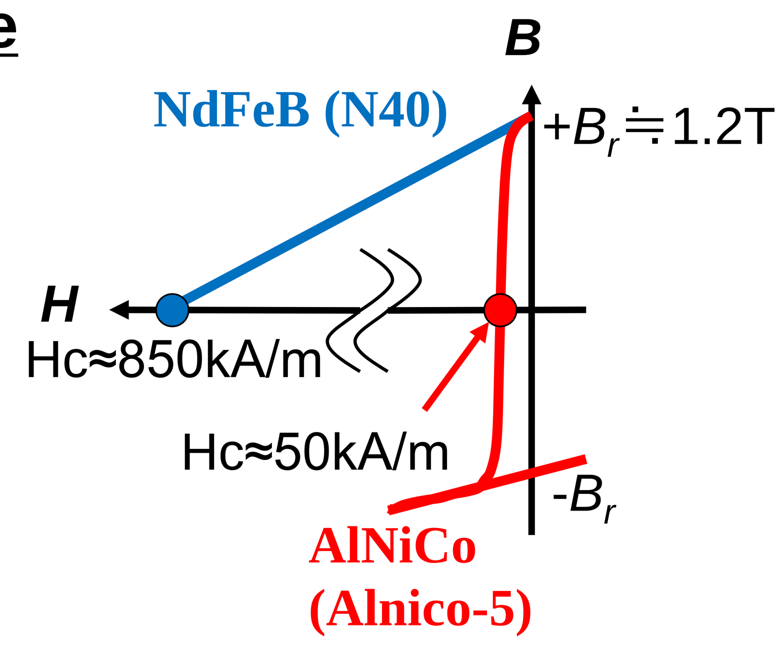
Broadband Vibrational Energy Harvester Using Electropermanent Magnet (EPM)

Basic configuration

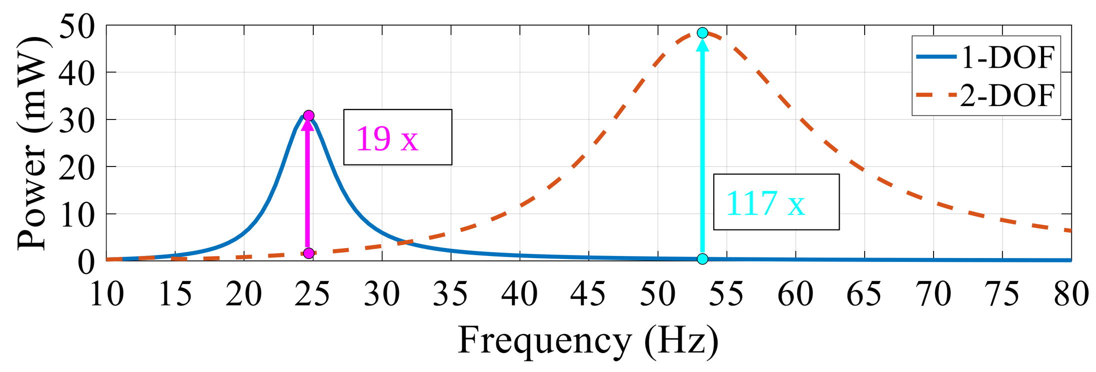


- The EPM utilizes both low- and high-coercivity magnets. The low-coercivity magnet is easily reversed by the short-time pulsed current.
- The EPM is the most suitable electromagnetic switching device because it does not consume stationary electrical power for maintaining the connection, compared to general electromagnets.
- The slight power is consumed only when electromagnetic attractive force of the EPM is turned on/off.

Principle

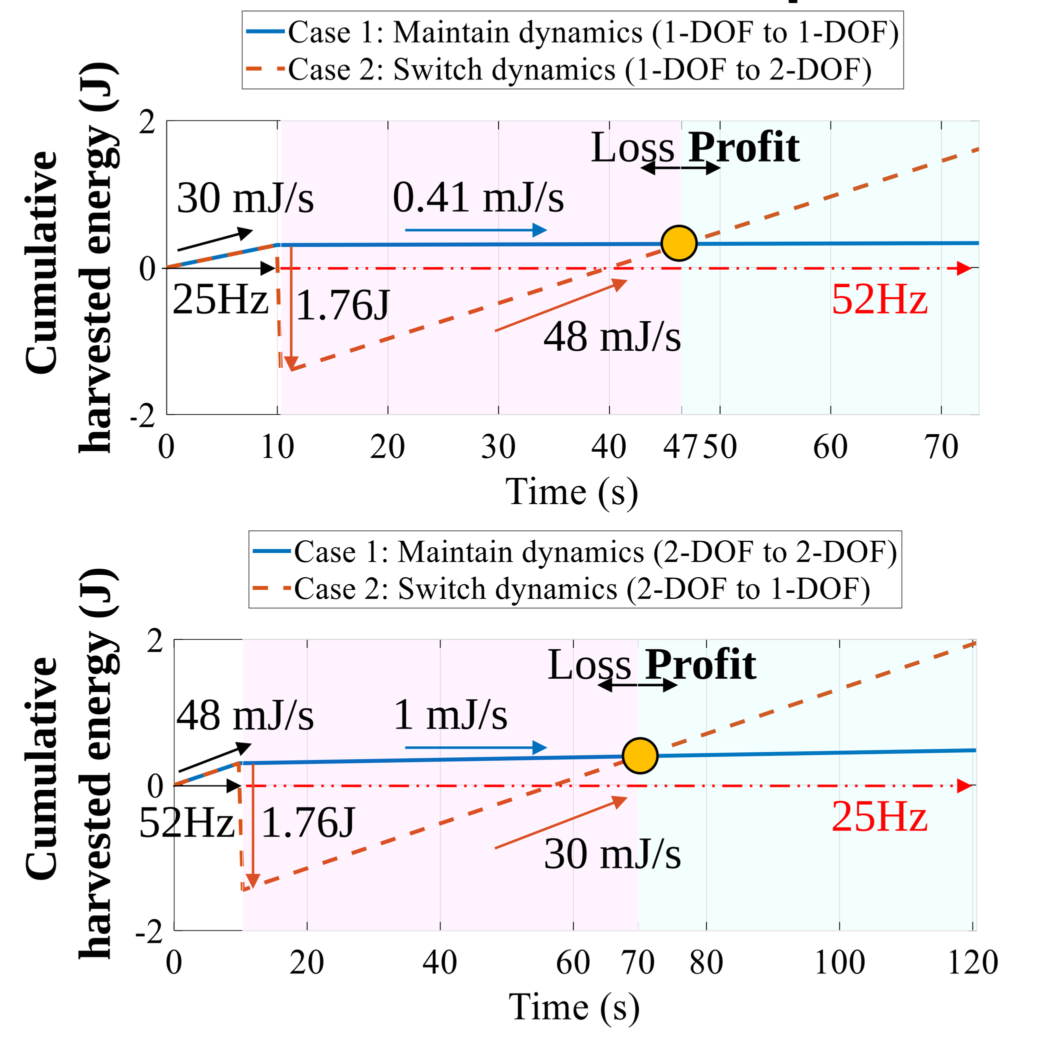


Harvesting performance



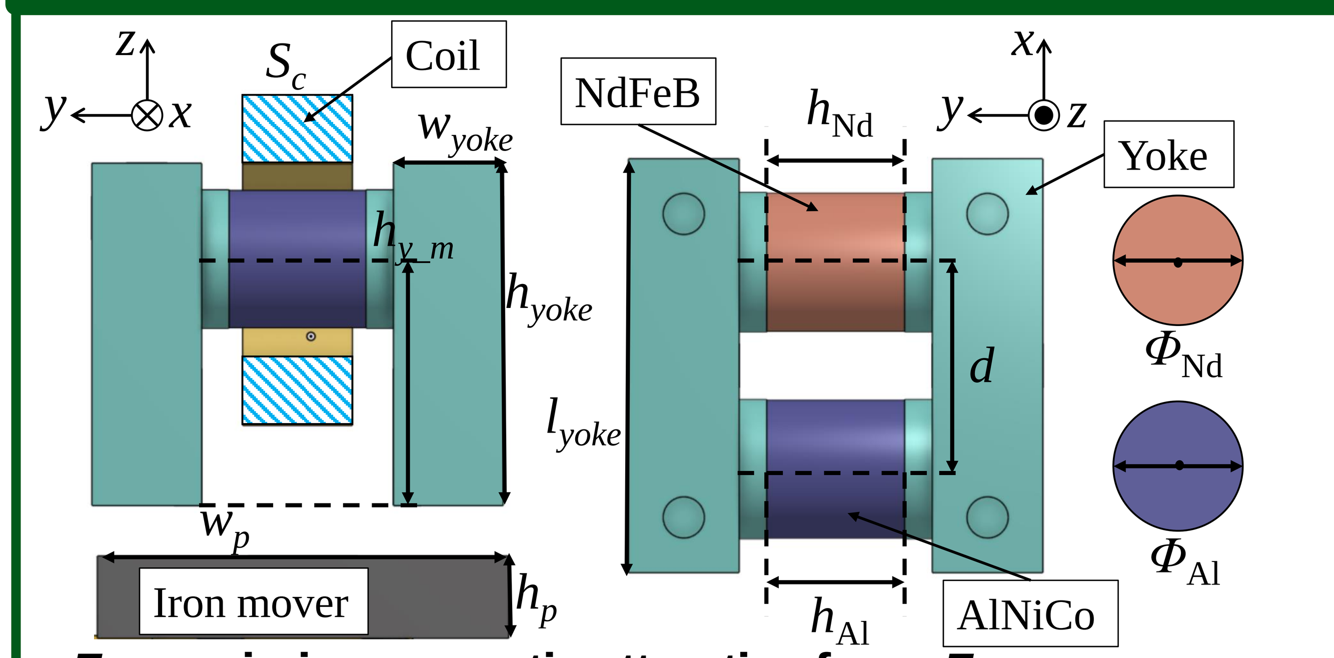
- This result indicates that the proposed VEH is able to harvest the vibrational energy in a wider frequency range, compared to a conventional 1-DOF VEH.

Time to reach breakeven point

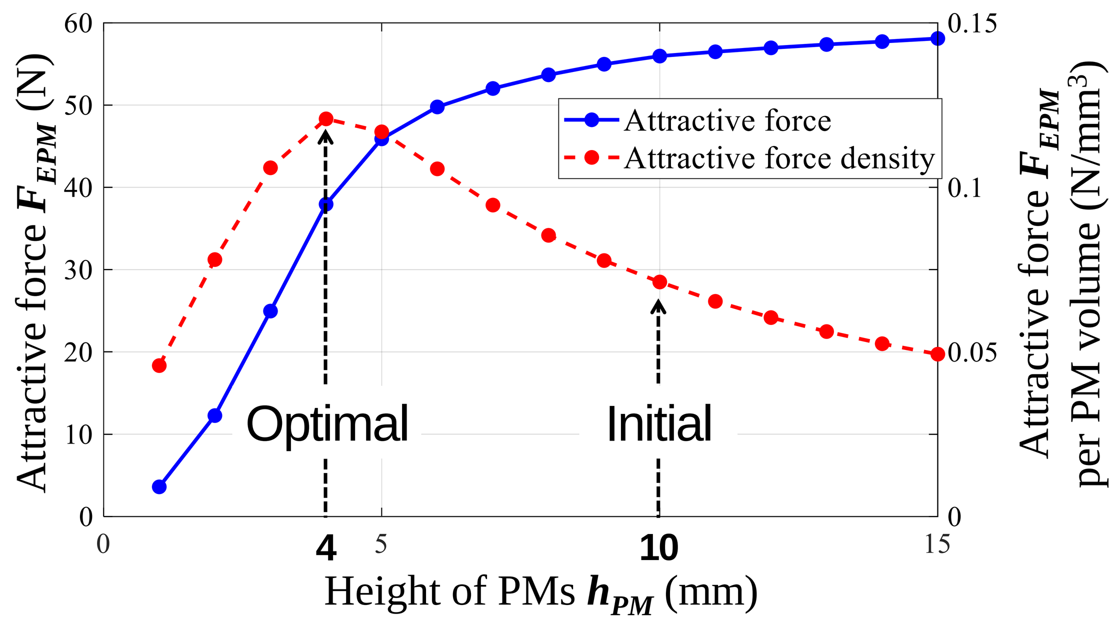


- DOF switching of the VEH is profitable even if the cumulative energy is consumed by applying pulsed current to the coil of the EPM

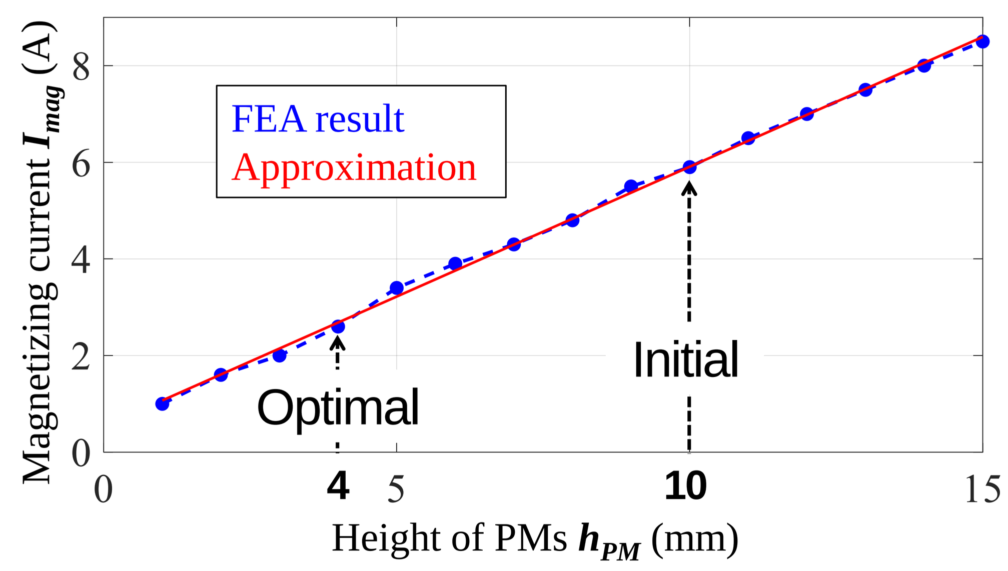
Parametric Optimization of EPM for Efficient Dynamical System Switching



F_1: maximize magnetic attractive force F_{EPM}
F_2: minimize magnetizing current I_{mag}
subject to S_c = const.



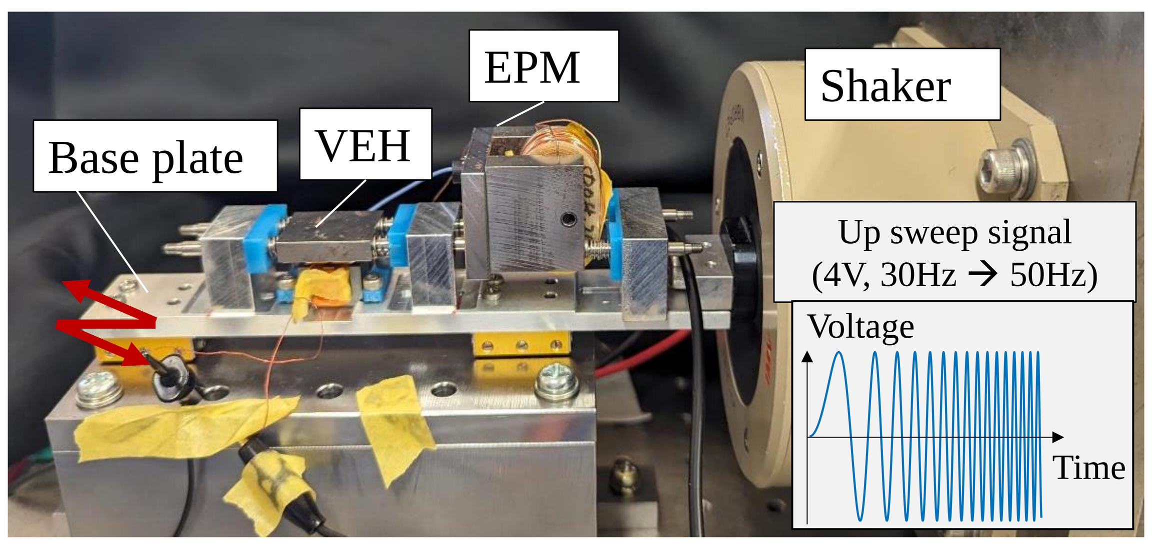
F_{EPM}: 56N → 38N (32% DOWN)
F_{EPM} per volume: 0.07N/mm³ → 0.12N/mm³ (70% UP)



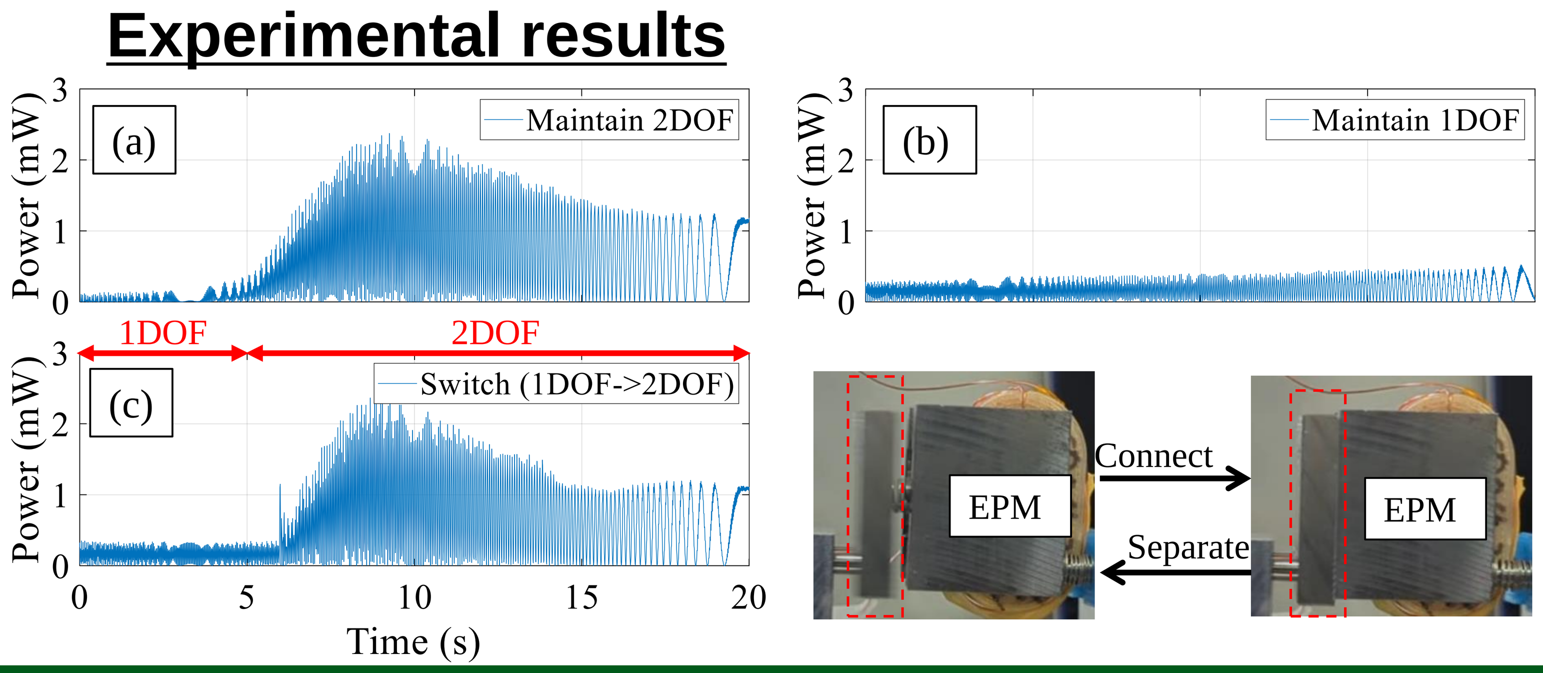
I_{mag}: 5.9A → 2.6A (56% DOWN)
Joule loss RI_{mag}^2 : 1.76 J → 0.35 J (80% DOWN)

Experimental Verification of Broadband Energy Harvesting

Experimental setup



Experimental results



Cumulative harvested energy (0s → 20s)

- ☐ Maintain 1 DOF: 5.2 mJ
- ☐ Maintain 2 DOF: 12.0 mJ
- ☐ Switching (1→2 DOF): 12.7 mJ

→ Further parameter tuning (mass *m* and *spring stiffness k*) will improve the broadband harvesting performance

Conclusion

- This paper proposed a new broadband VEH using an electropermanent magnet (EPM).
- Parameter optimization using 3-D FEA was carried out to decrease Joule loss during switching the DOF of the proposed VEH.
- The effectiveness of our VEH was verified through numerical simulation and experiment using a prototype.