Doubly Bistable Cantilever with Magnetic Tunability for Energy Harvesting

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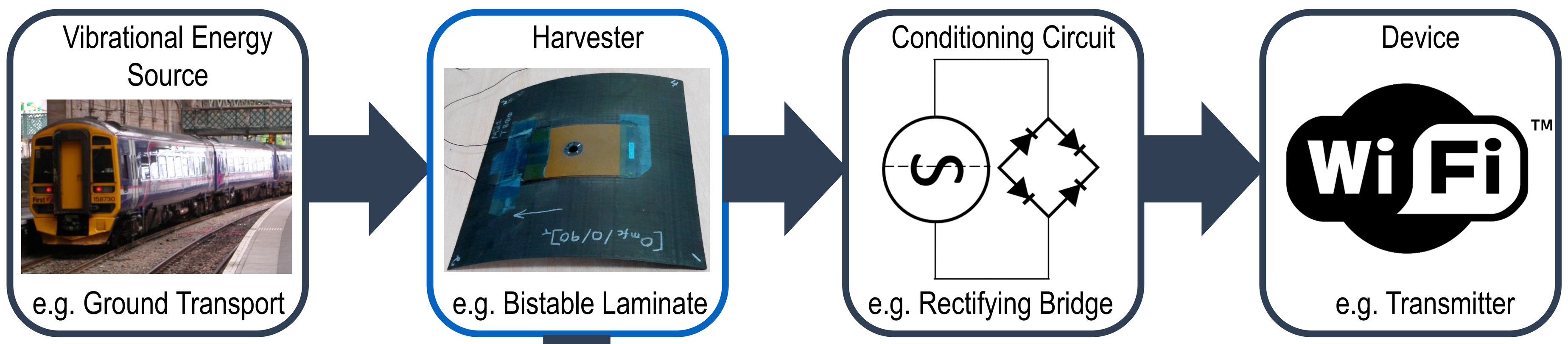
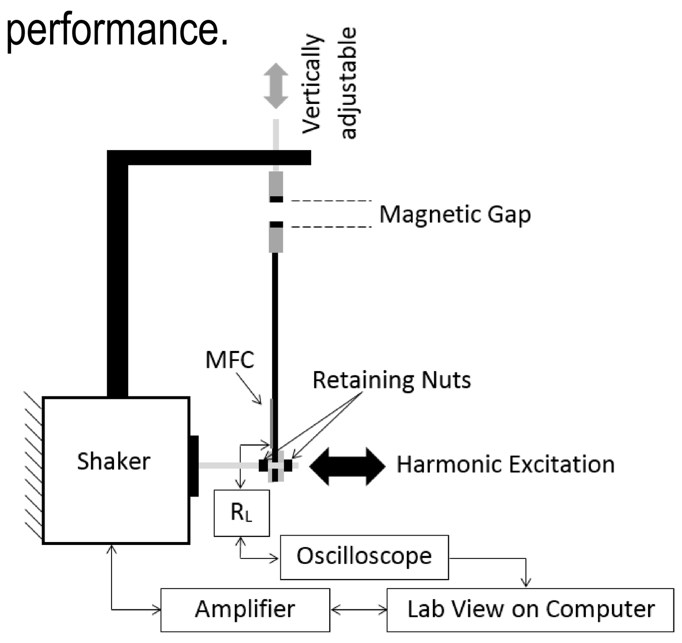
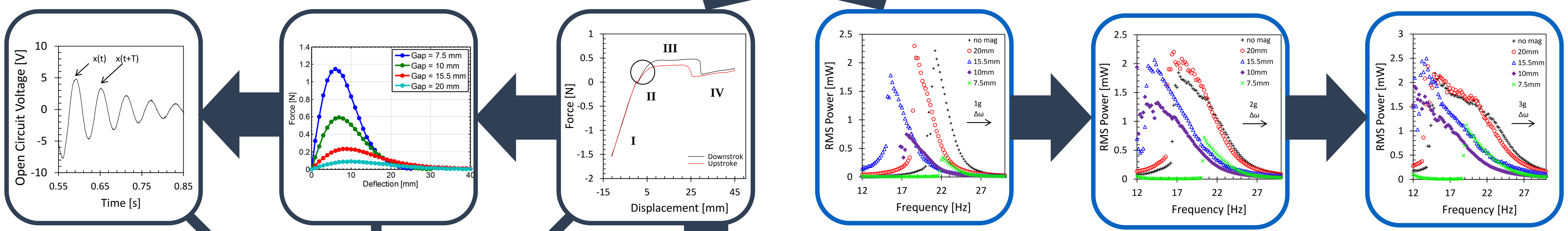
Vibrational energy harvesters with nonlinear response characteristics can mitigate the inherent narrowband harvesting limitation of linear harvesters. One such system is a bistable energy harvester using piezoelectric transduction.



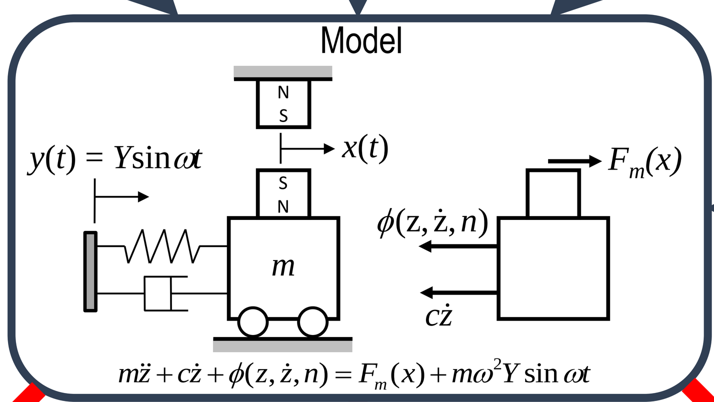
The strain energy landscape of a bistable system is a dual potential well where the two minima correspond to the two stable states, and the local maximum is the activation energy required to trigger a snap-through transition from one state to the other. It is shown that by reducing the height of the separation maximum and tailoring the geometry of the wells using magnetic interactions that the performance of the harvester can be improved in terms of peak power and broad bandedness.

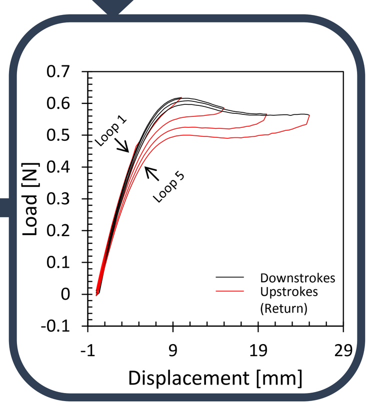
Magnets are used in repulsion at several gap distances from the cantilever tip in the experimental test rig as shown. Frequency sweeps are done at controlled g levels as shown, and the RMS power is used to evaluate the harvester's performance.





The system is modelled as a single degree of freedom in rectilinear coordinates experiencing base excitation as shown. The damping ratio c, nonlinear restoring function φ and F_m were all measured experimentally.

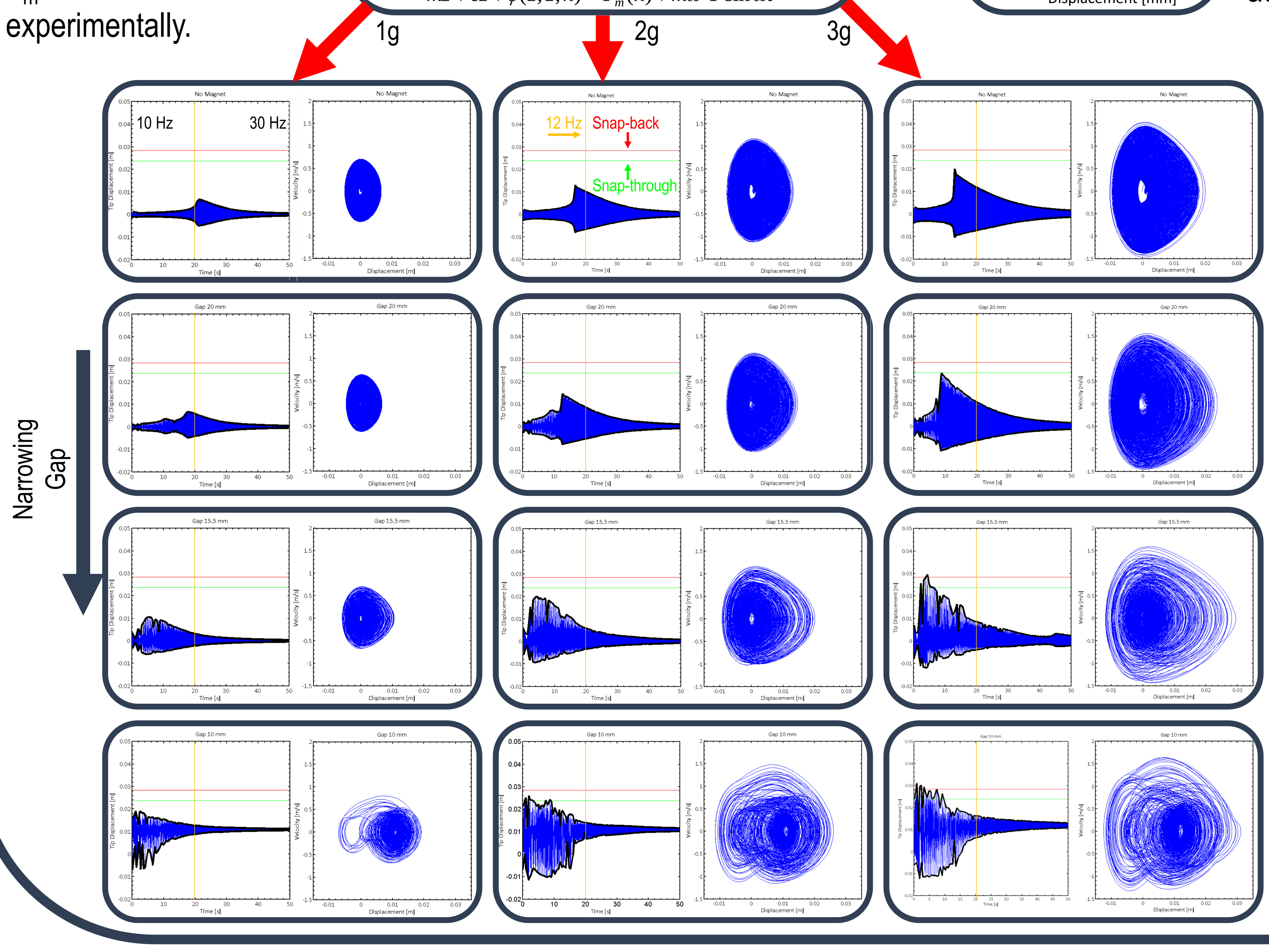




The model was able to predict the natural frequency of the harvester with adequate precision. Softening resulting from high forcing levels, and magnetic proximity was successfully observed. The onset of snap-through was predicted with reasonable accuracy.

Separation [mm]	Max power at 1g and bandwidth		Max power at 2g and bandwidth		Max power at 3g and bandwidth	
no magnet	2.21 [mW]	1.6 Hz	1.84 [mW]	5.4 Hz	2.19 [mW]	8.2 Hz
20	(+3.73%)	2 Hz	(+19.58%)	4.8 Hz	(+6.59%)	8 Hz
15.5	(-19.54%)	2.2 Hz	(+12.17%)	4 Hz	(+14.08%)	4 Hz
10	(-66.27%)	2.4 Hz	(+5.32%)	5.2 Hz	(+19.07%)	5.2 Hz
7.5	(-84.32%)	1.2 Hz	(-60.87%)	2 Hz	(-49.03%)	2.6 Hz

Separation [mm]	Max power at 1g an bandwidth		Max power at 2g and bandwidth		Max power at 3g and bandwidth	
no magnet	2.44 [mW]	2 Hz	1.95 [mW]	6.6 Hz	2.2 [mW]	8.4 Hz
20	(-7.78%)	2.4 Hz	(+13.87%)	5.2 Hz	(+3.25%)	8.6 Hz
15.5	(-22.19%)	3.4 Hz	(+8.78%)	5.4 Hz	(+11.00%)	5.8 Hz
10	(-69.19%)	2.6 Hz	(-7.29%)	5 Hz	(+105.14%)	5.6 Hz
7.5	(-85.11%)	1.6 Hz	(-63.38%)	2.6 Hz	(-47.94%)	3.6 Hz



Conclusions:

1. Natural Frequency is tunable
2. Power in increased with minimal cost of broad bandedness
3. Broad Bandedness can be increased by reducing peak power
4. Higher forcing levels call for narrower magnetic gaps

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