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Auxetic Strain Amplification For Enhanced Energy Harvesting Power

William J. G. Ferguson*, Qiang Li, Yang Kuang, Meiling Zhu

* H020.2, Harrison Building, North Park Road, Exeter, EX4 4QF

Abstract: By utilising an auxetic substrate in a PZT piezoelectric vibration energy harvester, we aim to increase the obtained power output. Finite Element simulations are used to optimize the design.

Introduction

Low frequency (2–10 Hz) vibrations can be harvested with a thin sheet of piezoelectric material (PZT-5A) fixed to the host surface in the supports of an aircraft's wing, or similar[1]. Strain from a longer area is concentrated into the PZT using a substrate suspended over the host. Further increases can be obtained by stretching the PZT laterally as it is pulled axially. This is possible with a partially auxetic (i.e. negative Poisson's ratio) substrate[2]. We have used COMSOL Multiphyics® to optimize the design. We have selected a re-entrant honeycomb array as the best structure for the auxetic region.

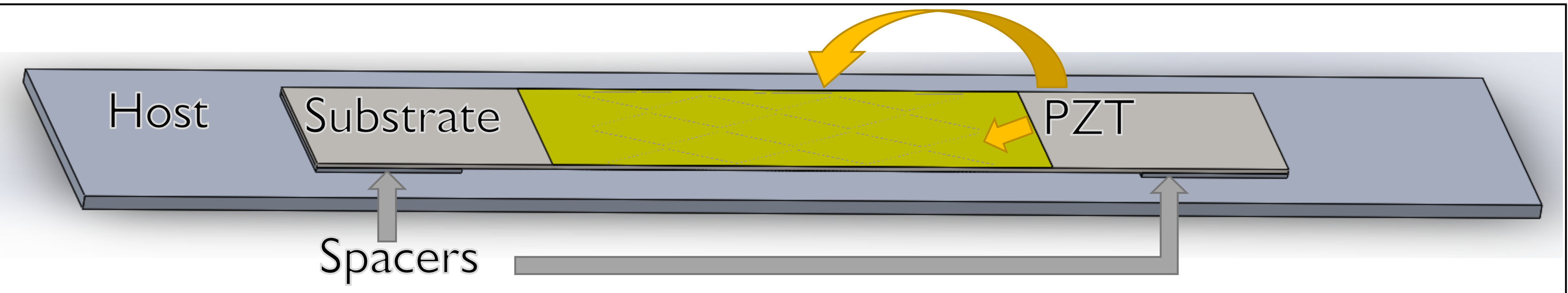

Fig 1: Substrate suspended over host on spacers; second layer of PZT on the substrate underside as indicated.

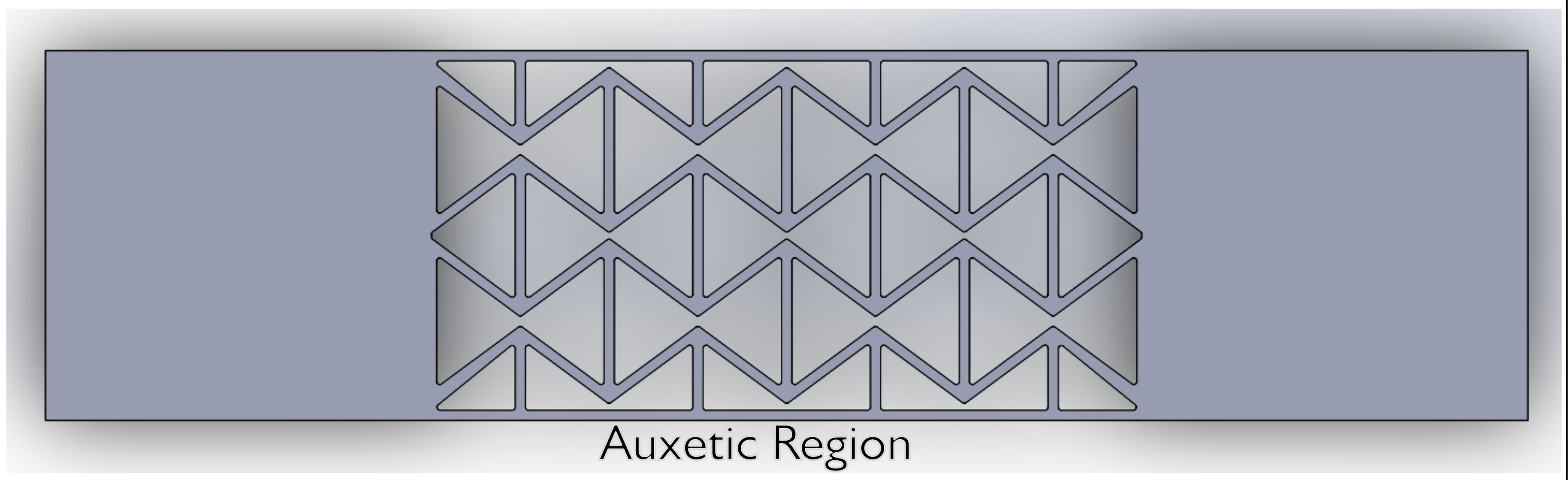

Fig 2: Re-Entrant Honeycomb auxetic substrate: 144.8×36.2×1 mm

Results

Simulated power output: **2.0 mW** under 10 Hz, 100 $\mu\varepsilon$ peak-to-peak tensional vibrations applied axially.
This is **2.15** times that of the equivalent plain substrate (without auxetic region) under identical conditions.

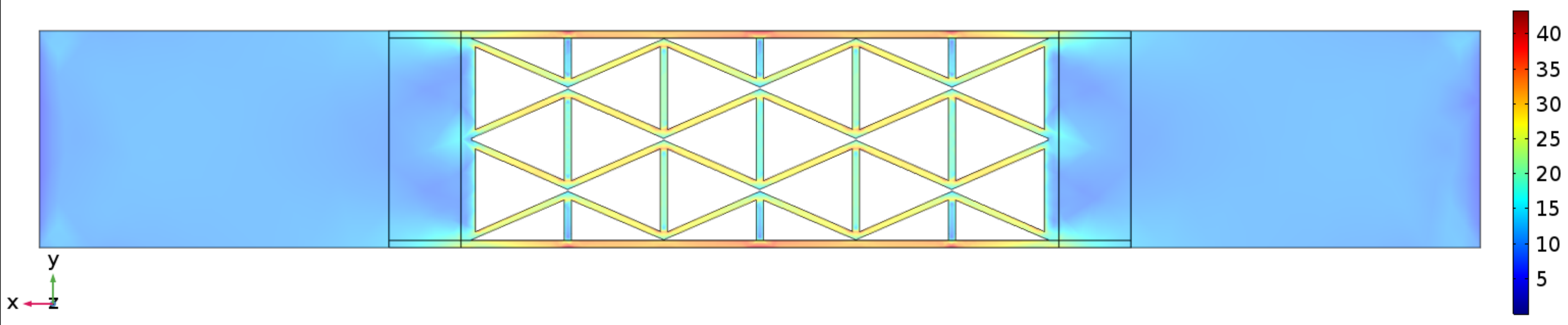

Fig 3: Substrate stress under tension in false colour; 0-40 MPa

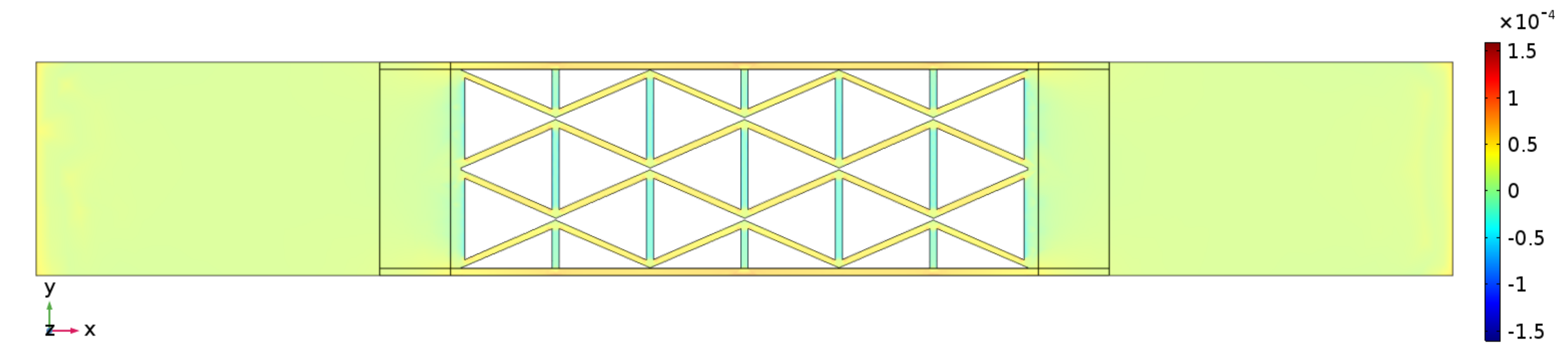

Fig 4: Substrate strain under tension in false colour; ±150 με

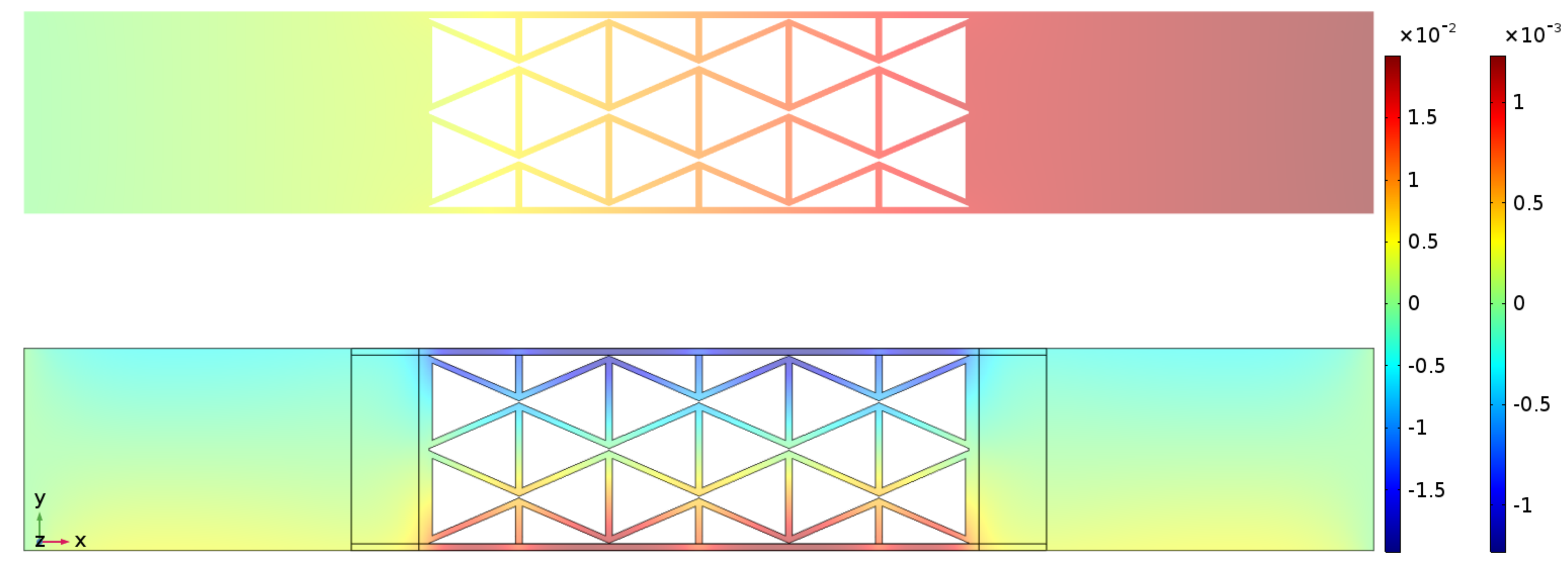

Fig 5: Substrate displacement fields under tension in X (top, left scale: ±15 mm, applied directly) & Y (lower, right scale: ±1 mm, induced) in false colour.

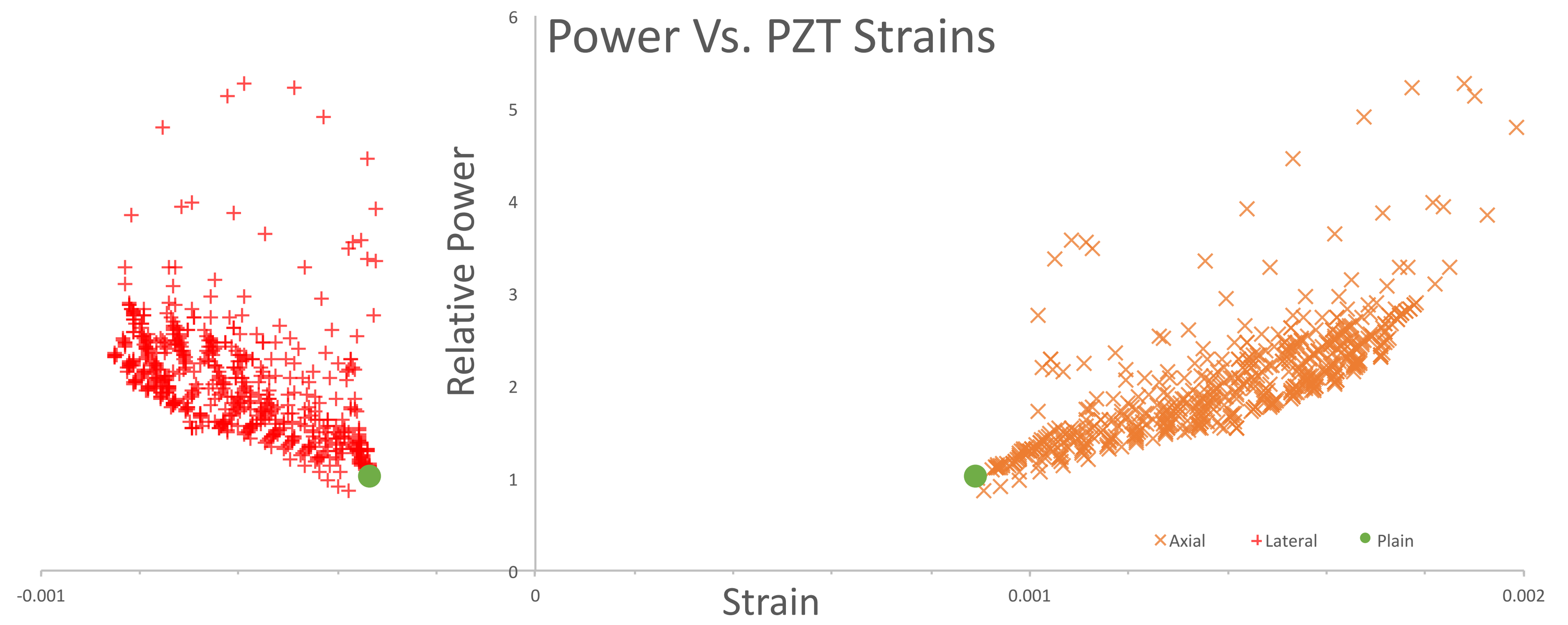

Fig 6: Relative power output from axial & lateral strains in PZT layers, independently show rising power from amplified strain. The gain in axial strain shows the presence of an auxetic region itself concentrates strain.

Discussion

The greatest challenge with this design is to amplify the strain, without exceeding the constraints of the material. PZT is brittle, having a tensile strength as low as 35 MPa. This limits the strain that can safely be externally applied to the substrate to around 100 $\mu\varepsilon$.

Future Work

The next stage will be to build prototypes of this and the plain designs to compare their real outputs. This harvested energy could one day be used for a distributed sensor network for structural health monitoring.

References

[1] Y. Shi, S. R. Hallett, M. Zhu (2016) '*Energy Harvesting behaviour for Aircraft Composites Structures using Macro-Fibre Composite*', Composite Structures
[2] K. Saxena, R. Das, E. P. Calius (2016) '*Three Decades of Auxetics Research: Materials with Negative Poisson's Ratio: Review*' Advanced Engineering Materials

wf234@exeter.ac.uk
ex.ac.uk/wf234
www.exeter.ac.uk/metamaterials

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