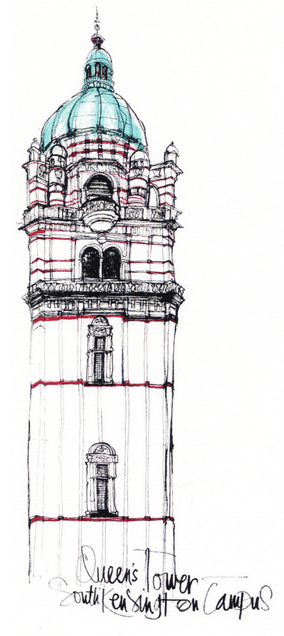
Imperial College London

# MINIATURE WIND ENERGY HARVESTER BASED ON FLOW-INDUCED VIBRATION



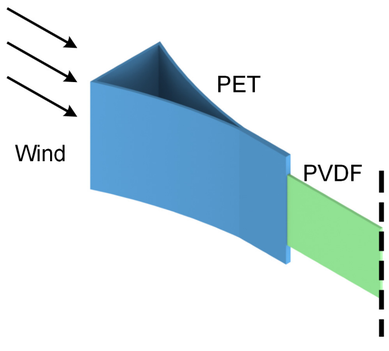

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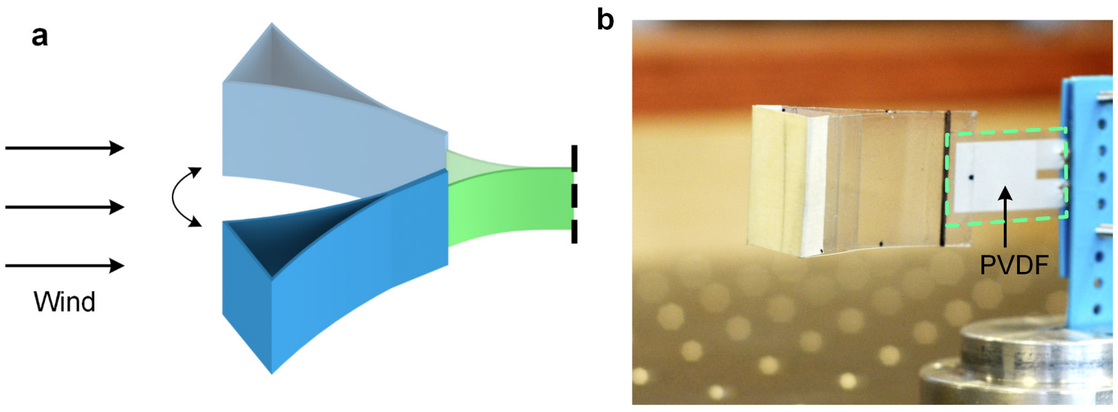


## ABSTRACT




This work demonstrates an experimental study of **wideband wind energy harvesting by self-sustained flow induced vibration**. We fabricated a novel folded structure using PET film as a bluffbody, which was directly mounted on a piezoelectric film to generate vibration in wind flow. The lock-in of the flow-induced vibration of the flutter was observed in our work. The vibration frequency of this device was locked at **10.8 Hz**, which was its natural frequency, across a wide wind speed range **from 5.8 m/s to 12.2 m/s**. The continuous resonance gives this device stable output in this wide range of wind speed. Just using a small piezoelectric PVDF film of 3 $cm^2$, the peak power output of our device can achieve **3.16 μW** and keep at a high level once the self-sustained flow induced vibration occurs.

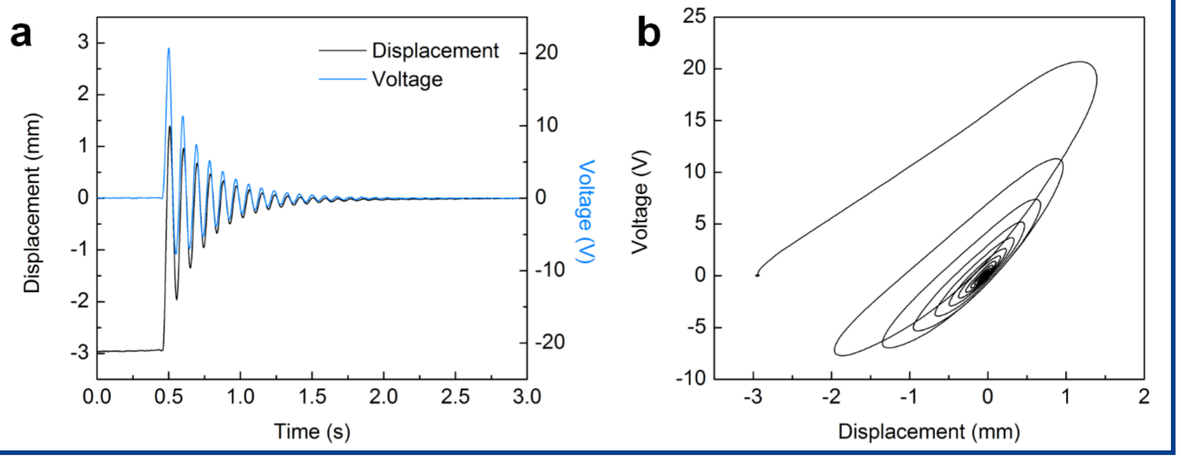

## WORKING PRINCIPLE



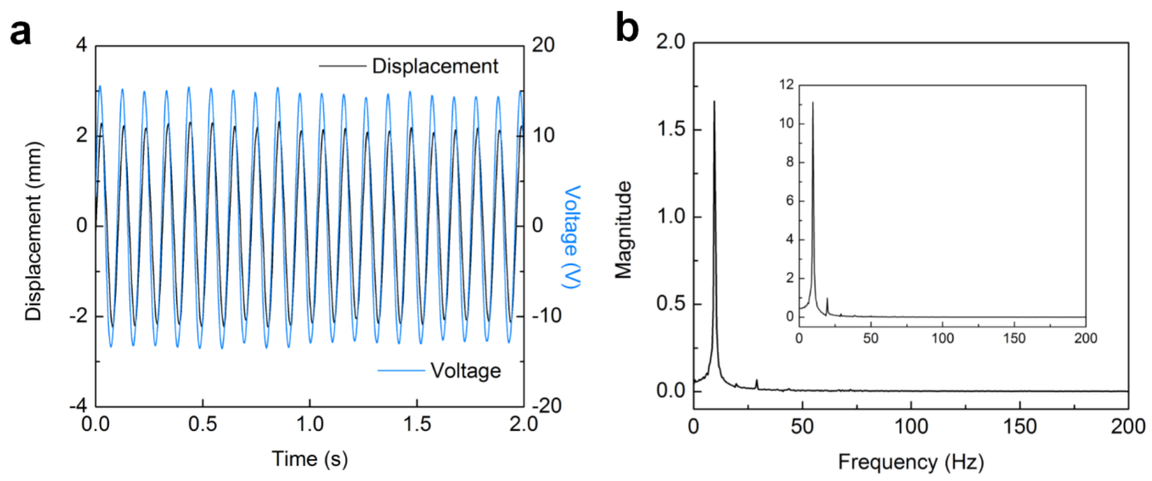

Flow-induced vibration has been used to harvest the wind energy based on both vortex-induced vibration and galloping. Compared with vortex-induced vibration, the vibration induced by galloping has lower vibration frequency and larger vibration amplitude. Here, we fabricated a miniature energy harvester based on galloping in the wind. The triangular prism-shaped bluffbody causes significant galloping and the PVDF piezoelectric film converts energy of mechanical vibration into electric energy.

## MEASUREMENT OF NATURAL FREQUENCY

Based on the principle of galloping, the vibration frequency will be locked at the natural frequency when self-sustained vibration is observed. Therefore, the natural frequency is of great importance for galloping-based energy harvester. We measured the natural frequency of the flutter by analysing the properties of the free vibration. The natural frequency is 10.8 Hz as shown blow.



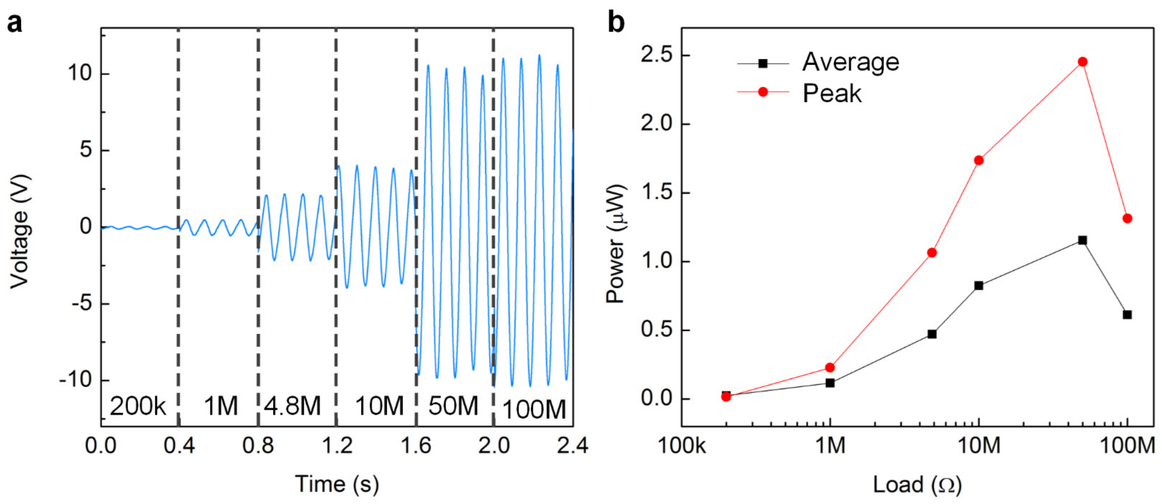

## TYPICAL OUTPUT AND FREQUENCY DOMAIN ANALYSIS




Figures above demonstrate the typical self-sustained galloping and the output of the PVDF film in the wind of 7 m/s with a 100 MΩ load resistor. The frequency domain analyses of the displacement and voltage (insert) show the vibration is locked at the natural frequency of the flutter. Both show a peak at 10 Hz.

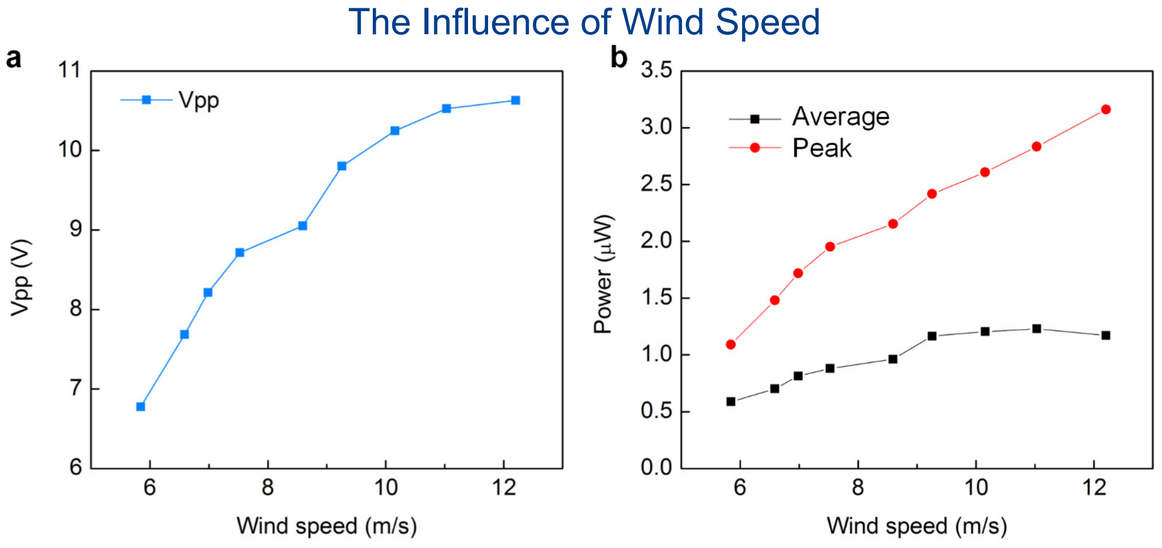
## PERFORMANCE OF MINIATURE WIND ENERGY HARVESTER

### Load Characteristic




The performance with different load resistance was measured at a wind speed of 7 m/s. With the increase of load resistance the output voltage increased up to 10 V. The output power reached the peak of 2.45 μW with a load of 50 MΩ.

### The Influence of Wind Speed




The relationship of the output and the wind speed is shown above. Load resistance was fixed at 10 MΩ. With the increase of wind speed, the peak-peak voltage increased to 10.6 V at 12.2 m/s from 6.8 V at 5.8 m/s, and peak power increased to 3.16 μW. The maximum average power is 1.23 μW at 11 m/s instead of 12.2 m/s. This may be caused by the relatively unsteady vibration at a large wind speed.

## FUTURE WORK

1. Adjust the geometry of energy harvesters to optimize output characteristics
2. AC-DC rectifiers and power management circuit
3. Applications to energize low-power sensors and other devices

## REFERENCES


1. S. Li, J. Yuan, and H. Lipson, “Ambient wind energy harvesting using cross-flow fluttering,” *J. Appl. Phys.*, vol. 109, no. 2, pp. 1–4, 2011.
2. S. Orrego *et al.*, “Harvesting ambient wind energy with an inverted piezoelectric flag,” *Appl. Energy*, vol. 194, pp. 212–222, 2017.


*Campus illustration by Kelly Stewart