SUB-GRAM IN-PLANE VIBRATION-DRIVEN ROBOT WITH INCLINED LEGS

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Outline

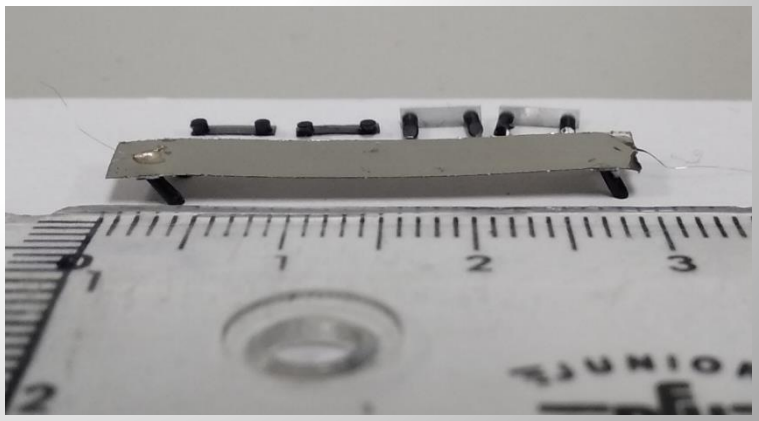
- Introduction
- Device design
- Materials and methods
- Results
- Conclusions

Motivation

1.1 m

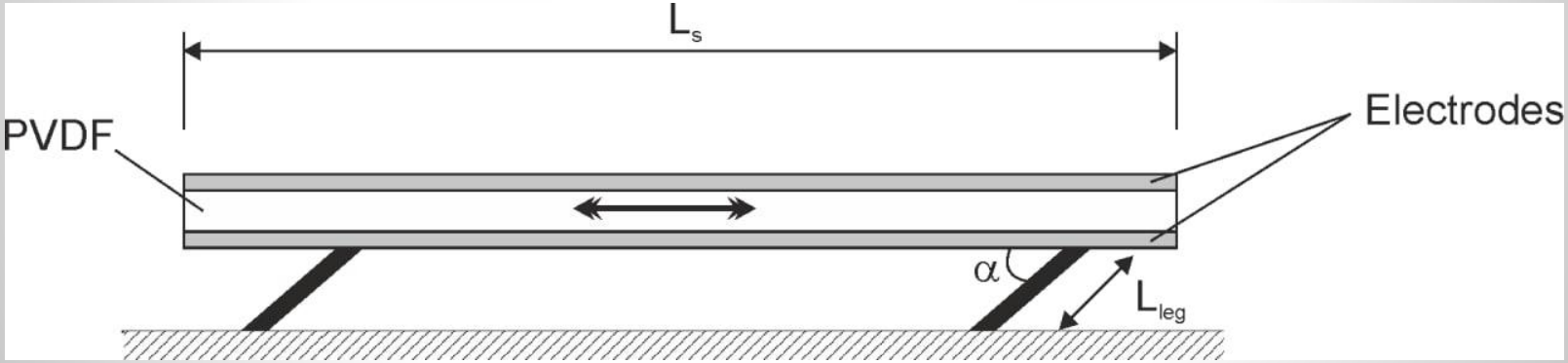
Miniaturization

3 cm



Our approach

Unimorph piezoelectric film with top and bottom electrodes for in-plane vibration

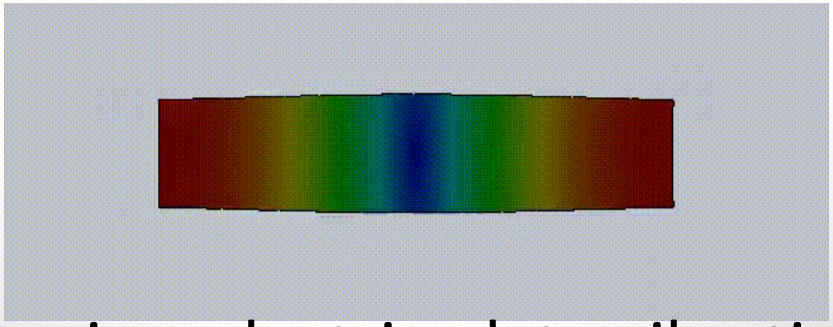


Combination of an extensional mode + inclined legs

Device design

- Shape of the extensional mode of vibration

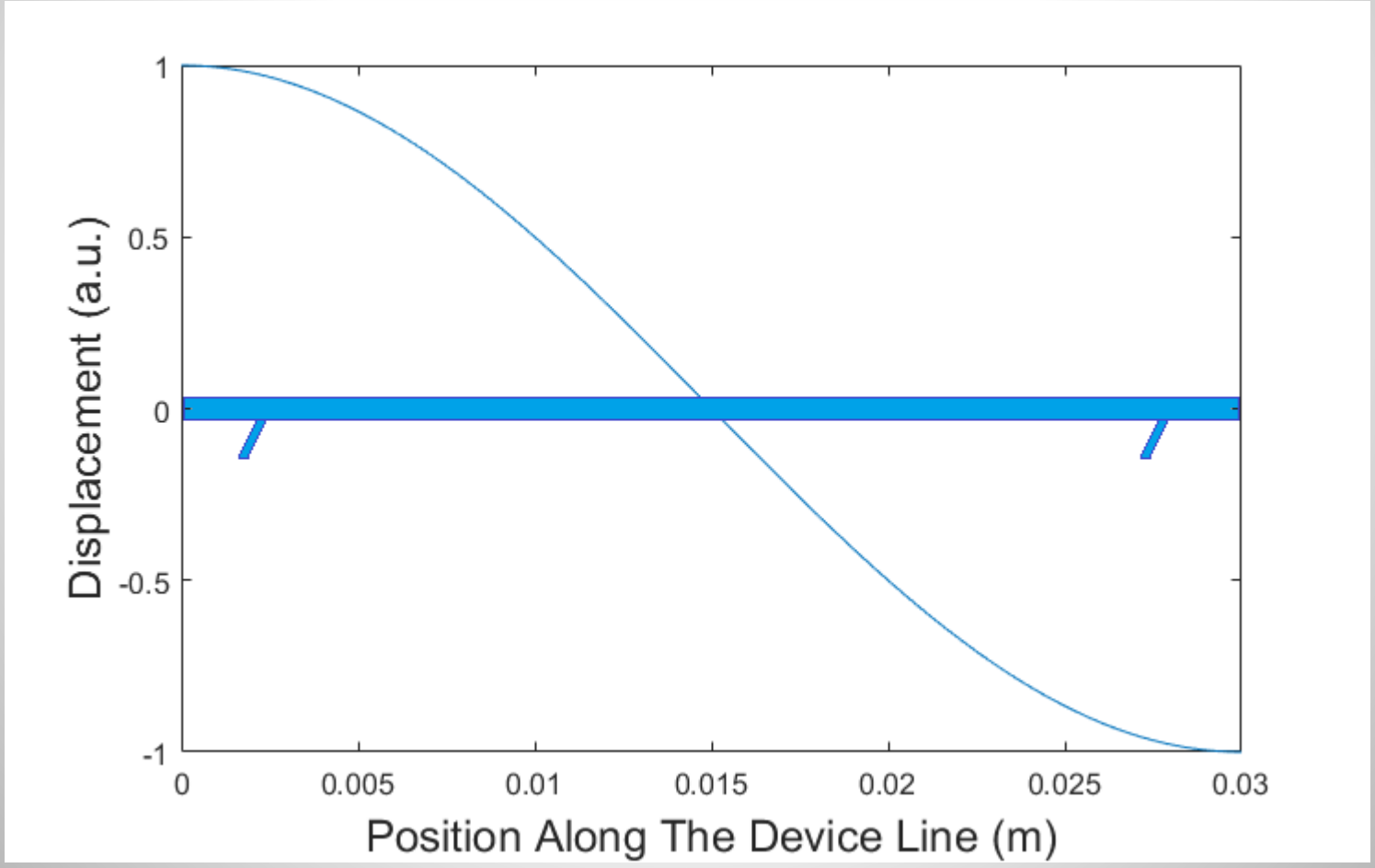
$$u = l \cos(\pi x / L)$$



Top view of the piezoelectric plate vibrating in the first extensional mode

Device design

- Modal shape ➡ Legs at the edges



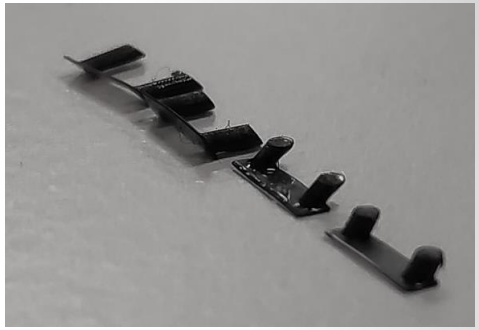
Robot platform

- Uniaxially oriented piezoelectric PVDF film
- Body size:
  - Length: 30 mm
  - Width: 5 mm
  - Thickness: 30 µm
- PVDF properties:
  - Density: 1760 kg/m^3
  - Young's modulus: 2 GPa
- Theoretical frequency of first extensional mode:

$$f_0 = \frac{1}{2L}\sqrt{\frac{E}{\rho}} = 17.7 \text{ kHz}$$

Robot legs

- Manufactured by SLA 3D printing using nylon resin
- Different configurations:
  - Angle = 45º or 60º
  - Height = 1 mm or 2 mm



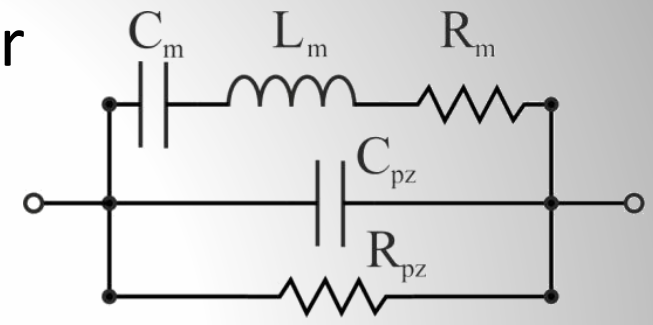
- Manually attached to body using epoxy resin

Electrical contacts

- Aluminium wire ø25 µm
- Conductive adhesive + silver painting

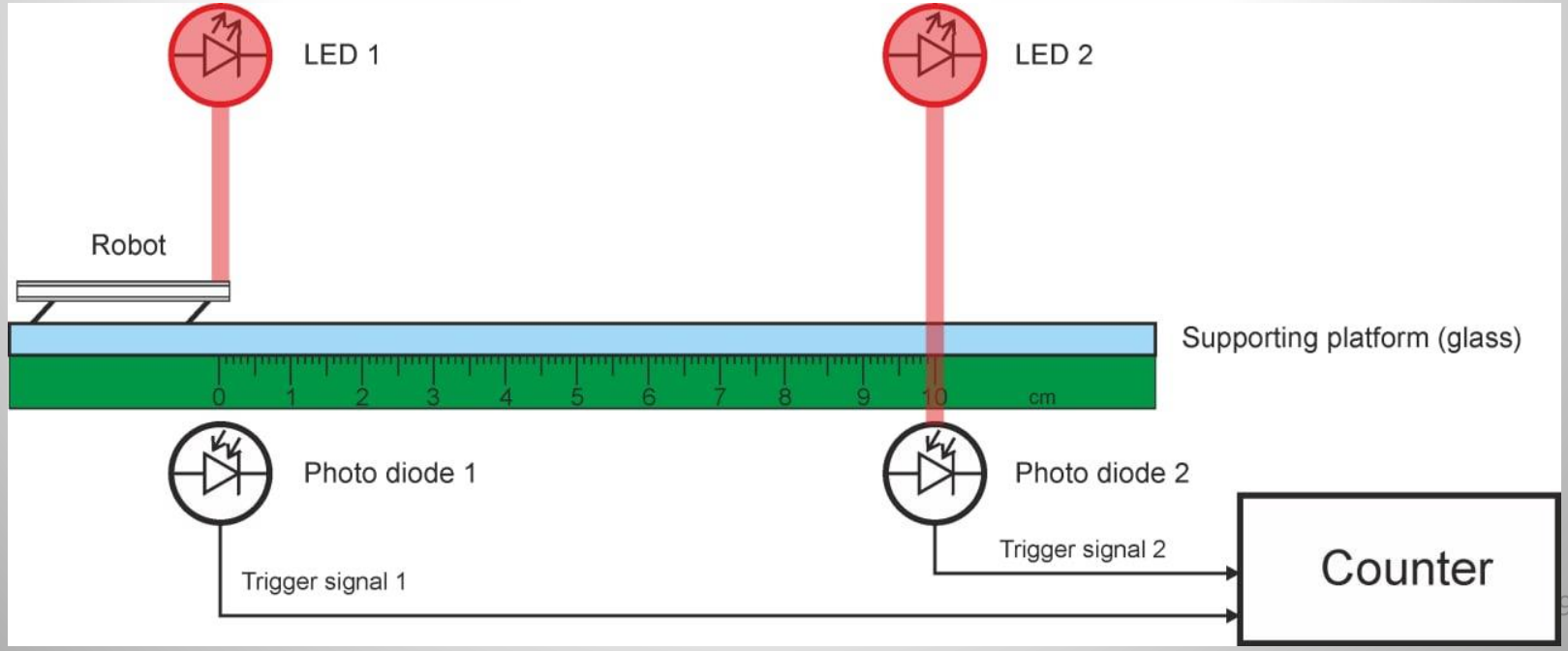
Electrical characterization

- Agilent 4294A impedance analyser

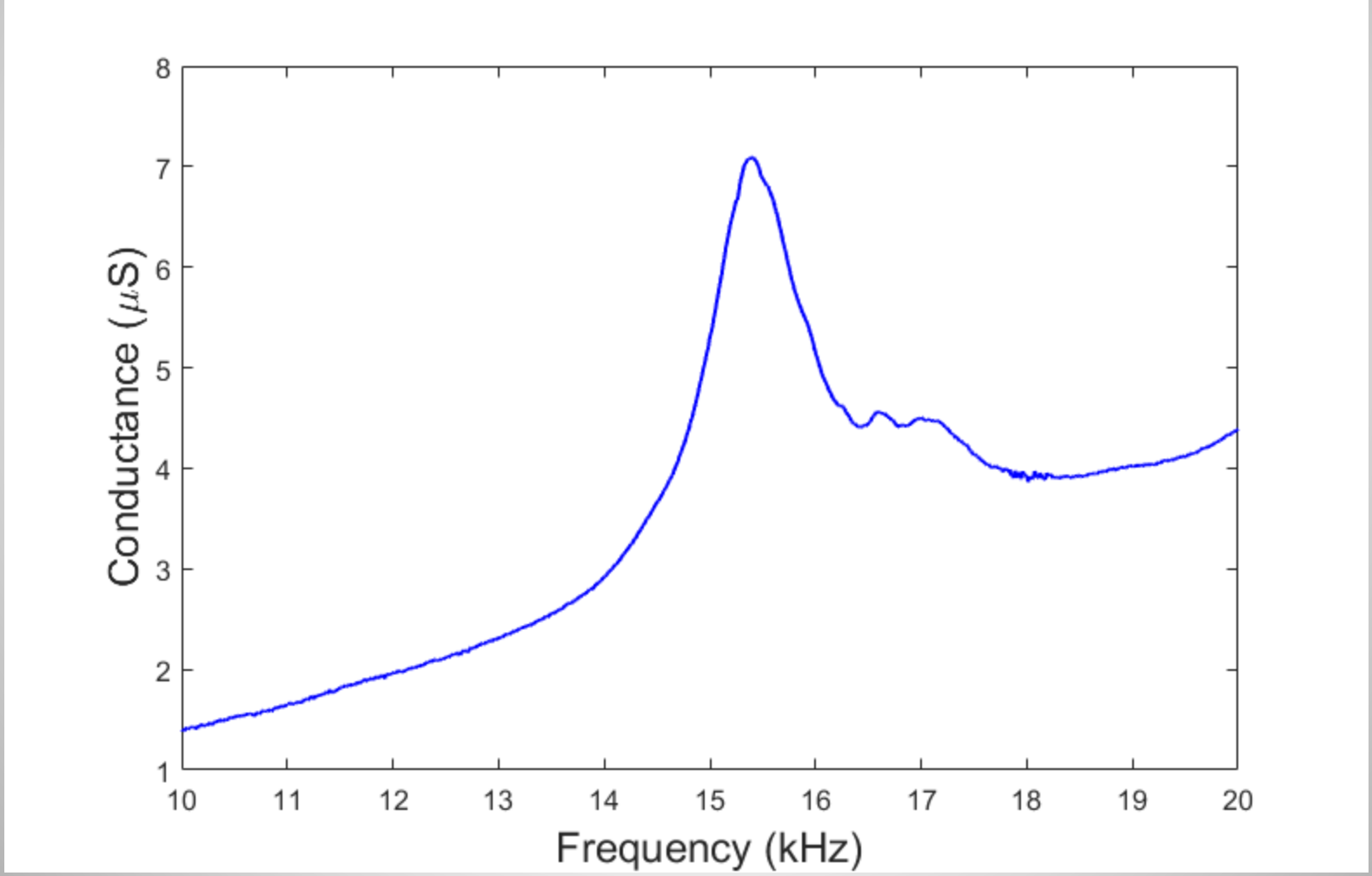


Speed characterization

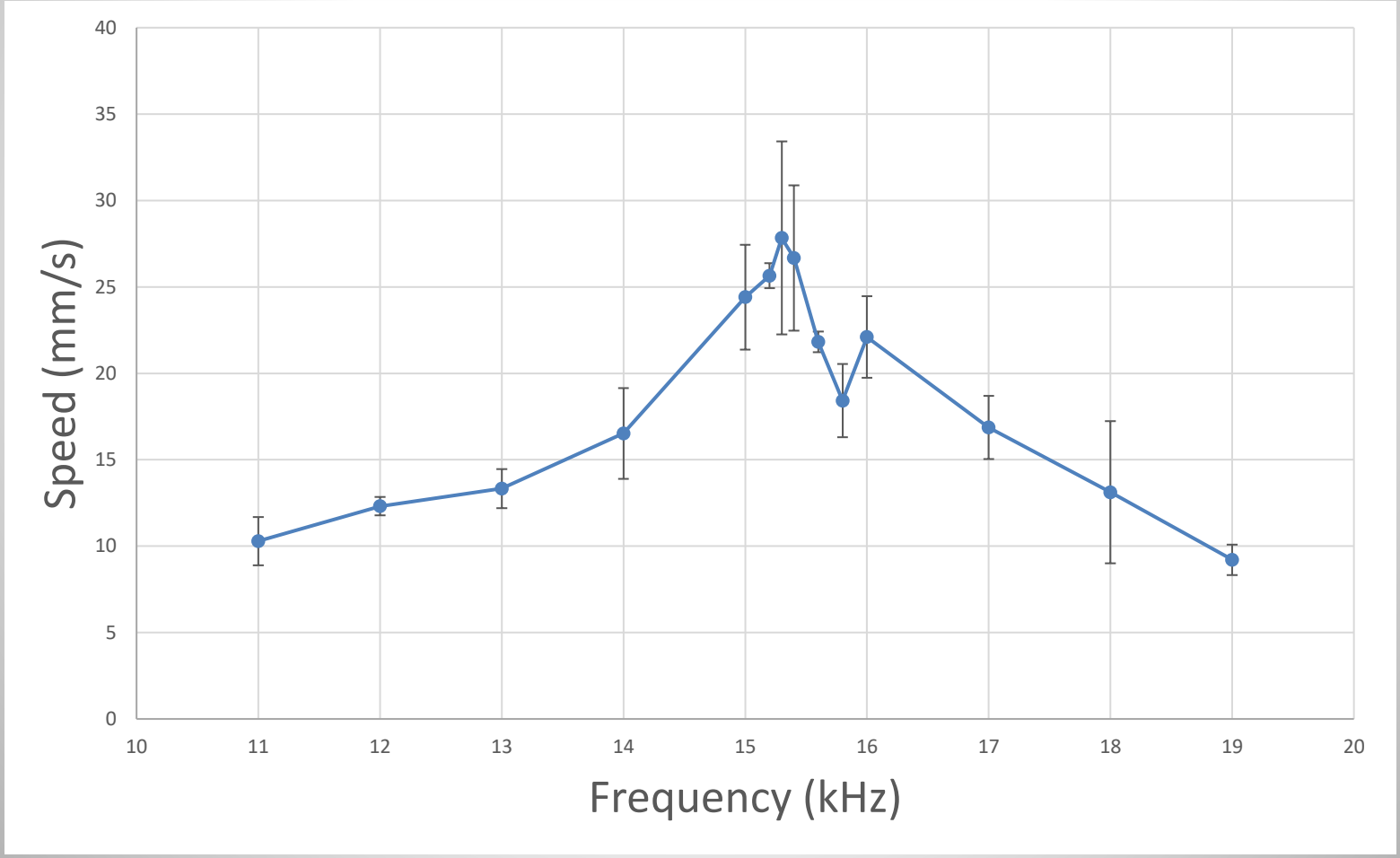
- Infrared LEDs + detectors + frequency counter



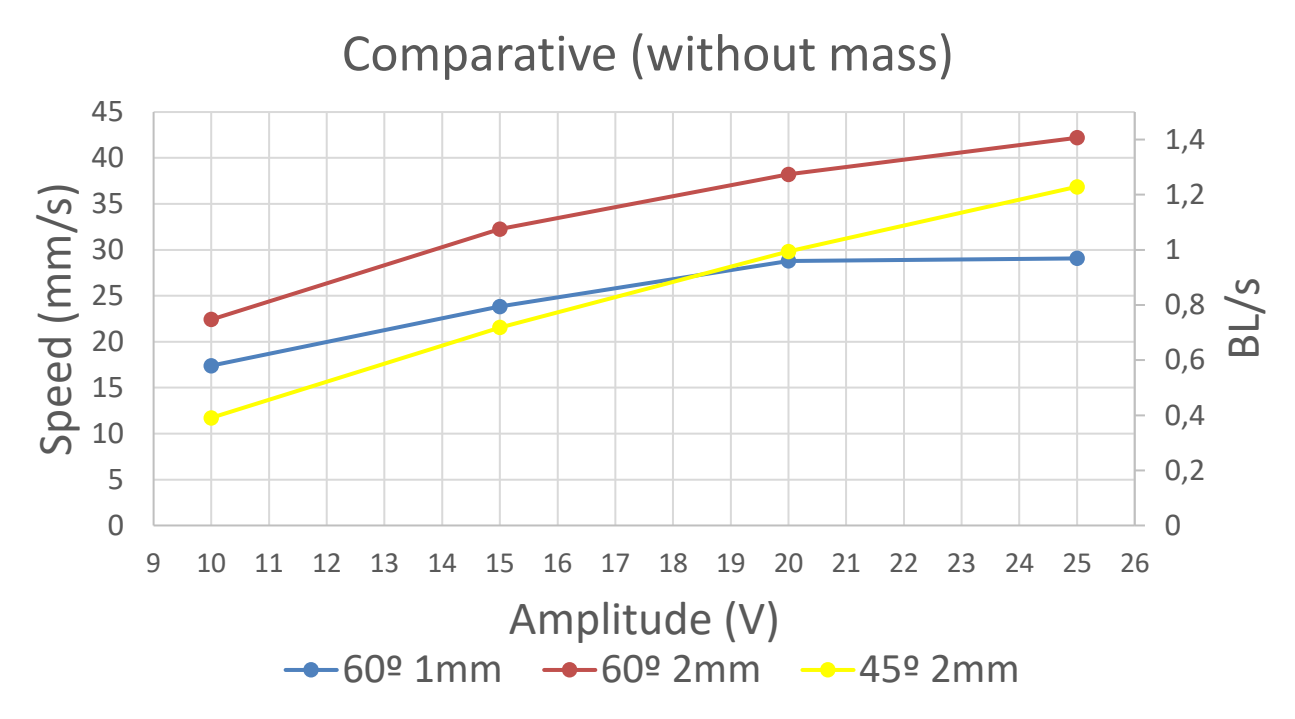
Electrical conductance



Measured speed against frequency around the fundamental extensional mode



Speed Vs. Excitation voltage for various leg-plate angles and leg lengths

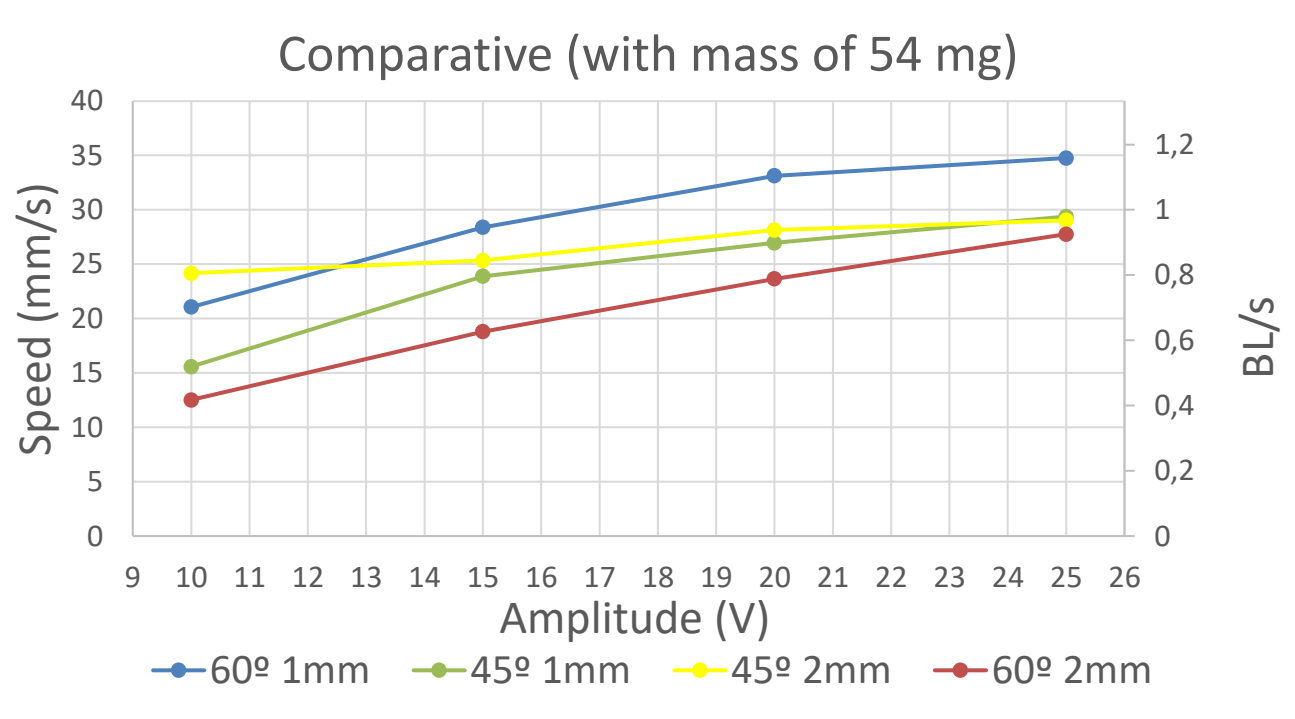


Speed seems to increase with leg length and 45º shows more linear behaviour

No locomotion for 45º 1mm sample ➡ Poor friction

Load mass of 54 mg on top to improve contact

Kinetic characterization

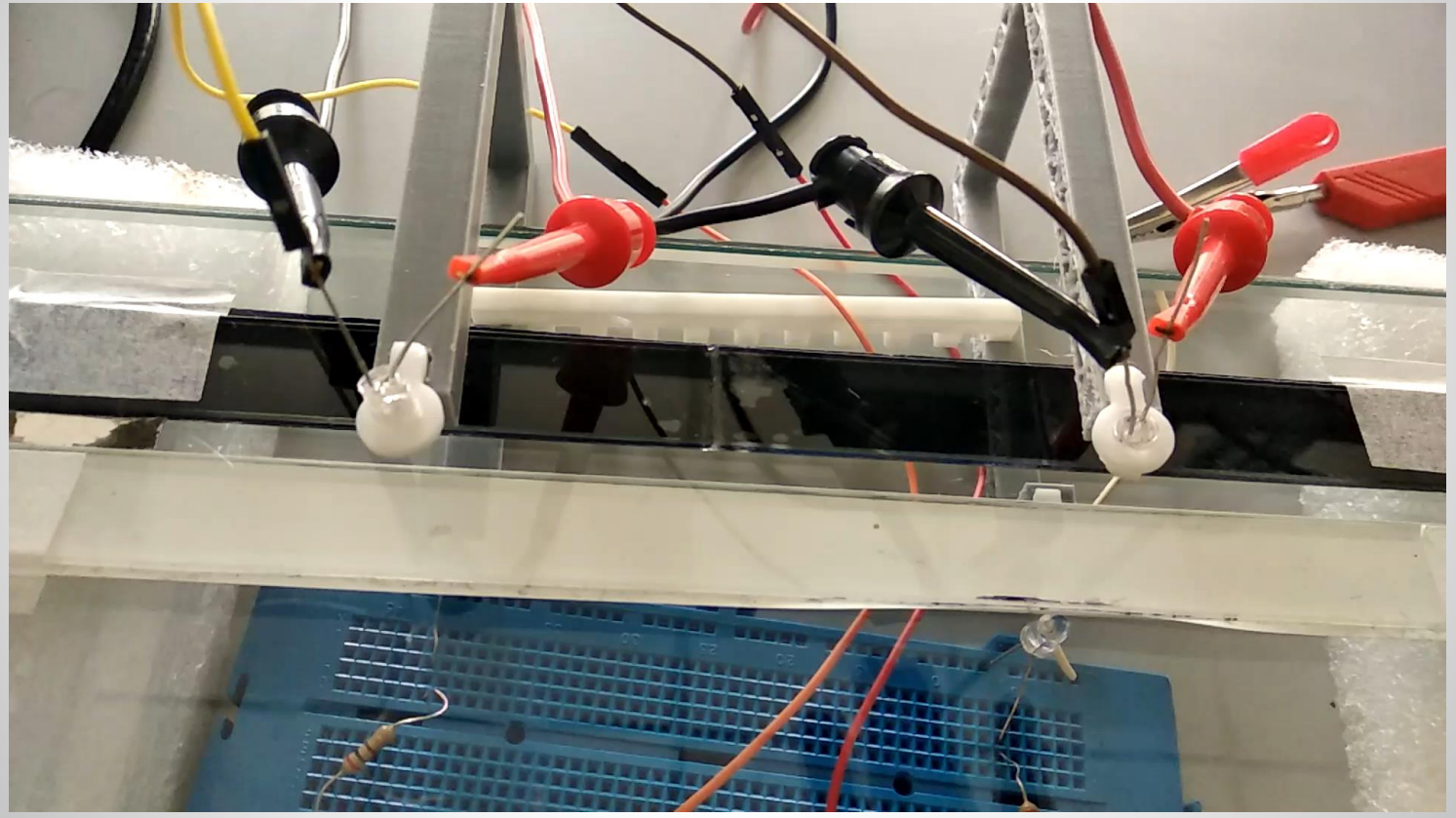


Fastest speed for 1mm 60º legs

For 2mm legs the speed decreases with added mass, increasing for the 1 mm leg

It may be related to the effect of mass on legs behavior

Video of sample locomotion



Conclusions

Design of piezoelectric film + flexible legs for in-plane extensional vibration

3D printing of legs with various geometries

Detection of in-plane vibration by impedance-validating the model

Achievement of locomotion by the combination of an extensional mode of vibration and inclined legs.

Speed vs. voltage has been compared for various legs and carrying masses (up to 3x the weight of the robot).

Sub-gram system with a speed greater than 1.4 BL/s at 25 V

Thanks for your attention