Elasto-Magnetic Pumps Integrated Within Microfluidic Devices

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Abstract. This work demonstrates the viability of providing fluid flow in point-of-care microfluidic devices using fully integrated elasto-magnetic pumping systems, powered by weak one dimensional oscillating magnetic fields.

Introduction

- This work integrates elasto-magnetic pumps into microfluidic devices to eliminate their reliance on external pumping systems.
- The elasto-magnetic pump shown in **Fig.1** performs a non-reciprocal motion operating on the same principles as the Purcell 3 link swimmer[1].
- The system is fabricated using techniques already commonly employed in the manufacturing of microfluidic devices.
- Due to the confinement of the fluid flows, the pump is able to produce fluid flow in either a forward or backward direction by the simple adjustment of the driving frequency.

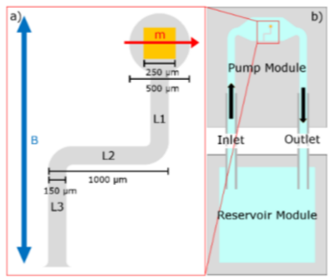


Figure 1. A schematic of the elasto-magnetic pump. The pump consists of 3 elasticated links, utilising a NdFeB magnet to couple to a magnetic driving field.

Simple Elasto-Magnetic Pumps Produce Tuneable Fluid Flow When Integrated Within Microfluidic Devices

Methods

- The pump is actuated using a 6mT, sinusoidally oscillating external magnetic field.
- The motion of the pump has parallels with that of cilia, with an example path shown in **Fig.2**, performing a characteristic power stroke and recovery stroke.

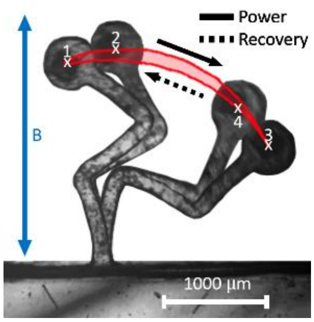


Figure 2. A schematic of the example path motion of the pump when actuated by an oscillating external magnetic field. The centre of the pump head follows the red path, passing through points 1-4.

- A closed channel with an integrated pump is used to test the flow rates produced and a schematic is shown in **Fig.3.**
- The fluid velocity was measured by injecting polystyrene microbeads and observing their net movement over time.
- The pump is fabricated from moulds created through SU-8 monolithography and the completed test device is assembled from layers of PDMS.

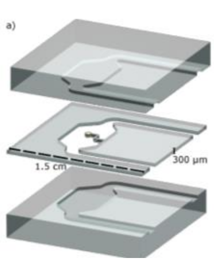
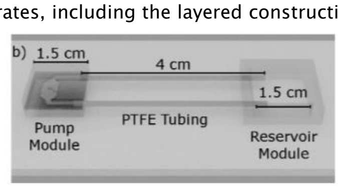


Figure 3. A schematic of the closed channel geometry used to test flow rates, including the layered construction.

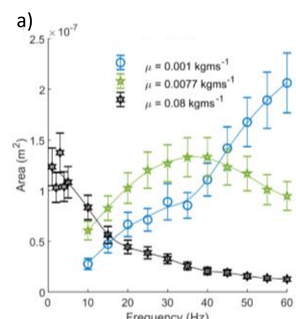


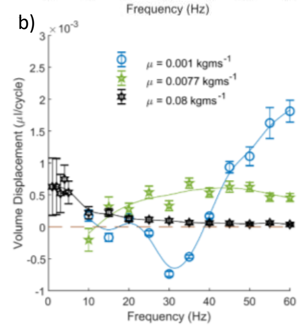
Results & Discussion

- The path of the pump depends on the driving frequency, and the area within the closed loop path depicted in **Fig.2** is shown here in **Fig.4a**.

Figure 4. a) The area of the hysteresis shown in **Fig.2**. as a function of frequency.
b) The recorded flow rate of the devices shown in **Fig.3**. as a function of frequency.

- Altering the driving frequency changes the phase difference between the motion of the hinges of the pump, as well as the total amplitude of motion.
- The resultant flow rates are shown in **Fig.4b**. The flow produced is largely linearly proportional to the areas swept, although with regions of negative flow production. This is due to the close bounding walls of the channel, and enables the device to change pumping direction without change of geometry.





References

[1] Purcell E, Life at low Reynolds number, American Journal of Physics, 1977 vol: 45 (1) pp: 3-11
[2] Gilbert AD, Ogrin FY, Petrov PG, Winlove CP. (2011) Theory of ferromagnetic microswimmers, *The Quarterly Journal of Mechanics and Applied Mathematics*, volume 64, no. 3, pages 239-263.

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