

Nature-inspired active mixing in a microchannel

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NATURE-INSPIRED ACTIVE MIXING IN A MICROCHANNEL

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Introduction

Many applications of microfluidics require efficient mixing of two or more liquids. Mixing at the microscale usually occurs through a rather slow diffusion process due to inherent laminar flow conditions. To speed-up mixing, numerous novel passive and active micromixers are currently being developed.^[1] We propose a new promising configuration for an active micromixer consisting of an array of individually addressable artificial cilia in the form of micro-actuators covering the channel wall, and that can be actuated by external means field. This concept is inspired by the motion of flagellated and ciliated micro-organisms such as shown in figure 1.

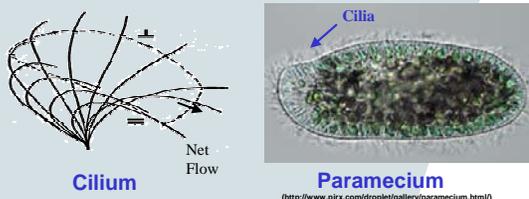


Figure 1. Example of micro-organism that use beating cycles of cilia (schematically shown in left) for their motility.

Objective

To design and develop a novel active micromixer - inspired by nature - for microfluidics applications.

Modeling

To assess the feasibility of the proposed concept, we carried out numerical simulations of one- and two-micro-actuator configurations, as shown in figure 2, using a fictitious domain method based fluid-structure interaction model.^[4]

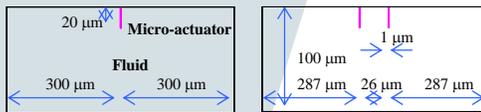


Figure 2. Schematic representation of single (left) and double (right) micro-actuator configurations in a microchannel studied.

The overall modeling strategy is as shown in figure 3 below.



Figure 3. The overall modeling strategy.

Two micro-actuator batch micromixer

As shown in figure 4, with a proper actuation scheme, two micro-actuators can indeed induce effective mixing by chaotic advection.

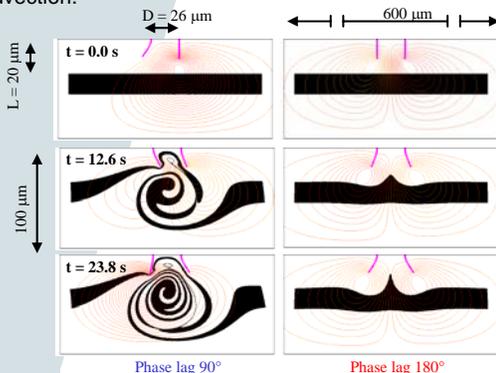


Figure 4. Mixing patterns obtained with two different actuation schemes showing "good" (left) and "no" (right) mixing are superimposed on flow streamlines (colored lines).

The dependency of mixing efficiency, measured in terms of the length stretch, on the actuation scheme and shown in figure 5, is less critical so long as its value is near the optimum value of 90°.

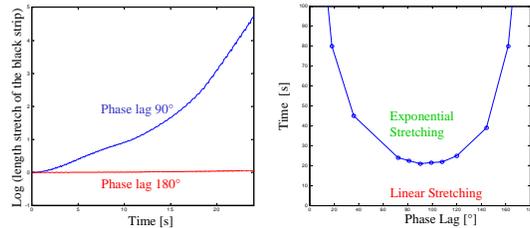


Figure 5. Quantification of mixing efficiency shown in figure 4 (left) is used to generate a phase diagram (right) where the optimal actuation scheme can be readily identified.

For optimal mixing, figure 6 suggests that the two micro-actuators should be placed as close to each other as possible, obviously taking care to avoid their collision, and they should preferably be actuated 90° out of phase.

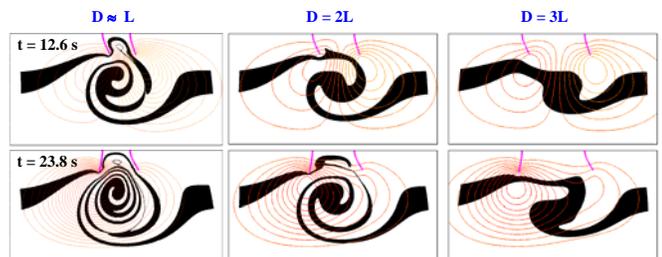


Figure 6. Mixing quality as a function of spacing (D) between the two micro-actuators having a length (L) of 20 μm . In all cases, the micro-actuators are actuated with a phase lag of 90° and at a frequency of 4 Hz.

Furthermore, for micro-actuators smaller than 20% of the channel height, the mixing effectiveness is higher when they are arranged on the same wall. However, as shown in figure 7, increasing the micro-actuator length improves the effectiveness of an opposite wall micro-actuator arrangement.

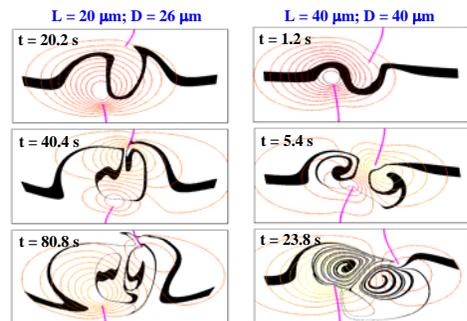


Figure 7. Improvement in mixing with an increase in the length (L) of micro-actuators for an opposite wall arrangement of the two micro-actuators. In both cases, the micro-actuators are actuated with a phase lag of 90° and at a frequency of 4 Hz.

Conclusions

- Nature-inspired cilia-like micro-actuators integrated in a microfluidic channel gives effective mixing by chaotic advection.
- With a well chosen geometrical arrangement and actuation scheme, mixing can even be obtained with only two micro-actuators.

References

- [1] D. J. Beebe et. al., *Annu. Rev. Biomed. Eng.*, **4**, 261, 2002.
- [2] R. van Loon et. al., *Int. J. Num. Meth. Fluids*, **46**, 533, 2004.