*3rd Micro and Nano Flows Conference*
*Thessaloniki, Greece, 22-24 August 2011*

# Numerical optimization of passive chaotic micromixers

Jens HARTING[1,2,*], Aniruddha SARKAR[2], Ariel NARVÁEZ[1]

* Corresponding author: Tel.: ++31 40 247 3766; Fax: ++31 40 243 8272; Email: j.harting@tue.nl
1 Department of Applied Physics, Eindhoven University of Technology, The Netherlands
2 Institute for Computational Physics, University of Stuttgart, Germany

**Keywords:** Micromixer, chaotic advection, lattice Boltzmann

## 1 Summary

In microfluidics mixing of different fluids is a highly non-trivial task due to the absence of turbulence. The dominant process allowing mixing at low Reynolds number is therefore diffusion, thus rendering mixing in plain channels very inefficient. Recently, passive chaotic micromixers such as the staggered herringbone mixer (SHM) were developed, allowing efficient mixing of fluids by repeated stretching and folding of the fluid interfaces. The optimization of the geometrical parameters of such mixer devices is often performed by time consuming and expensive trial and error experiments. We demonstrate that the application of the lattice Boltzmann (LB) method to fluid flow in highly complex mixer geometries together with standard techniques from statistical physics and dynamical systems theory can lead to a highly efficient way to optimize micromixer geometries. Here we will provide a review of our results published in [1] together with additional results on our simulations of multiphase flow in micromixers.

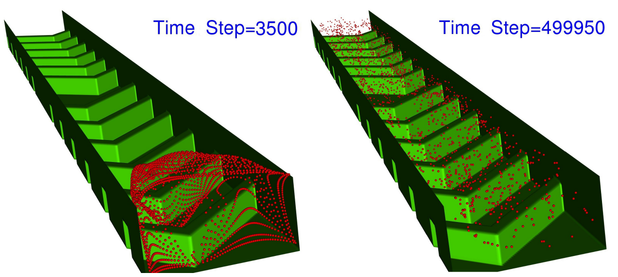


*Fig. 1: Snapshots from the tracer particle distribution inside the SHM at the begining (left) and towards the end (right) of the simulation.*

## 2 Simulation Methododology

For a description of the fluid flow inside the micromixer, we apply the lattice Boltzmann method, a simplified approach to solve the Boltzmann equation in discrete space, time and with a limited set of discrete velocities. In the context of the current work, the lattice Boltzmann method can be seen as a simple way to solve the Navier-Stokes equation. Its advantages include the ease to simulate flow in highly complex mixer geometries as well as the inherent parallel structure of the algorithm allowing an efficient use of massively parallel supercomputers. Massless and non-interacting tracer particles are introduced at the inlet of the micromixer and their velocities are integrated at each lattice Boltzmann time step. A general feature of chaotic systems is that two nearby trajectories diverge exponentially in time. The Lyapunov exponent is a possible measure for this effect. However, in real systems length and time scales are always finite requiring the application of the finite time Lyapunov exponent (FTLE) which we calculate from the tracer trajectories together with the renormalization algorithm of Wolf.

## 3 Results

The influence of different parameters which directly affect the performance of the SHM is evaluated. These are the ratio of height of the grooves to the height of the channel, the ratio of the horizontal length of the long arm to the channel width, the ratio of distance between the grooves to the length of the channel and the number of grooves per half cycle. Fig. 1 shows a typical snapshot from our simulations. At the beginning all tracers follow the flow in a highly ordered way, but towards the end of the simulation a very homogenuous distribution of particles can be observed. Fig. 2 depicts a typical example of such an optimization. The FTLE is plotted versus the non-dimensionalized groove distance. A well pronounced peak can be observed denoting the distance resulting in the most efficient mixer. In the second part of the presentation we will study multiphase flow in micromixers focusing on the interplay between the process of chaotic advection and diffusion between the fluids.

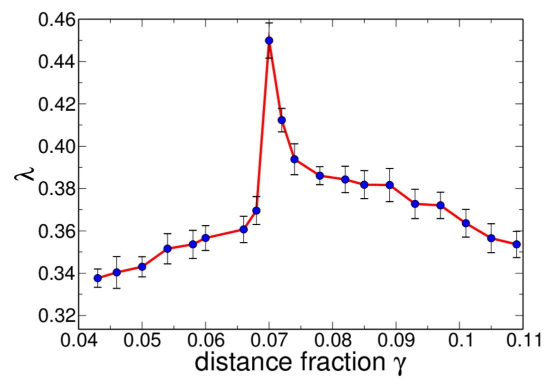


*Fig. 2: Finite time Lyapunov exponent versus non-dimensionalized groove distance.*

[1] A. Sarkar, A. Narváez, and J. Harting. Quantification of the degree of mixing in chaotic micromixers using finite time Lyapunov exponents. Submitted for publication, arXiv:1012.5549, 2010.