Spiral Microfluidic Channel for Particle Focusing and Sorting

A. El Hasni, U. Schnakenberg

elhasni@iwe1.rwth-aachen.de

Focusing and sorting of microparticles or biological cells in microfluidic systems for analysis applications is a process of great importance [1]**. Techniques employing external forces, such as dielectrophoresis, acoustic waves, and optical interference show integral limitation including modification of particles or cellular properties and reduced sample volumes due to the low operating flow rates** [2]**. Recently, high throughput passive particle separation based on inertial migration in curved microchannels has been reported. This method avoids the disadvantages of conventional techniques needing externally applied forces since only fluidic forces and particle size influence the particle separation** [3]**. We applied a spiral microchannel for focusing and sorting of a mixture of large-sized particles with a diameter of 20 µm, 40 µm, and 60 µm.**

Due to inertial lift forces arising from the parabolic nature of the laminar velocity profile in a Poiseuille flow, suspended particles migrate across the streamlines to an equilibrium position away from the channel centre. They equilibrate into focused streams along the perimeter of the microchannel. For a low aspect ratio rectangular microchannel, the lift force defined by the channel height is dominant resulting in two laterally broad focusing positions at the top and the bottom of the microchannel.
Adding curvature to the channel introduces a transverse Dean flow. This secondary rotational flow is perpendicular to the main flow direction and consists of two symmetric counter-rotating vortices in the top and bottom of the cross-sectional plane of the microchannel. Particles dispersed in a spiral microchannel experience a drag force introduced by these Dean vortices resulting in a movement along the Dean flow. Depending on the position in the microchannel particles migrate towards the inner wall or continue to flow along the Dean vortices. Near the inner wall inertial lift forces and Dean drag forces act in opposite directions leading to equilibration and focusing of particles into a single stream. Thus, the combination of inertial lift force and Dean drag reduces the equilibrium positions to a single one introducing a continuous inertial focusing [4].
Since the ratio of the lift force F_L to the Dean drag force F_D depends on particle size, particles with different diameter equilibrate at distinct positions resulting in a continuous separation of multi-sized particle mixture. Large particles equilibrate at a position close to the inner wall while small particles move away from it, see Fig. 1.

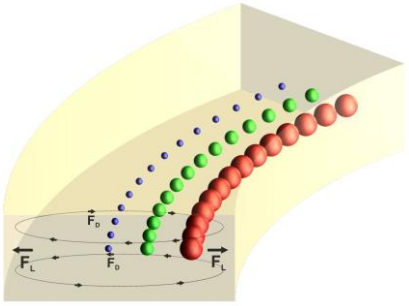

Fig. 1: *Schematic illustration of a curved microchannel with rectangular cross-section showing focusing positions of particles of different sizes. Lift force F_L, Dean drag force F_D, and Dean vortices are highlighted.*

To evaluate the principle for sorting large insect cells, particle focusing and sorting was carried out in a preliminary study using fluorescently labeled polystyrene particles with a diameter of 20 µm, 40 µm, and 60 µm [5]. The particles were labeled with blue, green, and red fluorophores, respectively.
The design consists of a 5 loop microchannel with spacing of 500 µm between the successive loops and a channel width of 500 µm. The height was fixed to 238 µm. The outlets opened into a 1.15 mm wide segment and split into five outlet ports for particle collection, see Fig.2. The microfluidic device was fabricated in polydimethylsiloxane (PDMS) using standard soft lithography techniques.

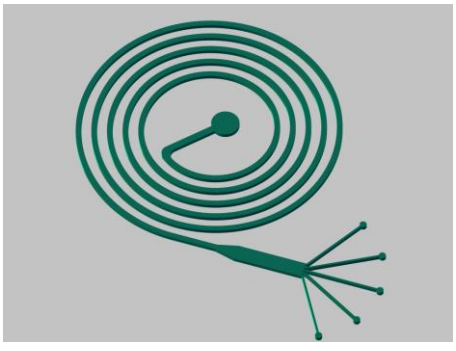

Fig. 2: *Schematic of the spiral microchannel*

To identify suitable flow rates for particle focusing and separation in the spiral microchannel the particles were first tested individually. For the three par-

ticle types focusing into a single particle stream occurred at flow rates greater than 1 ml/min. increasing the flow rate resulted in an increasing lateral displacement of the focused particle stream away from the inner channel wall.
After identifying the suitable flow rate range for particle focusing a particle mixture was injected in the microchannel. As shown in Fig. 3, using the fabricated microfluidic channel particle focusing and separation was successfully achieved. The position of the focused particle streams was adjusted by increasing the flow rate.

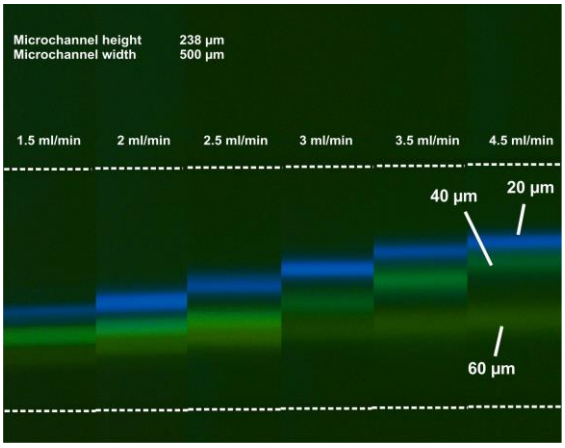

Fig.3: *Composite fluorescence image illustrating the positions of the focused particle streams within the microchannel at varying flow rates.*

Using appropriate flow rates each single particle stream can be directed directly into one the bifurcated outlet ports. Fig. 4 shows a successful collection of the focused particle streams at the outlet ports of the microchannel.

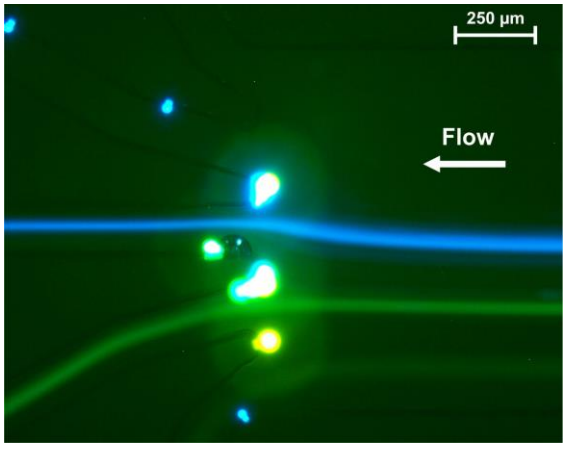

Fig.3: *Florescence image of the collection of the individual particle streams at the bifurcated outlet ports of the microchannel at a flow rate of 3 ml/min.*

Acknowledgments The project was supported by the excellence initiative of the German federal and state governments, grant Pathfinder project # OP-Pa91 (MIMIK).

Projectpartners

- Prof. Dr. P. Bräunig, Institute of Biology II, RWTH Aachen
  www.bio2.rwth-aachen.de

[1] X. Xuan, J. Zhu, and C. Church, “Particle focusing in microfluidic devices,” *Microfluidics and Nanofluidics*, vol. 9, no. 1, pp. 1-16, Mar. 2010.

[2] A. Russom, A. K. Gupta, S. Nagrath, D. Di Carlo, J. F. Edd, and M. Toner, “Differential inertial focusing of particles in curved low-aspect-ratio microchannels.,” *New journal of physics*, vol. 11, p. 75025, Jul. 2009.

[3] S. S. Kuntaegowdanahalli, A. A. S. Bhagat, G. Kumar, and I. Papautsky, “Inertial microfluidics for continuous particle separation in spiral microchannels,” *Lab on a chip*, vol. 9, no. 20, pp. 2973-80, Oct. 2009.

[4] D. R. Gossett and D. Di Carlo, “Particle focusing mechanisms in curving confined flows.” *Analytical chemistry*, vol. 81, no. 20, pp. 8459-65, Oct. 2009.

[5] A. El Hasni, K. Göbbels, A. L. Thiebes, P. Bräunig, W. Mokwa, and U. Schnakenberg, "Focusing and Sorting of Particles in Spiral Microfluidic Channels," 2011.