Particle Sorting on Microfluidic Chips using Optical Forces

Brandon Foley
Chemical Engineering, University of Wisconsin – Madison

NNIN REU Site: Center for Nanoscale Systems, Harvard University, Cambridge, MA
NNIN REU Principal Investigator: Federico Capasso, Physics, Harvard University
NNIN REU Mentors: Lulu Liu and Alexander Woolf, Physics, Harvard University
Contact: brfoley@wisc.edu, capasso@seas.harvard.edu, luluiliu@fas.harvard.edu, awoolf@fas.harvard.edu

Introduction:

Sorting particles using light can provide another means for particles separation. On-chip particle sorting has been used to sort particles based on size or using dielectrophoretic forces [1]. Optical forces can be used to sort particles that have similar chemical, physical, and electromagnetic properties, but different optical properties. It is especially difficult to separate particles that are enantiomers of each other, which have identical chemical and physical properties and differ only in their interactions with light. The scattering of circularly polarized light is dependent on the handedness of the chiral particle and of the circularly polarized light [2]. This difference in scattering will be used to push particles in different directions on a microfluidic chip. The microfluidic chip is a channel ending in a fork. The particles flow down the channel and are pushed either left or right, depending on the particle's handedness, causing the particles to travel the channel in the direction it was pushed. The goal of this study is to fabricate a flow chamber capable of sorting particles using optical forces.

Methods:

SU-8 Master Wafer Synthesis. The SU-8 master wafer was made using SU-8-3025 at a thickness of 20 μm using negative photoresist methods as outlined by MicroChem [3].

Flow Chamber Synthesis. The standard 10:1 monomer:cross-linking agent ratio for polydimethylsiloxane (PDMS) was mixed and degassed before pouring over the silicon master chip in a Petri® dish to a thickness of approximately 1 cm. The Petri® dish was then placed in an oven at 65°C for three hours. The PDMS was removed from the silicon wafer and plasma oxidized to adhere it to a glass slide. A 1.20 mm hole was punched in channel and a 1/16-inch O.D. tubing attached to flow the bead suspension into the microfluidic flow chamber, as shown in Figure 1.

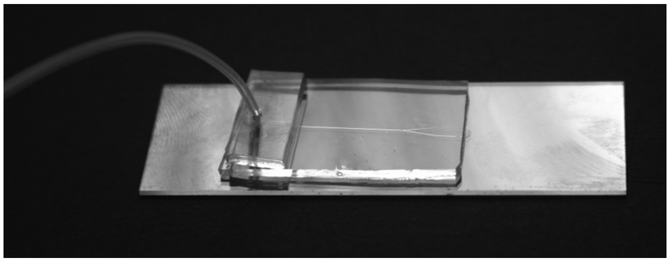

Figure 1: A PDMS flow chamber prototype for particle sorting using optical forces.

Controlling Flow Rate. The velocity of the beads needed to be slow so there would be enough interaction time with the laser for sufficient displacement to occur. The desired flow rate was 0.02 μL/h. Gravity was used as the driving force for the flow, and was controlled by installing two needle valves to increase or reduce the friction to adjust the flow rate through the microfluidic flow chamber.

Experiment. Glass beads with a diameter of 5 μm were flowed through the flow chamber at a rate of 10-30 μm/s. A 660 nm laser was shown on the beads to the right at a power of 3.2×10^{-4} mW/μm^2. The distribution of the beads at the fork were counted in the presence of the laser and compared to the distribution of the beads without the laser.

Results and Discussion:

The flow chamber successfully sorted beads using optical forces, as shown by the results in Table 1. Using Flow Chamber A, without the presence of radiation pressure, 50.8% ± 7.0% of the beads were entering the left channel at the fork. When 3.2×10^{-4} mW/μm^2 of radiation pressure was exerted on the beads towards the right, the fraction of beads travelling down the left channel decreased to 35.7% ± 6.3%. This verifies that optical forces are capable of potentially sorting particles.

Consistency was another important measure of the flow chambers. Flow chambers with the same design should behave similarly and the same flow chambers should have consistent behavior over time. As shown in Table 1, this was not the case for these flow chambers.

Chamber	Conditions	Left	Right	Total	Fraction Left	Error	Lower Bound	Upper Bound
A	Null	100	97	197	0.508	0.070	0.438	0.577
A	Laser Right, 3.2 x 10-4 mW/µm^2	79	142	221	0.357	0.063	0.294	0.421
B	Null	162	40	202	0.802	0.055	0.747	0.857
B	Laser Right, 3.2 x 10-4 mW/µm^2	164	75	239	0.686	0.059	0.627	0.745
B	Laser Left, 3.2 x 10-4 mW/µm^2	138	60	198	0.697	0.064	0.633	0.761
B	Null, retrial	56	60	116	0.483	0.091	0.392	0.574

Table 1, above: Results from preliminary experiments evaluating ability of optical forces to change distribution of beads.

Flow Chamber B had 80.2% ± 5.5% without the presence of radiation pressure, which is significantly higher Flow Chamber A. The behavior of Flow Chamber B also changed during experiments. The fraction of beads that travelled down the left channel at the fork after the experiments was 48.3% ± 9.1%. This difference suggests that morphological changes occurred. This could have been caused by dust clogging or unclogging from the channels or from beads sticking to the PDMS walls, causing a change in the flow. An example of clogging is shown in Figure 2.

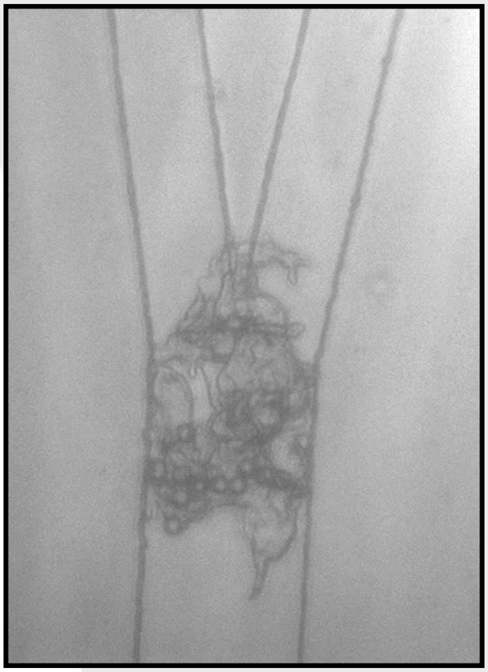

Figure 2, right: Dust clogging in the flow chamber at the fork.

Future Work:

To resolve issues involving dust clogging of channels, a filter will be added to the flow chamber. The filter consists of diamond-shaped pillars with decreasing gap sizes designed to block any pieces of dust that may clog the channel, while letting the beads pass through freely. Currently, there is a slight attraction between the beads and the PDMS walls. With a filter consisting of PDMS pillars, bead sticking may become a more important issue. To prevent bead sticking, the PDMS will be coated with negatively charged polymer. The glass beads naturally retain a negative charge, or polystyrene beads with carboxylic acid groups on the surface can be used, giving a negative charge to the polystyrene beads. The repulsion between the like-charges of the PDMS walls and the beads will prevent the beads from sticking to the filter or anywhere along the channels.

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