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Particles Focusing in Ferrofluids with Magnet

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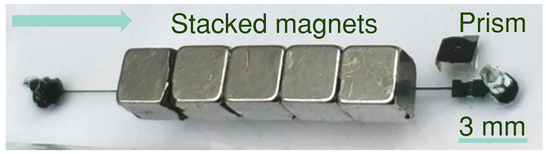
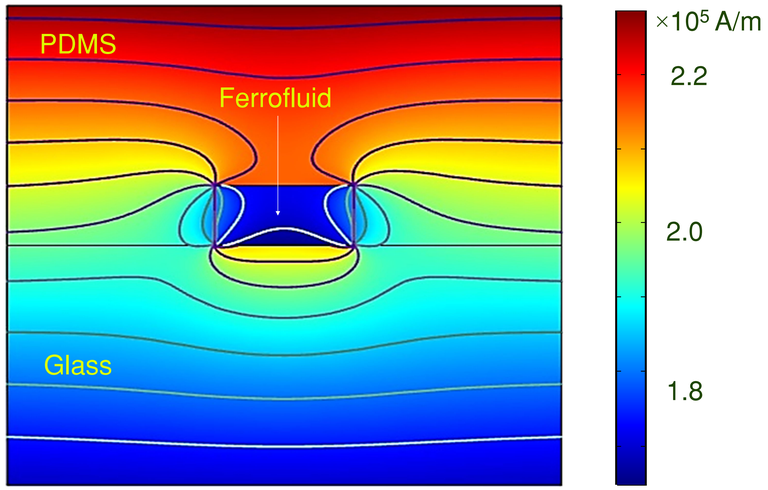
Overview

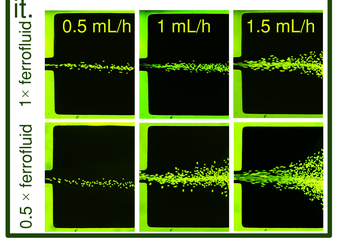
We are demonstrating a passive, tunable and sheathless focusing of diamagnetic particles in a microchannel ferrofluid flow with a single permanent magnets set. Particles are focused into a single stream near the bottom wall of a straight rectangular microchannel. Moreover, we performed an experimental study of the parametric effects of the system on particle focusing.





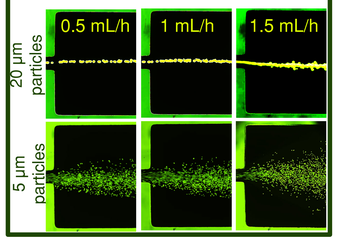
Ferrofluid Concentration

Particle focusing is better in higher concentrations since the magnetic force is linearly proportional to it.



Particle Size

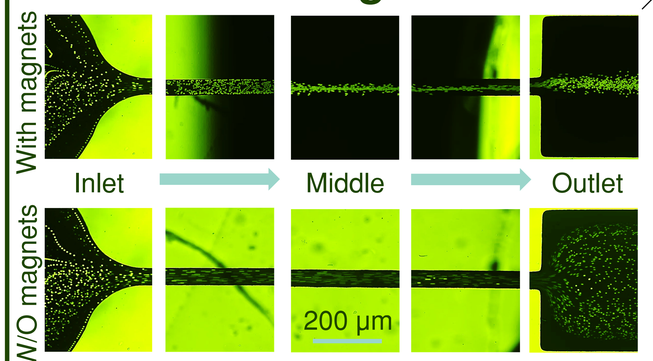
Big particles have better focusing and they form a nearly single-file stream. Since induced magnetic force is dependent on volume.



Motivation

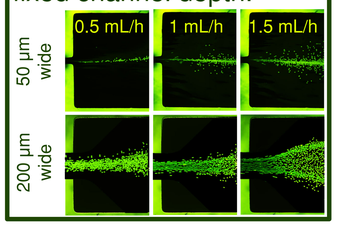
There has been increasing interest in the use of magnetic fluids to manipulate diamagnetic particles in microfluidic devices. Focusing particles into a single stream became a necessity in numerous applications. Current methods requires repulsive magnets or diamagnetic sheath flow, which is difficult to implement if particles need to be focused in both the horizontal and vertical directions for so-called three dimensional focusing. We eliminated the mentioned requirements by utilizing magnetic-field gradients.

Particle Focusing



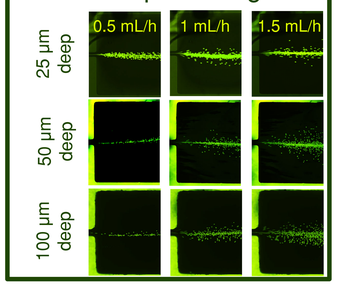
Width

Particles are significantly focused better in the narrower channel under the same flow rate and fixed channel depth.



Depth

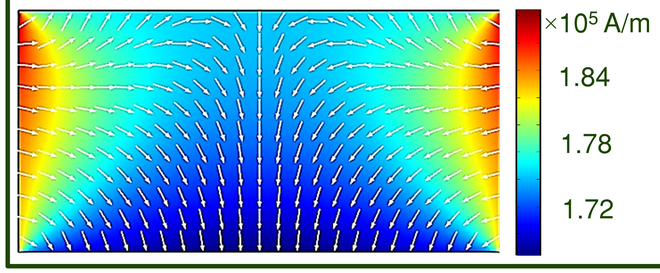
Particle focusing is not much different when the channel depth changes.



Theoretical Analysis

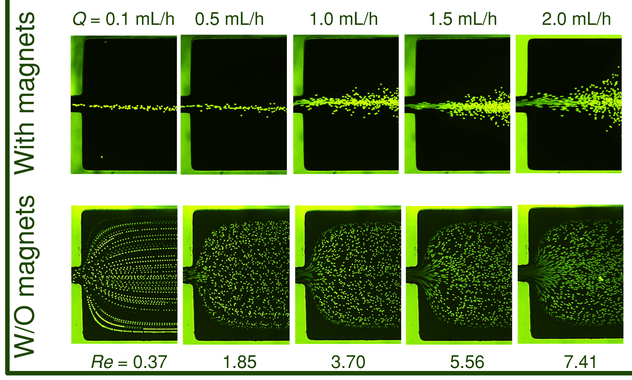
Particles in a magnetic ferrofluid experience a magnetic force, $\mathrm{F_M}$, and are pushed away from the magnetic source towards the low magnetic field region: $\mathbf{F}_M = -\frac{1}{6}\pi a^3 \mu_0 (\mathbf{M}_f \cdot \nabla)\mathbf{H} = -\frac{1}{12}\pi a^3 \frac{M_f}{H} \mu_0 \nabla \mathbf{H}^2$

The resulting magnetic force on diamagnetic particles is showed using the vector plot of $-\nabla \mathbf{H}^2$.



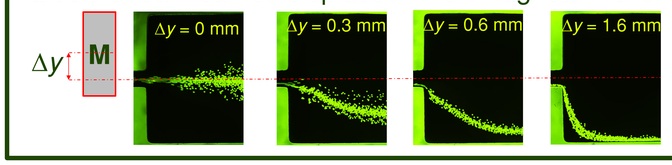
Ferrofluid Flow Rate

Increasing flow rate lowers the focusing of the 10 µm particles because their residence time in the effective working region of the magnets is shortened.



Magnet Position

Particle stream can be displaced when magnets move.



Conclusions

A method for 3D particle focusing in a ferrofluid flow with permanent magnets placed on top of the microfluidic chip was developed. We envision that our proposed method may potentially be used to achieve a continuous-flow particle separation by size.

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