PARTICLE MIGRATION OF A DILUTE BROWNIAN SUSPENSION IN A PRESSURE-DRIVEN FLOW
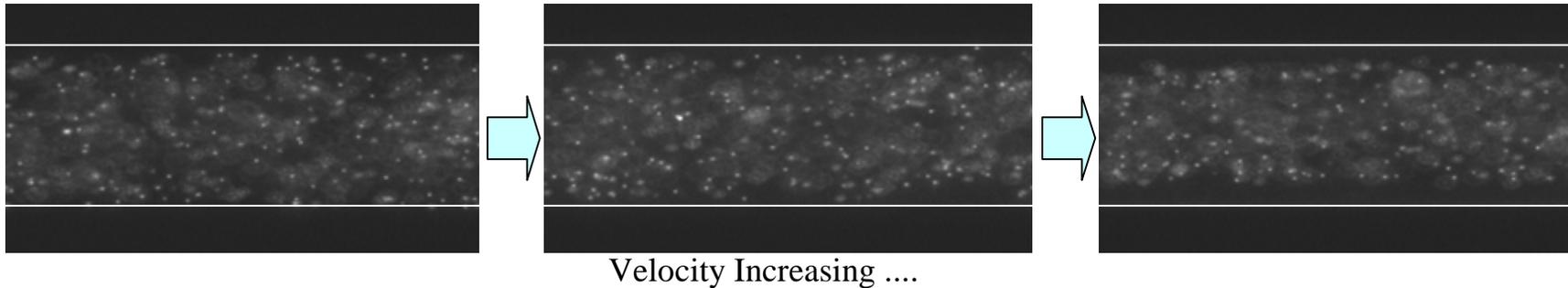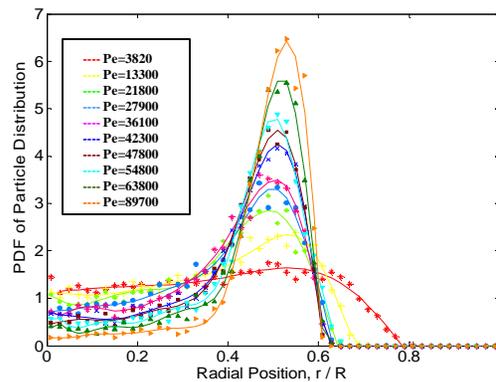
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Velocity Increasing ....

Migration of micro-scale Particles in micro channels is controlled both by hydrodynamic forces and by Brownian diffusion. Particle distribution due to migration is investigated under varied flow conditions using Epi-fluorescent microscopy micro PIV (particle image velocimetry) method.

PDF (relative concentration) of Particles from Low Pe (Brownian motion dominated) to High Pe (shear dominated)
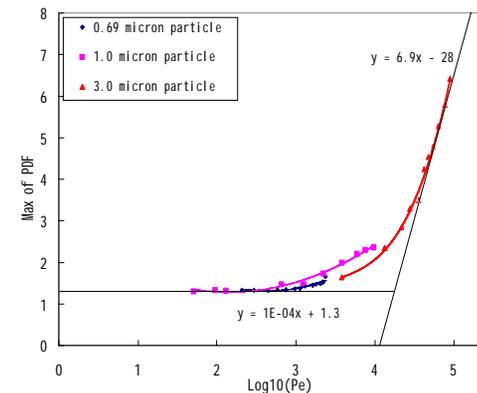


Migration Behavior Changing with Pe

Classification of Secondary Flow Effects using stereoscopic PIV in a counter-rotating cone-and-plate device for the study of Phytoplankton

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Sponsor: NSF

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- **Short description:** Phytoplankton are important to ecological health due to their filtration of carbon into the food chain. Jumars and Karp-Boss wish to study the phycosphere (surrounding liquid of phytoplankton) ,with high spatial resolution, at measurable shear strain-rates.

- **Objectives:** Create and Classify the characteristics of a "Flow Cell" that generates known shear strain-rates while visualizing the phytoplankton in 3-dimensions.

- **Methods:** Angular Stereoscopic PIV (Particle Image Velocimetry) techniques have been utilized to measure the in-plane and out-of-plane velocity components to a high-degree of accuracy. The cone-and-plate are individually driven by gear-reduced servo-motors, operating in opposite spin-directions to generate a null velocity along the geometry's line of symmetry while maintaining a linear shear strain-rate.

- **Results:** Preliminary Results show that the desired flow-field has been generated with negligible secondary flow effects at the requested shear strain-rate. Further characterization of the flow is underway.
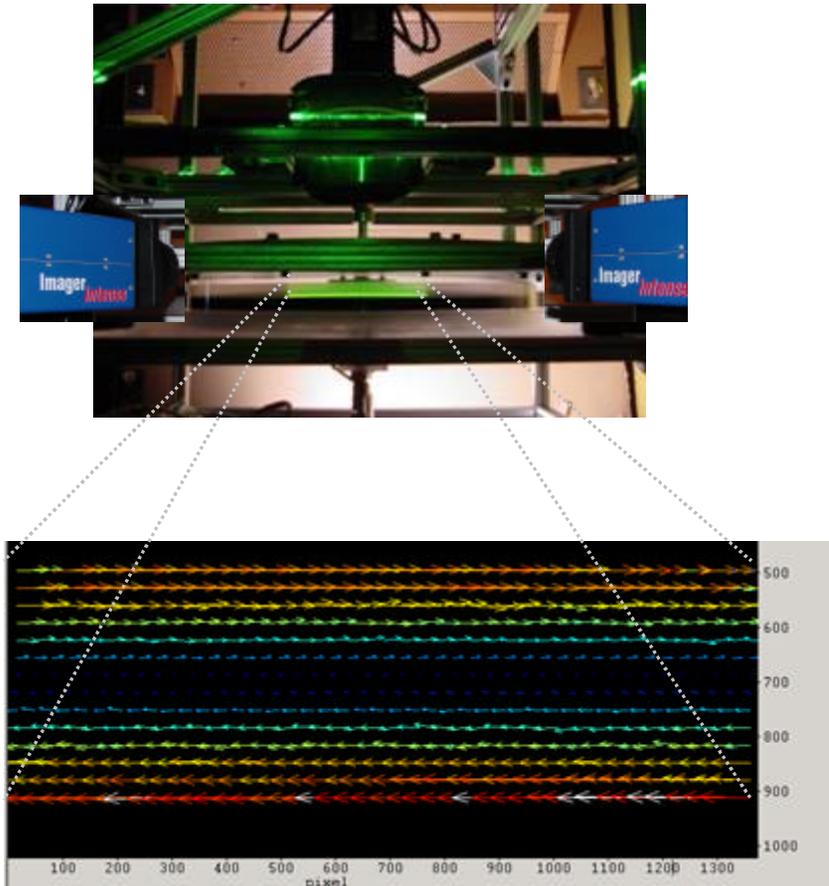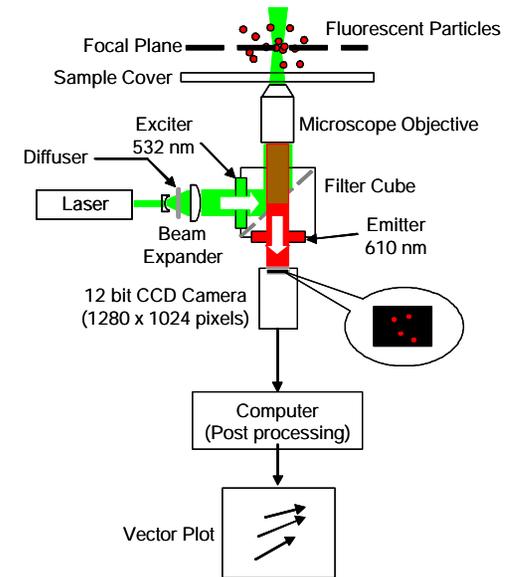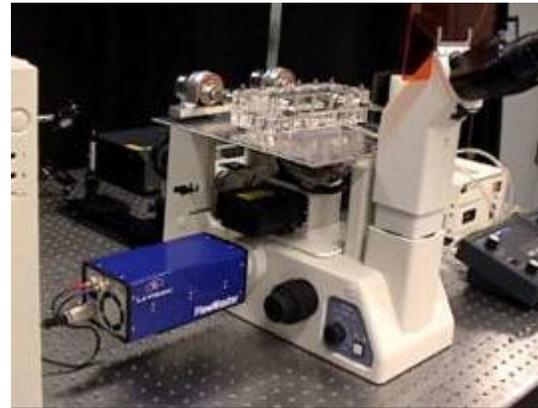
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Micro Particle Image Velocimetry

The µPIV system consists of three main components, which are a two cavity frequency-doubled Nd:YAG laser (New Wave Research, Inc.), a microscope (Nikon, TE200) with fluorescent filters and an interline transfer Charge Coupled Device(CCD) camera (LaVision, Inc). The wavelength and the pulse width of laser are 532nm and about 3~5ns, respectively. The figures on right hand side show the experimental setup and working principle of µPIV. The first laser beam is delivered into the inverted epi-fluorescent microscope through the beam expander assembly. The laser beam is guided to the flow field of the microchannel device by passing through a fluorescence filter cube and an objective lens. The filter cube, located below the objective lens, is an assembly consisting of the exciter (green filter), emitter (red filter), and a dichroic mirror. Because the dichroic mirror only transmits light in the range =610nm, the laser beam of 532nm is redirected to the objective lens. The beam coming out the objective lens illuminates the fluid and the seeding particles suspending in the fluid in a volume illumination manner. The fluorescent particles absorb the illuminating laser beam (~532nm, green) and emit a longer wavelength (~610nm, red). The signal from the measurement region includes the emitted light from both in-focus and out-of-focus particles, and the reflection from the background. The reflection from the background is eliminated by the emitter filter and the dichroic mirror while both the focused and unfocused particle images are imaged on the CCD camera. After a specified time delay Dt, depending on the flow speed, the same process as described above is performed to acquire the second image frame required for cross-correlation based interrogation.

Re = 210 at z = 0.345 mm

Wz[1/s]
6.76E-03
6.37E-03
5.99E-03
5.60E-03
5.21E-03
4.83E-03
4.44E-03
4.06E-03
3.67E-03
3.28E-03
2.90E-03
2.51E-03
2.12E-03
1.74E-03
1.35E-03
9.66E-04
5.79E-04
1.93E-04

5 m/s

$L_e/D_h = 0.6 /(0.035\,Re_D + 1) + 0.056\,Re_D$

$L_e/D_h = -5.033 + 0.037\,Re_D$

$L_e/D_h = 0.796 + 0.005\,Re_D$

Re_D

Entrance Length of Microchannel

Since the microfabrication techniques are typically planar processes based on film etching or developing, two important geometrical limitations exist. First, there is generally uniform depth throughout microfabricated devices. Therefore, the flow conditions upstream of channel entrance must be considered when studying entrance length in microchannels rather than simply assuming a uniform velocity profile. The second implication of planar microfabrication is that the cross-sections of the microchannels are usually rectangular or trapezoidal. This limitation makes entrance length estimation in microscale channels even more difficult since the accuracy of using entrance length correlations of a circular channel for rectangular channel entrance length estimation is not known in the microscale. Further, when two limitations is considered together, the results from the past researches on rectangular channels should also be applied carefully in microchannel, since the aspect ratio of H/W and W/H results in totally different inlet geometry.

A rectangular microchannel used in this experiment has the aspect ratio ~2.65 and the hydraulic diameter ~380? m. From the velocity filed measured with µPIV system(*see* the figure below), the velocity profile was found and its centerline velocity was used to find the entrance length, which is defined as the axial distance where the centerline velocity reaches 99% of fully developed maximum velocity. In moderate Reynolds number range, the dimensionless entrance length, x/(ReD·Dh), was found to be 0.033, which is 45% reduction compared to the conventional estimation. For low Reynolds numbers, the entrance length remains almost constant up to Re=100 and shows x/Dh = 0.9125. The coefficient 0.037 in second term of linear fit for moderate Reynolds numbers is comparable with 0.033 from moderate Reynolds number analysis. It seems that the low value of Le/Dh at Re=2100 is caused from the decaying exponential fit which is used to extract the entrance function. Also the linear fit for low Reynolds numbers shows a very slight increase as Re increases and therefore, the constant portion of 0.796 plays a major role in the low Reynolds number range. The constant 0.796 is also comparable with 0.9125, the dimensionless entrance length with the Reynolds number dependence.

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