

was narrow and contained a few extra peaks at 3.6 and 4.2 that correspond to two and three aggregated particles. For all output fractions, there were significant levels of 3.1 μm particles; however, the significant majority of the distribution of particles centered on 9- μm were collected from fraction 5.

[0226] Fraction 4 also contained some larger particles, as shown in FIG. 26B, where interestingly, the collected particles had a lower mean centered on 8- μm with a distribution that was 20% narrower than the initial distribution of large particles. The mean and standard deviation of the collected particles were determined by fitting the counts to a Gaussian distribution. The purity and yield for filtration of large particles from 3.1- μm particles is shown in FIG. 27, where percentages refer to absolute particle numbers. Purity is defined as the percentage of total particles in a fraction of the filtrate that were 3.1- μm in diameter, and yield is the percentage of total 3.1- μm particles recovered. As shown in FIG. 27, there are definite trade-offs between yield and purity, which can be useful for deciding collection strategies for particular applications.

Example 9

[0227] Another embodiment of the system can be described with reference to FIG. 28. Because large quantities of particles can be filtered in relatively short periods of time, separations like that shown in FIG. 25 can be easily cascaded in series to reach higher levels of enrichment if filtrate from the five outlets is merged into two pools. FIG. 28 presents data for a cascaded separation with two tiers. In one embodiment, filtration from fractions 1-4 were pooled and run through the system again, and the same was done with fraction 5. Key parameters that are reported at each tier are the absolute numbers of particles, the ratio between 3.1- and 9- μm particles (ratio 3/9) and the enrichment ratio (i.e., the tier X 3/9 ratio divided by tier 0 3/9 ratio). This sample consisted of pooling fractions 1-4 of the first pass, running this through the system, and collecting fractions 1-4 again. Notably, after two tiers of separation, ~56% of the initial 3.1- μm particles were collected in a sample, where the number of 9- μm particles was reduced by 3 orders of magnitude (i.e., 99.9% purification).

Example 10

[0228] In this example, the behavior of deformable particles is illustrated. In particular, droplets of a fluid that is generally immiscible in solution are shown to behave much like other particles in their focusing behavior in channels. In embodiments shown in FIGS. 29A-29C, various sized silicone oil droplets that are not rigid can also be separated using the system described herein. A continuous distribution of silicone oil droplets ($\rho=0.95\text{ g/cm}^3$, $\mu=10\text{ cst}$) (ranging in size from <1 to 20- μm) can be introduced into the system at a flow rate of 0.9 mL/min, as shown in FIG. 29A. In particular, as shown, the input solution of droplets is well mixed. After passing through the separation channel, larger droplets are seen to focus while smaller droplets remain unfocused. The five collected fractions showed obvious differences in content of large droplets by phase contrast microscopy that corresponded with the video results of focusing streamlines shown in FIG. 29A. The fractions also showed particle size distributions, represented in FIG. 29B, that agreed well with the microscopy data. The continuous droplet size distributions for the collected fractions clearly show a size cutoff for separation

with the exemplary geometry (3.7- μm by fitting the data from fraction 3 with a Boltzmann sigmoidal function to accurately determine the position of 50% depletion).

[0229] Following the distribution shown FIG. 29B, one can estimate that equal numbers of 4.5- μm particles could be filtered from 3- μm particles with a separation purity of >90% with 50% of the 3- μm particles being recovered. Interestingly, size cutoffs for rigid particles are similar to that of deformable particles. For example, rigid PDMS beads with a different distribution ranging from <2 to 40- μm were fractionated using the same system and flow settings, as shown in FIG. 29C. In this case, the size cutoff of fraction 3 was determined to be 4.0- μm slightly higher than for deformable particles. Another noticeable difference is the larger concentration of smaller particles in fraction 5 and the reduction in larger particles in fractions 1-3. Overall, the separation behavior for rigid and deformable particles appears remarkably similar, with the bulk of large particles collected in fraction 5 and to a lesser extent 4. In both cases, fraction 2 has the lowest concentration of particles over the entire size range.

Example 11

[0230] The size cutoff for an the exemplary system described above is useful for separation of platelets (2-4 μm) from other blood components, as illustrated in reference to FIG. 30. In one embodiment, the separation of platelets from blood cells in diluted blood (2% whole blood in PBS) can be examined using a same flow rate of 0.9 mL/min. The cellular components of blood range in size from 7 to 15- μm for spherical leukocytes (WBCs), to 6-8- μm ×2- μm for discoid RBCs, while platelets are between 2 and 4- μm in diameter. One microliter of blood contains $\sim 5\times 10^6$ RBCs, $(2-5)\times 10^5$ platelets, and $(5-10)\times 10^3$ WBCs². The original blood solution diluted to 2% was examined by flow cytometry, as shown in FIG. 30. The initial number ratio of platelets to other cellular components in blood was 0.04. After passing 10 mL of diluted blood (200- μL whole blood) through the system and collecting the five various fractions, enrichment or depletion of the platelet population was observed. In fraction 5, the amount of platelets was depleted compared to larger cells by a factor of 2, while in fraction 3 the relative amount of platelets was enriched by a factor of 100.

Example 12

[0231] The experimental data suggesting an optimal flow rate for focusing agree with theoretical predictions, despite theoretical assumptions of small R_p . At a low maximum channel velocity (U_m), lift is dominant; however, there is not enough distance in the channel for particles to reach equilibrium positions, as previously illustrated in FIG. 24 in the channel having the low particle Reynolds number R_p . As U_m increases, the ratio of lift to drag forces (R_D) approaches 1; here a single equilibrium position is favored due to the superposition of Dean drag and inertial lift forces, shown in the two channels having middle Reynolds numbers R_p in FIG. 24. As U_m increases further, R_p becomes less than 1 over the channel cross section and focusing is perturbed by Dean drag, as illustrated by the channel with a high R_p in FIG. 24. These results suggest that theory for finite R_p should have a dependence on increasing flow velocity similar to the small R_p theory used.

[0232] Using the experimental data determining size cutoffs for focusing, a semi-empirical relationship to predict