delivered at about 0.05 microliters per minute. To process just 100 cells per second, the cell concentration must be 120,000 per microliter or 120 million per milliliter. This concentration requirement in turn makes clogging even more likely. The problem is further compounded by the tendency of many types of cells to clump in high concentration and to settle out and stick to surfaces when sample delivery rates are slow. The system created by Doornbos, circumvents the clogging problem by using a conventional flow cell with flow resistors to slow the flow, but he found it very difficult to control precise focused delivery of the sample. This method also does not eliminate the need for slow volumetric delivery and highly concentrated samples.

[0008] Sheathless, non-focusing flow cytometers have been developed but these instruments suffer from low sensitivity due to the need for a focal spot size that will excite particles throughout the channel. The spot size is reduced by using very small capillary channels but particles flow within the channel at variable rates according to the laminar flow profile that develops in the channel. This results in different transit times and coincidence of particles in the laser spot which both make analysis more difficult. Also, background cannot be reduced by spatially filtering optics that are designed to collect light from a tightly focused core stream. This limits sensitivity and resolution.

[0009] Other approaches have been demonstrated to manipulate particles using acoustic radiation pressure in a laboratory setting. These devices are planar devices modeled in Cartesian coordinates. Applying an acoustic field generates a quasi-one-dimensional force field that focuses particles into a ribbon in a rectangular chamber. For laminar flow, the resulting distribution of particles across the chamber places the particles in different velocity stream lines. Particles in different stream lines will not only be in different locations but they will also flow at different velocities. This in turn results in different residence times for particles at a location within the device. Planar focusing does not align particles in a manner suitable for use with flow cytometers.

BRIEF SUMMARY OF THE INVENTION

[0010] ~~An embodiment of the present invention comprises an acoustic focusing capillary further comprising a capillary coupled to at least one vibration source and the at least one vibration source possessing a groove. The capillary of this embodiment is preferably coupled to the vibration source at the groove. The groove preferably has an approximately same cross-sectional geometry as the capillary. The capillary can be circular, elliptical, oblate, or rectangular. The vibration source preferably comprises a piezoelectric material. In this embodiment, the groove preferably increases an acoustic source aperture of the capillary.~~

[0011] ~~Another embodiment of the present invention comprises a method of manufacturing an acoustic focusing capillary. This embodiment further comprises providing a capillary and at least one vibration source, machining a groove into the vibration source, and coupling the at least one vibration source to the capillary at the groove. The groove preferably has an approximately same cross-sectional geometry as the capillary. The capillary can be circular, elliptical, oblate, or rectangular. The at least one vibration source preferably comprises a piezoelectric material. This embodiment can optionally comprise increasing the acoustic source aperture of the capillary.~~

[0012] In anyet another embodiment of the present invention, an apparatus that hydrodynamically and acoustically focuses particles in a particle stream comprises a flow chamber, an outer confine of the flow chamber for flowing a hydrodynamic fluid therethrough, a central core of the flow chamber for flowing the particle sample stream therethrough, and at least one transducer coupled to the chamber producing acoustic radiation pressure. ~~The transducer of this embodiment is preferably coupled to an outer wall of the flow chamber. The transducer can alternatively form a wall of the flow chamber.~~ The particle stream is acoustically focused and subsequently hydrodynamically focused.

[0013] AnotherA further embodiment of the present invention providescomprises a method of hydrodynamically and acoustically focusing a particle stream. This method preferably comprises flowing a sheath fluid into outer confines of a capillary, flowing a particle stream into a central core of the capillary, and applying acoustic radiation pressure to the particle stream within the sheath fluid. ~~The particle stream of this method can be hydrodynamically focused and subsequently acoustically focused. Alternatively, the particle stream is acoustically focused and hydrodynamically focused simultaneously.~~

[0014] Another method of hydrodynamically and acoustically focusing particles is provided instill a further embodiment of the present invention. The methodThis embodiment preferably comprises providing a fluid comprising particles therein, flowing a sheath fluid into outer confines of a flow chamber, flowing the fluid containing the particles into a central core of the flow chamber, and applying acoustic radiation pressure to the fluid comprising the particles. ~~This embodiment can also comprise analyzing the particles.~~

[0015] AnotherOne embodiment of the present invention providescomprises a method of hydrodynamically and acoustically focusingaligning particles ~~using acoustic radiation pressure~~. The methodThis embodiment preferably includes providing a fluid comprising particles therein, subjecting the fluid to acoustic radiation pressure, rotating the fluid 90 degrees, and subjecting the fluid to acoustic radiation pressure a second time to align the particles. ~~This embodiment can also comprise analyzing the aligned particles.~~

[0016] Another embodiment of the present invention provides~~comprises~~ a method of hydrodynamically and acoustically focusing particles in a fluid. The method~~This embodiment~~ includes flowing a fluid comprising particles therein, subjecting the fluid to acoustic radiation pressure in one planar direction to acoustically focus the particles, and flowing a sheath fluid in a second planar direction thereby hydrodynamically focusing the fluid in the second planar direction to further focus the particles.

[0017] ~~The present invention further includes methods for dislodging bubbles in a fluidic system. These methods comprise providing a fluid stream through a channel and resonating the channel at an acoustic frequency. These methods also include providing a fluid stream through a channel and vibrating the channel walls at a low frequency.~~

[0018] ~~An embodiment of the present invention is an apparatus that acoustically focuses particles into a quasi-planar arrangement in a fluid. This embodiment preferably comprises a capillary with an oblate cross-sectional geometry and at least one transducer coupled to the capillary. The capillary is preferably elliptical. This embodiment can further comprise an imager for imaging the particles.~~

[0019] ~~Another embodiment of the present invention comprises a method for acoustically focusing particles into a quasi-planar arrangement in a fluid comprising particles. The method preferably comprises flowing the fluid comprising particles therein through a flow chamber comprising an oblate cross-sectional geometry and subjecting the fluid to acoustic radiation pressure. The cross-sectional geometry of the flow chamber is preferably elliptical. This embodiment can also include imaging the particles.~~

[0020] Objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0021] The accompanying drawings, which are incorporated into and form a part of the specification, illustrate one or more embodiments of the present invention and, together with the