elements for performing similar or equivalent functions may also be used. In the embodiment illustrated, L1 transforms the multimode beam in the flow axis (18), while L2 acts to compress the multimode beam (26) along the beam width, or in the transverse flow axis (78). Surprisingly, it was found with sufficient compression in the transverse flow axis (78), a multimode diode laser (24) could be compressed to a suitable beam shape for sorting sperm and would have a uniform enough intensity profile for differentiating small variations in DNA content. This configuration was able to transform the multi-node, non-Gaussian beam profile, illustrated in FIG. 4A, to the profile having a more uniform intensity distribution, seen in FIG. 4B. The adjusted beam profile need not necessarily be Gaussian, or even near-Gaussian, but should provide each particle that passes through a very constant dosage of laser power, even when there are slight variations in the path each particle traverses through the beam spot. Surprisingly, this configuration was able to achieve an X-Y split suitable for sex sorting sperm as illustrated in a fluorescence histogram and bivariate plot in FIG. 5. Non-limiting examples of beam profiles which may be used include: Gaussian, flat top, rectangular, trapezoidal and combinations thereof.

As one non-limiting example, L1 may have a focal length of 80mm and L2 may have a focal length of 30mm. In the described configuration these lenses may be used to produce a beam profile ~~having a shape~~ having a width ~~or~~ roughly 140μm and a height of roughly 24 μm. Other similar configurations are contemplated herein which may include highly compressing a beam width of a multimode mode laser, and shaping the beam to a suitable beam spot for sorting sperm.

Turning now to FIG. 6, an alternative embodiment is depicted where the multimode diode laser (24) is combined with a second multimode diode laser (88). Optics (94) are illustrated for combining the multimode beam (26) with a second multimode beam (90), and any alternative or equivalent optical configurations may be also be used. Once combined, the combined multimode beam (92) passes through beam shaping optics (32) like those previously described. The resulting manipulated beam (92) may have improved power and uniform intensity characteristics suitable for sorting and analyzing particles at an interrogation zone.

Example 1

24. A method of processing particles comprising the steps of:
    a. flowing particles along a fluid flow path having an interrogation zone;
    b. producing ~~an~~ multimode beam directed at the interrogation zone, wherein the multimode beam has a transverse beam profile with multiple spatially separated intensity peaks;
    c. manipulating the multimode beam to create a compressed beam with uniform spatial intensity characteristics;
    d. illuminating particles at the inspection zone with the manipulated beam;
    e. detecting reflected or fluorescent light from particles as they pass the interrogation zone and producing a signal;
    f. classifying particles based upon the produced signals.

25. The method of processing particles according to claim 24 further comprising the steps of:
    a. selecting particles based on their classification;
    b. collecting selected particles.

26. The method of processing particles according to claim 24 wherein the step of manipulating the illumination beam further comprises the steps of:
    a. focusing the illumination beam; and
    b. shaping the illumination beam.

27. The method of processing particles according to claim 24 wherein the step of manipulating the illumination beam further comprises the steps of:
    a. compressing the beam height of the beam profile with a first element to a beam height between 10 and 30 micrometers.

28. The method of processing particles according to claim 24 wherein the step of manipulating the illumination beam further comprises the steps of:

elements for performing similar or equivalent functions may also be used. In the embodiment illustrated, L1 transforms the multimode beam in the flow axis (18), while L2 acts to compress the multimode beam (26) along the beam width, or in the transverse flow axis (78). Surprisingly, it was found with sufficient compression in the transverse flow axis (78), a multimode diode laser (24) could be compressed to a suitable beam shape for sorting sperm and would have a uniform enough intensity profile for differentiating small variations in DNA content. This configuration was able to transform the multi-node, non-Gaussian beam profile, illustrated in FIG. 4A, to the profile having a more uniform intensity distribution, seen in FIG. 4B. The adjusted beam profile need not necessarily be Gaussian, or even near-Gaussian, but should provide each particle that passes through a very constant dosage of laser power, even when there are slight variations in the path each particle traverses through the beam spot. Surprisingly, this configuration was able to achieve an X-Y split suitable for sex sorting sperm as illustrated in a fluorescence histogram and bivariate plot in FIG. 5. Non-limiting examples of beam profiles which may be used include: Gaussian, flat top, rectangular, trapezoidal and combinations thereof.

As one non-limiting example, L1 may have a focal length of 80mm and L2 may have a focal length of 30mm. In the described configuration these lenses may be used to produce a beam profile having a width of roughly 140μm and a height of roughly 24 μm. Other similar configurations are contemplated herein which may include highly compressing a beam width of a multimode mode laser, and shaping the beam to a suitable beam spot for sorting sperm.

Turning now to FIG. 6, an alternative embodiment is depicted where the multimode diode laser (24) is combined with a second multimode diode laser (88). Optics (94) are illustrated for combining the multimode beam (26) with a second multimode beam (90), and any alternative or equivalent optical configurations may be also be used. Once combined, the combined multimode beam (92) passes through beam shaping optics (32) like those previously described. The resulting manipulated beam (92) may have improved power and uniform intensity characteristics suitable for sorting and analyzing particles at an interrogation zone.

Example 1

A 150mW UV diode laser having an initial beam width of about 6800μm and beam height of about 1900μm was operated at a wavelength in the range 370-380nm and was modified with beam shaping optics to produce a suitable sperm sorting configurations. The intensity of the beam profile can be seen in FIG. 4A. The laser was mounted at an appropriate orientation to provide a beam with suitable aspect ratio to match desired aspect ratio and beam profile at the inspection point of flow cytometer.

The laser has a multi-mode transverse beam profile (M squared of greater than 1.5) and is shaped and or focused using optical elements (such as lenses/refractive elements, mirrors/reflective elements, phase elements, and the like) to alter the beam profile to provide sufficient intensity and uniformity for cell illumination at the inspection point. Specifically, a cylindrical lens with an 80mm focal length was placed in the beam axis in order to compress the beam height in the flow axis. A second cylindrical lens with a focal length of 30mm was placed in the beam axis, orthogonally to the first, to provide compression of the beam width in the transverse flow axis. This approach produced the pseudo Gaussian profile beam seen in FIG. 4B, by compressing the spatial modes of the laser beam a final beam spot was produced with a beam height about 24 μm in the flow axis and a beam width about 140 μm in the transverse flow axis.

Sperm nuclei stained with Hoechst 33342 was flowed though this beam spot in a sperm sorting configuration to produce two distinct populations (Seen as a histogram and bivariate plot in FIG. 5). By passing cells (to be measured) through the altered laser beam, scatter and or fluorescence light can be collected and with suitable spectral selection elements, be partitioned/separated to one or more detectors and measurements can be made to identify and characterize different cells such as in the case for sperm cells, the presence of an X or Y chromosome. This information can in turn be used to determine further processing steps on that cell such as selection, sorting, altering function of the cell as non-limiting examples.

Example 2

A 200mW UV diode laser having an initial beam width of 1700 μm and beam height of about 200μm was operated at a wavelength in the range 370-380nm was modified with beam shaping optics to produce a suitable sperm sorting configurations. The laser was

mounted at an appropriate orientation to provide a beam with suitable aspect ratio to match desired aspect ratio and beam profile at the inspection point of flow cytometer. Namely, the laser was mounted at 90 degrees (about beam axis) to provide an initial laser beam aspect ratio that is well suited to further beam shaping and focusing optics that provide sufficiently uniform cell illumination conditions. Specifically, the final desired aspect ratio was in the neighborhood of approximately 20μm x160μm.

The laser has a multi-mode transverse beam profile (M squared of greater than 1.5) and is shaped and or focused using optical elements (such as lenses/refractive elements, mirrors/reflective elements, phase elements, and the like) to alter the beam profile to provide sufficient intensity and uniformity for cell illumination at the inspection point. Specifically, a cylindrical lens with a 15mm focal length was placed in the beam axis in order to compress the beam height in the flow axis. A second cylindrical lens with a focal length of 25mm was placed in the beam axis, orthogonally to the first, to provide compression of the beam width in the transverse flow. This configuration produced a pseudo Gaussian profile beam, or other uniform beam profile by compressing the spatial modes of the laser beam. This arrangement of a crossed cylindrical lens pair are used to produce a 26 μm (vertical, cell flow axis) by 160 μm (horizontal, across flow axis) spot suitable for sorting sperm. These dimensions can be altered, for example to provide a 26 by 100 μm spot.

As can be easily understood from the foregoing, the basic concepts of the present invention may be embodied in a variety of ways. As such, the particular embodiments or elements of the invention disclosed by the description or shown in the figures accompanying this application are not intended to be limiting, but rather exemplary of the numerous and varied embodiments generically encompassed by the invention or equivalents encompassed with respect to any particular element thereof. In addition, the specific description of a single embodiment or element of the invention may not explicitly describe all embodiments or elements possible; many alternatives are implicitly disclosed by the description and figures.

It should be understood that each element of an apparatus or each step of a method may be described by an apparatus term or method term. Such terms can be substituted where desired to make explicit the implicitly broad coverage to which this invention is

24. A method of processing particles comprising the steps of:

a. flowing particles along a fluid flow path having an interrogation zone;

b. producing a multimode beam directed at the interrogation zone, wherein the multimode beam has a transverse beam profile with multiple spatially separated intensity peaks;

c. manipulating the multimode beam to create a compressed beam with uniform spatial intensity characteristics;

d. illuminating particles at the inspection zone with the manipulated beam;

e. detecting reflected or fluorescent light from particles as they pass the interrogation zone and producing a signal;

f. classifying particles based upon the produced signals.

25. The method of processing particles according to claim 24 further comprising the steps of:

a. selecting particles based on their classification;

b. collecting selected particles.

26. The method of processing particles according to claim 24 wherein the step of manipulating the illumination beam further comprises the steps of:

a. focusing the illumination beam; and

b. shaping the illumination beam.

27. The method of processing particles according to claim 24 wherein the step of manipulating the illumination beam further comprises the steps of:

a. compressing the beam height of the beam profile with a first element to a beam height between 10 and 30 micrometers.

28. The method of processing particles according to claim 24 wherein the step of manipulating the illumination beam further comprises the steps of: