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[54] **SCATTERING CELL EMPLOYING ELECTROSTATIC MEANS FOR SUPPORTING A PARTICLE**

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[52] **U.S. Cl.**................ **356/103,** 317/262, 250/41.9, 356/208

[51] **Int. Cl.**.......... **G01n 21/00,** H01g , B01d 59/44

[58] **Field of Search**..................... 219/7.5; 250/41.9; 209/127, 128; 324/32; 317/262; 356/102, 103, 104

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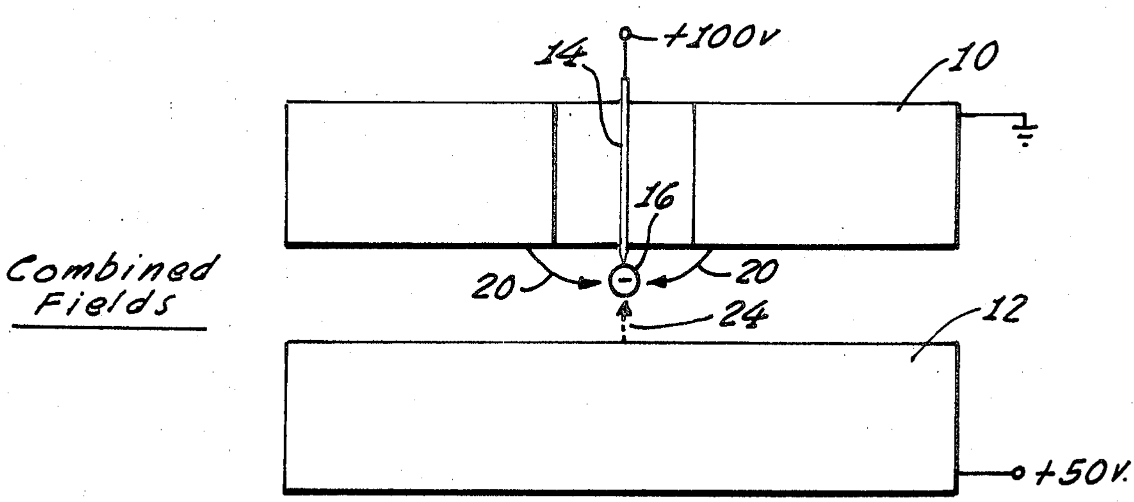
[57] **ABSTRACT**

A levitator for use with a light scattering photometer unit including a spaced pair of plate electrodes to provide an electric field for producing a first electrostatic force on a charged particle located between the spaced plate electrodes and with the levitator additionally including a pin electrode extending through and insulated from one of the plate electrodes to provide an electric field for producing a second electrostatic force and with the combination of the first and second electrostatic forces suspending the charged particle between the plate electrodes at a location spaced from but adjacent to the pin electrode. An automatic servo system includes an optical detector for detecting the position of the charged particle to produce a control signal to adjust the electric fields to maintain the charged particle in the proper position.

14 Claims, 8 Drawing Figures



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4 Sheets-Sheet 1

Fig. 1a

Up and In

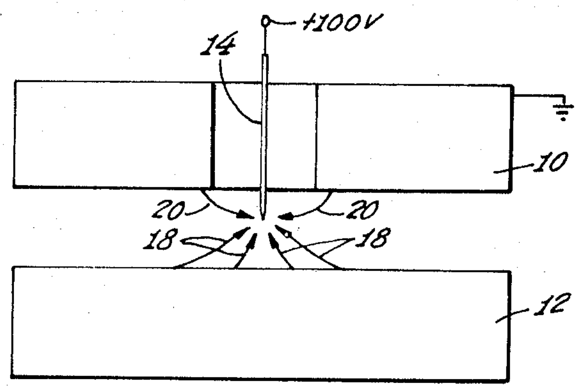

Fig. 1b

Down

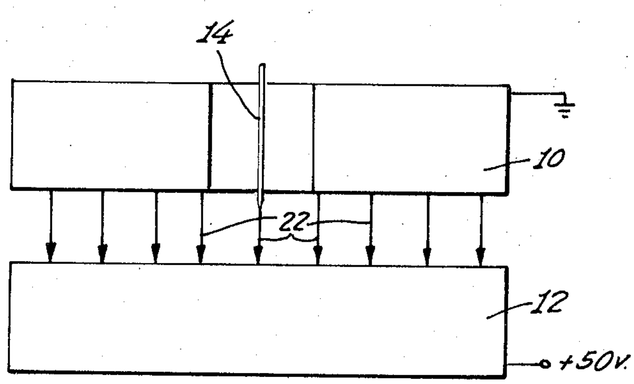

Fig. 1c

Combined Fields

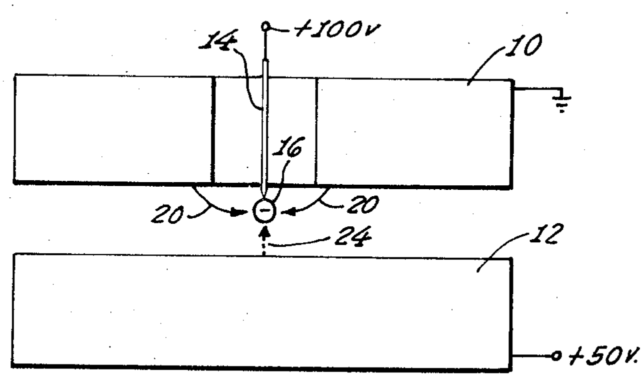

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Fig. 2

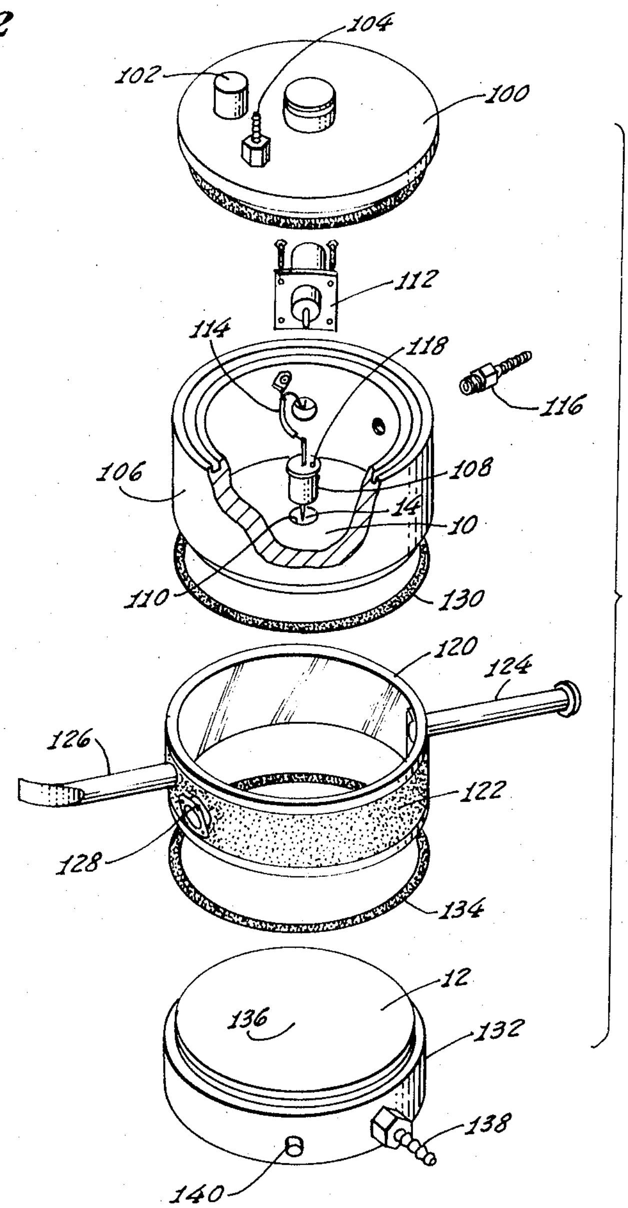

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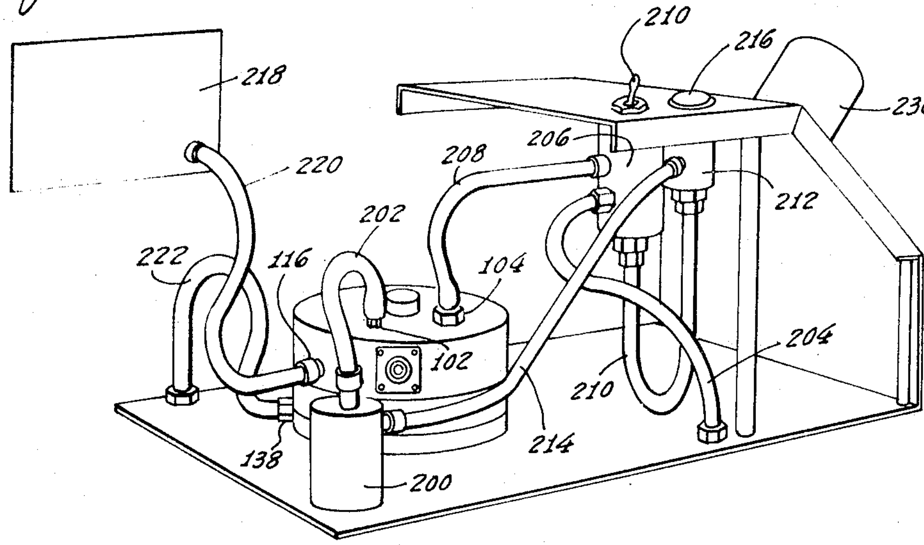
Fig. 3



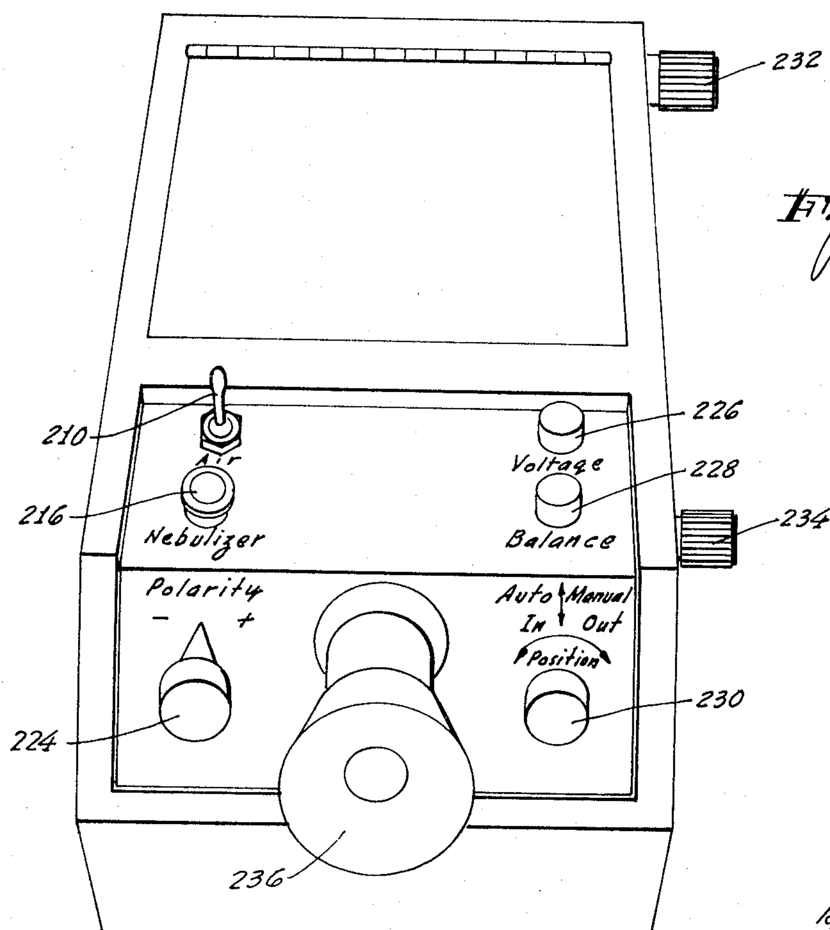


Fig. 4

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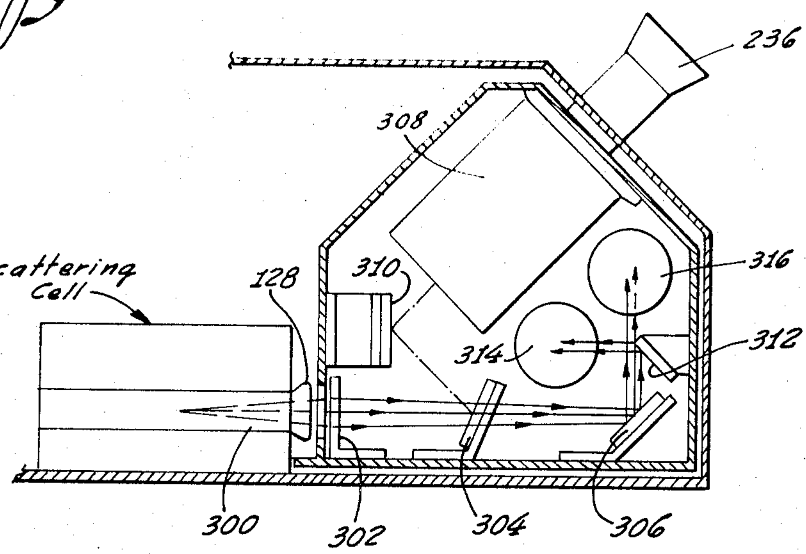
Fig. 5



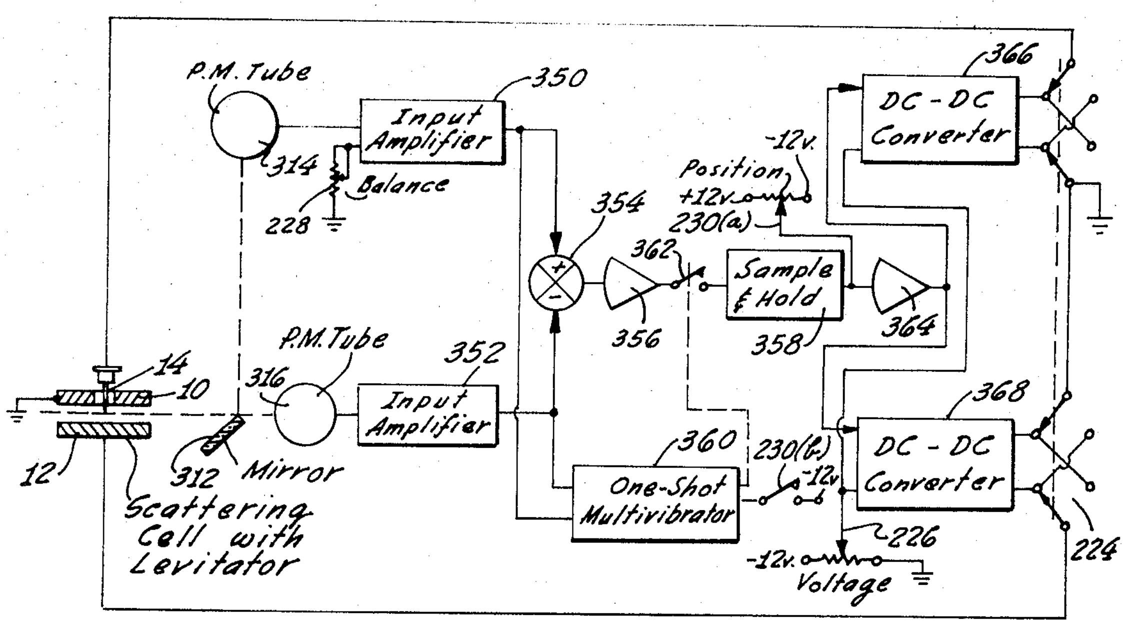


Fig. 6

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SCATTERING CELL EMPLOYING ELECTROSTATIC MEANS FOR SUPPORTING A PARTICLE

The present invention is directed to a levitator for use with a light scattering photometer unit. As one specific example, the light scattering photometer unit may operate in the following manner. Microparticles, whose light scattering properties are to be investigated, are located in a beam of light produced by a light source, preferably the light energy produced by the light source is polarized and at a single frequency, such as the light energy produced by various lasers. The microparticles may be of many types, such as bacteria or latex spheres of about 1 micrometer in diameter, but the levitator of the present invention could also be used with particles of greater or lesser size. The light scattered by the microparticle is intercepted by a detector mounted beneath a periscope which moves in an arc around the particle. The signal from the detector is amplified to drive a recorder to record a plot of the scattered light intensity as a function of the angle of the detector relative to the incident beam of light, this plot being a differential light scattering pattern.

A clearer understanding of the operation of a light scattering photometer may be had with reference to U.S. Pat. application Ser. No. 777,837, filed on Nov. 21, 1968, in the name of Philip J. Wyatt now U.S. Pat. No. 3,624,835, and Ser. No. 34,243, filed on May 4, 1970, in the names of Philip J. Wyatt, et al., and both assigned to the same assignee as the instant application.

In the present invention, a stream of microparticles whose light scattering properties are to be investigated is introduced into a scattering chamber such as by nebulizing a liquid suspension or by any other convenient means. Most microparticles upon being nebulized from a liquid suspension or when collected from an aerosol source naturally tend to have a small positive or negative charge. An individual microparticle is isolated and positioned in the center of a laser beam through the use of pneumatic and electrical controls. Once the particle is suspended in the laser beam, the particle may be automatically held in position by means of an automatic servo mechanism so that the light scattering properties of the particle may be investigated.

Generally, the particle is maintained in the proper position through the use of a levitator which includes a pair of parallel plate members serving as electrodes and with a third pin electrode extending through but insulated from one of the parallel plate electrodes. The combination of the three electrodes provides for electric fields to maintain the particle suspended between the parallel plates and in a position for interception with the light beam.

In the prior art it is known to use a pair of parallel plate electrodes to suspend a particle between the electrodes. For example, Millikan, in the early part of this century, used parallel plate electrodes to suspend small oil drops between the plates. Generally, with the prior art apparatus, the plates were charged to provide an electric field interacting with the charge of the particles to counterbalance the force of gravity to maintain the particle between the plates. The difficulty with this type of apparatus is that the particle would not necessarily be centered and would tend to move off from between the plates. In addition, the electric field would have to be very accurately maintained and parallel to the gravitational field which required that the plates be very accurately aligned and perpendicular to the local gravitational field or the particle would tend to move within the space between the plates. These above difficulties made the use of the Millikan-type apparatus impractical other than for demonstrations.

In order to overcome some of the difficulties of the Millikan apparatus, Fletcher, in 1914, added a third electrode which took the form of a small plate located within and insulated from one of the parallel plates, which third electrode was used to produce an electric field to pull the particle in toward the center, and also to counterbalance the gravitational forces on the particle. By using this center electrode at selected times to produce an electric field between the center electrode and the pair of parallel plate electrodes, the particle could be returned to the center position. The difficulty with the Fletcher apparatus is that the size of the radial field produced by the small third electrode and used for centering is limited by the fact that, in addition to producing the radial field, the third electrode also produces a vertical field. The vertical field is limited to a level to counterbalance gravity which, in turn, limits the size of the radial field. The Fletcher apparatus, therefore, provides for a very weak radial field which is often not effective.

In order to overcome the shortcomings of both the Millikan and Fletcher apparatus, the present invention uses a pair of spaced parallel plate electrodes and with a pin electrode extending through and insulated from one of the plate electrodes. In a preferred embodiment of the invention the pin electrode extends through the top electrode and wherein the two parallel plate electrodes are charged to provide an electric field to produce a force which is "down" to add to the gravitational force on the particle. In order to compensate for this electric field produced by the parallel plate electrodes, the center pin electrode is charged relative to each of the plate electrodes to provide a field to produce a force which is "up" to overcome both the effects of gravity and the electric field pushing down thereby balancing the particle between the plates. This "up" field is therefore relatively large since it must overcome both the "down" field and gravity.

In addition to the "up" field produced by the pin electrode, a radial field is also produced, which is quite large since it is produced by the same charge as the "up" field. This combination of fields provides a strong radial field to maintain the particle in a centered position while the pair of fields, one "up" and one "down," is used to overcome the effects of gravity to maintain the particle between the plates. Once the particle is in the center position, a servo system with an optical detector may adjust the magnitude of the fields to keep the particle suspended in the proper position.

The above arrangement of two parallel plates forming a pair of electrodes and with a third electrode extending through and insulated from one of the parallel plates so as to provide for a strong radial field while still balancing the particle may be energized in a number of different ways. For example, the electrodes may be energized alternately so that the "up" and "in" field can be produced alternately with the "down" field to produce the strong net radial field. The alternation must be rapid relative to any rate of motion of the particle. In addition, both fields may be produced simultaneously so as to produce the strong net radial field while still providing the balancing of the particle. The invention will be described with reference to an arrangement wherein the fields are produced simultaneously, but it is to be appreciated that the fields could be applied alternately, as explained above.

A clearer understanding of the invention will be had with reference to the following description and drawings, wherein:

FIG. 1*a*, 1*b*, and 1*c* illustrate in schematic form the operation of the three-electrode levitator of the present invention;

FIG. 2 illustrates in detail a particular construction for a scattering cell including a levitator for receiving and suspending the microparticles;

FIG. 3 illustrates a general arrangement of the scattering cell 1 of FIG. 2 in combination with the various pneumatic controls for introducing microparticles in the cell;

FIG. 4 illustrates a view of the control panel used to provide the electrical and pneumatic control of the microparticles within the scattering cell of FIG. 2;

FIG. 5 illustrates the arrangement of the optical detector and other optics for use with scattering cell of FIG. 2; and

FIG. 6 illustrates a block diagram of a servo for controlling the position of the microparticles within the scattering cell.

Referring first to FIGS. 1*a*, 1*b*, and 1*c*, a schematic representation of the levitator of the present invention is shown. Specifically, the levitator includes a pair of parallel plate electrodes **10** and **12** and a third pin electrode **14** extending through but insulated from the electrode **10**. As shown in FIG. 1*c*, the various electrodes may have potentials applied thereto, the values of which, shown in FIG. 1*c*, are representative only. For a given particle, the electrode **10** may have a reference potential or be at ground, the electrode **12** may have a potential on the order of +50 volts, and the electrode **14** may have a potential on the order of +100 volts. These positive potentials for the electrical energy applied to the electrodes **12** and **14** are based on an assumption that the microparticle to be suspended has a negative charge as shown by charged particle **16** located in a suspended position. If the particle had a positive charge, instead, then the corresponding voltages on electrodes **10, 12** and **14** would be reversed.

Referring now to FIG. 1a, it can be seen that the difference in potential between the electrodes **12** and **14** provides for strong electric field producing a force which is "up" and "in" as shown by arrows **18**. The difference in potential between the electrodes **10** and **14** provides for strong electric field producing a force which is radial and "in," as shown by the arrows **20**. If the electrode **12** had no potential, a negatively charged particle would therefore be drawn toward the center pin electrode **14**.

Referring now to FIG. 1*b*, the difference in potential between the electrodes **10** and **12** provides for weak electric field producing a force which is "down," as shown by the arrows **22**, and if no potential were applied to electrode **14**, a negatively charged particle would be pulled downward toward the electrode **12**. Since the particle also is pulled downward by the force of gravity, the electric field as shown by the arrows **22** is in a direction to increase this downward movement.

FIG. 1*c* shows the combination of these electric fields. Specifically, the strong radial electric field **20** is still present to hold the particle **16** in a center position. A combined vertical field **24** is a combination of the fields **18** and **22** shown in FIGS. 1*a* and 1*b* and is weaker than the field shown by the arrows **20**. This weak vertical field is used to counterbalance the force of gravity of the charged particle **16**. It can be seen, therefore, that by the use of this three-electrode structure, and specifically in the particular manner in which this three-electrode structure is energized, the gravitational forces acting on the charged particles may be counterbalanced by a weak vertical field, while at the same time a strong radial field is used to pull the charged particle into a central position.

It is to be appreciated that the pin electrode **14** may extend through the bottom electrode instead of the top electrode and with the electric fields arranged to provide for the charged particle properly positioned between the electrodes. Also, the plane of the plate electrodes need not be perpendicular to the force of gravity and the plate electrode may be disposed in any angular relationship to the force of gravity and with the charged particle still held suspended between the plate electrodes.

FIG. 2 is an exploded view of a scattering cell including a levitator of the present invention to receive microparticles and to provide for the detection of the differential light scattering properties of these particles. Since air currents may exert a substantial force on a suspended particle, preferably all parts of the scattering cell are pneumatically sealed to one another, as by O-rings, and the inlet and outlet also include means permitting them to be selectively pneumatically sealed from exterior pressure fluctuations. The scattering cell includes a cover member **100**, having an inlet connector **102** and a flush connector **104**. The cover fits over a settling chamber **106** which receives the microparticles. The cover and settling chamber are sealed by an O-ring **107**. The base **10** of the settling chamber **106** is the first upper electrode **10** shown in FIG. **1**. The pin electrode **14** extends through an insulating plug **108** which is received in an opening **110** in the base **10**.

An electrical connector **112** is mounted on the outside wall of the settling chamber **106** to provide for the application of electrical potential through the wire **114** to the pin electrode **14**. The plate electrode **10** and the settling chamber **106** are grounded through the electrical connector **112**. A bellows connector **116** extends through the wall of the settling chamber **106**. An opening **118** in the insulator **108** allows microparticles to pass from the settling chamber **106** into the light scattering area of the scattering cell of FIG. **2**.

The light scattering area is formed by a transparent cell member **120** which includes a masked section **122**. Light energy, such as from a laser beam, passes into the transparent cell **120** through an entrance mask **124**. A light trap **126** receives the light energy after it passes through the transparent cell. A light exit **128** may be provided through the masked portion **122** so that the interior of the cell may be visually observed with a microscope in a manner to be described in a later portion of this specification. This sealed light exit is wedged at a slight angle to the axis of the scattering cell in the preferred embodiment to avoid reflecting light back into the cell in the horizontal plane in which scattered light is viewed. The settling chamber **106** and the transparent cell **120** are sealed by an upper O-ring **130**.

The light energy, when appropriately directed through the transparent cell 120 from the entrance port 124, intersects any microparticle located at the proper position in the transparent cell and provides for differential light scattering in accordance with the differential light scatteringproperties of scattering properties microparticle. This differential light scattering may be detected by viewing the differentially scattered light at different angular positions through the transparent portion of the transparent cell 120.

A base member 132 supports the lower plate electrode 12. The base member 132 and the transparent cell 120 are sealed using a lower O-ring 134. An opening 136 extends through the lower plate electrode and is connected to an exhaust connector 138 to provide the exhausting of microparticles within the transparent cell 120. Finally, an electrical connection for applying potential to the lower plate electrode 12 is provided by electrical connector 140 which may be an opening to receive a plug, such as a banana plug.

FIG. 3 illustrates a typical manner in which the scattering cell of FIG. 2 may be interconnected with other elements to introduce microparticles to the transparent cell. Specifically, a nebulizer 200 may be used to provide individual microparticles to the scattering cell through a hose 202 connected to the inlet connector 102. The nebulizer 200 operates in a known manner using a supply of a filtered gas, such as air to atomize portions of a liquid suspension of microparticles and provide a stream of the gas containing individual microparticles. As another example, microparticles may be introduced by drawing an aerosol of microparticles into a syringe, thus connecting the outlet of the syringe to line 202 and selectively injecting the entrained microparticles by collapsing the syringe.

When a nebulizer is employed, a supply of air is coupled through a hose 204 and is connected to an air control valve 206. The air control valve 206 has two outputs, one of which is through a hose member 208 directly to the flush connector 104. An air control switch 210 controls the application of air from the hose 204 through the hose 208 to flush out the scattering cell. A second output from the air control valve 206 is through a hose 210 to a nebulizer control valve 212. The output from the nebulizer control valve is through a hose member 214 which is connected to the nebulizer 200. A nebulizer button control member 216 is used to control the application of air to the nebulizer 200. When the button 216 is pushed, air is supplied to the nebulizer 200 to provide for the introduction of microparticles contained in the stream of air through the hose 202 to the inlet connector 102.

A bellows assembly 218 is used to supply a gentle supply of air through a hose member 220 to the bellows connector 116. Finally, an exhaust hose 222 is connected to the exhaust connector 138 to provide for an exhaust of any microparticles within the scattering cell. The interior of the scattering cell is pneumatically isolated from any external air pressure changes and the flow through the scattering cell is controlled by the bellows assembly 218 and the nebulizer 200.

FIG. 4 illustrates the control panel of the levitator of the present invention. As shown in FIG. 3, the control panel includes an air control switch 210 and a nebulizer button switch 216. In addition, the control panel of FIG. 4 includes a polarity control knob 224, a voltage control knob 226, a balance control knob 228, an automatic-manual-position knob 230, a bellows control knob 232 and a focus control knob 234. Also, an eyepiece 236 of a microscope extends from the control panel.

The use of the various control knobs shown on the control panel of FIG. 4 are as follows:

The air control switch 210 in its forward position provides for the flushing of the scattering cell with a clean gas, such as filtered air. In the rear position of the switch 210, the air control valve 206 shown in FIG. 3 is connected to have the air supplied to the nebulizer control valve 212. The nebulizer control button 216, when pushed, supplies air to the nebulizer to spray particles from the nebulizer into the scattering cell. The polarity knob 224 controls the electrode voltages to be either plus or minus so that particles of either charge polarity can be levitated within the scattering cell.

The voltage knob 226 sets the maximum voltage which may be applied to the scattering cell electrodes. The balance knob 228 is set to balance the input to the servo system for the desired position of the particle. The position knob 230 may be in one of two modes, depending upon whether the knob is pulled out or whether the knob is pushed in. When the knob 230 is pulled out, the levitator is in the manual mode. Rotating the knob 230 adjusts the voltages provided to the electrodes so as to move the particle within the scattering cell. When the knob is pushed in, the levitator is in the automatic mode, and the levitator servo controls the electrode voltages to maintain the particle in the proper position within the scattering cell.

The bellows control knob 232 is used to flex a small bellows to move air and particles slowly through the scattering cell. Finally, the focus control knob 234 is used to focus the microscope so as to visually observe the center of the scattering cell.

FIG. 5 illustrates the optical arrangement for visually observing the center of the scattering cell and for providing for an optical detection of the position of the particle within the scattering cell. The light energy scattered by the particle near the center of the scattering cell, as shown by arrows 300, leaves the scattering cell through the exit 128 and is focused by a lens structure 302 onto a beam splitter 304. A portion of the light energy passes through the beam splitter 304 to a diagonal mirror 306. A second portion of the light energy is reflected by the beam splitter 304 to a viewing mirror 310 and may be viewed through a microscope 308. When the eyepiece 236 of the microscope 308 is properly focused, a visual observation may be had of the central region of the scattering cell.

The light energy which impinges on the diagonal mirror 306 is directed upward toward a second diagonal mirror 312. A portion of the light energy is reflected by the second diagonal mirror 312 to a first photomultiplier 314. In addition, a portion of the light energy from the diagonal mirror 306 passes by the second diagonal mirror 312 to impinge on a second photomultiplier 316. The combination of the two photomultipliers 314 and 316 with the second diagonal mirror 312 may be used to provide an optical detection of the vertical position of the particle within the scattering cell. For example, if there are no particles in the scattering cell in the path of the laser beam, then no light energy would be scattered out of the exit 128 and no light energy would therefore pass to the diagonal mirror 306. If there is a particle in the path of the light beam within the scattering cell, then the position of this particle determines the intensity distribution of the scattered light passing through the exit which in turn determines the amount of light energy which is received by each of the two photomultipliers **314** and **316**. In this way, the vertical position of the particle determines the relative output of the photomultipliers **314** and **316**.

FIG. **6** illustrates the operation of the automatic servoing of the levitator so as to maintain the microparticle in the proper position within the scattering cell. In FIG. **6** the three-electrode levitator of the present invention, including the parallel plate electrodes **10** and **12** and the center pin electrode **14** is shown with the plate electrode **10** grounded and with voltages applied to the electrodes **12** and **14**. A laser beam supplies light energy to the scattering cell and a scattered portion of the light energy is directed toward the mirror **312**. The scattered light strikes the edge of the mirror **312** which divides this scattered light between the two photomultiplier tubes **314** and **316**. The intensity of the light received by the two photomultiplier tubes **314** and **316** is equal when the particle is in the proper position within the scattering cell.

The output from the photomultipliers **314** and **316** are applied to a pair of matched characteristic logarithmic input amplifiers **350** and **352**, which logarithmic amplifiers convert the photomultiplier output current to a voltage proportional to the logarithm of the current from the photomultiplier. The use of logarithmic amplifiers maintains constant servo gain and provides servo stability for a wide range of particles. The balance control **228** is adjusted to provide equal gain for equal signals into the input amplifiers **350** and **352**. The outputs from the amplifiers **350** and **352** are applied to a difference circuit **354** and the difference between the two voltages is amplified by isolation amplifier **356** and applied to a sample and hold circuit **358**. The output of the sample and hold circuit **358** is controlled by a one-shot multivibrator **360** which controls a switch **362**. Since a pulsed laser is used in a preferred embodiment, the output signals from the input amplifiers **350** and **352** are used to control the multivibrator **360**. If a continuous wave laser is used, the sample and hold circuit may be ommitted, or replaced by an averaging circuit.

The position control **230**(a) which is the resistive control portion of the positioning control switch **230** shown in FIG. **4** is used to control an input signal to an isolation amplifier **364**. In addition, the position control switch **230** may be either in a manual or an automatic mode as controlled by the switch portion **230**(b) of the position control. The manual mode is when the switch **230**(b) is closed, which controls the multivibrator **360** to maintain the switch **362** in an open position. At this time only the position control **230**(a) effects the voltages applied to the electrodes of the levitator. When the switch **230**(b) is in the open position, the servoing is automatic. At this time input signals are provided from the differencing circuit **354** to the sample and hold circuit **358** so that the output of the sample and hold circuit is an error signal in accordance with the position of the particle.

As indicated above, the output from the sample and hold circuit **358** is applied to the isolation amplifier **364** and then to a pair of d-c to d-c converters **366** and **368**. The maximum output from the d-c to d-c converters **366** and **368** is adjusted by the voltage control **226**, but below that maximum value the output from the d-c to d-c converters are control signals which are applied through the polarity switch **224** to the electrodes **12** and **14** to maintain the particle in the proper position within the scattering cell.

The operation of the levitator in isolating and positioning an individual particle within the laser beam with the structure shown in FIGS. **2–5** is as follows:

First, the nebulizer **200** is filled with a suspension of the microparticles to be studied and the hoses are connected to the scattering cell in the manner shown in FIG. **3**. The various electrical power requirements are coupled to the instrument so that the laser (or other light source) is energized and the electrodes in the levitator are also energized. Initially the polarity control **224** may be positioned to the plus position. The voltage control **226** is adjusted to zero volts which is normally in the full counter-clockwise position. The position control **230** is in the manual mode and turned counterclockwise which normally means that the particle is pulled downward.

In order to clear the scattering cell, the air toggle switch **210** is switched forward to flush the scattering cell with clean air. This may be visually observed by watching through the eyepiece **236** of the microscope **308** until no particles can be seen passing through the laser beam. When this has occurred, toggle switch **210** is returned to the rear position to connect up the nebulizer **200**. The nebulizer button **216** may then be pushed briefly a few times until several particles are observed passing through the laser beam with each pulse of the nebulizer button **216**. Now the bellows knob **232** may be moved back and forth to move particles slowly through the beam. The larger particles may be easily seen and for smaller particles the defraction images of the particles appear as sharply defined concentric rings will be visible through the microscope. The focus knob **234** may be adjusted for maximum image sharpness.

When there is a bright image in the field of view of the microscope, representing a particle, the voltage control **226** may be turned up until the image can be observed moving in response to the voltage control **226**. The motion of the particle should be in the downward direction. If the motion is not downward, this means that the polarity of the particle is reversed and the polarity control **224** should be switched to the minus position. The position knob **230** may be moved to arrest the downward motion of the particle and bring the particle back toward the center of the field of view of the microscope. Actually, both the voltage and position controls may be simultaneously manipulated so as to stop the particle's motion before it leaves the region within which it can be seen.

If the particle is lost, then the voltage and position controls may be returned to zero and the nebulizer button pushed again to bring new particles in the field of view. Since the particles may have different polarities, it is important to remember that the polarity control may have to be reversed in order to provide the downward motion. As an alternative to the above, it may be more convenient to begin with the polarity control **224** at the zero position and with the voltage control **226** set high enough to produce relatively fast motion. The positioning of the particle may then be accomplished by simultaneously manipulating the polarity and position controls instead of the voltage and position controls.

When a particle has been positioned in the center of the field of view and remains nearly stationary, then the position control 230 is pushed in to place the levitator in the automatic mode. This engages the automatic servo control shown in FIG. 6 so as to hold the particle fixed within the light beam. The voltage control 226 may be turned completely up so as to provide a maximum automatic servoing of the position of the particle within the levitator.

The present invention therefore provides a simple structure for positioning a microparticle within a beam of light, such as light from a laser, and maintaining that particle automatically in this position. The levitator includes a pair of parallel plate electrodes and a third electrode extending through and insulated from one of the plate electrodes. In a preferred embodiment of the invention, the pair of parallel plate electrodes provide an electric field to pull the particle down to aid the force of gravity and with the center electrode providing an electric field to pull the particle up and counterbalance the downward forces and also to pull the particle toward the center. This structure allows for a relatively strong electric field to be used to pull the particle into the central position. The maintaining of the position of the particle may be automatically controlled using an optical detector in combination with a servo system.

The invention has been described with reference to a particular embodiment but the invention is only to be limited by the appended claims.

We claim:

1. A scattering cell for receiving charged particles for intersection with a beam of light and including a levitator for suspending charged particles within the scattering cell, including

a pair of parallel plate electrodes and an insulating wall member forming an included space and including an entrance area for a beam of light,

a third pin electrode extending through and insulated from one of the parallel plate electrodes,

first means for introducing charged particles into the enclosed space,

second means for providing a beam of light through the entrance area of the wall member and past a position adjacent to the third pin electrode,

third means for supplying an electrical potential between the pair of parallel plate electrodes to produce a first electric field in a first direction, and

fourth means for supplying an electrical potential between the pin electrode and the pair of parallel plate electrodes to produce a second electric field in a second direction opposite to the direction of the first electric field to form a composite field between the pair of plate electrodes to balance forces operating on any charged particles located between the pair of plate electrodes and to produce a third radial electric field to pull any charged particles located between the pair of plate electrodes toward a position adjacent the pin electrode.

2. The scattering cell of claim 1 wherein the first means for introducing charged particles into the enclosed space includes a nebulizer.

3. The scattering cell of claim 1 additionally including a bellows assembly for pneumatically controlling the movement of the charged particles in the enclosed space.

4. The scattering cell of claim 1 additionally including controls for adjusting the magnitude and polarity of the electrical potentials applied to the electrodes.

5. The levitator of claim 1 additionally including means detecting the position of a charged particle located between the electrodes and for providing an error signal representing the difference between the actual position of the charged particle and a desired position for the charged particle and for adjusting the potential applied to the electrodes to adjust the position of the charged particle.

6. The levitator of claim 1 wherein the enclosed space is pneumatically isolated from any external changes in pressure.

7. A scattering cell for receiving microparticles and including a levitator for suspending a microparticle in a fixed location to be intercepted by a beam of light, including

an electrode structure including a pair of electrodes spaced from each other and supplied with an electrical potential between the pair of electrodes to produce a first electric field on a microparticle located between the pair of electrodes and including a third pin electrode extending through and insulated from one of the first pair of electrodes and supplied with an electrical potential between the third electrode and the pair of electrodes to produce a second electric field to oppose the first electrical field on the microparticle located between the pair of electrodes to balance the microparticle and to produce a radial electric field to pull the microparticle to a position adjacent to and on the axis of the third pin electrode,

first means for introducing microparticles between the pair of electrodes, and

second means for producing a beam of light to pass through the position adjacent to the third pin electrode to intercept microparticles at such position.

8. The scattering cell of claim 7 wherein the first means for introducing microparticles between the pair of electrodes includes a nebulizer.

9. The scattering cell of claim 7 additionally including a bellows assembly for controlling the movement of the microparticles between the pair of electrodes.

10. The scattering cell of claim 7 additionally including controls for adjusting the magnitude and polarity of the electrical potentials applied to the electrodes.

11. The levitator of claim 7 additionally including means detecting the position of a microparticle located between the pair of electrodes and for providing an error signal representing the difference between the actual position of the microparticle and a desired position for the microparticle and for adjusting the potential applied to the electrodes to adjust the position of the microparticle.

12. The levitator of claim 7 wherein the electrodes structure forms an enclosed space and wherein the enclosed space is pneumatically isolated from any changes in external pressure.

13. A scattering cell for receiving charged particles for intersection with a beam of light and including a levitator for suspending charged particles within the scattering cell, including

a pair of parallel plate electrodes and an insulating wall member forming an included space and including an entrance area for a beam of light, a detection area for observing scattered light at different angular positions relative to the charged particles, and a beveled port for observing a portion of the scattered light, a third pin electrode extending through and insulated from one of the pairs of parallel plate electrodes,

first means for introducing charged particles into the enclosed space,

second means for providing a beam of light through the entrance area of the wall member and past a position adjacent to the third pin electrode,

third means for supplying an electrical potential between the pair of parallel plate electrodes to produce a first electric field in a first direction,

fourth means for supplying an electrical potential between the pin electrode and the pair of parallel plate electrodes to produce a second electric field in a second direction opposite to the direction of the first electric field to form a composite field between the pair of plate electrodes to balance forces operating on any charged particles located between the pair of plate electrodes and to produce a third radial electric field to pull any charged particles located between the pair of plate electrodes toward a position adjacent the pin electrode, and

fifth means for detecting the portion of the scattered light passing through the beveled port and for providing an error signal representing the difference between the actual position of the charged particle and a desired position for the charged particle and for adjusting the potential applied to the electrodes to adjust the position of the charged particle.

14. The scattering cell of claim **13** wherein the fifth means includes a beam splitter for directing the scattered light to a pair of light detecting devices and with the difference between the output from the light detecting devices providing the error signal.

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