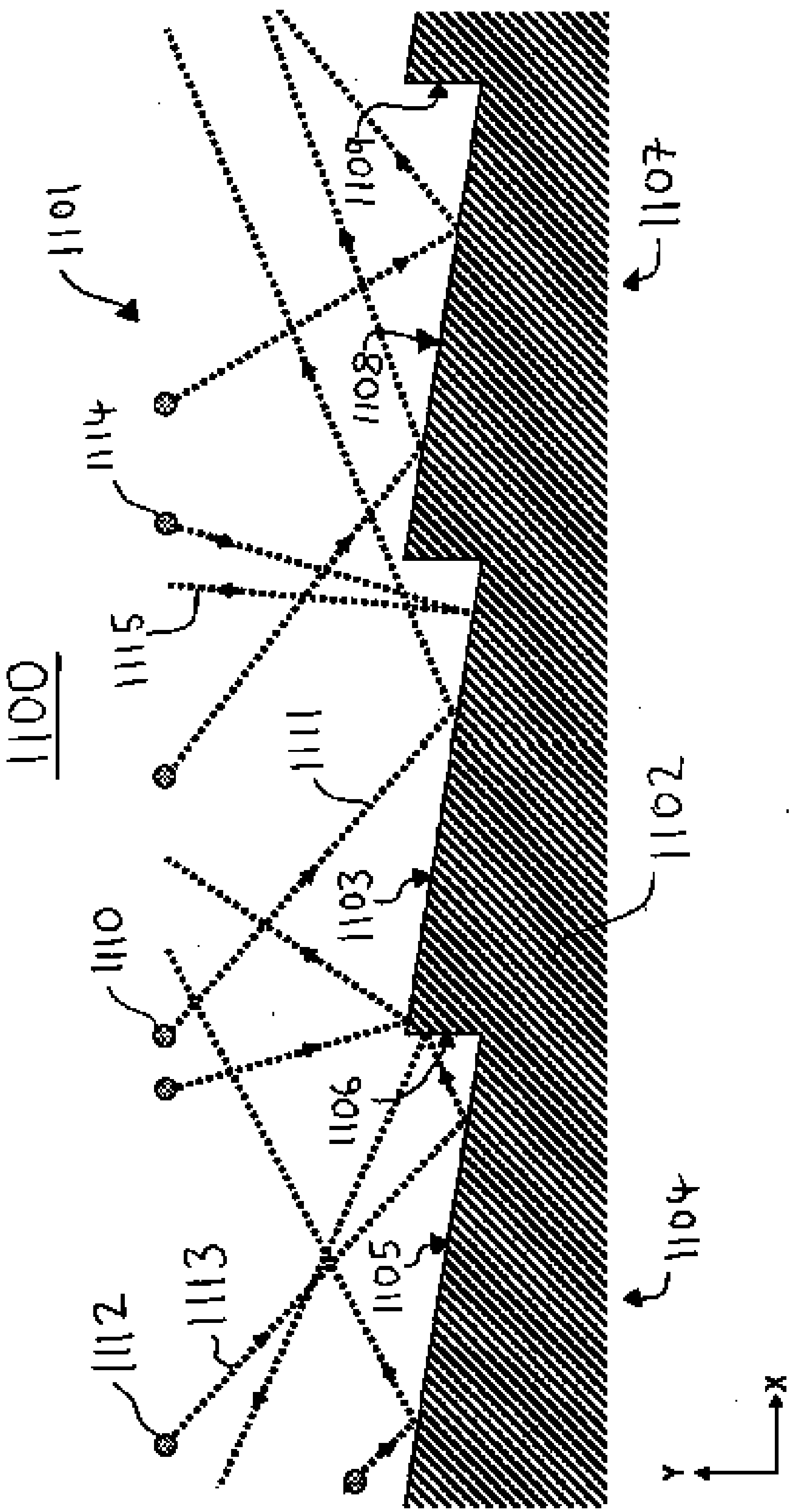
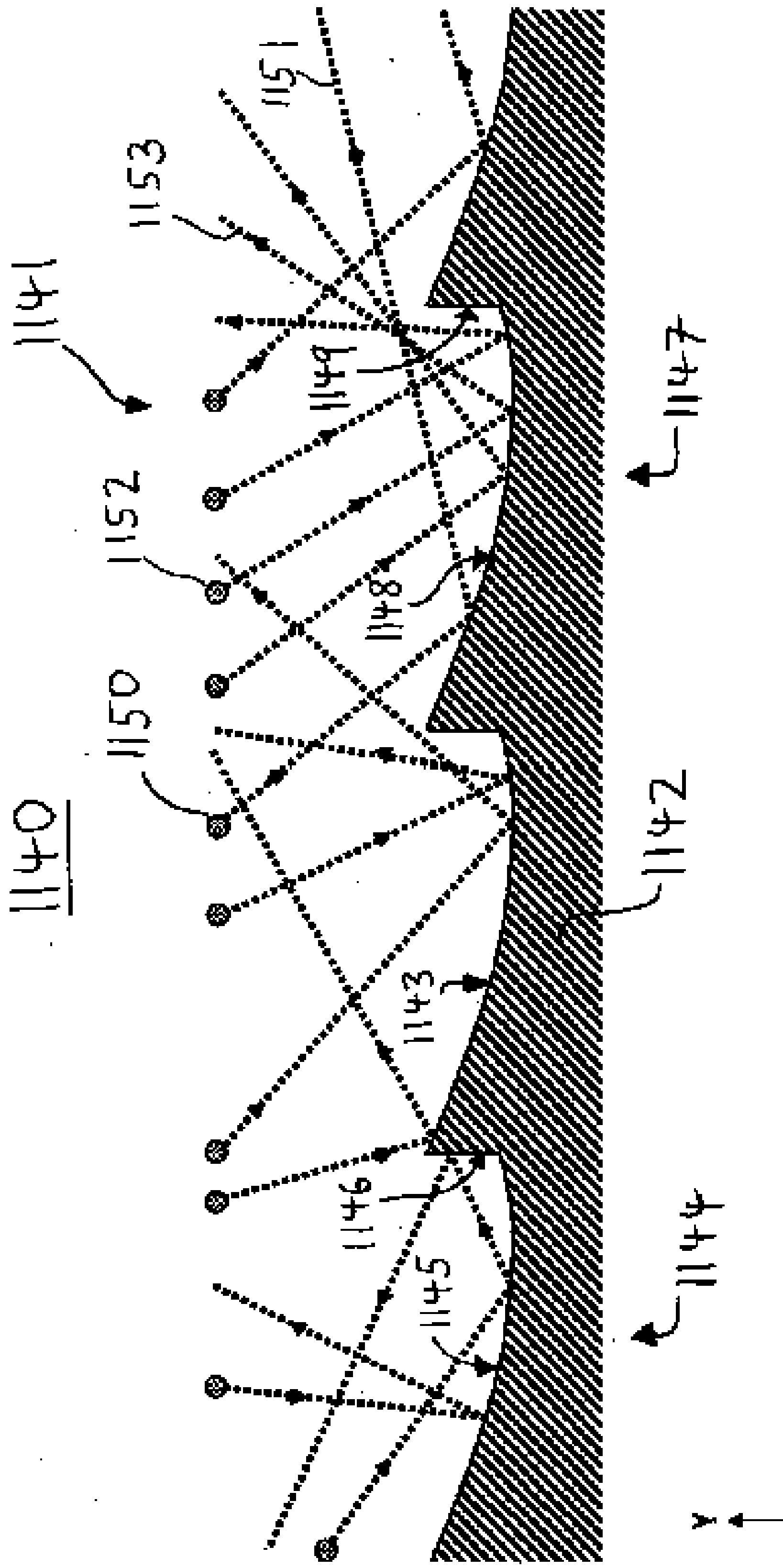


1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
X
Y

FIG. 1


1140
1141
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1143
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1148
1149
1150
1151
1152
1153
X
Y

FIG. 2

Provisional Application for United States Patent

TITLE: FILTRATION APPARATUS AND METHOD

INVENTOR: PAUL NEISER

BRIEF DESCRIPTION OF THE DRAWINGS

[0001] In the drawings, which are not necessarily drawn to scale, like numerals can describe similar components in different views. Like numerals having different letter suffixes can represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

[0002] FIG. **1** is a cross-sectional view of one embodiment of the invention.

[0003] FIG. **2** is a cross-sectional view of another embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0004] The term "medium" used herein describes any material which is capable of containing, carrying, transporting, or transferring an object of interest. A medium can be a plasma, a gas, a liquid, a solid, or a vacuum, for example. By default, and unless specified, a medium refers to the collection of all objects which interact with a specified apparatus.

[0005] The term "object" used herein describes any component of a medium. An object can be described as a particle, such as a dust particle, a soot particle, an ice particle, a water droplet, a water molecule, a large molecule, a small molecule, or an atom. Other examples of objects are subatomic particles such as electrons, neutrons, or protons. An object can also be described as a wave, such as an acoustic wave, a seismic wave, an ocean wave, a gravity wave, a photon, or a phonon. The invention applies to any medium which can be considered to comprise distinct objects. An object can have a property of interest, as well as a defining property, which can be used to distinguish an object from other objects of the medium.

[0006] One can define a "dynamic boundary condition" as a simplified scenario in which the properties of the medium at a first reservoir and a second reservoir are identical and uniform in time and space.

[0007] One can define a "static boundary condition" as a simplified scenario in which a first and second reservoir are finite in size and isolated from each other and any other reservoirs apart from an embodiment of the invention, such as a filtering apparatus, allowing the exchange of OI between the first and second reservoirs. In the static boundary condition, the macroscopic properties of interest of the medium in the first and second reservoirs have reached a steady state value, i.e. a value that is substantially constant in time and space, i.e. substantially uniform throughout a reservoir. Such macroscopic properties can refer to the pressure, temperature, or density of a medium, for example.

[0008] A "default boundary condition" for an example filtering apparatus can refer to a model scenario in which the properties of the medium at a first reservoir and a second reservoir are identical and uniform in time and space.

[0009] A "baseline scenario" can refer to a scenario in which an example embodiment comprising a filtering apparatus is replaced by a "baseline apparatus" comprising a solid, impermeable, possibly reflective, flat filtering apparatus, and subjected to default boundary conditions.

[00010] A "baseline probability" can refer to the probability for any object which interacts with a baseline apparatus to be located at a specified side of the baseline apparatus after the interaction is completed in a baseline scenario. For example, the baseline probability can be 50% for any side of the baseline apparatus.

[00011] The "characteristic width" of a focusing apparatus is the extent of a focusing apparatus in a direction perpendicular to a local flow of objects of interest which interact with the focusing apparatus.

[00012] The "characteristic length" of a focusing apparatus is the average displacement of objects of interest throughout an interaction with a focusing apparatus within a filtering apparatus.

[00013] The "characteristic dimension" of a focusing apparatus is the average distance travelled by objects of interest throughout an interaction with a focusing or deflection apparatus. In general, the characteristic dimension is a dimension which is relevant to the way in which the filtering apparatus interacts with objects of interest.

[00014] FIG. 1 is a cross-sectional view of one embodiment of the invention. Some features of the apparatus shown in FIG. 1, as well as some of the principles of operation of the apparatus share similarities with the apparatus shown in the other figures, and will therefore not be described in the same detail in the context of FIG. 1, and vice versa.

[00015] There is a first reservoir 1100, in which the medium comprises objects of interest, or "OI", which are schematically represented by individual particles, such as the schematic representation of OI 1112. OI are assumed to be spherical in shape in this simplified embodiment. In FIG. 1, for simplicity, the medium can be considered to be an ideal gas comprising monatomic molecules. In other embodiments the medium can consist of other types of objects, such as water molecules. In other embodiments, OI need not be spherical, but can take any shape. For example, OI can be a diatomic molecule, or a polyatomic molecule, or an aerosol particle like a dust particle or pollen, which can take a wide variety of shapes. A medium can also comprise several different types of objects, such as sodium and chlorine ions found in salt water, or electrons in a conductor. An OI can also be a subatomic particle such as an electron, positron, or photon. An OI can also be a virtual particle, or virtual object, such as a virtual photon, a virtual electron, virtual quarks, or a virtual positron, as describe by quantum field theory. These virtual particles give rise to the zero point energy and associated effects, such as the Casimir effect. Note that the mean free path of virtual particles can be on the order of tens of nanometers. Note that virtual particles also exist in a vacuum.

[00016] The filtering plate 1101 comprises a bulk material 1102, which comprises a first surface 1103. Bulk material 1102 can be made of any suitable material, such as metal, composite, or ceramic. In some embodiments, bulk material 1102 can also be described as a fabric. Bulk material 1102 can comprise graphene in some embodiments. Bulk material 1102 is configured to be perfectly reflective to OI in this embodiment. In other embodiments, bulk material 1102 can have a reflectivity which is greater than zero and less than one. Note that the reflections can be specular or diffuse in this embodiment and embodiments of this type. In the depicted scenario, the reflections of OI from the surface 1103 of bulk material 1102 are specular.

[00017] In this embodiment surface 1103 is planar and comprises segments of two dimensional surfaces, such as surface 1105 and surface 1106. Surface 1106 is two dimensional and parallel to the YZ-plane. Surface 1103 can be considered to be generated by the extrusion of bulk material 1102 in the positive or negative Z-direction. In other embodiments, such as the embodiment depicted in FIG. 7, the surface 1103 can also be cylindrical or circular in three-dimensional form. In other embodiments, surface 1103 can also be elliptical, square, or rectangular in form. In other embodiments, surface 1103 can be in any three dimensional form, provided the principles of operation are maintained.

[00018] Surface 1103 comprises several identically configured segments, such as segment 1104 or segment 1107. Each segment can be considered to be a focusing apparatus, or a deflection apparatus, which is configured to deflect or redirect objects of interest which interact with surface 1103 in a desired direction. In embodiment 1101, each segment comprises a first surface, such as first surface 1105 or first surface 1108, and a second surface, such as second surface 1106, or second surface 1109. In FIG. 1, the first surface 1105 is inclined at an angle, such that the surface normal is directed in the positive X-direction and in a plane parallel to the XY-plane. The angle between the surface normal and the Y-axis is denoted the "inclination angle". The inclination angle can range from a value greater than zero degrees to a value smaller than ninety degrees. The extent of a segment, such as segment 1104 or segment 1107 along the X-axis, which in this case is also equal to the extent of the first surface along the X-axis, is denoted the "width of a segment". The "depth of a segment" is the extent of a segment along the Y-axis, which in this case is also equal to the extent of the first surface along the Y-axis, or the extent of a second surface, such as second surface 1106 or second surface 1109, along the Y-axis. In this embodiment, the second surfaces, such as second surface 1106, is planar in shape and parallel to the YZ-plane.

[00019] Examples of interactions between OI and the bulk material 1102 are shown in FIG. 1, as exemplified by trajectory 1113 of OI 1112, trajectory 1111 of OI 1110, or trajectory 1115 of OI 1114. As a result of the aforementioned inclination angle of the first surfaces, such as first surface 1105 or first surface 1108, the motion of OI after colliding with the first surfaces is preferentially in the positive X-direction.

[00020] Note that the type of interaction between the OI and the filtering plate 1101 is a function of the inclination angle and the width of a segment, amongst other parameters such as parameters pertaining to the mean free path of objects of interest in the surrounding medium. For a certain value of such parameters, the OI which approach the surface 1103 can, on average, experience a net deflection in the positive X-direction in some embodiments. In a dynamic boundary condition, this can lead to a net diffusion, or a bulk flow, of OI in the positive X-direction. An "initial velocity" is the velocity of an OI immediately prior to interacting with apparatus 1101, i.e. prior to colliding with surface 1103, e.g. with a first surface 1105 or a second surface 1106. A "final velocity" is the velocity of an OI immediately after interacting with apparatus 1101, i.e. after colliding with surface 1103, e.g. with a first surface 1105 or a second surface 1106. Due to the geometry of the surface 1103, the average initial velocity vector of OI can be different to the average final velocity vector of OI. For example, in a hypothetical scenario, such as a scenario in which there is a static boundary condition, the average initial velocity can be directed in the negative Y-direction and parallel to the Y-axis, while the average final velocity can be directed in the positive X- and Y-direction. The non-zero component in the positive X-direction can lead to a net diffusion of OI in the positive X-direction. In other embodiments, or other applications, the average component of the final velocity in the positive X-direction can be larger than the average component of the initial velocity in the positive X-direction, where the average is calculated over all OI which interact with the filtering apparatus 1101.

[00021] The inclination angle can be 50 degrees in some embodiments. The inclination angle can be 45 degrees in some embodiments. The inclination angle can be 30 degrees in some embodiments. The inclination angle can be 15 degrees in some embodiments. The inclination angle can be 10 degrees in some embodiments. The inclination angle can be 5 degrees in some embodiments. Note that in some embodiments, or some methods of operation, the bulk flow of OI which is induced by the interaction of OI with the filtering apparatus 1101 can be in the negative X-direction instead of in the positive X-direction.

[00022] As a result of a bulk flow induced by the interaction of OI with the surface 1103 of bulk material 1102 of filtering apparatus 1101 in the positive X-direction, there is a net force on filtering apparatus 1101 in the negative X-direction. This force can be employed to do mechanical work, for example. The mechanical work can in turn be converted into electrical work by an electrical generator, for instance. The energy for this work is provided by the thermal energy of OI in the first reservoir 1100. Thus a filtering apparatus 1101 can be employed to convert thermal energy into useful work.

[00023] The characteristic dimension of the embodiment shown in FIG. 1 can be considered to be the larger of the two numbers describing the width of a segment and the depth of a segment, for example.

[00024] FIG. 2 is a cross-sectional view of one embodiment of the invention. Some features of the apparatus shown in FIG. 2, as well as some of the principles of operation of the apparatus share similarities with the apparatus shown in the other figures, and will therefore not be described in the same detail in the context of FIG. 2, and vice versa.

[00025] There is a first reservoir 1140, in which the medium comprises objects of interest, or “OI”, which are schematically represented by individual particles, such as the schematic representation of OI 1150.

[00026] The filtering plate 1141 comprises a bulk material 1142, which comprises a first surface 1143. Bulk material 1142 can be made of any suitable material, such as metal, composite, or ceramic. In some embodiments, bulk material 1142 can also be described as a fabric.

[00027] In this embodiment surface 1143 comprises segments of surfaces, such as surface 1145 and surface 1146. Surface 1145 is concave in shape, as shown. Surface 1146 is two dimensional and parallel to the YZ-plane in this embodiment. Surface 1143 can be considered to be generated by the extrusion of bulk material 1142 in the positive or negative Z-direction. In other embodiments, the surface 1143 can also be cylindrical or circular in three-dimensional form. In other embodiments, surface 1143 can also be elliptical, square, or rectangular in form. In other embodiments, surface 1143 can be in any three dimensional form, provided the principles of operation are maintained.

[00028] Surface 1143 comprises several identically configured segments, such as segment 1144 or segment 1147. Each segment can be considered to be a focusing apparatus, or a deflection apparatus, which is configured to deflect or redirect objects of interest which interact with surface 1143 in a desired direction. In embodiment 1141, each segment comprises a first surface, such as first surface 1145 or first surface 1148, and a second surface, such as second surface 1146, or second surface 1149. In FIG. 2, the first surface 1145 is inclined at an angle, such that the surface normal is directed in the positive X-direction and in a plane parallel to the XY-plane. The aveage angle between the surface normal and the Y-axis is denoted the “inclination angle”. The inclination angle can range from a value greater than zero degrees to a value smaller than ninety degrees. The extent of a segment, such as segment 1144 or segment 1147 along the X-axis, which in this case is also equal to the extent of the first surface along the X-axis, is denoted the “width of a segment”. The “depth of a segment” is the extent of a segment along the Y-axis, which in this case is also equal to the extent of the first surface along the Y-axis. In this embodiment, the second surfaces, such as second surface 1146, is planar in shape and parallel to the YZ-plane.

[00029] Examples of interactions between OI and the bulk material 1142 are shown in FIG. 2, as exemplified by trajectory 1153 of OI 1152, or trajectory 1151 of OI 1150. As a result of the aforementioned inclination angle of the first surfaces, such as first surface 1145 or first surface 1148, the motion of OI after colliding with the first surfaces is preferentially in the positive X-direction.

[00030] Note that the type of interaction between the OI and the filtering plate 1141 is a function of the inclination angle and the width of a segment, amongst other parameters such as parameters pertaining to the mean free path of objects of interest in the surrounding medium and the shape of the first and second surfaces, such as first surface 1145 and the second surface 1146. For a certain value of such parameters, the OI which approach the surface 1143 can, on average, experience a net deflection in the positive X-direction in some embodiments. In a dynamic boundary condition, this can lead to a net diffusion, or a bulk flow, of OI in the positive X-direction, for example. Due to the geometry of the surface 1143, the average initial velocity vector of OI can be different to the average final velocity vector of OI. For example, in a hypothetical scenario, such as a scenario in which there is a net motion of the filtering apparatus 1141 relative to the medium in reservoir 1140 in the negative X-direction, the average initial velocity vector of OI can be directed in the positive X-direction and in the negative Y-direction, as shown in FIG. 2. The average final velocity can be directed in the positive X- and Y-direction, where the component in the positive X-direction of the average final velocity is larger than the component in the positive X-direction of the average initial velocity. The non-zero net component in the positive X-direction can lead to a net diffusion or a net acceleration of OI in the positive X-direction.

[00031] The inclination angle can be 50 degrees in some embodiments. The inclination angle can be 45 degrees in some embodiments. The inclination angle can be 30 degrees in some embodiments. The inclination angle can be 15 degrees in some embodiments. The inclination angle can be 10 degrees in some embodiments. The inclination angle can be 5 degrees in some embodiments. Note that in some embodiments, or some methods of operation, the bulk flow of OI which is induced by the interaction of OI with the filtering apparatus 1141 can be in the negative X-direction instead of in the positive X-direction.

[00032] As a result of a bulk flow induced by the interaction of OI with the surface 1143 of bulk material 1142 of filtering apparatus 1141 in the positive X-direction, there is a net force on filtering apparatus 1141 in the negative X-direction. This net force can be employed as a thrust force, for example, which can be employed to reduce the drag acting on the filtering apparatus 1141 due to the motion of the filtering apparatus relative to the medium. Embodiments can be employed to propel an aircraft, a propeller blade, or a ship, for instance. The fuselage or propeller or hull surface can be manufactured in accordance with embodiments of the invention, for example. This force can be employed to do mechanical work, for example. The mechanical work can in turn be converted into electrical work by an electrical generator, for instance. The energy for this work is provided by the thermal energy of OI in the first reservoir 1140. Thus a filtering apparatus 1141 can be employed to convert thermal energy into useful work.

[00033] The characteristic dimension of the embodiment shown in FIG. 2 can be considered to be the larger of the two numbers describing the width of a segment and the depth of a segment, for example.

[00034] In some example embodiments, the characteristic dimension of a focusing apparatus, or a channel segment, or a surface feature, of a filtering apparatus is smaller than a number several orders of magnitude larger than the smallest mean fee path of objects of interest within an adjacent reservoir, such as first reservoir 1100. In accordance with some embodiments, the characteristic dimension is smaller than a value three orders of magnitude larger than the smallest mean fee path of objects of interest within an adjacent reservoir. In other words, the ratio of the smallest mean free path of an object of interest in an adjacent reservoir to the characteristic dimension is larger than 0.001 in some embodiments.

[00035] The ratio of the mean free path of an object of interest in a specified reservoir to the characteristic dimension of a focusing apparatus is denoted the "relative length", or "RL". Unless otherwise specified, the medium or the reservoir which provides the mean free path in the calculation of the RL is the medium or reservoir with the smallest mean free path. The mean free path is measured adjacent to the filtering apparatus or to the channel opening. The mean free path is measured exclusively within the medium, i.e. exclusively between collisions of objects of interest with other objects, i.e. objects other than the bulk material of the filtering apparatus or objects other than objects associated with, or employed by, the filtering apparatus. The relative length describes the size of the focusing apparatus relative to the properties of the surrounding medium. In embodiments in which the medium can be described as a fluid, this ratio can be referred to as the Knudsen number.

[00036] For RL which are multiple orders of magnitude smaller than 0.001, the focusing effect of the focusing apparatus can be non-zero, but negligibly small. In other example embodiments of the invention, the RL can be 0.01. The RL can also be 0.1, for example. The RL can be 1 in another example. The RL can be 10 in another example. The RL can also be larger than 10. In general, a larger RL increases the performance of the focusing apparatus or filtration system, but increases the complexity or difficulty of manufacture. An increase in the characteristic dimension relative to the mean free path of objects of interest in an adjacent reservoir can increase the probability of scattering of objects of interest as they travel through the filtering apparatus or interact with the focusing apparatus. This can reduce the focusing or redirection effect of the filtering apparatus on the trajectories of objects of interest, and reduce the performance of the filtering apparatus.

[00037] For example, the mean free path of nitrogen gas at standard temperature and pressure is approximately 60 nanometers. For applications of a filtering apparatus in which the objects of interest are nitrogen atoms, and in which the first, and, if applicable, second reservoirs, are at standard temperature and pressure, the characteristic dimension can be smaller than 60 micrometers in some embodiments. For instance, the characteristic dimension can be about 60 nanometers, where “about” and “approximately” as used herein refer to a value within plus or minus 30% of the stated figure. In another example filtering apparatus, the characteristic dimension can be about 6 micrometers. The characteristic dimension associated with another embodiment can be about 600 nanometers, for example. The characteristic dimension associated with another embodiment can be about 6 micrometers, for example.

[00038] In another example, the mean free path of electrons in the conduction band in copper can be considered to be approximately 40 nanometers. In embodiments of a filtering apparatus in which the objects of interest are electrons, the bulk material, such as bulk material 1102 can comprise an electrical insulator. The bulk material can optionally comprise material with a reflectivity which is greater than zero with respect to electrons. In these and other example embodiments, the bulk material can comprise material with a different refractive index with respect to objects of interest, i.e. electrons in this case, for example. In embodiments of the invention in which the objects of interest are electrons in the conduction band, and in which the medium in the first and second reservoir is copper, the characteristic dimension associated with some embodiments can be less than or equal to 40 micrometers, for example. For instance, the characteristic dimension can be less than or approximately equal to 400 nanometers. The characteristic dimension associated with some embodiments can alternatively be about 40 nanometers, for example. The characteristic dimension of a filtering apparatus or a focusing apparatus can be approximately 4 micrometers, for instance. The characteristic dimension of a filtering apparatus or a focusing apparatus can be approximately 4 nanometers, in another example.

[00039] For embodiments in which the objects of interest behave like waves, such as photons, phonons, acoustic waves, or ocean waves, for example, the mean free path can be very large, possibly even infinitely large. For very large values of mean free path, some objects of interest rarely or never scatter within a medium, such as a first reservoir or a second reservoir. This can be due to the superposition principle, which applies to some wave types. Since the mean free path of some of these objects of interest is larger than the mean free path in the aforementioned examples, the characteristic dimension of the embodiments can be larger as well. This can significantly reduce the complexity associated with the manufacture of a filtering apparatus. A sufficiently large ratio of the mean free path relative to the characteristic dimension of the filtration apparatus should preferably be maintained.

[00040] A medium can be located in a first reservoir, or the interior of a focusing apparatus. The characteristic dimension of a filtering apparatus which is configured to interact with photons can be about ten meters, for example. The characteristic dimension can be about 1 centimeter in another example. The characteristic dimension can be serval nanometers in another example. The focusing portions of the example embodiments shown in the figures function in a manner comparable to optical telescopes or solar concentrators, for instance. In other embodiments, lenses can be used to perform the focusing of the trajectories of objects of interest. The lenses can employ refraction or diffraction, for example. As mentioned, in such embodiments, the objects of interest can be waves or wavelike particles, such as acoustic waves, ocean waves, gravity waves, phonons, photons or electrons. The calculation of the mean free path of photons in the medium surrounding and enveloping the bulk material in a filtering apparatus preferably takes into account photon-object scattering, i.e. collision between photons and other objects in the medium, such as air molecules. This effect can be mitigated by evacuating the portion of the filtering apparatus which is concerned with the focusing of the objects of interest, e.g. the photons, by removing, or reducing the concentration of, other objects of interest, e.g. air molecules, which would otherwise interfere with, and reduce the mean free path of, the objects of interest. For example, the focusing portion of the filtering apparatus, such as the example channel system in FIG. 5, can be located in a vacuum, or a region of reduced density of objects of interest, or any other objects which can unintentionally scatter an object of interest.

[00041] The manner in which a filtration apparatus is manufactured depends on the scale or the characteristic dimension of a filtration apparatus. For example, consider an application example in which the mean free path of objects of interest in a medium is about one millimeter. The characteristic dimension of an example embodiment of a filter system for such an application can be about one centimeter. Structures of this scale can be readily manufactured and mass produced using conventional mechanical manufacturing techniques, such as computer numerical controlled (CNC) mills, selective laser sintering (SLS), photolithography and etching, additive printing processes, and so on.

[00042] Embodiments of a filtering apparatus for which the characteristic dimension is on the order of nanometers can be manufactured with semiconductor manufacturing equipment and procedures. For example, grayscale electron beam or ion beam lithography can be employed to manufacture molds with large arrays of repeating patterns of complex geometry at the nanometer scale. These molds can be employed to imprint the desired surface features on a substrate using nanoimprint lithography. This method can be employed to manufacture embodiments as shown in the examples of FIGS. 1-2, for example. In another example, embodiments can be manufactured using nanometer scale additive manufacturing techniques, such as electron beam induced deposition. These and other manufacturing techniques can benefit from interference effects to manufacture the aforementioned large arrays of complex structures. These methods are known in the field of interference lithography, for example. Subtractive manufacturing techniques such as deep reactive ion etching can be employed to manufacture surfaces of filtration apparatuses. In the manufacture of some embodiments, subtractive and additive manufacturing techniques can be employed.

[00043] Unless specified or clear from context, the term "or" is equivalent to "and/or" throughout this paper.