(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 September 2017 (21.09.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/160315 A1

(51) International Patent Classification:
B01D 45/12 (2006.01)

(21) International Application Number:
PCT/US2016/023224

(22) International Filing Date:
18 March 2016 (18.03.2016)

(25) Filing Language: English

(26) Publication Language: English

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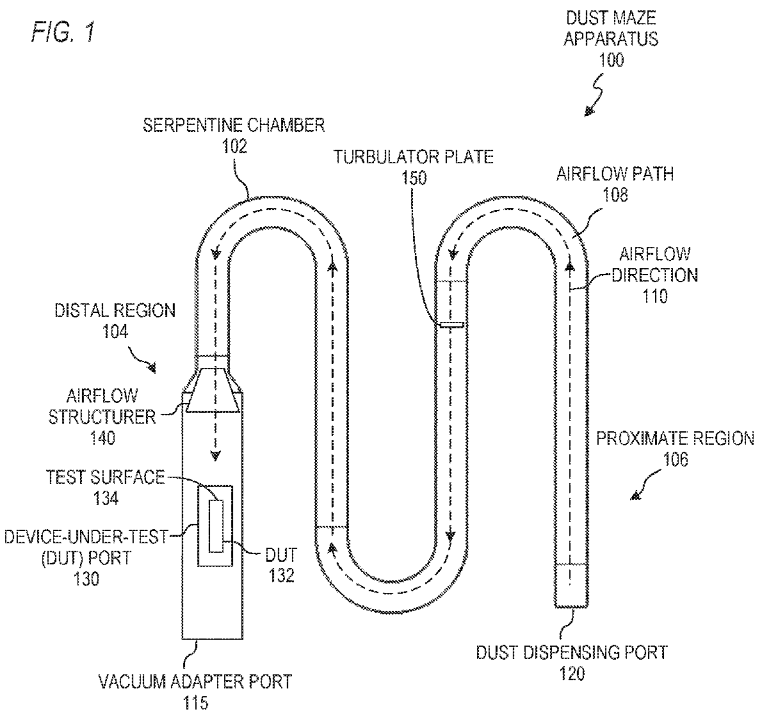
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

[Continued on next page]

(54) Title: DUST MAZE

FIG. 1



(57) Abstract: Example implementations relate to a dust maze. For example, in an implementation, a dust maze may include a serpentine chamber having a distal region, a proximate region, and an airflow path within the serpentine chamber with an airflow direction defined from the proximate region towards the distal region. The dust maze also may include a device-under-test port disposed at the distal region to accept insertion of a device-under-test into the airflow path. Dust particles may be injected at the proximate region, the dust particles to be carried by the airflow along the airflow direction.

WO 2017/160315 A1

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

DUST MAZE

BACKGROUND

[0001] Computing devices in computing environments, such as data centers, may utilize optical connectivity components. Airborne particulate, including micrometer-scale dust particulate, may be present in computing environments. Particulate may accumulate on optical connectivity components and affect optical power transmission through the optical connectivity components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Various examples will be described below with reference to the following figures.

[0003] FIG. 1 depicts an example dust maze apparatus.

[0004] FIG. 2 depicts an example dust application system.

[0005] FIG. 3A depicts an example dust application system.

[0006] FIG. 3B depicts another view of the example dust application system of FIG. 3A.

[0007] FIGS. 4A, 4B, and 4C depict an example adjustable diaphragm in various states.

[0008] FIG. 5 depicts example vacuum adjusters.

[0009] FIG. 6 depicts another view of the example dust application system of FIG. 3A.

[0010] FIG. 7 depicts another view of the example dust application system of FIG. 3A.

[0011] FIG. 8 depicts a portion of an example dust application system.

[0012] FIGS. 9A, 9B, 9C, and 9D depict various example airflow structurers.

[0013] FIGS. 10A, 10B, and 10C depict an example optical jumper carrier.

[0014] FIG. 11 is a flow diagram depicting an example method for applying dust particles to a device-under-test.

[0015] FIG. 12 is a flow diagram depicting another example method for applying dust particles to a device-under-test.

[0016] FIG. 13 depicts an example optical jumper carrier cradle.

[0017] FIG. 14 depicts an example optical jumper carrier cradle relative to an imager.

[0018] Throughout the drawings, identical reference numbers may designate similar, but not necessarily identical, elements.

Detailed Description

[0019] Computing devices may utilize optical connectivity components. For example, optical connectors may employ lens ferrules on optical blindmate connectors. In some cases, lens ferrules (also referred to as optical ferrules) may comprise an array of lenses, each lens being on the order of 200 microns in diameter.

[0020] Airborne particulate, including micrometer-scale dust particles, may be present in computing environments such as data centers. Particulate may accumulate on optical connectivity components and affect optical power transmission through the optical connectivity components. Accordingly, it may be useful to perform a dust occlusion test by applying micrometer-scale dust particles to optical components in a controlled manner, measuring the degree of dust occlusion of those optical components, and determining the effect of various degrees of dust occlusion on optical power transmission or optical power loss.

[0021] Some dust chambers for applying dust particles to a device-under-test are constructed as large boxes, often multiple feet in depth, width, and/or height, and utilize fans to blow dust particles onto the device-under-test. However, for small devices-under-test (e.g., a small optical component, such as the lens ferrule described above) and using such dust chambers, it may be difficult to control the conditions of a dust occlusion test and to perform such a dust occlusion test with repeatability. For example, micrometer-scale dust particles may fail to be randomly distributed in such a dust chamber, and thus the amount and pattern of dust particles applied to a small optical component may be unpredictable and non-uniform. Additionally, micrometer-scale dust particles, which may be pose health risks to human operators, may be difficult to clean and remove from such a dust chamber. Large dust chambers also may be nonconducive to automation of dust test procedures.

[0022] Examples disclosed herein may relate to a dust maze apparatus. In some implementations, the dust maze apparatus may have configurable aspects, such as a serpentine chamber, an airflow structurer, or turbulator plate(s). By virtue of examples described herein, dust particles may be applied through a dust maze apparatus to a device-under-test, and more particularly, to an optical ferrule, in a repeatable and controllable manner.

[0023] FIG. 1 depicts an example dust maze apparatus 100. FIG. 1 may be deemed a plan view of a dust maze apparatus 100. The dust maze apparatus 100 includes a serpentine chamber 102 having a distal region 104, a proximate region 106, and an airflow path 108 within the serpentine chamber 102 with an airflow direction 110 defined from the proximate region 106 towards the distal region 104.

[0024] The dust maze apparatus 100 includes a vacuum adapter port 115 at the distal region 104 to couple a vacuum device (not shown) to the dust maze apparatus 100. For example, the vacuum device may be any device that generates suction, such as a centrifugal air pump. As used herein, a port may describe a feature that includes a pass-through, a hole, or an optically transparent or translucent window or window pane. A port may be disposed in a structure, such as a wall of the serpentine chamber 102.

[0025] The dust maze apparatus 100 includes a dust dispensing port 120 at the proximate region 106 of the serpentine chamber 102. In operation, airflow path 108 may be enclosed within the serpentine chamber 102 and effectively sealed from the environment outside the serpentine chamber 102, except for two openings: at the vacuum adapter port 115 (which may be coupled or sealed to the vacuum device or a conduit thereof) and at the dust dispensing port 120. The airflow path 108 may be to transport dust particles injected at the dust dispensing port 120, from the dust dispensing port 120 to the vacuum adapter port 115.

[0026] The dust maze apparatus 100 includes a device-under-test (DUT) port 130 disposed at the distal region 104 upstream (i.e., in a direction opposite of the airflow direction 110, or in other words, towards the proximate region 106) of the vacuum adapter port 115. The DUT port 130 may accept insertion of a DUT 132 into the airflow path 108. The DUT 132 when inserted into the DUT port 130 may have a test surface 134 exposed against the airflow direction 110.

[0027] The dust maze apparatus 100 includes an airflow structurer 140 disposed within the serpentine chamber 102 in the distal region 104 upstream from the DUT port 130. The dust maze apparatus 100 also may include a turbulator plate 150 disposed within the serpentine chamber 102 upstream from the airflow structurer 140. In some implementations, the turbulator plate 150 may be among a plurality of turbulator plates disposed within the serpentine chamber 102 to perturb the airflow along the airflow path 108. The airflow structurer 140 may then modify or structure the perturbed airflow for delivery to the DUT 132, and more particularly, to the test surface 134.

[0028] FIG. 2 depicts a dust application system 200 that may be useful for applying dust particles to a device-under-test. The dust application system 200 employs a dust maze apparatus 201. The dust maze apparatus 201 may be analogous in some respects to the dust maze apparatus 100. For example, the dust maze apparatus 201 may include a serpentine chamber 202 having a distal region 204, a proximate region 206, and an airflow path 208 within the serpentine chamber 202 with an airflow direction 210 defined from the proximate region 206 towards the distal region 204. The dust maze apparatus 201 may also include a DUT port in the distal region 204, and more particularly, the DUT port may be an optical jumper port 230. In some implementations, the dust maze apparatus 100 may serve as or form part of the dust maze apparatus 201.

[0029] The dust application system 200 also may include a vacuum device 260 (e.g., a centrifugal air pump) to pull airflow through the dust maze apparatus 201, from the proximate region 206 to the distal region 204, that is, along the airflow direction 210.

[0030] The dust application system 200 also may include a dust dispenser 270 to inject dust particles 272 into the dust maze apparatus 201 at the proximate region 206. For example, the dust dispenser 270 may be a solid aerosol generator.

The dust particles 272 may be carried or transported along the airflow direction 210 by airflow generated by the vacuum device 260. As but one example, the dust particles 270 may be microscopic, and more particularly, may be approximately 20 microns or less in diameter. For example, the dust particles 270 may be silica-based and may be compliant with the ISO12103-1 specification and/or ASHRAE specifications.

[0031] In some implementations, the dust application system 200 also may include an optical jumper carrier 280 to carry an optical ferrule 290 through the DUT port (optical jumper port 230) and to position an endface 292 of the optical ferrule 290 for exposure to the dust particles 272 (when carried by airflow). The optical ferrule 290 may thus be deemed a DUT (e.g., 132) and the endface 292 of the optical ferrule 290 may be deemed a test surface (e.g., 134). For example, the optical ferrule may be on the order of single-digit millimeters thick and may include an array of optical lenses or bare optical fibers (e.g., a 16x4 array), where the lenses or fibers may be on the order of 200 microns in diameter.

[0032] In other implementations, the DUT port and aspects thereof (e.g., size, shape, etc.) may be configured or designed to introduce and position various DUTs for exposure to dust particles 272 carried by airflow through the dust maze apparatus 201. That is, the dust application system 200 is not limited to receiving the optical jumper carrier 280 and testing the optical ferrule 290. For example the DUT port may include a plurality of optical jumper ports 230 for testing multiple optical ferrules simultaneously. In another example, the DUT may be an optical connector, and the dust application system 200 may be useful for testing the efficacy of the optical connector (and/or a shutter or cover thereof) in protecting an optical ferrule from dust particles 272. In some examples, the DUT may be at least a portion of an optical backplane, and the DUT port may be large enough to accommodate the portion of the optical backplane.

[0033] FIGS. 3A and 3B depict different viewing angles of a dust application system 300, which may be an example implementation of the dust application system 200. The dust application system 300 may share many similar features with the dust application system 200, including a dust maze apparatus 201 that includes a serpentine chamber 202 (having a distal region 204 and a proximate region 206). Additionally, as will be described below, the dust application system 300 also employs a vacuum device 260 and a dust dispenser 270 analogous to those described above with respect to FIG. 2. The dust application system 300 is illustrated as employing an optical jumper carrier 280, and similarly to dust application system 200, the dust application system 300 is not limited to testing an optical ferrule 290 carried by an optical jumper carrier 280, but may be configured to test various DUTs. At least some parts of the dust application system 300 may be mounted to a platform 395.

[0034] The dust application system 300 also includes a vacuum adapter port 315 at the distal region 204, and more particularly, at an open end of the serpentine chamber 202 at the distal region 204. The vacuum adapter port 315 provides an opening of the serpentine chamber 202 to which the vacuum device 260 (or a conduit thereof) may be coupled, thus allowing the vacuum device 260 to pull air from the serpentine chamber 202. In an implementation of the example dust application system 300, the vacuum device 260 is coupled to a bifurcated yoke 321 that has a first inlet 322, and the first inlet 322 in turn may be coupled or sealed to the opening in the proximate region 204, namely the vacuum adapter port 315. In this manner, the yoke 321 serves as part of an airflow conduit from the serpentine chamber 202 to the vacuum device 260. The bifurcated yoke 321 also has a second inlet 324, which will be described further below.

[0035] An implementation of the dust application system 300 may also include a dust dispensing port 320 at the proximate region 206, and more particularly, at an open end of the serpentine chamber 202 at the proximate region 206. The dust dispenser 270 may be positioned near to or within the dust dispensing port 320. The dust dispenser 270 may inject dust particles 272 into the dust dispensing port 320, and the dust particles 272 may be carried through the dust maze apparatus 201 by airflow generated by the vacuum device 260, in an airflow direction from the proximate region 206 towards the distal region 206. In some implementations, the dust dispensing port 320 may remain at least partially open to the environment outside the serpentine chamber 202, to act as an inlet from which the vacuum device 260 draws air to produce airflow.

[0036] An implementation of the dust application system 300 may also include a vacuum hood 302 adjacent to and/or at least partially surrounding the dust dispenser 270. The vacuum hood 302 can be coupled to the second inlet 324 of the bifurcated yoke 321, such that, when the vacuum device 260 is operated, air flow may be drawn through the vacuum hood 302. Air flow through the vacuum hood 302 may be useful for capturing excess dust particles 272 expelled by the dust dispenser 270 and not injected into the dust maze apparatus 201 (e.g., dust particles 272 that either fail to enter or return out of the dust dispensing port 320), without interfering with airflow drawn into the dust maze apparatus 201 at the dust dispensing port 320.

[0037] In some implementations, a vacuum adjuster may be provided at the vacuum adapter port 315 and/or the first inlet 322 to adjust airflow generated by the vacuum device 260 and drawn through the dust maze apparatus 201 (in an airflow direction 210 as described above). In some implementations, a vacuum adjuster may be provided at the second inlet 324 to control airflow drawn through the vacuum hood 302 by the vacuum device 260. For example, as illustrated in FIG. 3B, airflow through the first inlet 322 (and eventually through the dust dispensing port 320) and the second inlet 324 (and thus the vacuum hood 302), when the vacuum device 260 is active, may be independently varied by respective adjustable diaphragms 326, 328 integrated in the first inlet 322 and the second inlet 324.

[0038] For example, FIG. 4A illustrates the adjustable diaphragm 326 or 328 in a fully opened state, FIG. 4B illustrates the adjustable diaphragm 326 or 328 in a partially opened state, and FIG. 4C illustrates the adjustable diaphragm 326 or 328 in a fully closed state. Additionally or alternatively, other example vacuum adjusters may be employed, as shown in FIG. 5, including an interchangeable restrictor plate 502 (selected from restrictor plates of different opening sizes) or an adjustable peripherally-vented grille regulator 504. For example, the regulator 504 may be cylindrical (although other conduit shapes may be employed) and may have closeable vents along its circumference, where opening the vents to draw air through the vents may decrease the airflow through the dust maze apparatus 201.

[0039] Referring again to FIG. 3, in some implementations of dust application system 300, the dust maze apparatus 201 may include a viewing region 310. The viewing region 310 may be within the distal region 204 of the serpentine chamber 202, and more particularly, upstream from the optical jumper port 230. The viewing region 310 includes an illumination port 312 to receive light 314 (e.g., generated by light source 316) into the serpentine chamber 202 across the airflow path (e.g., 208), and a view port 318 for observation of dust particles 272 transported along the airflow path 208 and illuminated by light 314 received through the illumination port 312. In some implementations, the light source 316 may be a laser and the light 314 may be a fanned laser beam.

[0040] FIG. 6 depicts another view of the dust application system 300. In some implementations, the dust application system 300 may be modular. For example, the serpentine chamber 202 may be configured from modular segments, such as a “U”-shaped segment 606 and a straight segment 604 (or other shapes, such as a “J”-shaped segment), joined end-to-end (e.g., joint 608). Although the dust maze apparatus 201 is depicted in the Figures in an “M”-shaped configuration, different layouts are also possible. Each of the modular segments may include a chamber well portion 602 and a chamber cover (removed in FIG. 6 to show interior of dust maze apparatus 201) to removably seal an open region of the chamber well portion 602.

[0041] In some implementations, at least some of the modular segments may include turbulator plate receptacles in the chamber well portion 602 or the chamber cover. For example, the turbulator plate receptacles may be slots within which turbulator plates 650 may be installed. In this manner, a plurality of configurable turbulator plates 650 may be arranged within the serpentine chamber 202 to perturb airflow in the airflow path 208 and to trap large dust particles. For example, as described above, dust particles 272 of 20 micron diameter may be selected for use with a dust application system (300) to test an optical ferrule 290 having lenses or fibers each 200 microns in diameter. Occasionally, such dust particles 272 may clump together to form large clusters, approximately 100 to 200 microns in diameter, which would interfere with a dust occlusion test. Thus, the turbulator plates 650 may be useful for causing precipitation of such clusters, and particularly, to simulate precipitation of large dust particles that may occur in a non-test field environment. Additionally, the turbulator plates 650 may be useful for perturbing airflow and mixing dust particles 272 into a random distribution. Various configurations of turbulator plates (e.g., in terms of shape, size, quantity, arrangement, etc.) may be employed, depending on the characteristics of the dust particles 272 (e.g., size) and airflow.

[0042] To illustrate the foregoing, FIG. 7 depicts a side view of the dust application system 300 with a cutaway of the serpentine chamber 202, revealing top turbulator plates 650A installed in the chamber cover and bottom turbulator plates 650B installed in the chamber well portion. By virtue of the turbulator plates 650A and 650B, airflow through the serpentine chamber 202 may be turbulent airflow 700.

[0043] Referring again to FIG. 6, the dust maze apparatus 201 may include an airflow structurer 640 disposed within the serpentine chamber 202 in the distal region 204 upstream from the DUT port (e.g., optical jumper port 230). The airflow structurer 640 may modify or structure the perturbed airflow for delivery to the DUT. For example, FIG. 8, depicts a cutaway of the serpentine chamber 202 in the proximate region 204, revealing a concentrator-type airflow structurer 640 that condenses the airflow-carried dust particles 272 to the optical ferrule endface 292 of an optical ferrule held by the optical jumper carrier 280, which has been introduced into and rests on the optical jumper port 230.

[0044] FIGS. 9A, 9B, 9C, 9D depict non-limiting examples of airflow structurer 640, and the arrow in each figure illustrates an airflow direction. The design, configuration, and selection of airflow structurer 640 may be a function of the dust occlusion test performed using the dust application system 300 and/or the characteristics of the DUT(s) tested by the dust application system 300. FIG. 9A illustrates a short airflow concentrator, and FIG. 9B illustrates a long airflow concentrator. For example, the length of the airflow concentrator may be selected for targeted delivery of dust particles 272 to the test surface of the DUT (e.g., optical ferrule endface 292). FIG. 9C illustrates a laminar airflow diffuser, which may be useful for restoring turbulent air, as perturbed by the turbulator plates, to laminar airflow and for delivering dust particles 272 to a large DUT or a plurality of DUTs (e.g., a plurality of optical ferrules 290 and respective endfaces 292). FIG. 9D illustrates a laminar airflow diffuser that is longer than the laminar airflow diffuser illustrated in FIG. 9C. The diffuser of FIG. 9D may be useful for providing direct or targeted application of dust particles 272 in laminar airflow. In some implementations, multiple airflow structurers 640 may be employed.

[0045] FIG. 10A illustrates the optical jumper carrier 280. FIGS. 10B and 10C illustrate additional details of the optical jumper carrier 280, according to an implementation. As shown in FIG. 10B, the optical jumper carrier 280 includes a first half 1010 and a second half 1020. The first half 1010 and the second half 1020 may mate (e.g., mechanically, magnetically, by adhesive, etc.) and may hold the optical ferrule 290 within a clamp head of the optical jumper carrier 280. Additionally, the first half 1010 of the optical jumper carrier 280 have include a track 1012 for affixing or holding an optical fiber body 1002, which is attached to and terminated by the optical ferrule 290. In some implementations, a clip 1030 may be assembled to the optical jumper carrier 280, and may be useful for aligning and/or securing the optical jumper carrier 280 to the optical jumper port 230, as illustrated in FIG. 8.

[0046] FIG. 10C illustrates a magnified view of the encircled portion of FIG. 10A. FIG. 10C shows that, when the first half 1010 of the optical jumper carrier 280 is mated to the second half 1020 of the optical jumper carrier 280, the optical ferrule 290 is clamped between a clamp head portion 1014 of the first half 1010 and a clamp head portion 1024 of the second half 1020. When the optical ferrule 290 is clamped as shown, the optical ferrule endface 292 may be exposed, to airflow-carried dust particles 272 for example.

[0047] FIG. 11 is a flowchart of an example method 1100 for applying dust particles to a device-under-test. In some implementations, method 1100 may be performed in an automated manner, by robotics for example. In some implementations of the present disclosure, one or more blocks of method 1100 may be executed substantially concurrently or in a different order than shown in FIG. 11. Some of the blocks of method 1100 may, at times, be ongoing and/or may repeat. In some implementations of the present disclosure, method 1100 may include more or fewer blocks than are shown in FIG. 11.

[0048] Method 1100 begins at block 1102 and continues to block 1104, where a dust maze is provided. In some implementations, the dust maze provided may be the dust maze apparatus 100, 200, or 300 described above. For example, the dust maze provided at block 1104 may include a serpentine chamber having a distal region, a proximate region, and an airflow path within the serpentine chamber with an airflow direction defined from the proximate region towards the distal region; a DUT port such as an optical jumper port disposed at the distal region; an airflow structurer within the serpentine chamber upstream of the DUT port; and a turbulator plate within the serpentine chamber upstream of the airflow structurer.

[0049] At block 1106, a DUT, such as an optical jumper carrier carrying an optical ferrule, is inserted through the DUT port (e.g., optical jumper port). The DUT is positioned within the DUT port to expose a test surface (e.g., an endface of an optical ferrule) to injected dust particles carried by the airflow, as will be described below.

[0050] At block 1108, vacuum is provided at the distal region to generate airflow within the dust maze in the airflow direction. For example, a vacuum device may be coupled to the distal region to provide vacuum.

[0051] At block 1110, dust particles are injected at the proximate region, the injected dust particles to be carried by the airflow along the airflow direction. Some of the dust particles may impinge and land on the test surface of the DUT. After block 1110, method 1100 may end.

[0052] FIG. 12 is a flowchart of an example method 1200 for applying dust particles to a device-under-test. In some implementations, method 1200 may be performed in an automated manner, by robotics for example. In some implementations of the present disclosure, one or more blocks of method 1200 may be executed substantially concurrently or in a different order than shown in FIG. 12. Some of the blocks of method 1200 may, at times, be ongoing and/or may repeat. In some implementations of the present disclosure, method 1200 may include more or fewer blocks than are shown in FIG. 12. In some examples, method 1200 may employ a dust application system, such as dust application system 200 or 300, that includes a dust maze (e.g., dust maze apparatus 201).

[0053] Method 1200 begins at block 1202 and continues to block 1204, where an optical ferrule is set in an optical jumper carrier. More particularly, block 1204 may include blocks 1206, 1208, 1210. At block 1206, an optical fiber body which the optical ferrule terminates is removably affixed to a track in a first half of the optical jumper carrier. At block 1208, the optical ferrule is aligned to a clamp head portion of the first half. At block 1210, a second half of the optical jumper carrier is mated to the first half to clamp the optical ferrule between the clamp head portion of the first half and a clamp head portion of the second half.

[0054] At block 1212, the optical jumper carrier assembled in block 1204 is inserted through an optical jumper port of a dust maze to expose an endface of the optical ferrule to injected dust particles carried by airflow through the dust maze. At block 1214, vacuum is provided at a distal region of the dust maze to generate airflow within the dust maze. At block 1216, dust particles are injected at a proximate region of the dust maze, the injected dust particles to be carried towards the optical jumper carrier by the airflow generated at block 1214. In some implementations, dust particles may be injected at block 1216 for a predetermined amount of time according, for example, to a test protocol. Blocks 1212, 1214, and 1216 may be analogous in many respects to blocks 1106, 1108, 1110 described above, respectively.

[0055] At block 1218, the optical jumper carrier carrying the optical ferrule is transferred from the optical jumper port (thus removing it from the dust maze) to an optical jumper carrier cradle having a complementary shape to the optical jumper carrier. At block 1220, the optical jumper carrier cradle is positioned to locate the optical ferrule within a field of view of a microscopic imager. At block 1222, the method 1200 may end.

[0056] FIG. 13 illustrates an optical jumper carrier cradle 1302 to receive the optical jumper carrier 280. When the optical jumper carrier 280 is inserted into the optical jumper carrier cradle 1302, the optical ferrule endface 292 is exposed for examination. FIG. 14 illustrates the optical jumper carrier 280 inserted in the optical jumper carrier cradle 1302, and the cradle 1302 can be moved to locate the exposed optical ferrule endface 292 within a field of view of an imager 1402.

[0057] In view of the foregoing description, it can be appreciated that the dust maze apparatus and the dust application system provide a controllable and repeatable way to apply micrometer-scale dust particles to a device-under-test, such as an optical ferrule. For example, modularity of the serpentine chamber, variable vacuum adjusters, various example airflow structurers, and configurable turbulator plates provide a number of variables to adjust how dust particles are delivered and applied to the DUT. Additionally, airflow through the dust maze apparatus may follow a horizontal snaking through the serpentine chamber and a vertical snaking around the turbulator plates, which may randomize the distribution of dust particles and provide a uniform application of dust particles to the DUT. Owing at least in part to the serpentine chamber, the dust application system also may be more compact and easier to clean than a dust chamber.

[0058] Moreover, by virtue of the vacuum hood adjacent to the dust dispenser, release of dust particles into the surrounding environment may be minimized, thus reducing dust-related health risk to human operators and being sufficiently clean for use in proximity to dust-sensitive equipment, such as an imaging system or microscope. Furthermore, because the dust application system may be used in proximity to an imaging system, a robotic test system may be readily employed to pick and place a DUT into the dust application system, apply dust particles to the DUT using the dust application system, remove the DUT from the dust application system, move the DUT to the imaging system, and perform image capture of the test surface of the DUT.

[0059] Additionally, utilizing the optical jumper carrier and optical jumper carrier cradle to handle an optical ferrule may provide robust transport between the dust application system and an imaging system, without disturbing dust particles that have been deposited on to the optical ferrule endface. Accordingly, a cumulative dust occlusion test (with incremental increases in occlusion) may be performed on the same optical ferrule by, for example, applying dust particles for a predetermined time, moving the optical ferrule to the imaging system via the cradle, imaging the optical ferrule endface, and repeating the process.

[0060] In the foregoing description, numerous details are set forth to provide an understanding of the subject matter disclosed herein. However, implementation may be practiced without some or all of these details. Other implementations may include modifications and variations from the details discussed above. It is intended that the following claims cover such modifications and variations.

What is claimed:

1. A dust maze apparatus comprising:

a serpentine chamber having a distal region, a proximate region, and an airflow path within the serpentine chamber with an airflow direction defined from the proximate region towards the distal region;

a vacuum adapter port at the distal region to couple to a vacuum device;

a dust dispensing port at the proximate region;

a device-under-test (DUT) port disposed at the distal region upstream of the vacuum adapter port, the DUT port to accept insertion of a DUT into the airflow path, the DUT when inserted into the DUT port having a test surface exposed against the airflow direction;

an airflow structurer disposed within the serpentine chamber in the distal region upstream from the DUT port; and

a turbulator plate disposed within the serpentine chamber upstream from the airflow structurer.

2. The dust maze apparatus of claim 1, wherein the DUT is an optical ferrule inserted into the DUT port by an optical jumper carrier, and the test surface includes an endface of the optical ferrule.

3. The dust maze apparatus of claim 1, further comprising a vacuum adjuster at the vacuum adapter port to adjust airflow generated by the vacuum device, the vacuum adjuster including an interchangeable restrictor plate, an adjustable diaphragm, or an adjustable peripherally-vented grille regulator.

4. The dust maze apparatus of claim 1, wherein the airflow path is to transport dust particles injected at the dust dispensing port to the vacuum adapter port, and

the turbulator plate is among a plurality of configurable turbulator plates arranged within the serpentine chamber to perturb air flow in the airflow path and to trap large dust particles.

5. The dust maze apparatus of claim 1, further comprising a viewing region upstream from the DUT port, wherein

the viewing region includes:

an illumination port to receive light into the serpentine chamber across the airflow path, and

a view port for observation of dust particles transported along the airflow path and illuminated by light received through the illumination port.

6. The dust maze apparatus of claim 1, wherein the airflow structurer is an airflow concentrator or a laminar airflow diffuser.

7. The dust maze apparatus of claim 1, wherein the serpentine chamber is configured from modular segments joined end-to-end,

each of the modular segments include a chamber well portion and a chamber cover to removably seal an open region of the chamber well portion, and

at least some of the modular segments include turbulator plate receptacles in the chamber well portion or the chamber cover.

8. A method comprising:

providing a dust maze that includes:

a serpentine chamber having a distal region, a proximate region, and an airflow path within the serpentine chamber with an airflow direction defined from the proximate region towards the distal region,

an optical jumper port disposed at the distal region,

an airflow structurer within the serpentine chamber upstream of the optical jumper carrier, and

a turbulator plate within the serpentine chamber upstream of the airflow structurer;

providing vacuum at the distal region to generate airflow within the dust maze in the airflow direction;

injecting dust particles at the proximate region, the injected dust particles to be carried by the airflow along the airflow direction; and inserting an optical jumper carrier carrying an optical ferrule through the optical jumper port to expose an endface of the optical ferrule to injected dust particles carried by the airflow.

9. The method of claim 8, further comprising setting the optical ferrule in the optical jumper carrier by:

removably affixing an optical fiber body, which the optical ferrule terminates, to a track in a first half of the optical jumper carrier,

aligning the optical ferrule to a clamp head portion of the first half, and

mating a second half of the optical jumper carrier to the first half to clamp the optical ferrule between the clamp head portion of the first half and a clamp head portion of the second half.

10. The method of claim 8, further comprising:

after injecting dust particles for a predetermined amount of time, transferring the optical jumper carrier carrying the optical ferrule from the optical jumper port to an optical jumper carrier cradle having a complementary shape to the optical jumper carrier; and

positioning the optical jumper carrier cradle to locate the optical ferrule within a field of view of a microscopic imager.

11. A dust application system comprising:

a dust maze apparatus that includes:

a serpentine chamber having a distal region, a proximate region, and an airflow path within the serpentine chamber with an airflow direction defined from the proximate region towards the distal region, and

an optical jumper port disposed at the distal region;

a vacuum device to pull airflow through the dust maze apparatus, from the proximate region to the distal region;

a dust dispenser to inject dust particles into the dust maze apparatus at the proximate region, the dust particles to be carried by the airflow along the airflow direction; and an optical jumper carrier to carry an optical ferrule through the optical jumper port and to position an endface of the optical ferrule for exposure to the dust particles.

12. The dust application system of claim 11, wherein the dust maze apparatus includes:

an airflow structurer disposed within the serpentine chamber in the distal region upstream from the optical jumper port, wherein the airflow structurer is an airflow concentrator or a laminar airflow diffuser, and

a turbulator plate disposed within the serpentine chamber upstream from the airflow structurer.

13. The dust application system of claim 11, wherein the optical jumper carrier includes a first half and a second half, the first half and the second half to mate magnetically and to hold the optical ferrule within a clamp head of the optical jumper carrier.

14. The dust application system of claim 11, wherein the dust maze apparatus includes a viewing region upstream from the optical jumper port, the viewing region including:

an illumination port to receive light into the serpentine chamber across the airflow path, and

a view port for observation of dust particles transported along the airflow path and illuminated by light received through the illumination port.

15. The dust application system of claim 11, wherein the vacuum device is coupled to a bifurcated yoke having a first inlet and a second inlet,

the first inlet being sealed to an opening at the proximate region,

the second inlet being coupled to a vacuum hood adjacent to the dust dispenser to capture excess dust not injected into the dust maze apparatus, and airflow through the first inlet and the second inlet, when the vacuum device is active, are independently varied by respective adjustable diaphragms integrated in the first inlet and the second inlet.

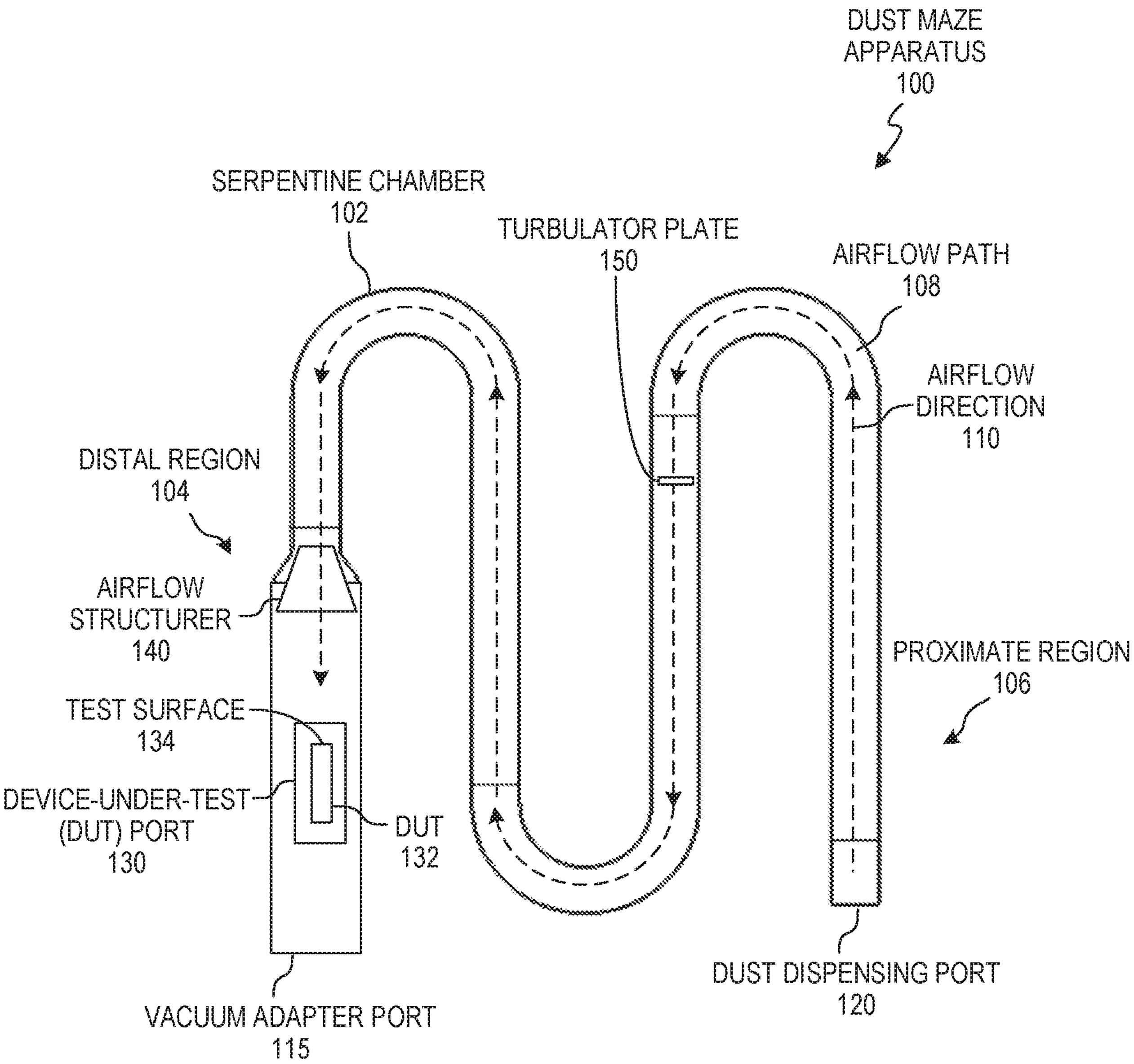
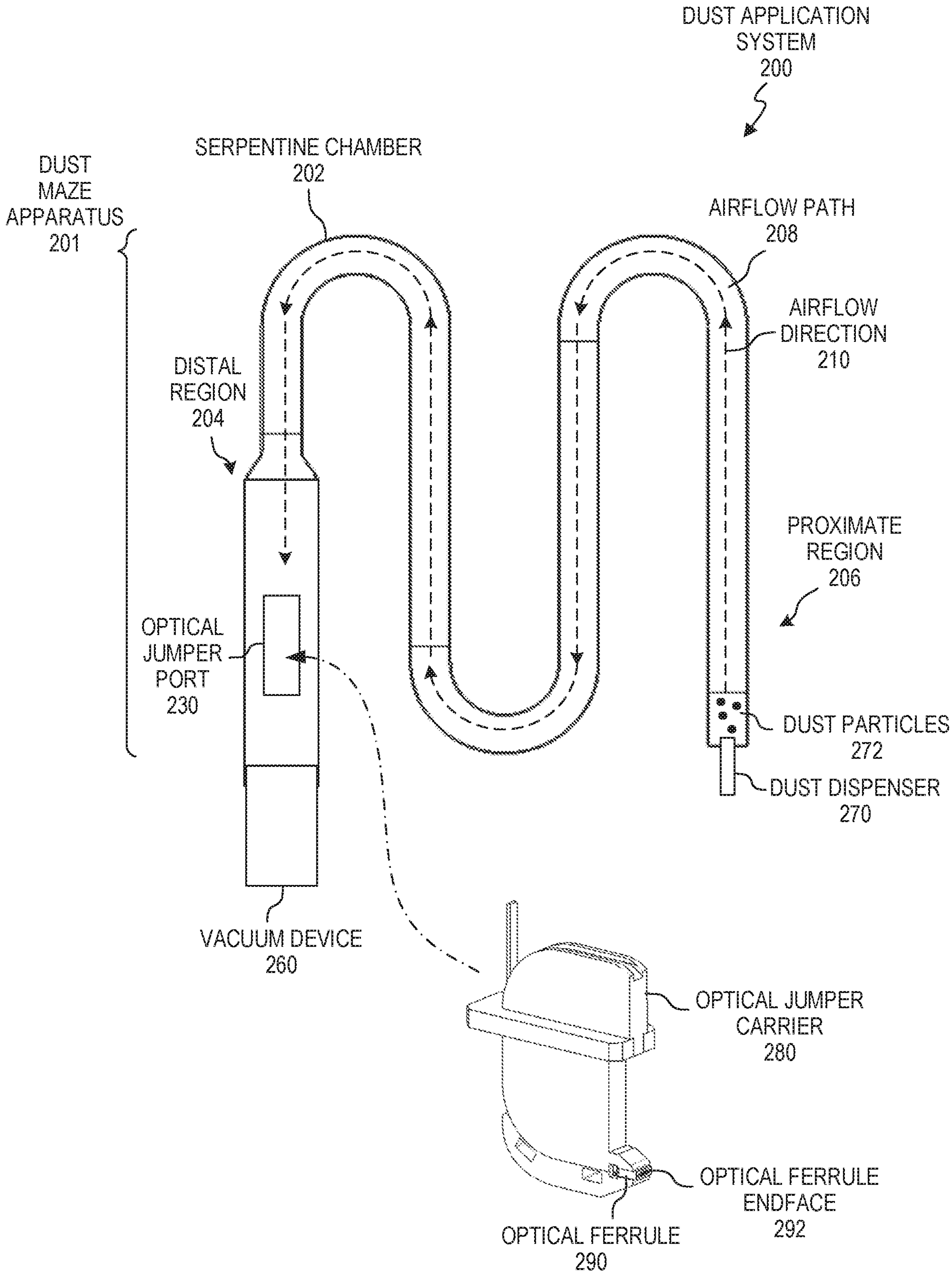

DUST MAZE APPARATUS 100
SERPENTINE CHAMBER 102
TURBULATOR PLATE 150
AIRFLOW PATH 108
AIRFLOW DIRECTION 110
DISTAL REGION 104
AIRFLOW STRUCTURER 140
TEST SURFACE 134
DEVICE-UNDER-TEST (DUT) PORT 130
DUT 132
PROXIMATE REGION 106
VACUUM ADAPTER PORT 115
DUST DISPENSING PORT 120

FIG. 1



DUST APPLICATION SYSTEM 200
SERPENTINE CHAMBER 202
DUST MAZE APPARATUS 201
AIRFLOW PATH 208
AIRFLOW DIRECTION 210
DISTAL REGION 204
PROXIMATE REGION 206
OPTICAL JUMPER PORT 230
DUST PARTICLES 272
DUST DISPENSER 270
VACUUM DEVICE 260
OPTICAL JUMPER CARRIER 280
OPTICAL FERRULE ENDFACE 292
OPTICAL FERRULE 290

FIG. 2

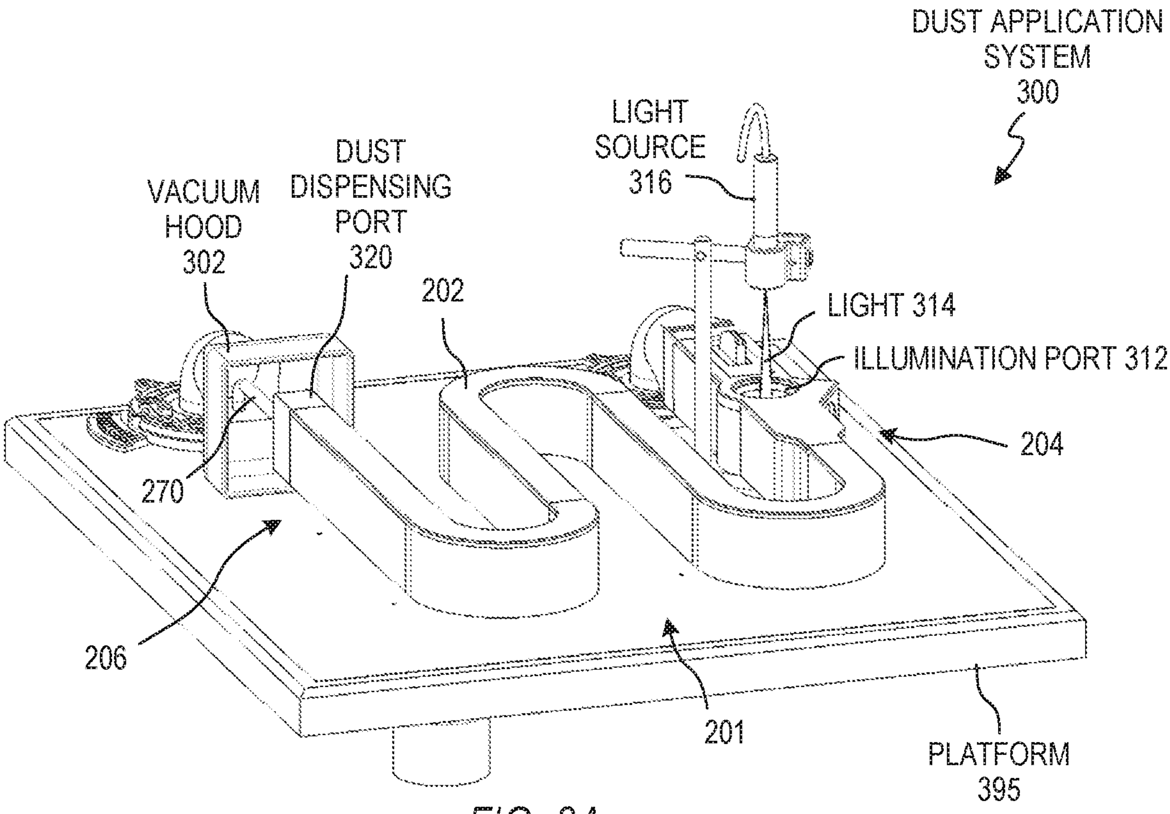

DUST APPLICATION SYSTEM 300
LIGHT SOURCE 316
DUST DISPENSING PORT 320
VACUUM HOOD 302
202
LIGHT 314
ILLUMINATION PORT 312
204
270
206
201
PLATFORM 395

FIG. 3A

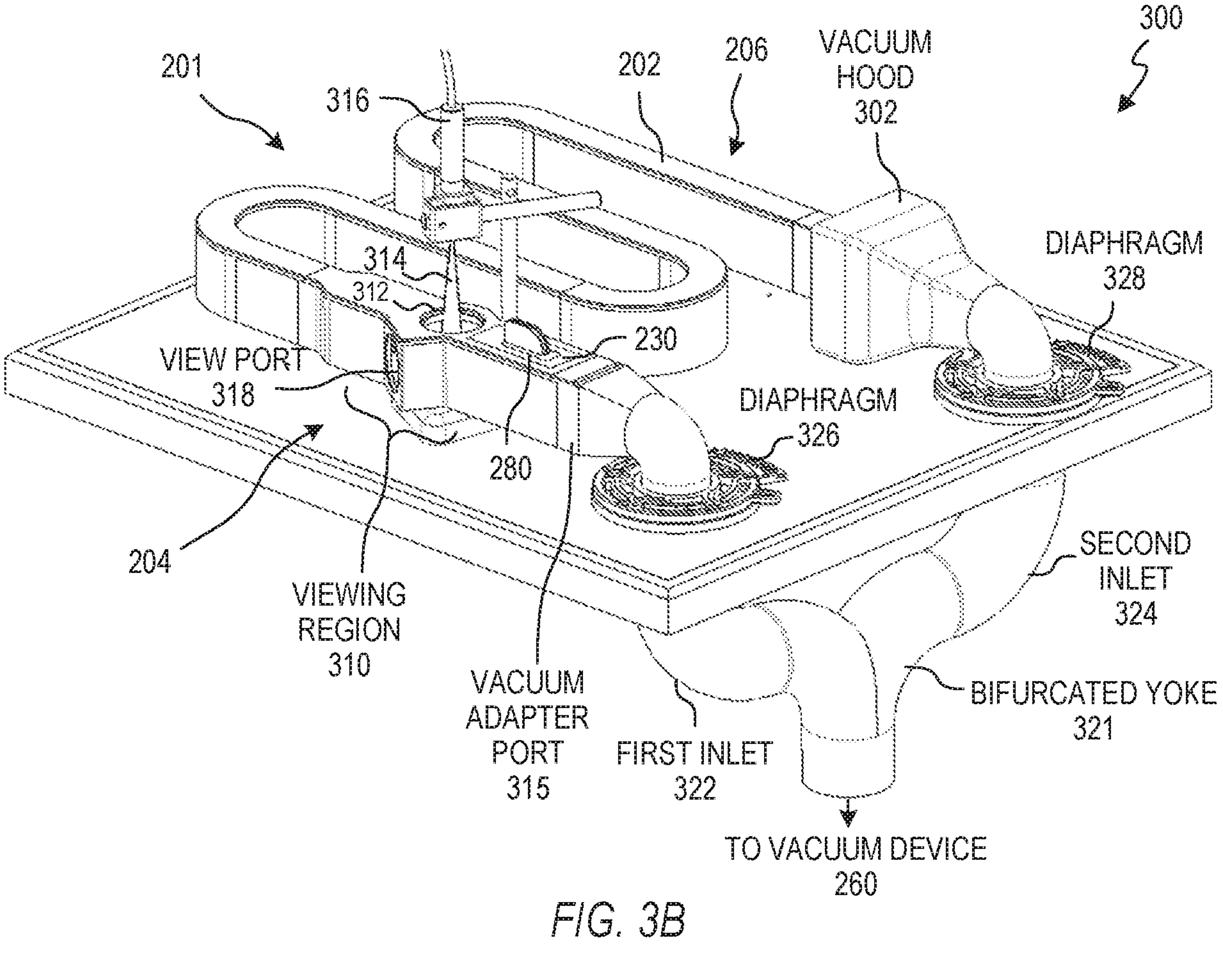

300
201
202
206
VACUUM HOOD 302
316
314
312
230
VIEW PORT 318
DIAPHRAGM 328
DIAPHRAGM 326
280
204
VIEWING REGION 310
VACUUM ADAPTER PORT 315
SECOND INLET 324
BIFURCATED YOKE 321
FIRST INLET 322
TO VACUUM DEVICE 260

FIG. 3B

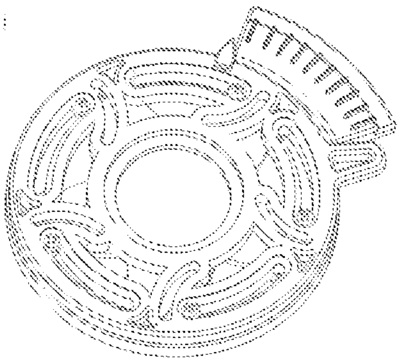


FIG. 4A

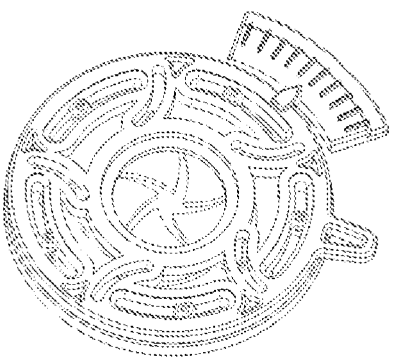


FIG. 4B

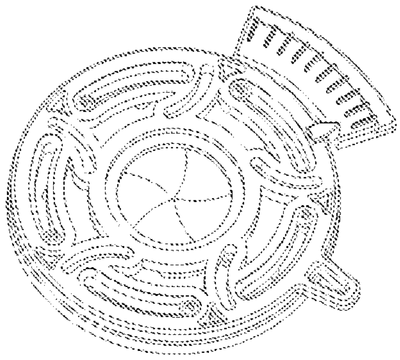


FIG. 4C

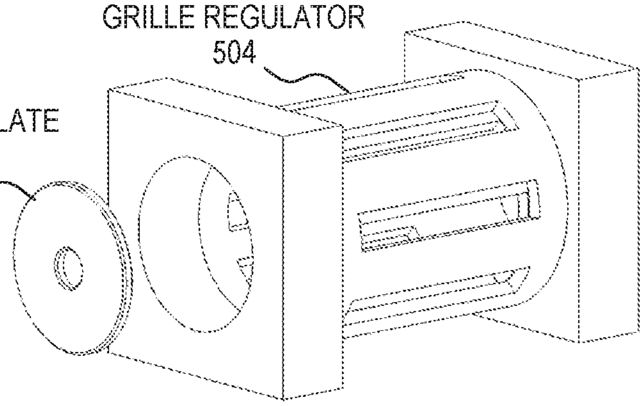


FIG. 5

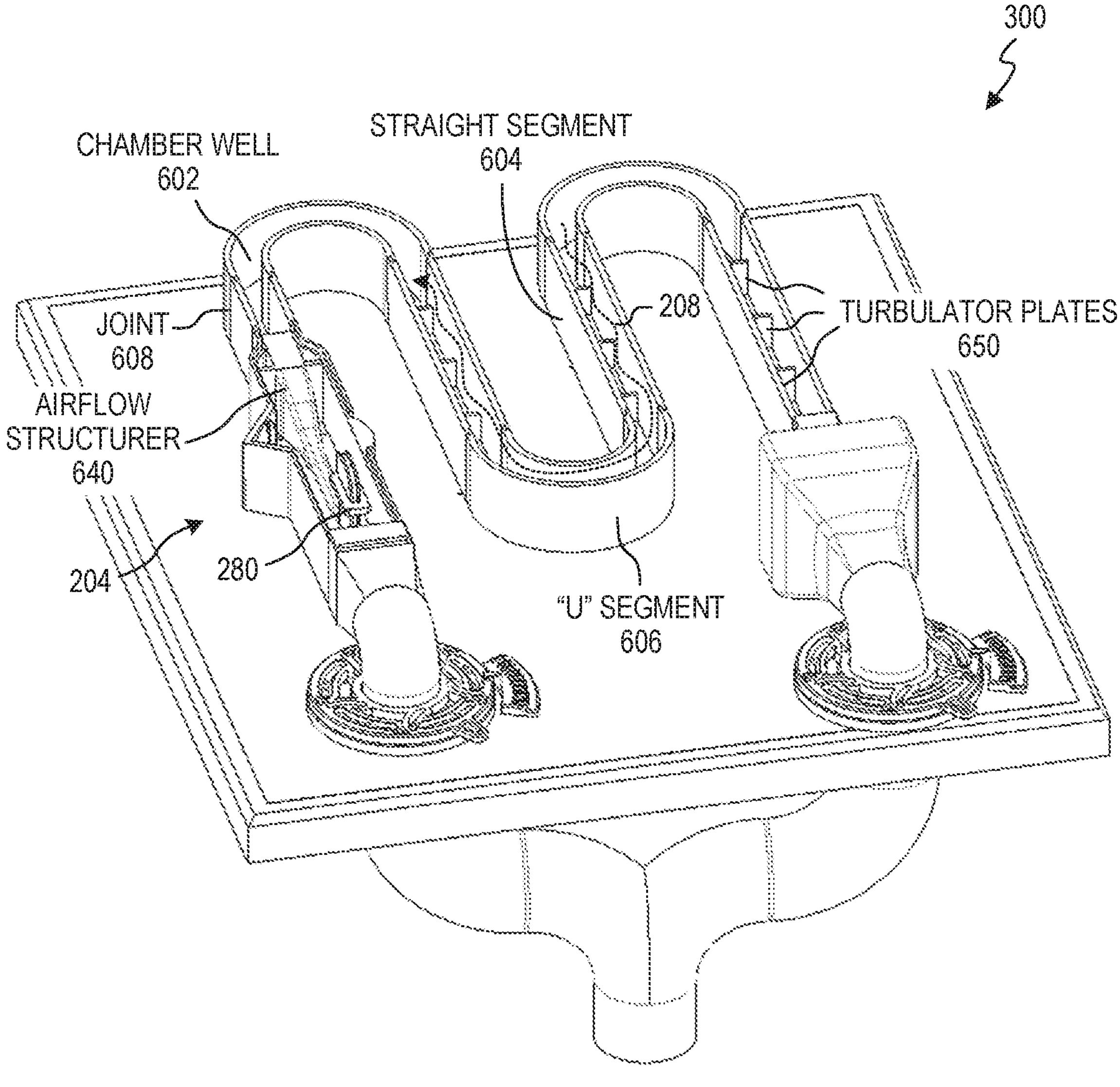

300
CHAMBER WELL
602
STRAIGHT SEGMENT
604
208
TURBULATOR PLATES
650
JOINT
608
AIRFLOW
STRUCTURER
640
204
280
"U" SEGMENT
606

FIG. 6

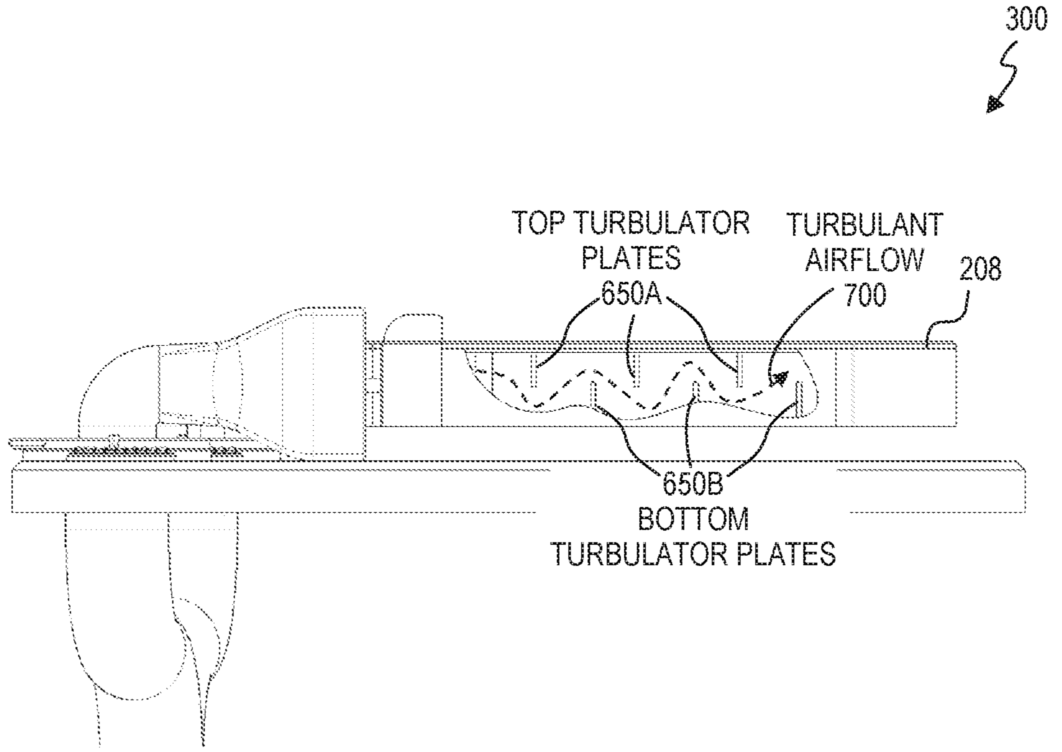

300
TOP TURBULATOR PLATES 650A
TURBULANT AIRFLOW 700
208
650B BOTTOM TURBULATOR PLATES

FIG. 7

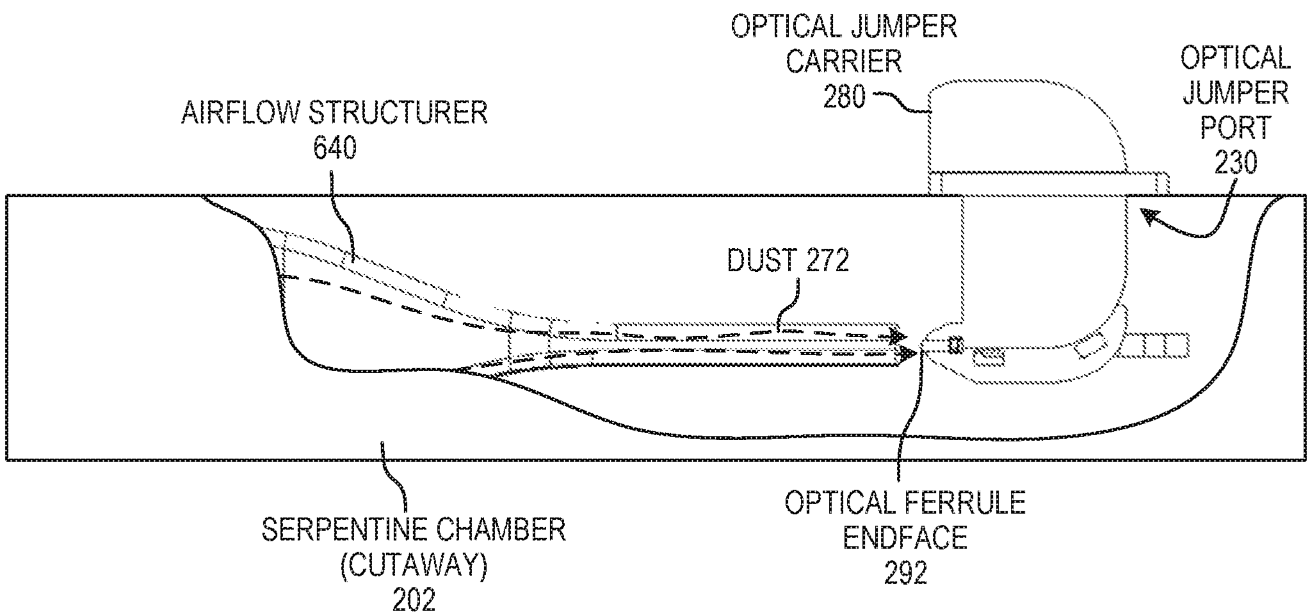

OPTICAL JUMPER CARRIER 280
OPTICAL JUMPER PORT 230
AIRFLOW STRUCTURER 640
DUST 272
SERPENTINE CHAMBER (CUTAWAY) 202
OPTICAL FERRULE ENDFACE 292

FIG. 8

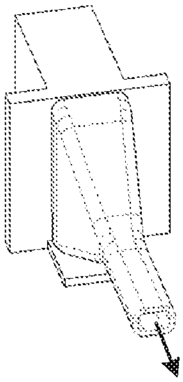


FIG. 9A

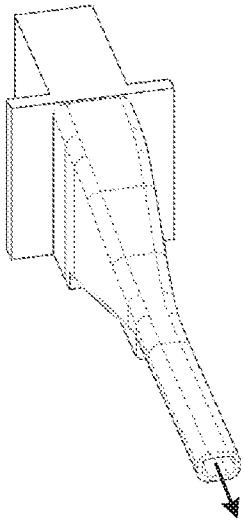


FIG. 9B

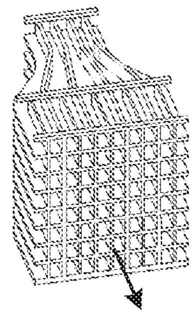


FIG. 9C

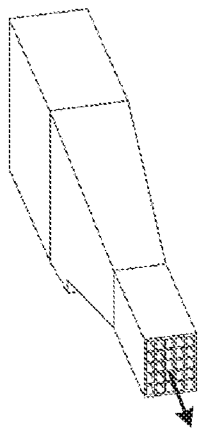


FIG. 9D

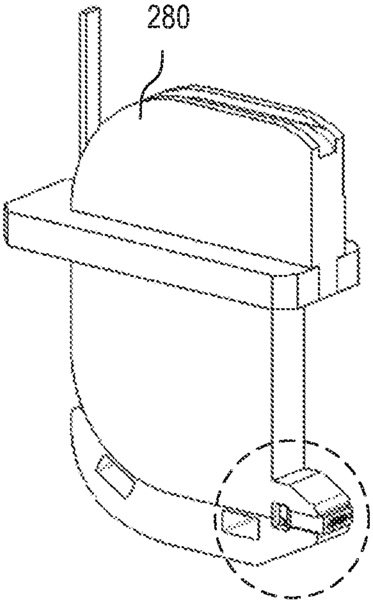


FIG. 10A

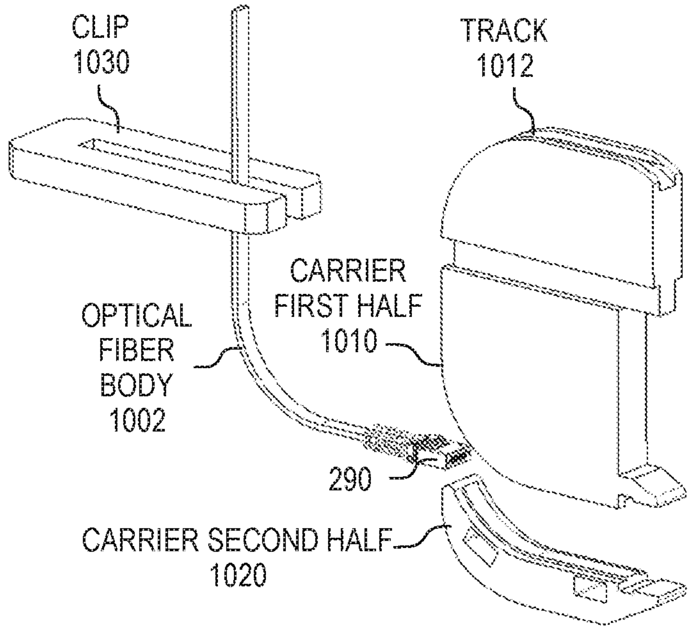


FIG. 10B

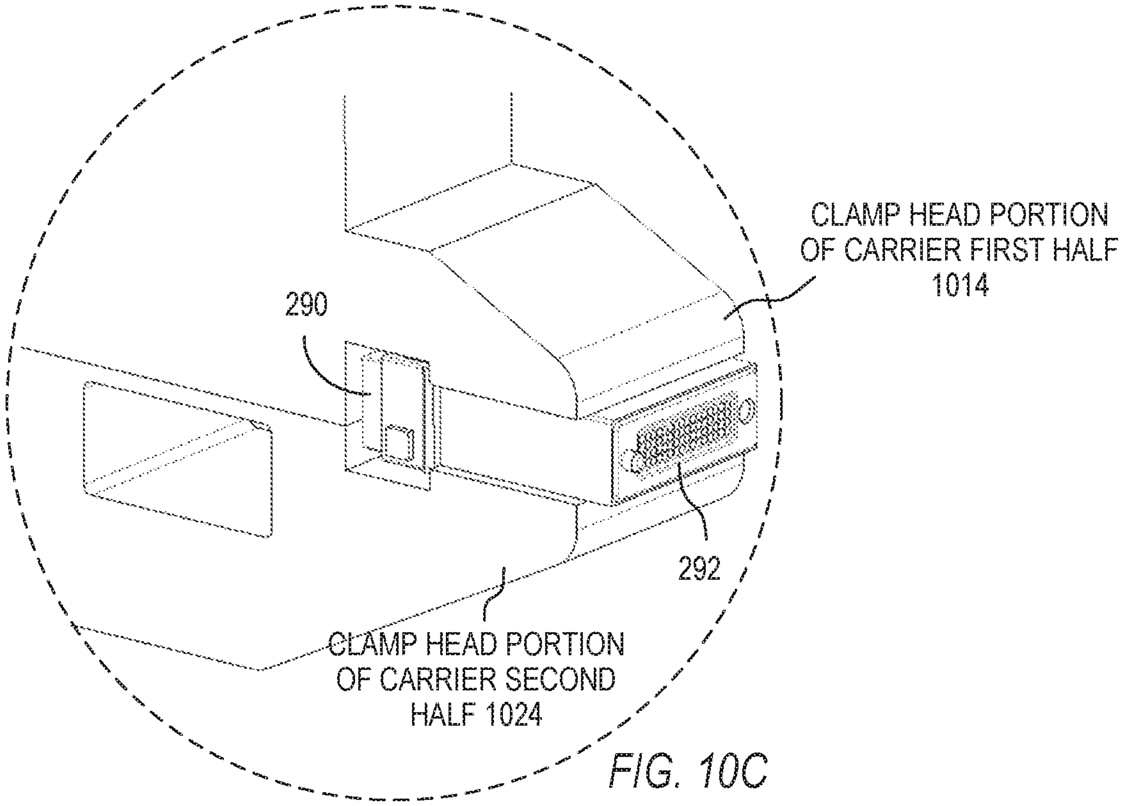


FIG. 10C

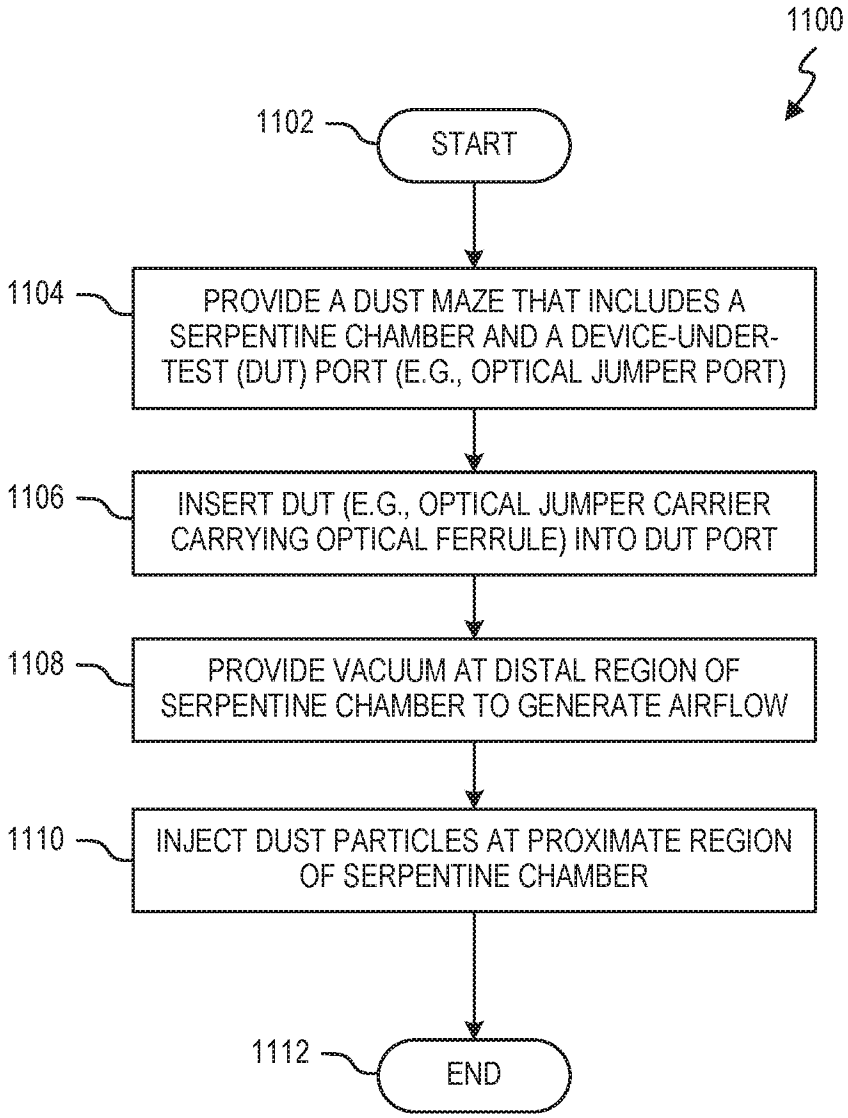

1100
1102
START
1104
PROVIDE A DUST MAZE THAT INCLUDES A SERPENTINE CHAMBER AND A DEVICE-UNDER-TEST (DUT) PORT (E.G., OPTICAL JUMPER PORT)
1106
INSERT DUT (E.G., OPTICAL JUMPER CARRIER CARRYING OPTICAL FERRULE) INTO DUT PORT
1108
PROVIDE VACUUM AT DISTAL REGION OF SERPENTINE CHAMBER TO GENERATE AIRFLOW
1110
INJECT DUST PARTICLES AT PROXIMATE REGION OF SERPENTINE CHAMBER
1112
END

FIG. 11

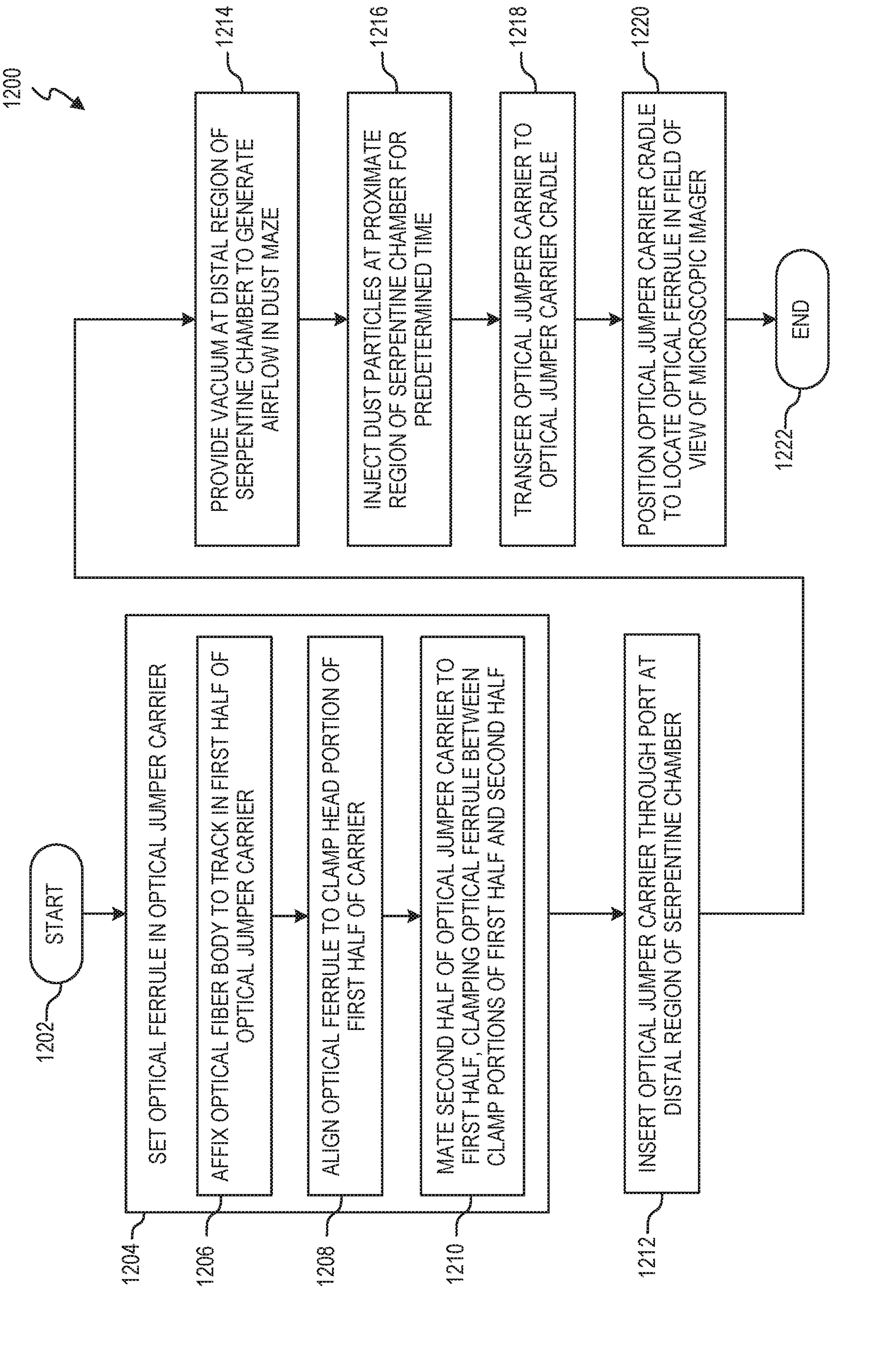

1200
START
1202
SET OPTICAL FERRULE IN OPTICAL JUMPER CARRIER
1204
AFFIX OPTICAL FIBER BODY TO TRACK IN FIRST HALF OF OPTICAL JUMPER CARRIER
1206
ALIGN OPTICAL FERRULE TO CLAMP HEAD PORTION OF FIRST HALF OF CARRIER
1208
MATE SECOND HALF OF OPTICAL JUMPER CARRIER TO FIRST HALF, CLAMPING OPTICAL FERRULE BETWEEN CLAMP PORTIONS OF FIRST HALF AND SECOND HALF
1210
INSERT OPTICAL JUMPER CARRIER THROUGH PORT AT DISTAL REGION OF SERPENTINE CHAMBER
1212
PROVIDE VACUUM AT DISTAL REGION OF SERPENTINE CHAMBER TO GENERATE AIRFLOW IN DUST MAZE
1214
INJECT DUST PARTICLES AT PROXIMATE REGION OF SERPENTINE CHAMBER FOR PREDETERMINED TIME
1216
TRANSFER OPTICAL JUMPER CARRIER TO OPTICAL JUMPER CARRIER CRADLE
1218
POSITION OPTICAL JUMPER CARRIER CRADLE TO LOCATE OPTICAL FERRULE IN FIELD OF VIEW OF MICROSCOPIC IMAGER
1220
END
1222

FIG. 12

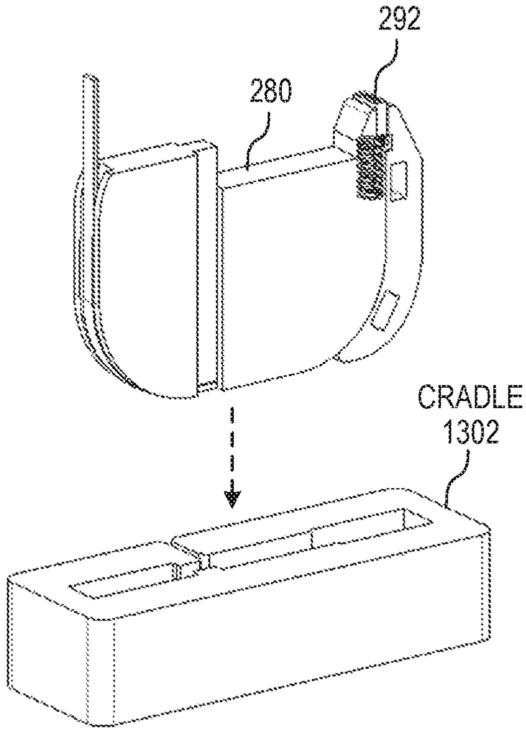


FIG. 13

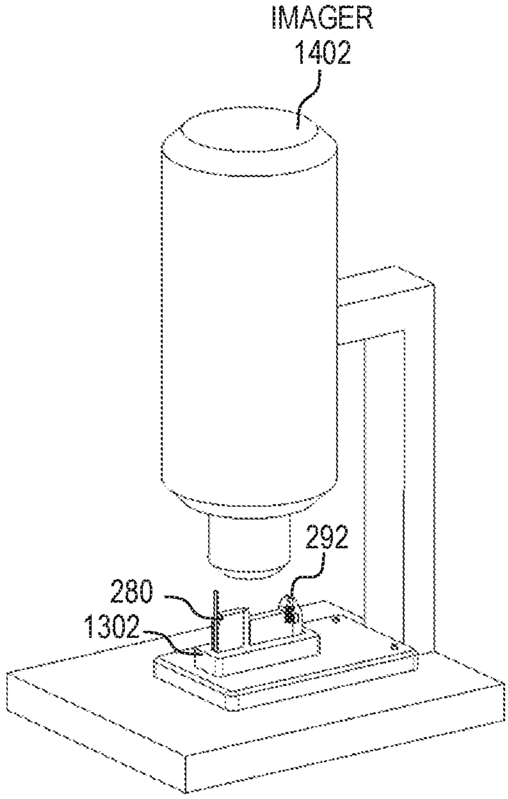


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/023224

A. CLASSIFICATION OF SUBJECT MATTER

B01D 45/12(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D 45/12; B01D 46/02; G01M 11/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: dust, device under test, tube, optical ferrule, jumper, carrier

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 103234573 A (ZHANGJIAGANG LANGYI MECHANICAL AND ELECTRICAL EQUIPMENT CO., LTD.) 07 August 2013 See abstract; paragraphs [0022], [0026]; claim 1; and figure 1.	1-15
Y	US 2016-0061690 A1 (CORNING OPTICAL COMMUNICATIONS LLC.) 03 March 2016 See paragraph [0010]; claim 1; and figure 3B.	1-15
A	US 2898803 A (MORRISON, CHARLES A. et al.) 11 August 1959 See column 3, lines 6-48; claim 1; and figure 1.	1-15
A	CN 103976690 A (PUTIAN UNIVERSITY) 13 August 2014 See paragraphs [0012], [0022]; claim 1; and figure 1.	1-15
A	US 2009-0056548 A1 (WOO, EDWARD J. et al.) 05 March 2009 See paragraph [0021]; and figure 1.	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 December 2016 (08.12.2016)	**08 December 2016 (08.12.2016)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
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Facsimile No. +82-42-481-8578

Authorized officer
CHO, KI YUN
Telephone No. +82-42-481-5655

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 103234573 A	07/08/2013	CN 103234573 B	18/03/2015
US 2016-0061690 A1	03/03/2016	WO 2016-033139 A1	03/03/2016
US 2898803 A	11/08/1959	None	
CN 103976690 A	13/08/2014	None	
US 2009-0056548 A1	05/03/2009	CN 101821057 A	01/09/2010
		CN 101821057 B	22/02/2012
		EP 2203274 A2	07/07/2010
		EP 2203274 A4	16/09/2015
		US 8070862 B2	06/12/2011
		WO 2009-032785 A2	12/03/2009
		WO 2009-032785 A3	07/05/2009