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(54) NANO-STRUCTURED NUCLEAR RADIATION SHIELDING

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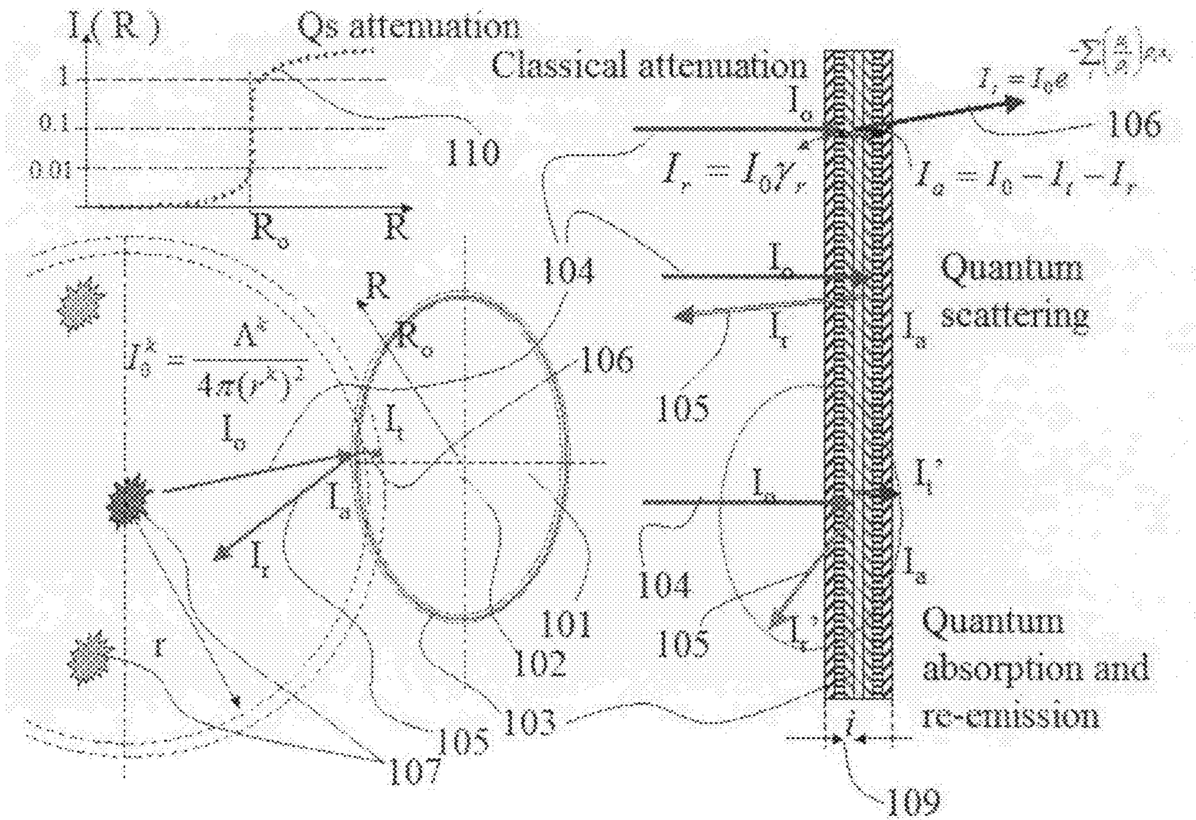
(57) ABSTRACT

The nuclear shielding is bulky and difficult to handle due to the reduced stopping power between the neutral radiations (X, gamma, n) and materials. It is proven that these radiations reflect at grazing angles on special substrates called super-mirrors that contain nano-layers of various materials. The usage of nano-structures in ordered manner or nano-tubes may create the super-mirror like wave-guide for this neutral radiation driving it and turning at angles greater than 90 degrees in few microns only. The usage of ferro or piezo electric nano-structures generates a shield that has the wave-guides path dependent on a control voltage. The resultant device is a shield for nuclear reactor criticality control, minimizing the nuclear reactor shielding and making an electric control of the power level by adjusting the shielding transmission. Other devices as X, n imaging device, or radiation funneling to increase the efficiency of using thin absorbents are some of the potential applications.



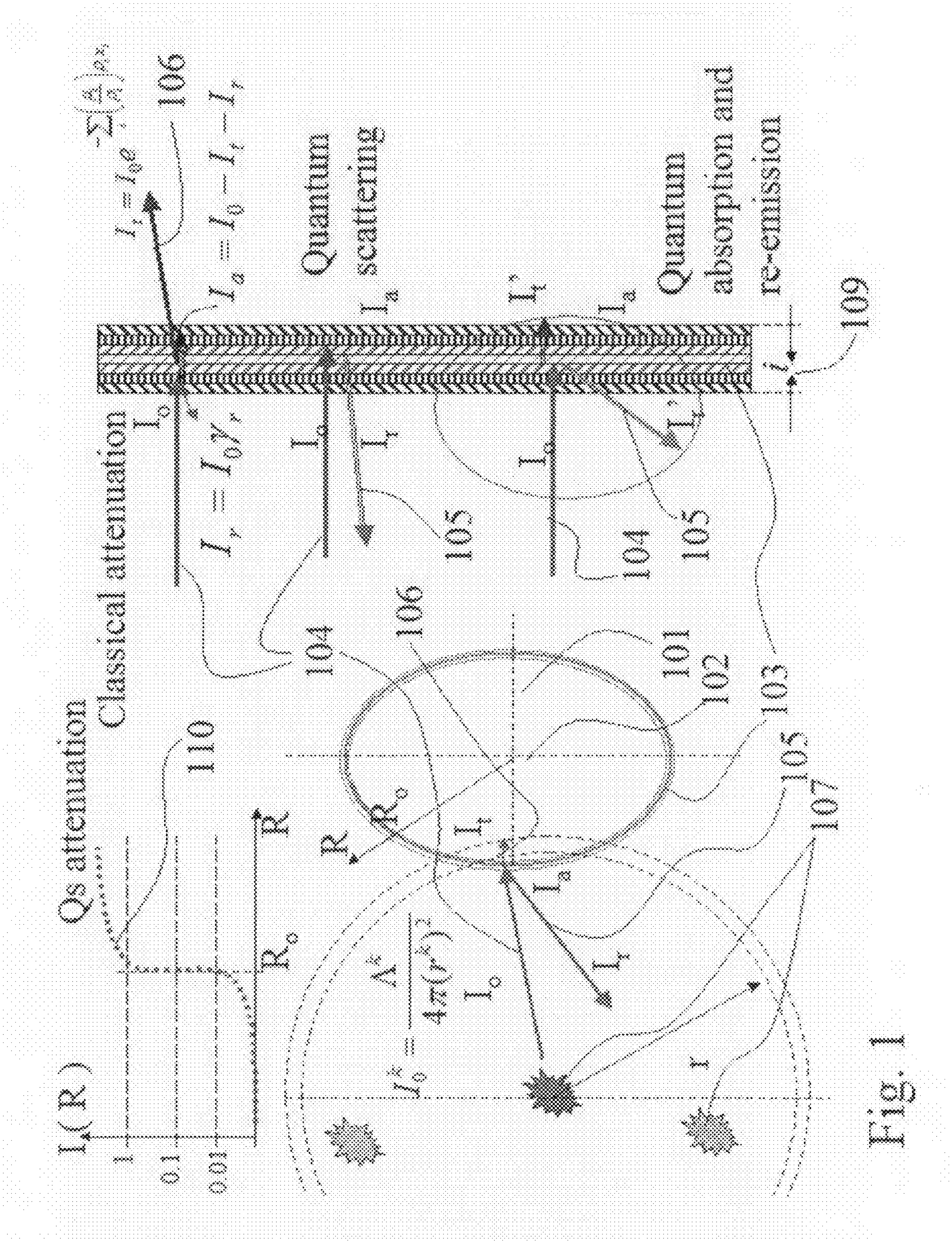

Qs attenuation
Classical attenuation
Quantum scattering
Quantum absorption and re-emission
I(R)
R
R_o
1
0.1
0.01
$I_r = I_0 \gamma_r$
$I_a = I_0 - I_t - I_r$
101
102
103
104
105
106
107
109
110

Fig. 1

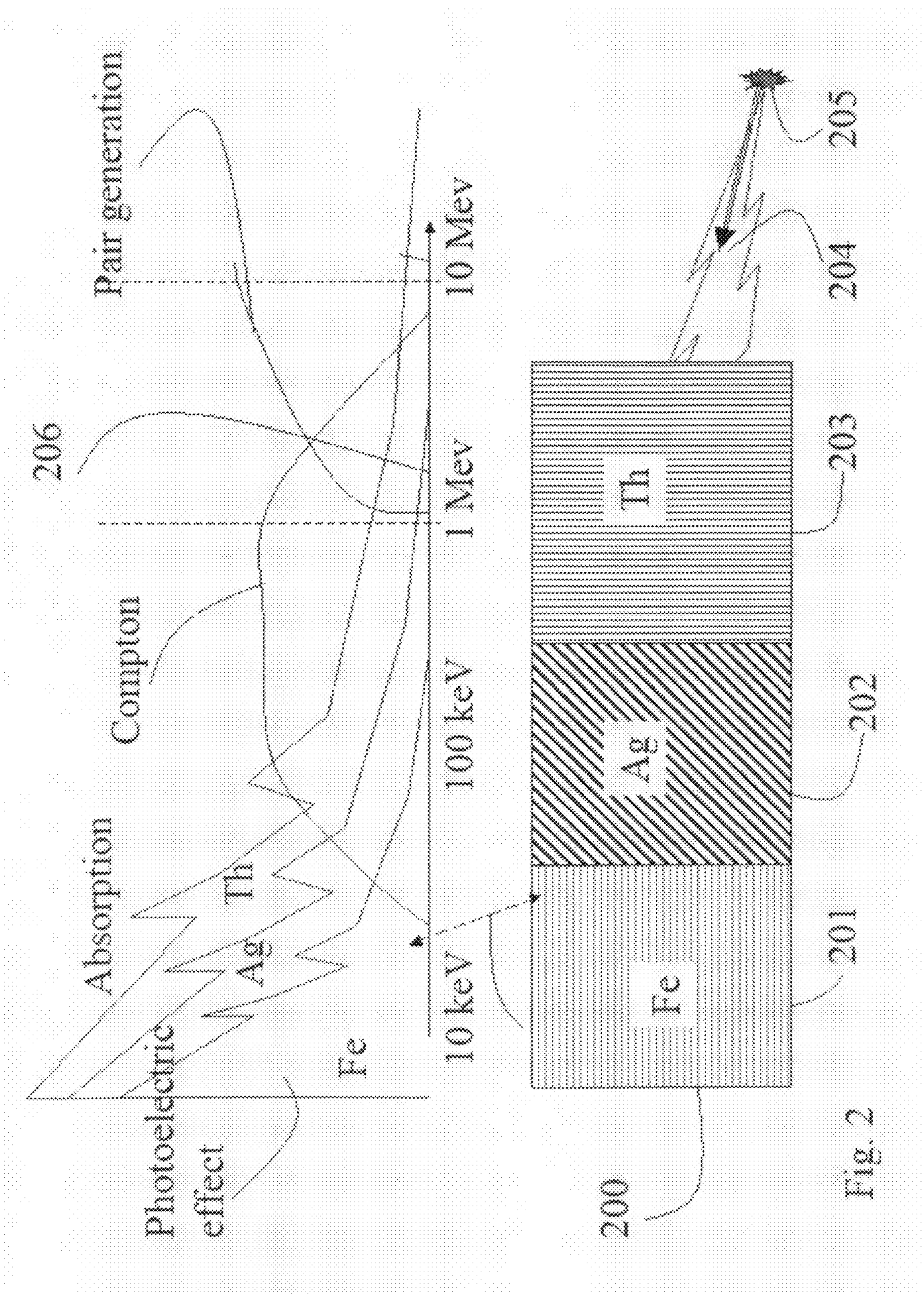

Photoelectric
effect
Absorption
Compton
Pair generation
206
Fe
Ag
Th
10 keV
100 keV
1 Mev
10 Mev
200
Fe
201
Ag
202
Th
203
204
205

Fig. 2

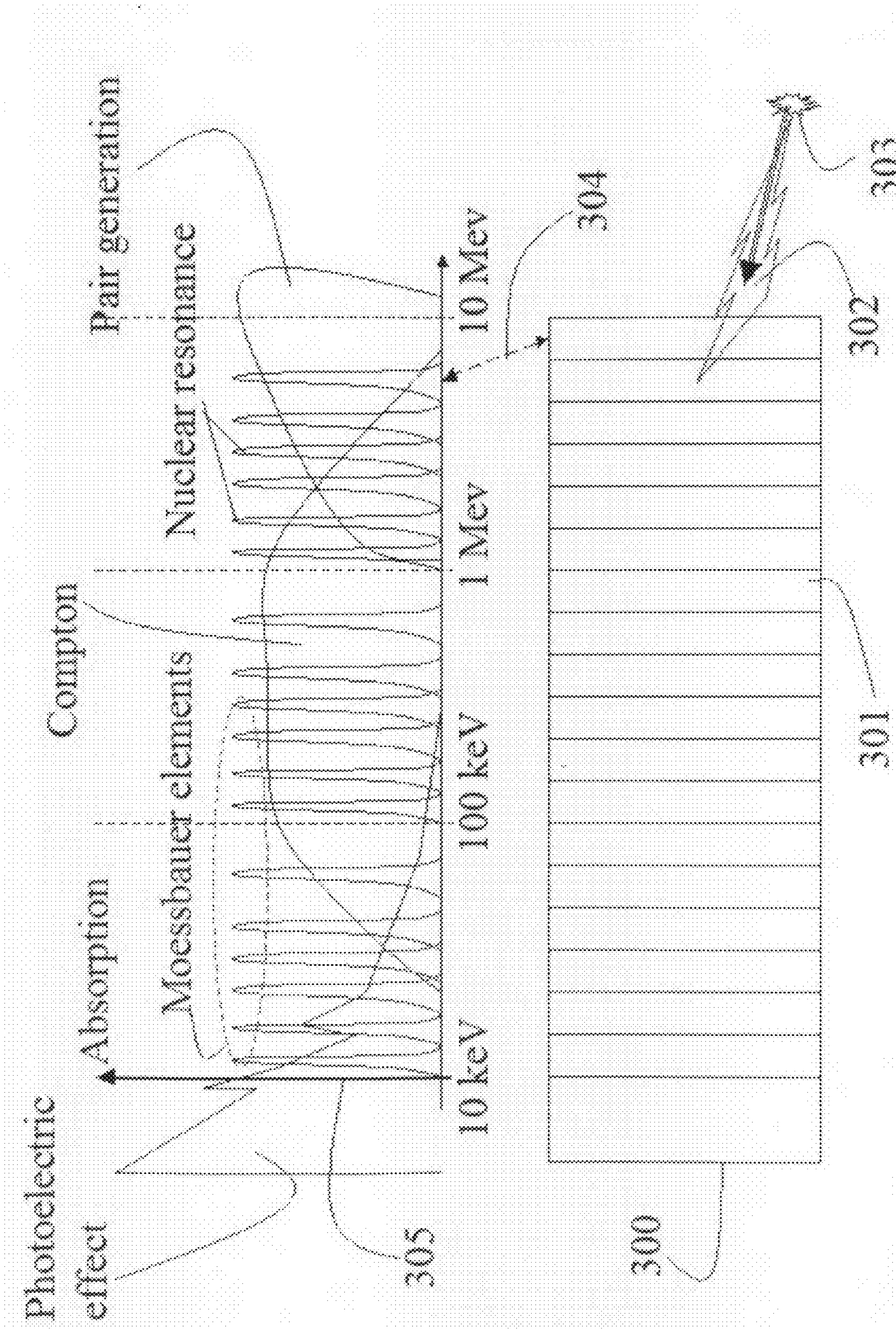

Photoelectric effect
Absorption
Moessbauer elements
Compton
Nuclear resonance
Pair generation
10 keV
100 keV
1 Mev
10 Mev
300
301
302
303
304
305

Fig. 3

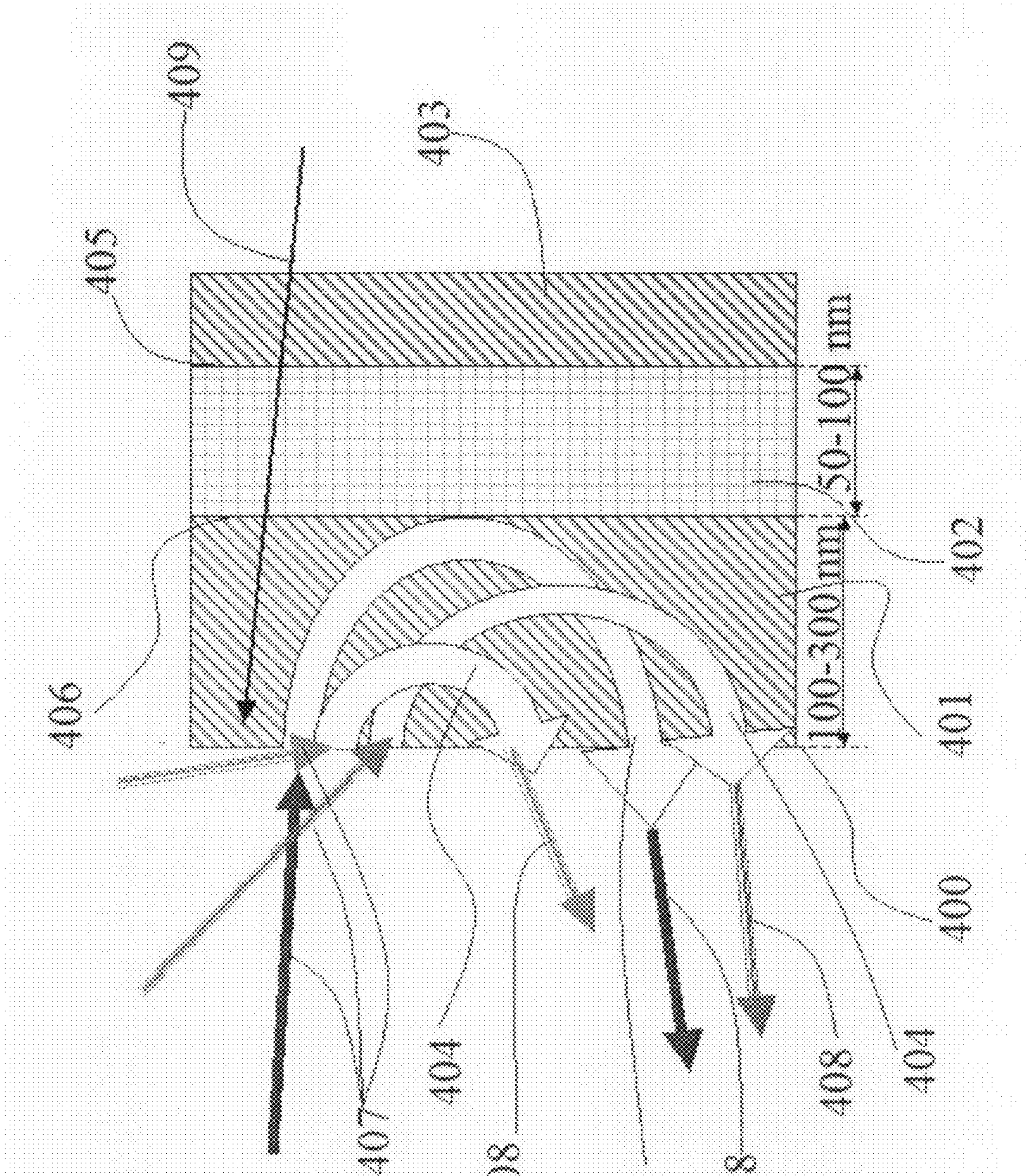

409
403
405
50-100 nm
402
100-300nm
401
400
406
407
404
408
404
408
404
408
404
408

Fig. 4

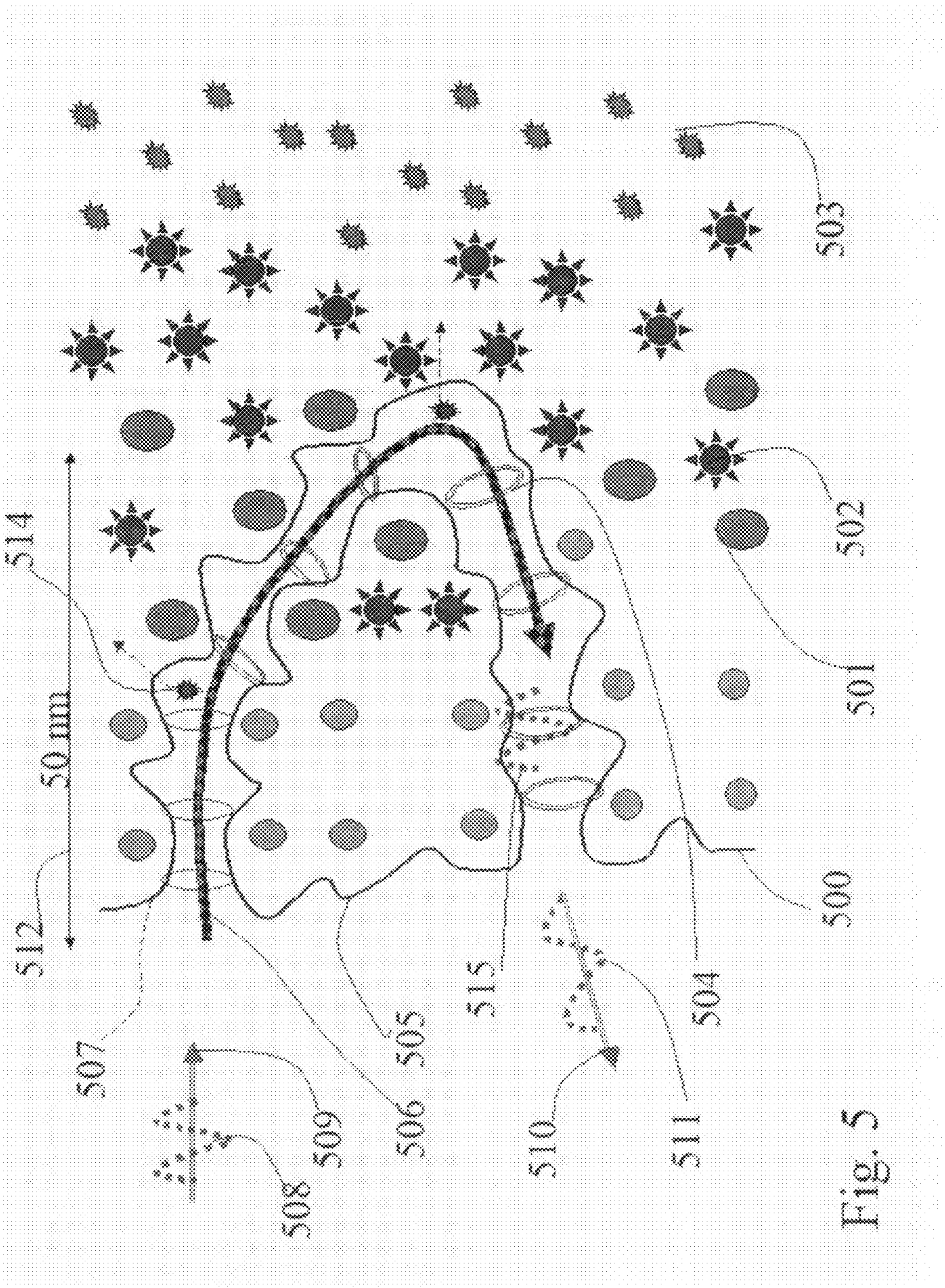


Fig. 5

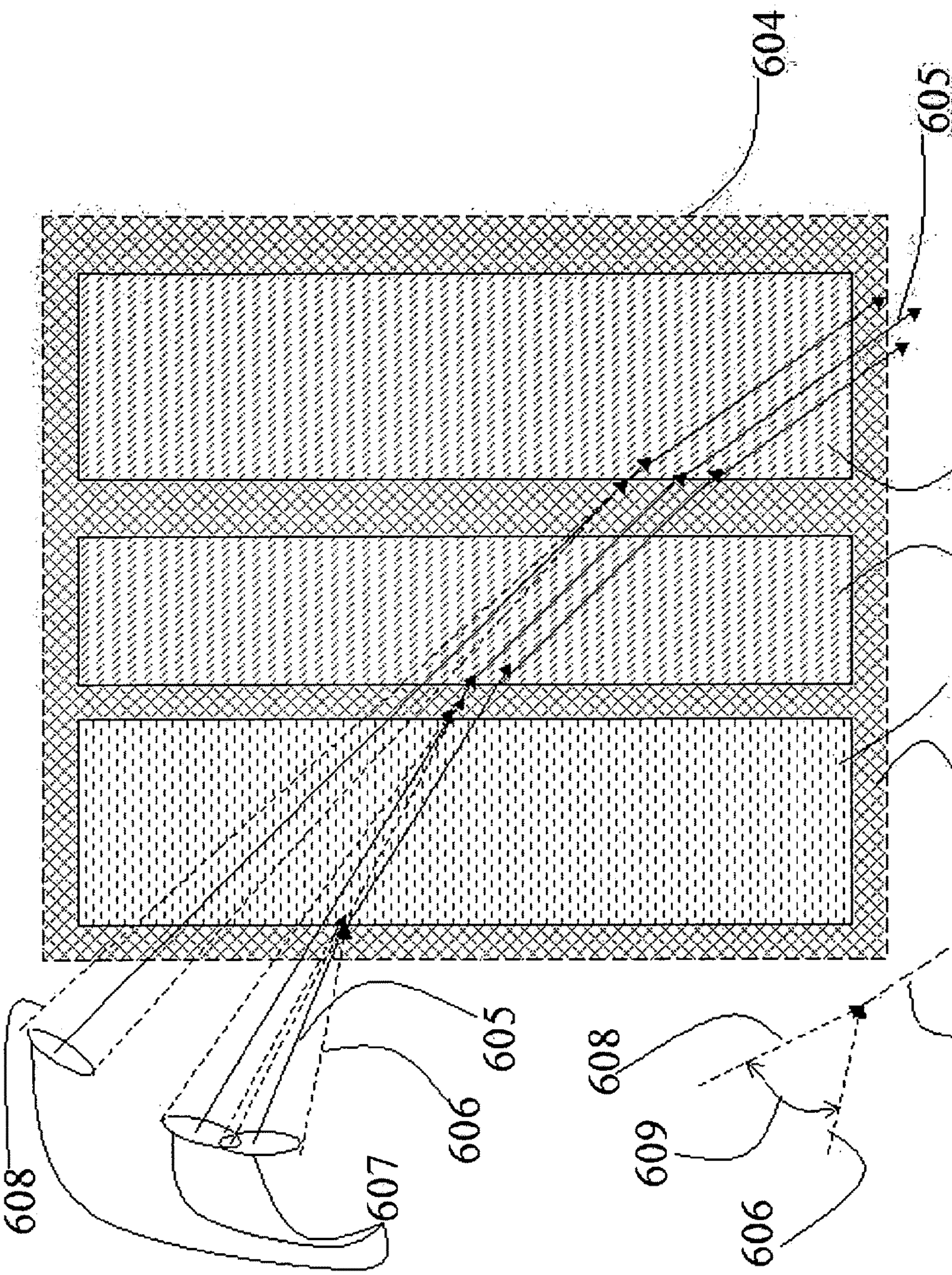


Fig. 6

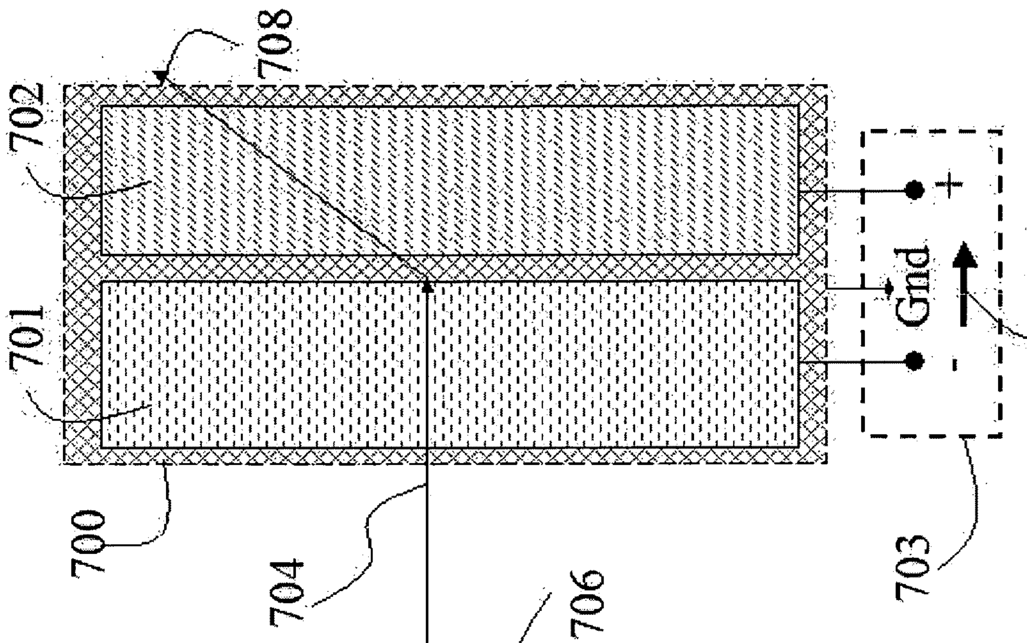


Fig. 7B

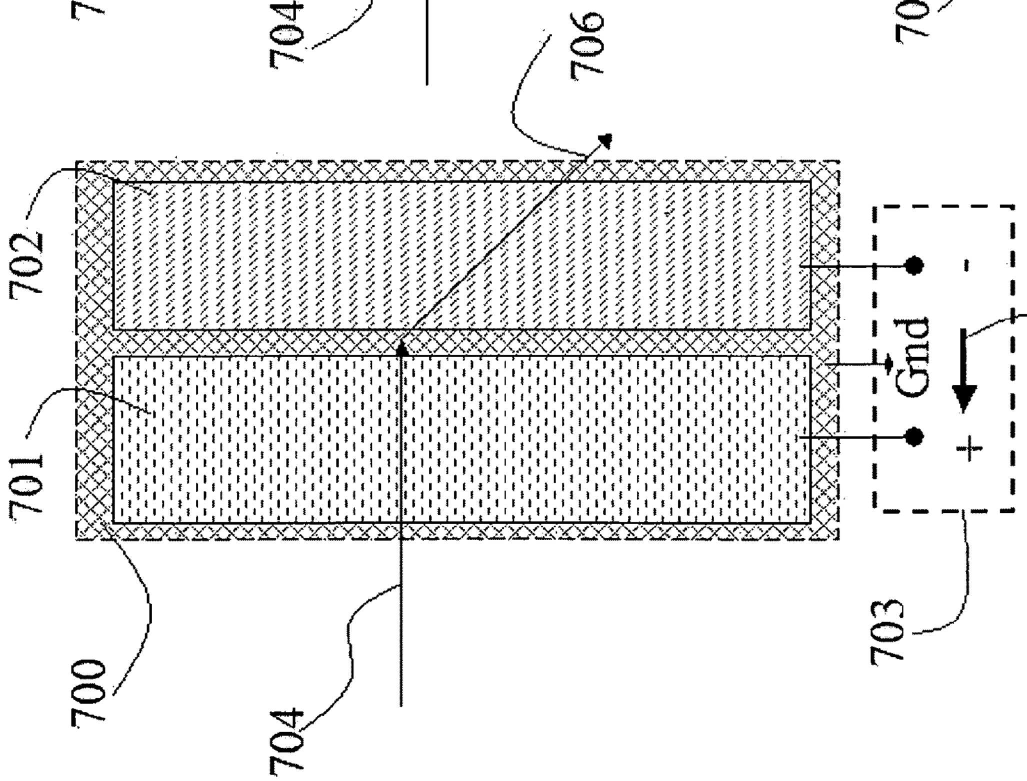


Fig. 7A

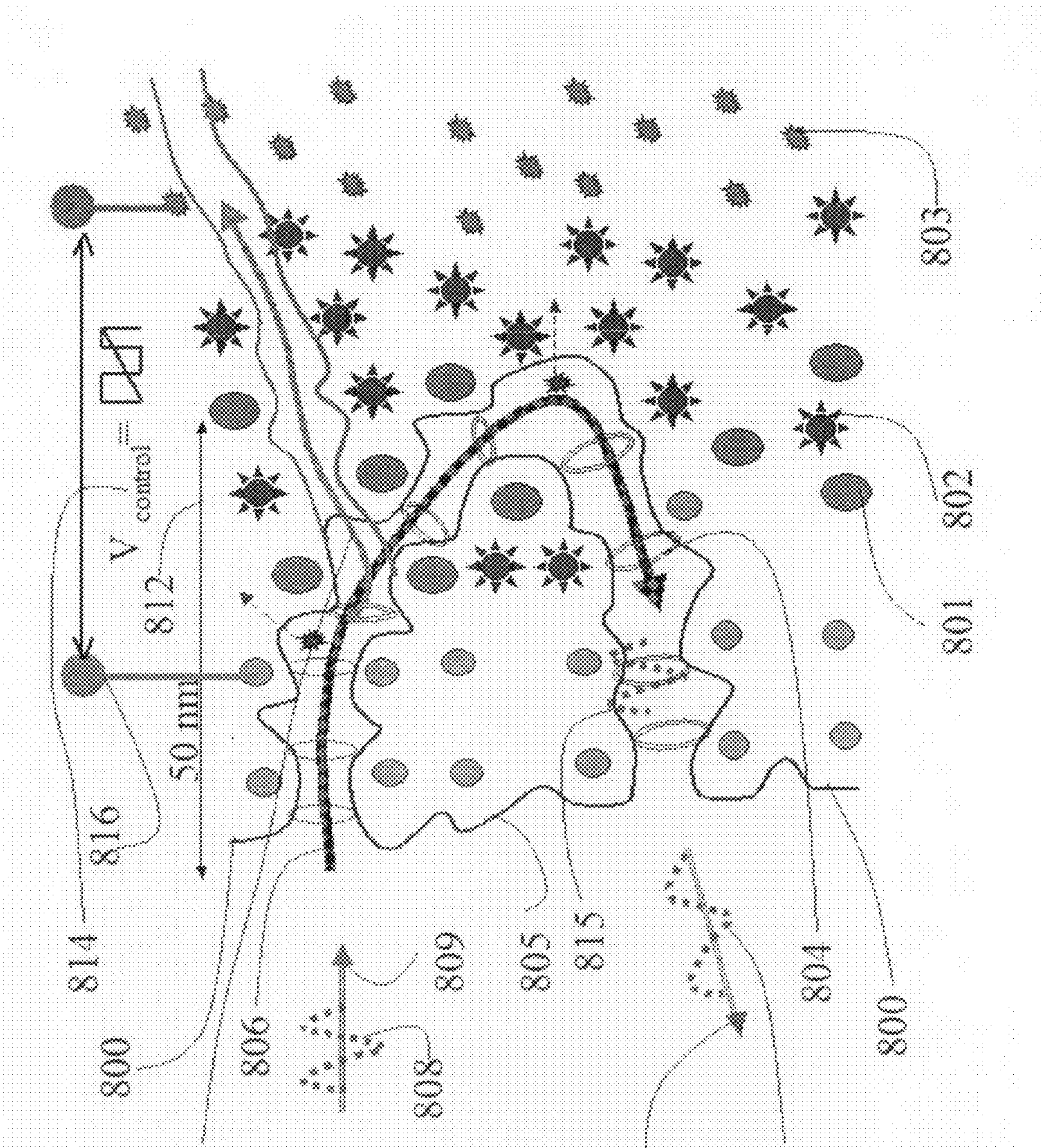

803
802
801
814
816
812
50 nm
V control =
800
817
806
808
809
805
815
810
811
804
800

Fig. 8

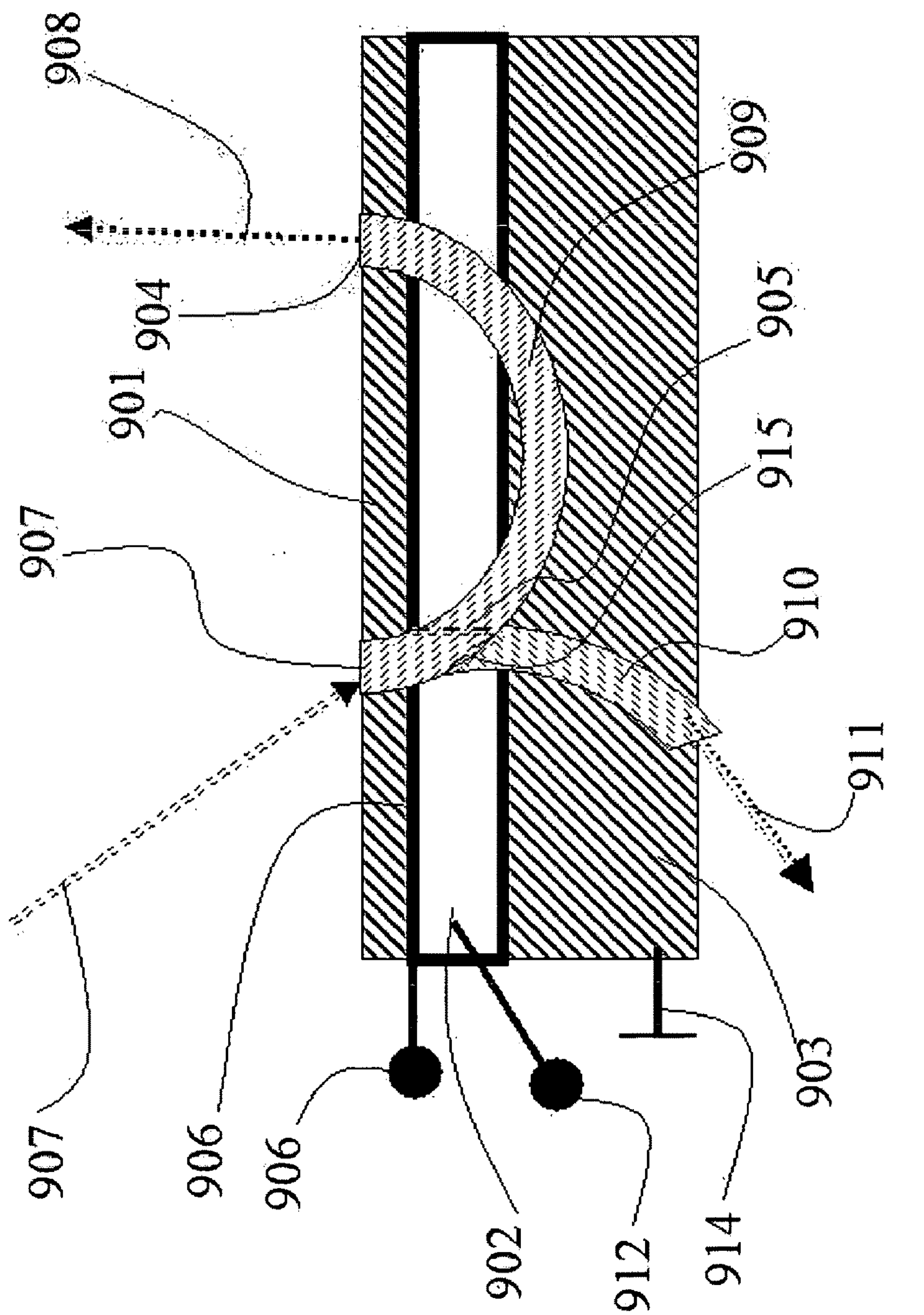


Fig. 9

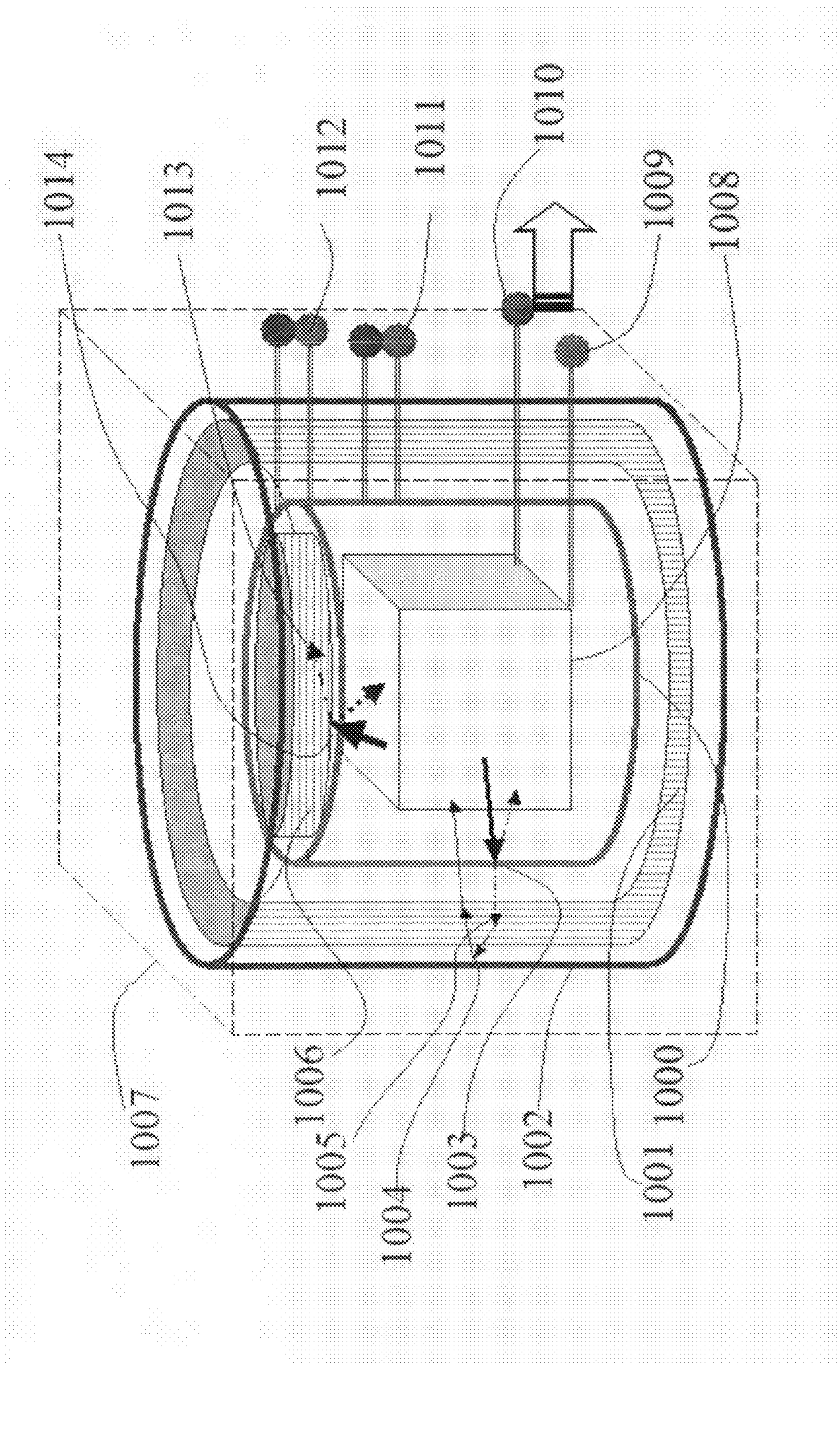

1014
1013
1012
1011
1010
1009
1008
1007
1006
1005
1004
1003
1002
1001
1000

Fig. 10

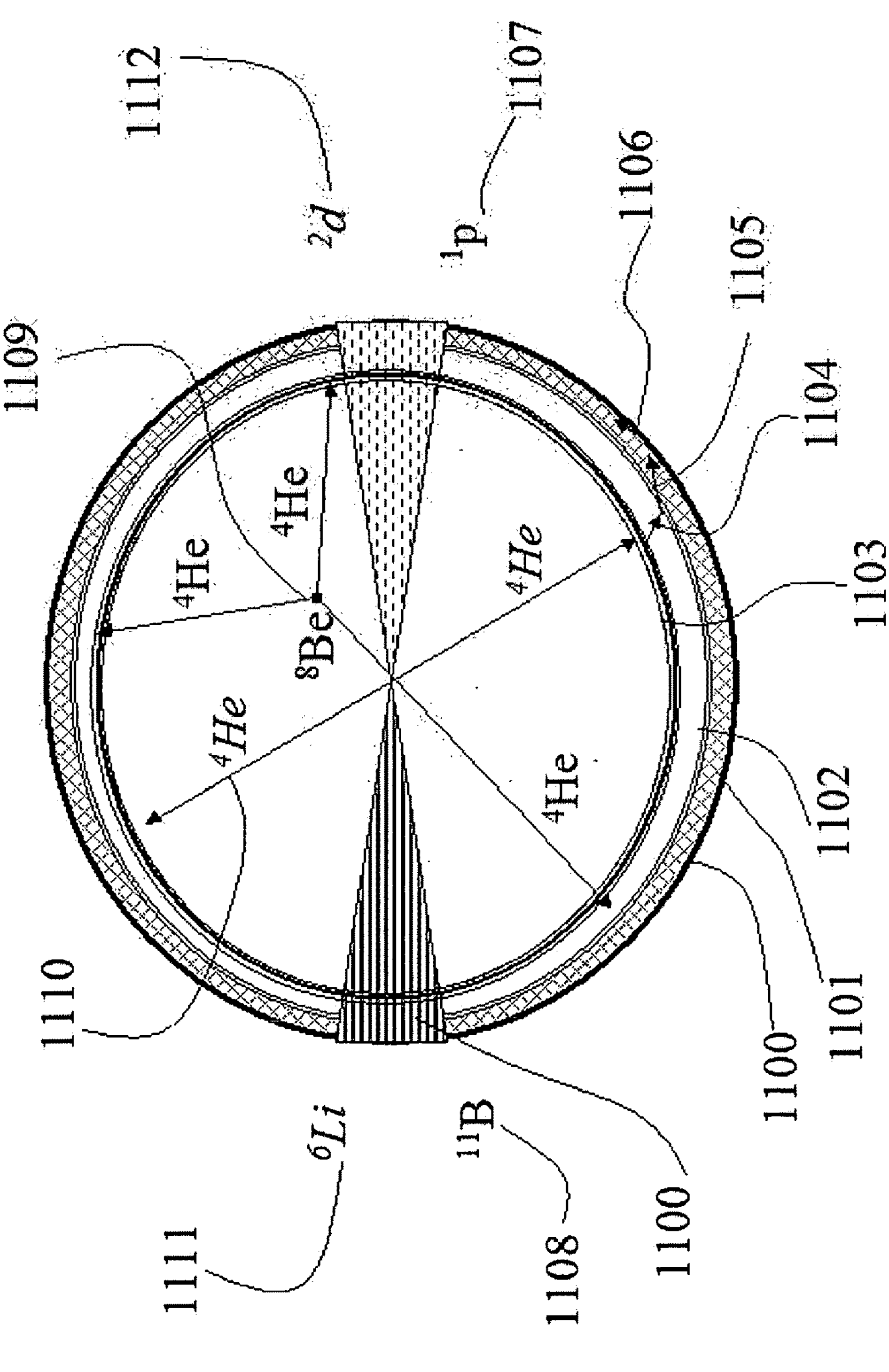

1112
2d
1p
1107
1109
1106
1105
1104
1103
1102
1101
1100
1110
1111
6Li
11B
1108
1100
4He
4He
4He
4He
4He
4He
8Be

Fig. 11

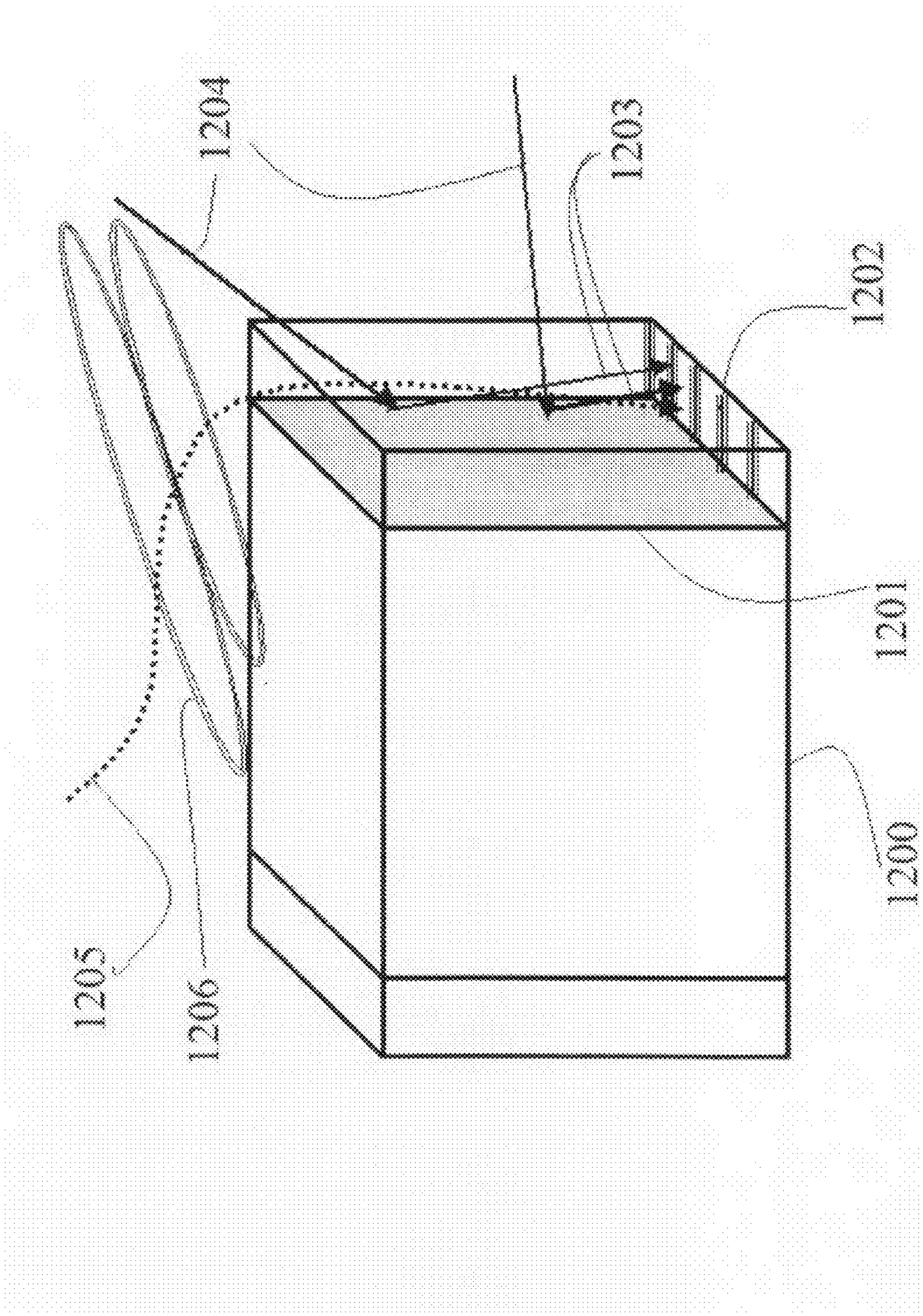


Fig. 12

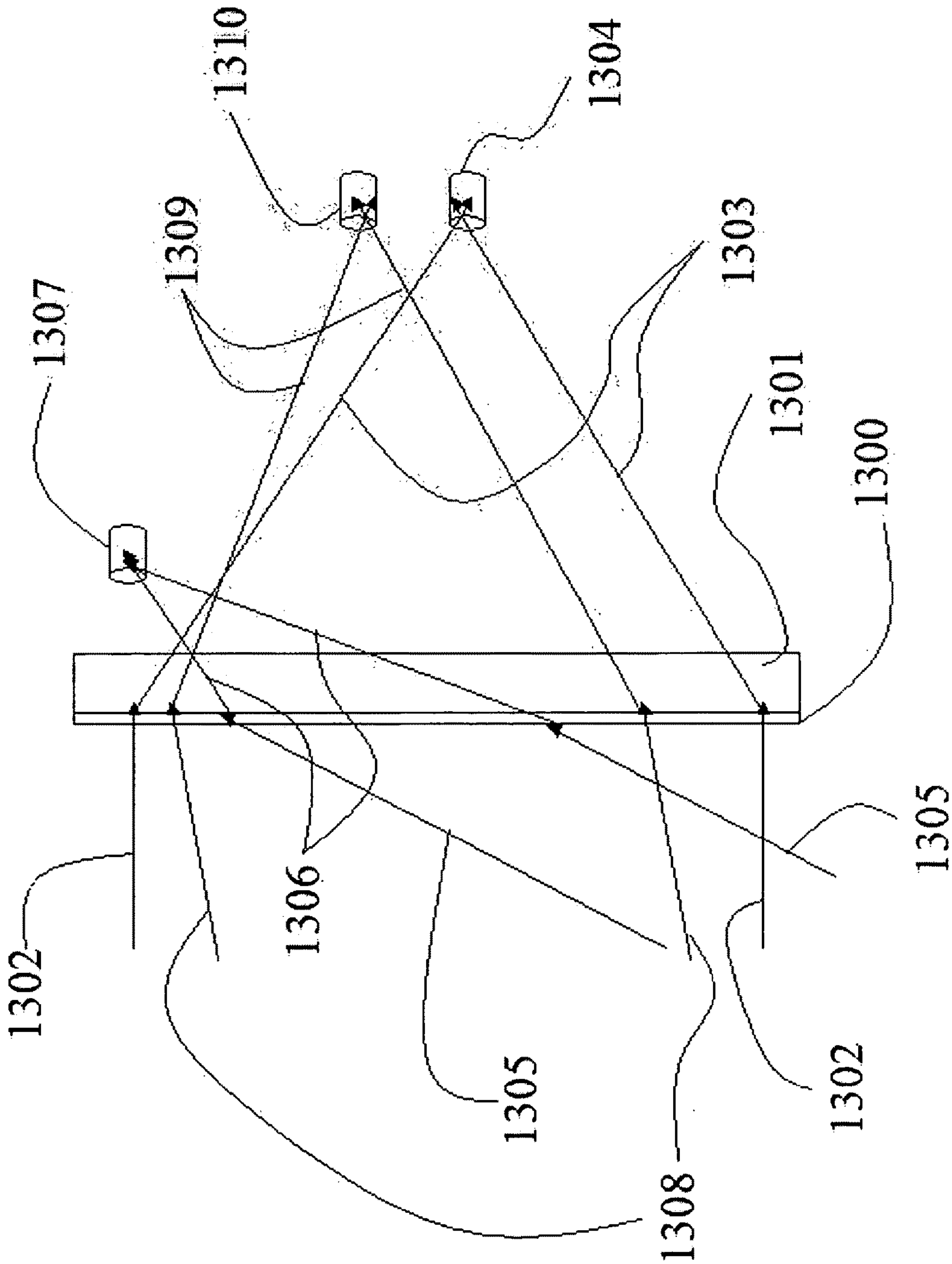

1310
1304
1309
1303
1307
1301
1300
1305
1306
1302
1305
1302
1308

Fig. 13

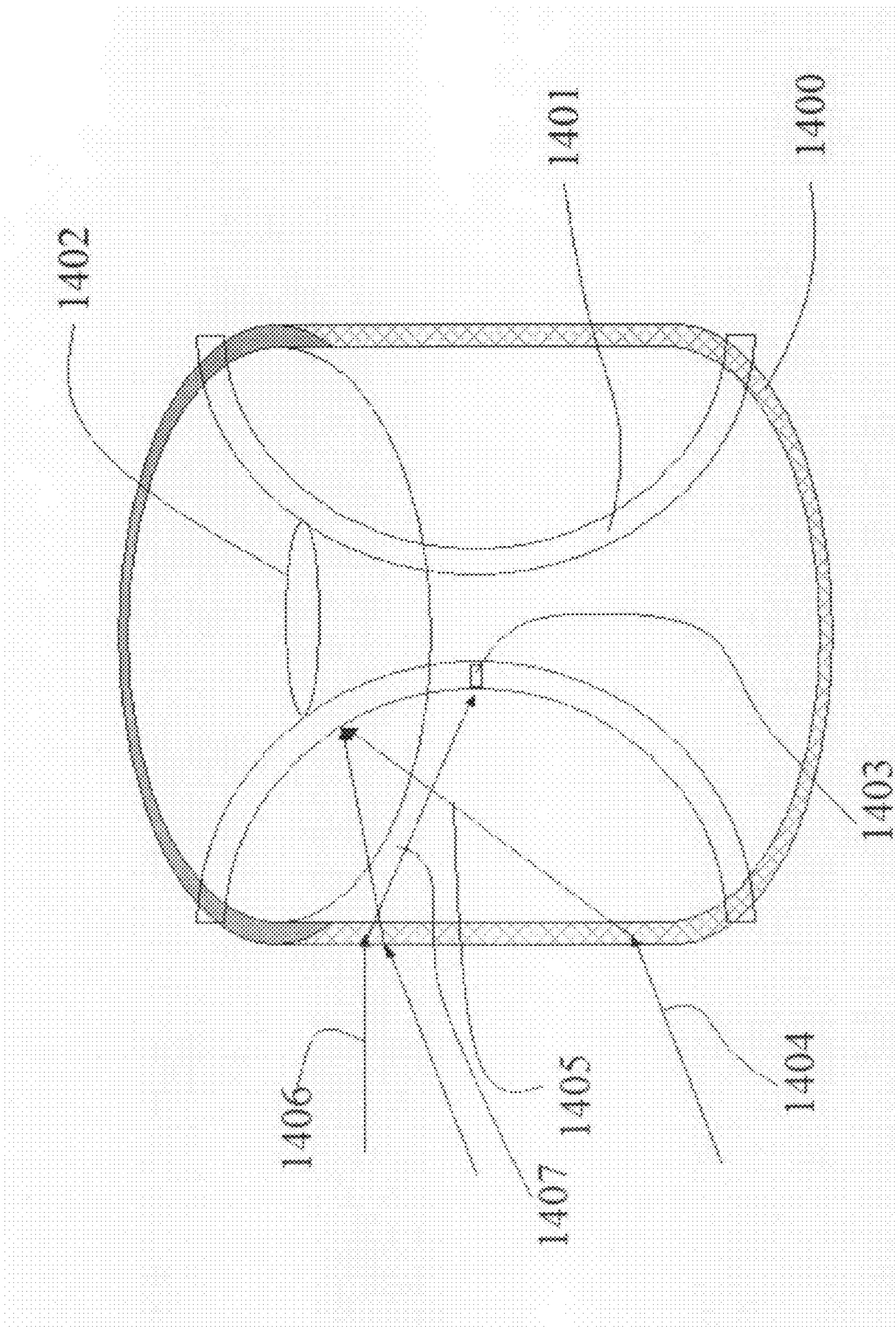


Fig. 14

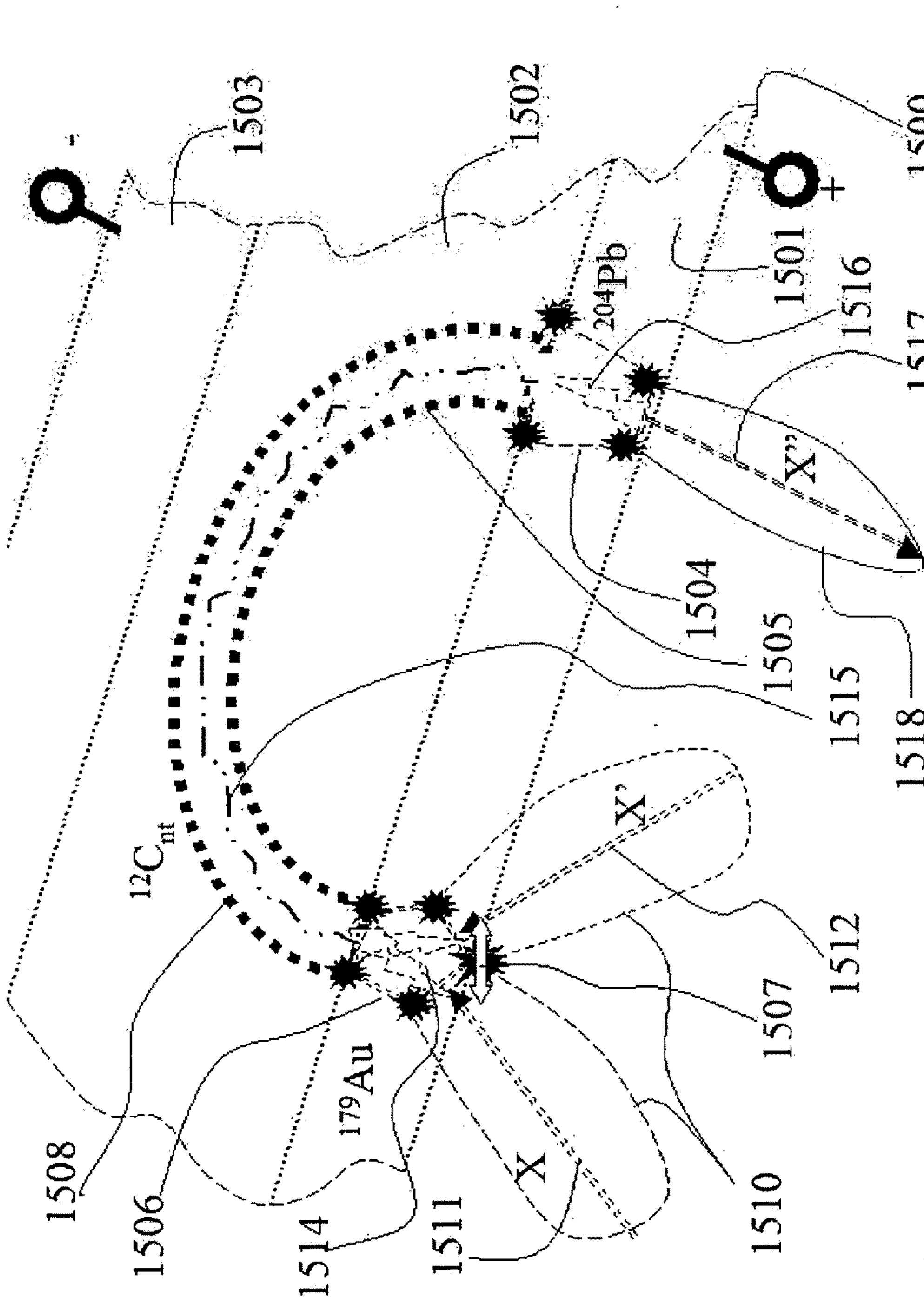

1500
1501
1502
1503
1504
1505
1506
1507
1508
1510
1511
1512
1514
1515
1516
1517
1518
^{204}Pb
$^{12}C_{nt}$
^{179}Au
X
X'
X''
+
-

Fig. 15

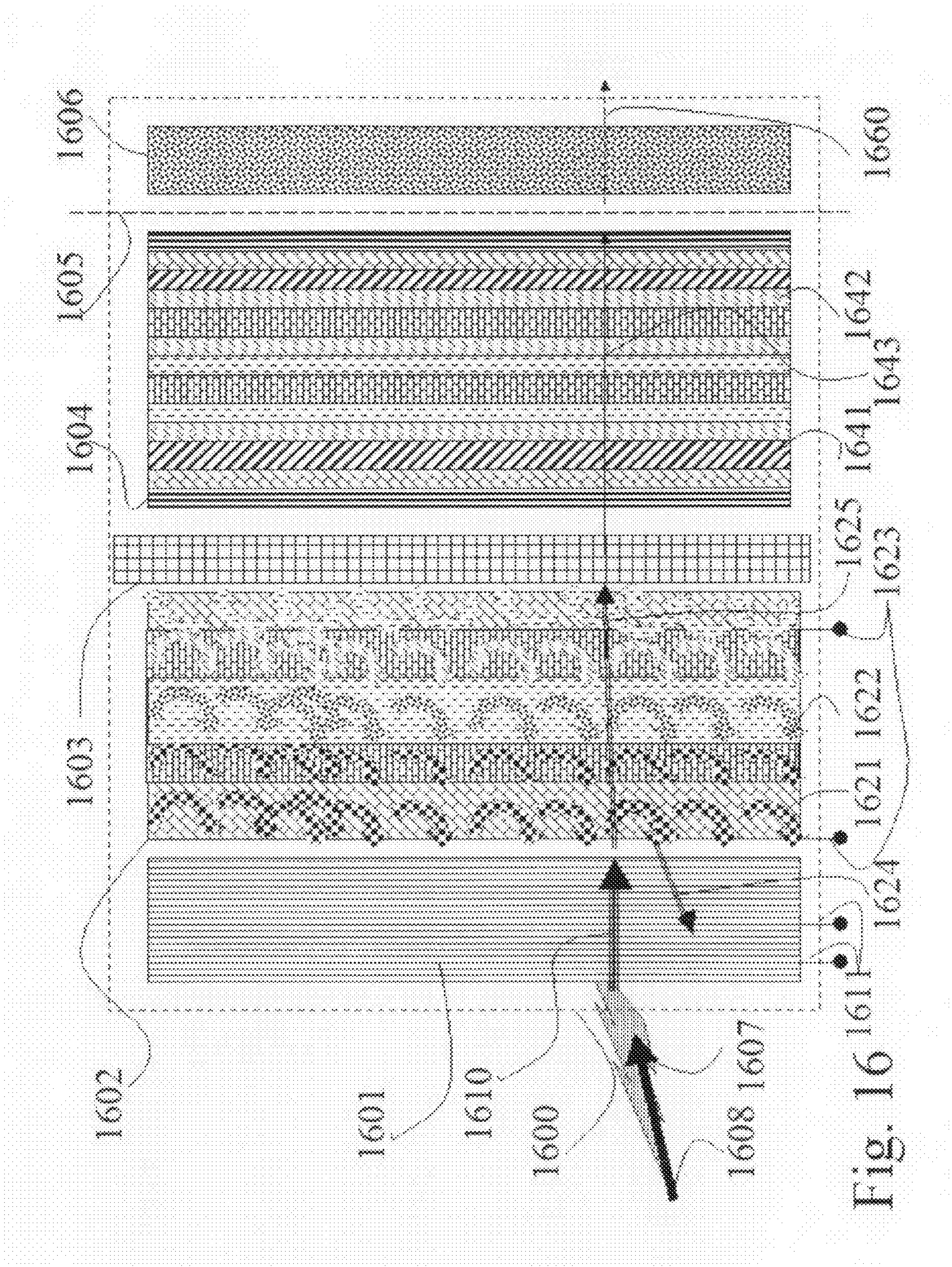
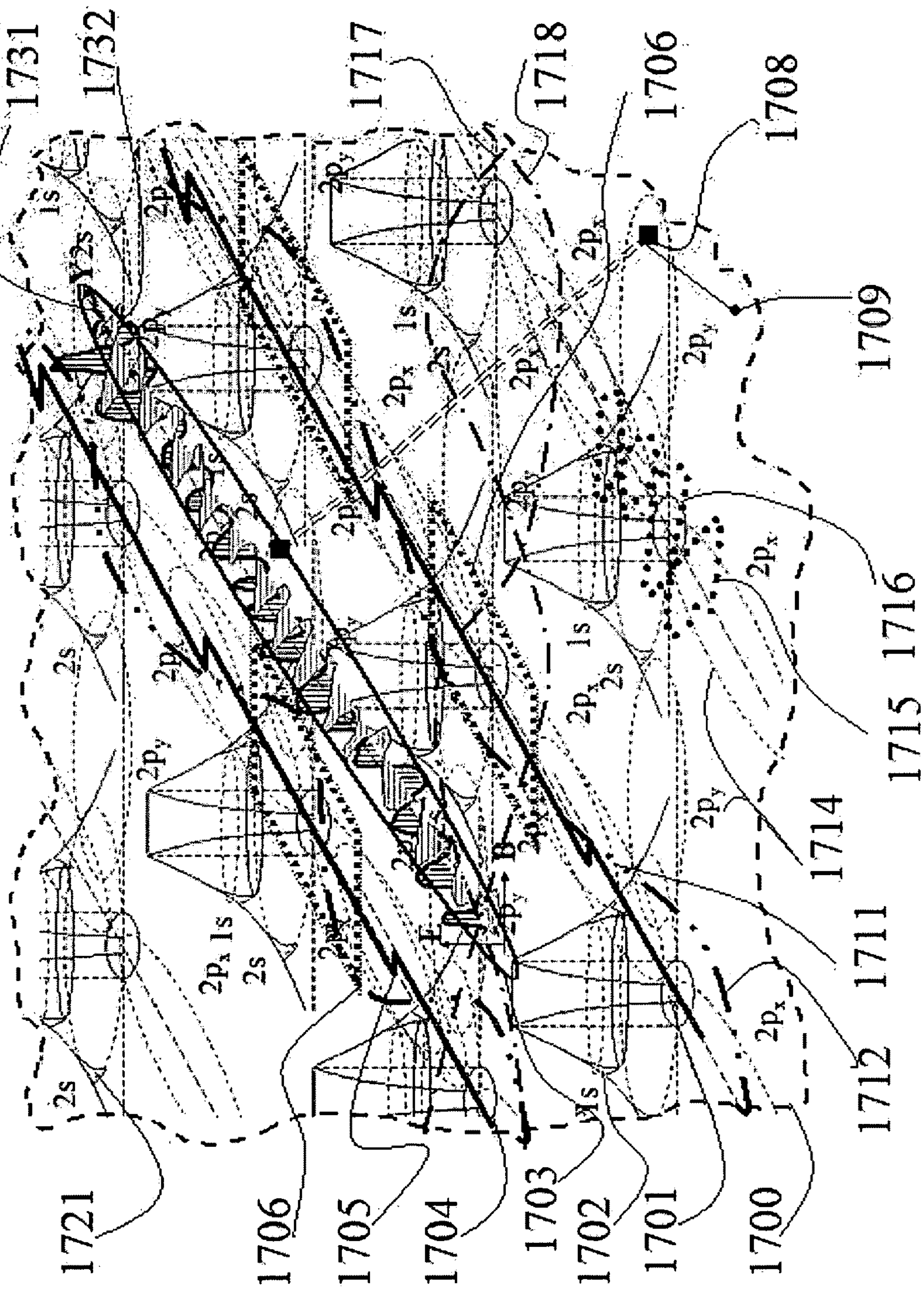

1606
1605
1604
1603
1602
1601
1610
1600
1608
1607
1611
1624
1621
1622
1623
1625
1641
1643
1642
1660

Fig. 16


1731
1732
1717
1718
1706
1708
1709
1716
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1700
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1703
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1705
1706
1721

Fig. 17

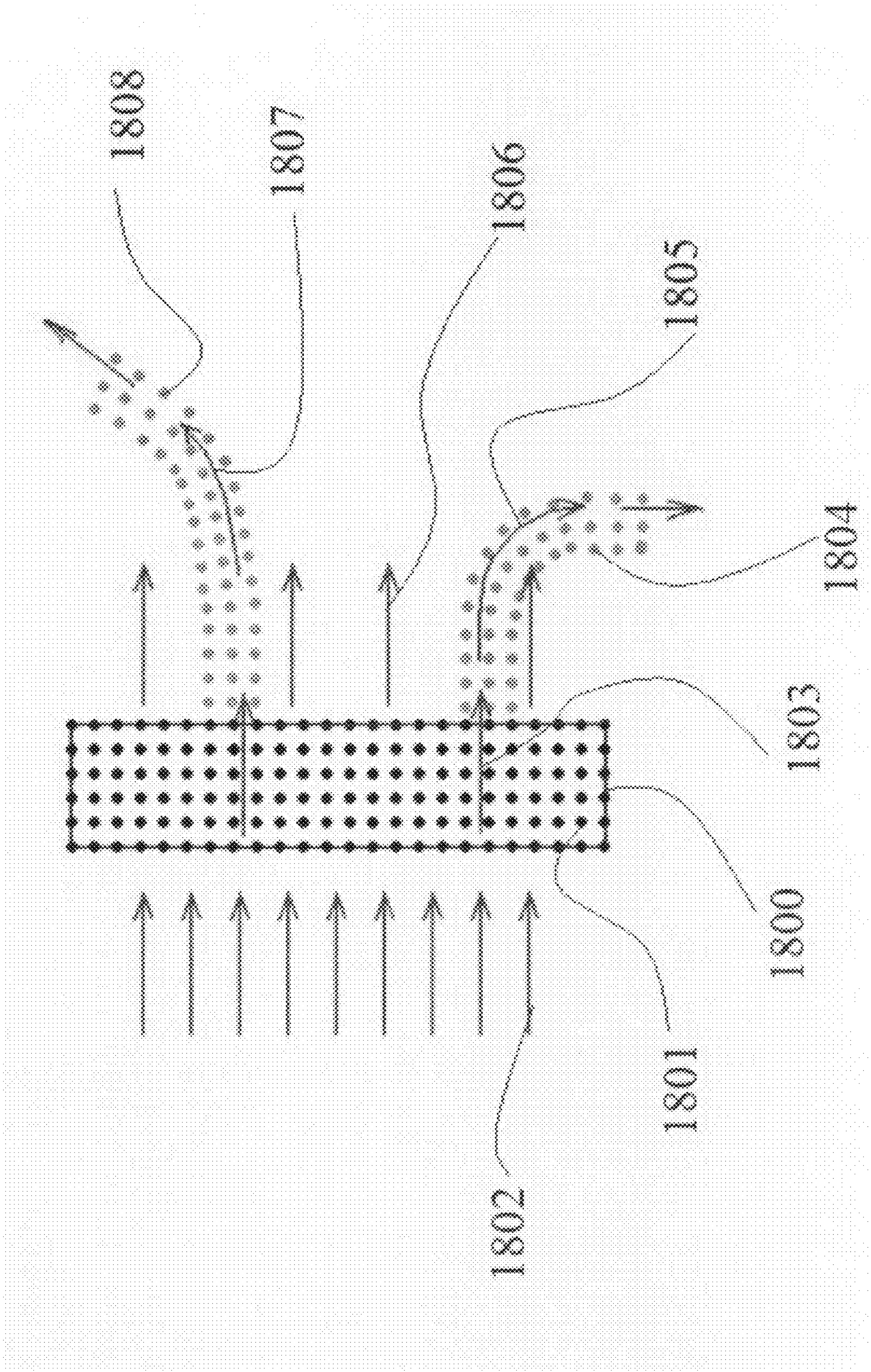

Fig. 18

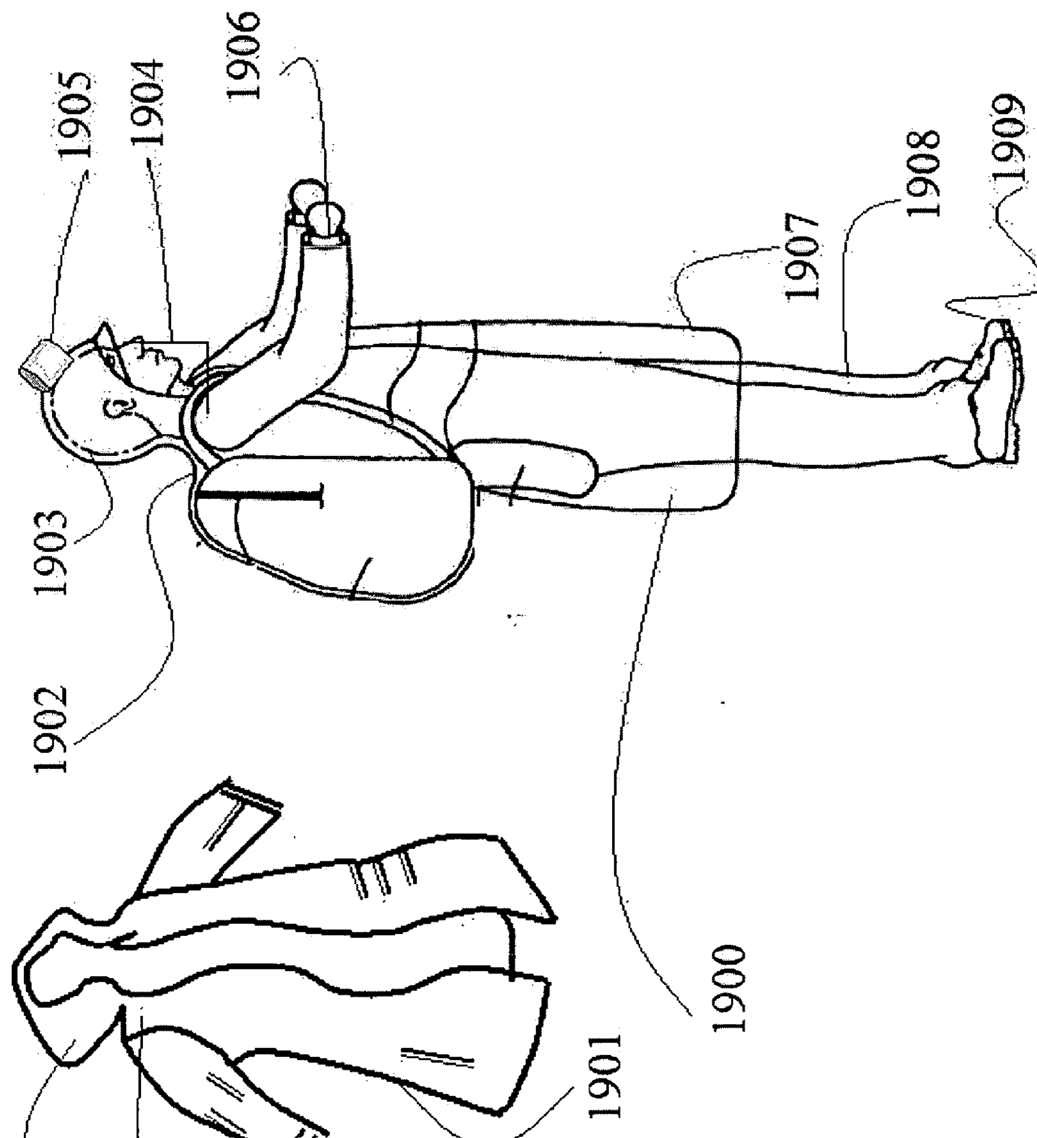

Fig. 19

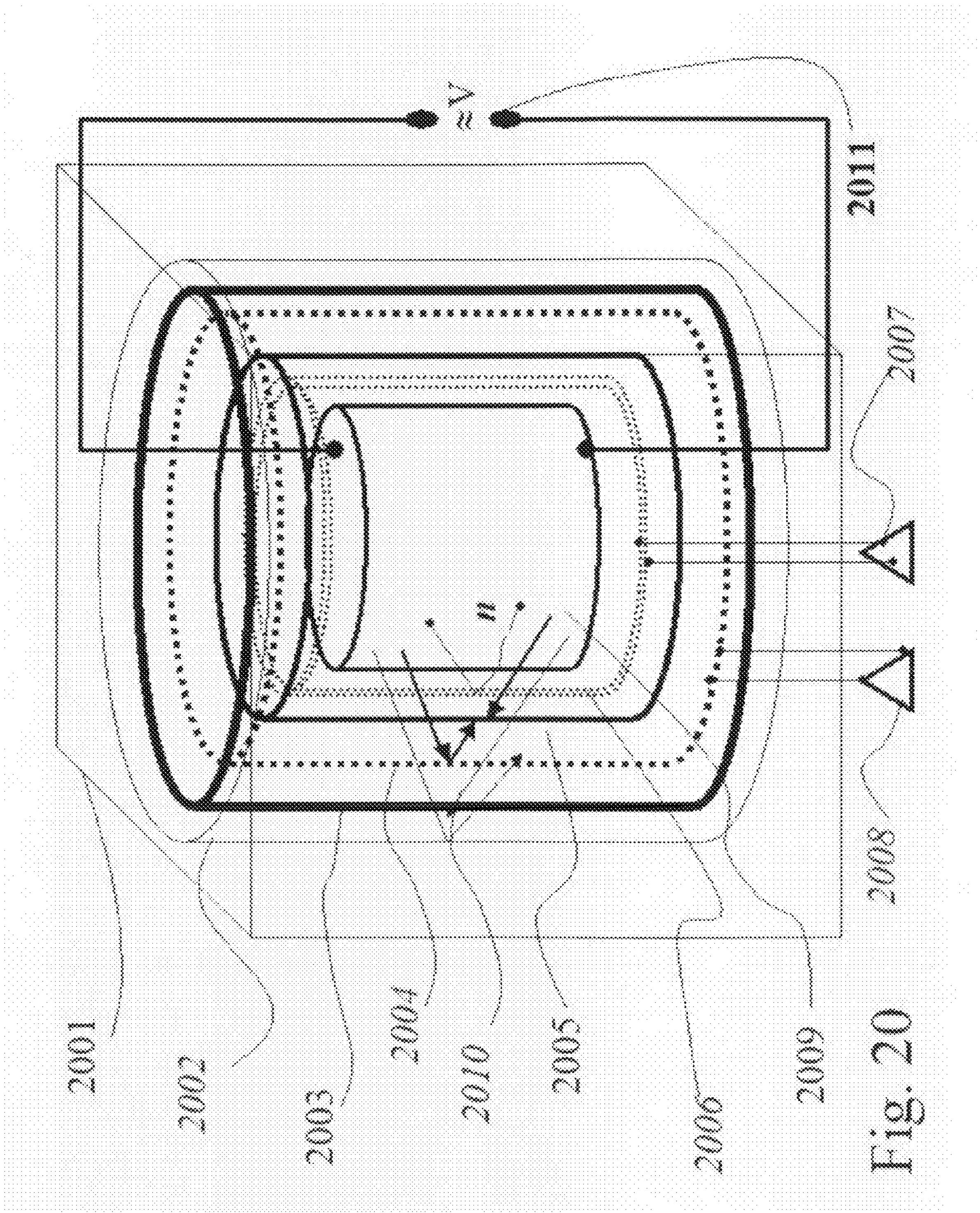

Fig. 20

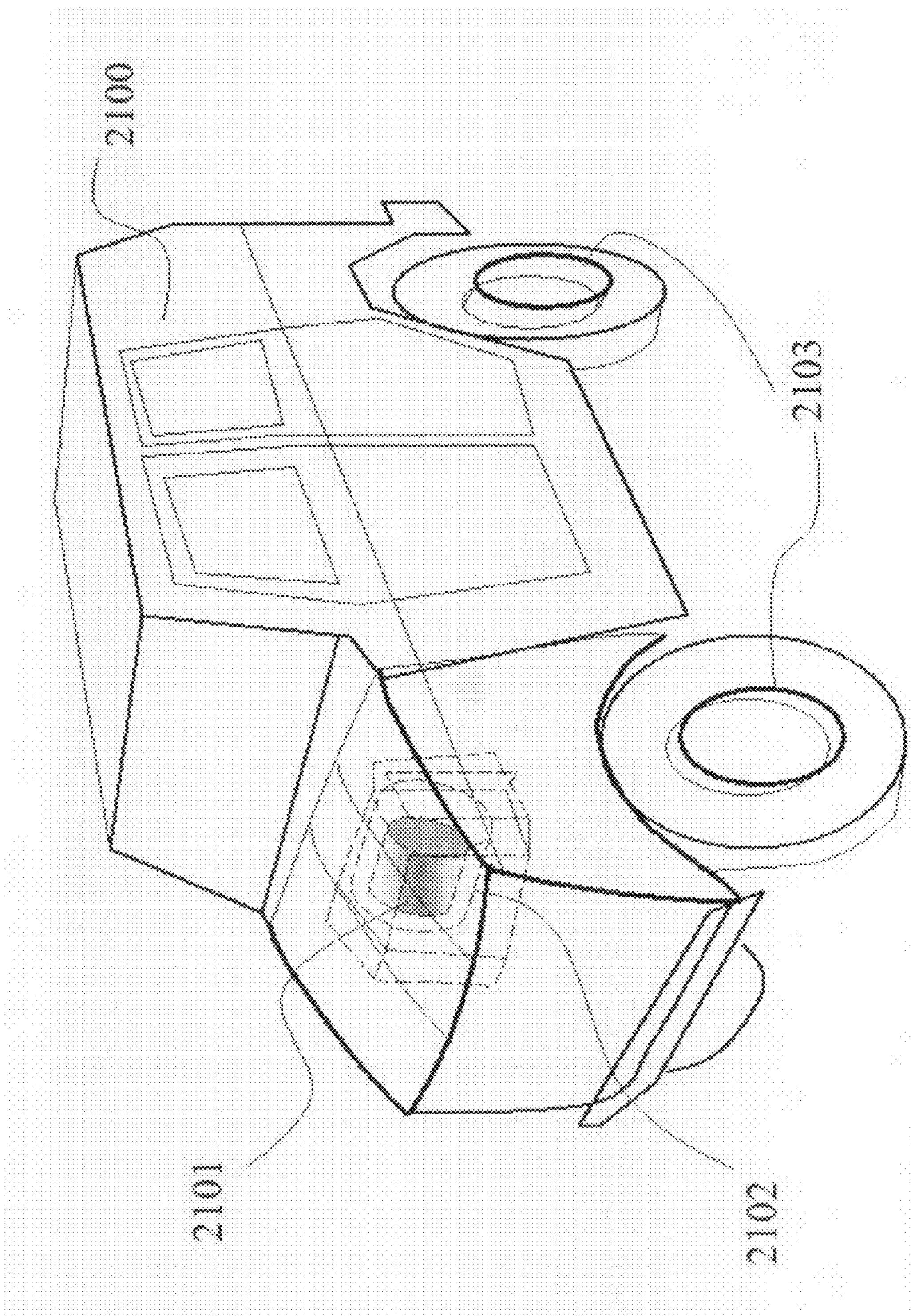

Fig. 21

NANO-STRUCTURED NUCLEAR RADIATION SHIELDING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/9934,412 filled on Jun. 13, 2007, which is hereby incorporated by reference in this entity.

BACKGROUND

[0002] The channeling experiments proven that the radiation may be trapped inside atomic lattices and driven in a similar manner with that the microwave and optical radiation is driven through the wave-guides and respectively optic fiber. Charged particles and X-ray channeling has already reached the applications in accelerator and space technology.

[0003] The new development based on nano-structures pushes the limits of channeling towards the high-energy radiation domain driving to applications of an exceptional importance.

[0004] The present solution of using complex nano-structures that can be electrically controlled open the way to a new revolution in nuclear energy.

SUMMARY

[0005] A novel material that comprises a plurality of nano-structures that is able to trap and guide nuclear radiation in a controlled manner. The material is made of a plurality of controlled grown nano-structures, able to gyrate the radiation at desired angle. The material may be build in hetero-structures inserting electric sensitive materials than make its channeling properties vary.

[0006] A device made using such material that controls the radiation direction possible of being used as control device in nuclear reactor replacing the control rods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1**—The principia of radiation shielding

[0008] FIG. **2**—The radiation degradation and absorption

[0009] FIG. **3**—The principia of multilayer decreasing energy resonant absorption attenuation

[0010] FIG. **4**—The radiation gyration schematics by bended micro wave-guides and nano-fibers

[0011] FIG. **5**—The bended molecular wave-guide made in multi-layered clustered material

[0012] FIG. **6**—The radiation funneling mechanism by channeling

[0013] FIG. **7**—X gamma and neutrons radiation switch

[0014] FIG. **8**—The "miu" radiation switch with digital control

[0015] FIG. **9**—A monolayer "miu" switch schematics

[0016] FIG. **10**—The nuclear reactor control by variable transmission "miu" switch shielding

[0017] FIG. **11**—The use of a radiation funneling shielding to shield a plasma focused fission device

[0018] FIG. **12**—A space-shuttle radiation-shielding device for charged particles and X, gamma rays

[0019] FIG. **13**—Multi-focusing multi-layer

[0020] FIG. **14**—Space imaging device

[0021] FIG. **15**—Adapted nano-tube wave-guide example

[0022] FIG. **16**—The complete shielding structure

[0023] FIG. **17**—The atomic level low energy gamma ray channeling

[0024] FIG. **18**—The radiation selective extractor/gyrator

[0025] FIG. **19**—The radiation raincoat-like individual protective equipment

[0026] FIG. **20**—Mobile miniaturized nuclear reactor

[0027] FIG. **21**—Mobile nuclear powered SUV

DETAILED DESCRIPTION

[0028] FIG. **1**—Shows the method of radiation shielding based on classical and non-classical approaches. The sources **107** are supposed to emit radiation in space with a spherical symmetry, having the intensity at a distance r from the source given by formula presented in the figure where A is the source's activity for the radiation k. This is the radiation intensity that hits a shielding element on the external surface. The ray **104** represents the radiation Pointing vector hitting the shield and having the intensity on its surface I_0^k. The shield **103** has a thickness made from elemental layers "i" **109** a volume content **101** and an associated coordinates system **102**.

[0029] At the contact with the surface **103** the radiation **104** is reflected **105** and refracted **106**. The ration Ir **105** per Io **104** gives the "albedo" figure also called the reflection coefficient, while the It **106** versus I0 **104** ratio gives the transmitted radiation. In current nuclear radiation calculations It is assumed equal with I0 because the reflection factor is smaller than 2% and is depending on incidence angle and energy. The classical absorption theory based on random interaction is following the exponential law having the absorption coefficient depending on material, density and radiation energy. The absorption length is defined as being the length where It becomes 1/e from Io or the sum at the exponent of the absorption factors equals 1.

[0030] There is important to understand that the absorbed radiation does not disappear, it is considered absorbed because it disappears from its original group "k" but the absorption location becomes a source reemitting the absorbed energies in other forms depending on the mechanism of interaction. The quantum scattering is covering the

[0031] Thompson and Compton scattering as well the nuclear absorption and reemission also called non-elastic scattering, or resonant absorption.

[0032] The quantum absorption, often called resonant absorption is based on the nuclear quantum resonance mechanism that is exciting the inner energy levels and excites the absorption element that further decays emitting the energy in various, specific forms, becoming a secondary radiation source.

[0033] The curve **110** shows the desired attenuation characteristic mainly based on high albedo, impossible to rich in the classical cases for X, gamma rays and neutrons due to their particularities of the interaction with matter. The multi-layer shielding **103** made from individual material layers "i" **109** is showing the actual approach in radiation shielding, that is presenting as disadvantage low absorption factor requiring important thickness and weight.

[0034] FIG. **2**—Shows the radiation degradation and absorption mechanism used in the actual best radiation shielding. The shielding **200** has a structure arbitrarily taken for exemplification purposes. It is made from an inner layer of iron "Fe" **201**, shielded by a layer of silver "Ag" **202** that is shielded at exterior by a layer of thorium **203**. As the chart **206** shows thorium having the biggest electronic density and mass density exhibits the biggest absorption coefficient for the radiation **204** generated by a radioactive source **205**.

[0035] If the radiation energy is greater than 1.022 MeV the interaction process is dominated by the pair generation as shown in the plot **206** that has a relative vertical scale. The pair electron-positron shares the difference of energy as kinetic energy. Both are stopping in the shielding matter by generating showers of knock-on electrons that generates a lot of X rays behind them. When the positron energy becomes small enough it annihilates with a lattice electron reemitting the mass energy of 1022 KeV plus a share of the electron chemical bounding energy by two photons of a little bit more than 511 KeV.

[0036] These photons shut at near 180 deg. Represents a new gamma rays source localized somewhere in the Thorium **203** bulk. Another effect according to the plot **206** is the Compton effect. This effect is based on the collision between a photon with an electron, that generates a recoiled electron and a lower energy photon. The recoiled electron is stopped in the lattice generating showers of knock-on electrons with associated X rays, while the lower energy photon in similar with a new source of radiation appeared somewhere inside the shielding, with some angular distribution, given by the Compton effect particularities.

[0037] Up to now from a mono-energetic radiation source we obtained an associated large energy spectrum of lower energy radiation, but mainly conserving the initial energy. At lower energy the materials start to exhibit different absorption curves while at higher energies the density was what made the differences in absorption coefficient.

[0038] The reasons for this energy degrading material combination is that Thorium **203** with high density high stopping power to stop down most of the initial beam **204** energy producing its own high energy X rays, Compton and annihilation rays. These Thorium secondary generated energies are stopped down in silver **202** with at its turn emits more moderated energies that are dumped in Iron **201**. The iron still emits 5.6 KeV as K-alpha specific X ray higher energy and a bunch of specific L, M lines. Aluminum—plastic linear may take out these lines leaving lines only lower than 1 KeV and a bunch of the entire attenuated spectrum. This kind of shielding drives to centimeters of material thickness and specific weight in tones.

[0039] FIG. **3**—Shows the procedure of enhancing the attenuation coefficient by using a multi-layer decreasing energy resonant absorption attenuation geometry as an embodiment of the present invention. As we observed from the FIG. **2** the attenuation coefficient of materials over 500 keV is practically the same and only the density makes a difference. Density means weight and this turns into excessive weight that impairing the applications. For neutrons the problem is even more difficult, requiring several feet of absorbent materials around.

[0040] Keeping in mind the Moessbauer effect and the most used elements there is possible that under the thorium layer from FIG. **2 203** to introduce a cascade of Mossbauer elements within mm thick plurality of layers. These elements will enhance the absorption cross-section by the addition of the nuclear resonance that has the final effect the increase in scattering because each absorption is followed by a reemission. In FIG. **3** the entire shield **300** is made from nuclear resonant layers arranged in the order of increasing the nuclear resonant energy towards the radioactive source **303** that produces the irradiation beam **302**. The line **304** shows the assignment of the nuclear resonance in the plot **305** to the shield layer **301**.

[0041] The comb looking nuclear resonances are coming to enhance the absorption cross-section of the multi-material shielding **300**, finally reducing its thickness and weight.

[0042] The theoretical predictions show a mass reduction of more than 50% from the shielding **200** to **300**, but that is not enough for most of the applications. In conclusion, by introducing centers of absorption and reemission of the radiation more than 50% of the incident radiation is backscattered and more than 80% or the radiation power is taken by the shield.

[0043] FIG. **4**—Shows a main embodiment of the invention represented by the radiation gyration schematics by bended micro wave-guides and nano-fibers. The main driving idea is the concept of radiation channeling in crystals. This concept is proven and in current use for charged particles and neutrons. More using elastic crystals there is possible to easy bend the beams of particles and neutrons similar to light in the optic-fibers,

[0044] The development of nano-technologies offered the possibilities to push the wave frequencies even higher.

The radiation shielding is efficient when it denies the radiation access without being damaged in time by radiation-combined effects of power deposition. The shield **400** is made by a few hundreds nm thick channeling layer **400** separated by the interface **406** from a highly absorbent layer **402** stick by the interface **405** from the backing layer **403**.

[0045] The incident radiation **407** is hitting the layer **401** in the input resonators of the nano-channels **404** that drives the radiation coming at various angles and drives it our of the structure **408** bending it at various angles between 90-180 deg.

[0046] The structure is not interfering with the radiation coming from the opposite direction **409**.

[0047] The intermediary layer **402** separated by the interfaces **405** and **406** is used to apply electric current in order to switch or enhance the reflection properties of the structure, making a control.

[0048] FIG. **5**—Shows a main embodiment of the invention showing the way a bended molecular wave-guide is made by using multi-layered clustered material. The high reflection material is made of several layers of molecular clusters. The input layer **500** is creating a rarefied electronic structure based on fulerenes or metallic spheres, able to create a resonance cavity to trap radiation inside, in the wave guide made by the molecular orbital **505** The incident wave **508** having the Poynting vector **509** towards the material is reaching a input structure **505**, **507** that guides it inside on a resonant path **506**. The changes of the molecular distribution from the material **500** to **501** and **502** makes the molecular wave-guide turns, driving the wave back outside by slight interaction with electronic charges **514**, and being resonantly trapped into the middle of the wave guide isopotential electronic orbital surfaces **504**.

[0049] The material **501** is implanted over the interface **500-502** modifying the cluster end in order to produce the wave-guide bending driving the wave inside **515** towards outside **511** traveling in opposite direction **510**. The material **502** is deposited on a structural resistance material **503** that may be a polymer, fabric or metal-ceramic sheet.

[0050] The total depth of the channels remains small in the domain of 50 nm to several hundred nanometers making that the total impulse transfer due to radiation direction change to be taken by several thousands atomic structures the total energy taken from the radiation being small.

[0051] The slight interaction with the electronic structures and hard interaction with the nuclear structures keeps the wave on track changing the direction in small steps. The generation along the channel of orbital magnetic moments is welcomed for neutrons gyration creating a focusing defocusing molecular structure similar to particle accelerators. The resonance between neutron spin turning and the magnetic orbital moment alternating is generating the turning force. For practical reasons a 90 deg. Gyration seems enough for most of the shielding purposes.

[0052] For nuclear reaction control purposes up to 180 deg. Gyration angle seems appropriate to keep the radiation in a specific location.

[0053] FIG. **6**—shows another practical approach of the radiation funneling mechanism by channeling into molecular wave-guides and turning it a little bit. The higher input acceptance angle versus unidirectional escape angle from the channel will modify the initial radiation admittance.

[0054] The radiation **605** having a variable energy enters in the reflective solid **600** at a certain angle acceptable distribution **607**, accepted for channeling in the first layer **601**, that turns it and deliver on a bended angle, suitable for the next layer **602**. The incident radiation coming in the **602** layer acceptable angle did not interact by channeling with the upper layer **601** and it is added at the **602**-layer entry level with the **601**-output radiation.

[0055] The second layer **602** output is cumulating with the direct radiation coming up to the angle limit **608** and added to the previous output. By this way the radiation incident on the material's surface between angles **606** and **608** forming the angular acceptance **609** is delivered inside the narrow exit angle **605**. The material may be continued with several other layers in the direction **604** such as a 2*Pi incidence angle to be diverted in a single direction.

[0056] FIG. **7**—is shoving another embodiment of the invention that allows the X gamma and neutrons radiation switch from a direction to another by using a combination of fero-electric and piezo-electric clustered materials. This is important because it introduces the capability of electronic control over the direction the radiation is driven. The application of the voltage on the active layer modifies the structure and orientation of the molecular wave-guides due to electrical anisotropy of the piezo and ferro electric clusters. The simplest device is a lamellar bimaterial with the piezo-electric material being deposited as a layer on the channeling material shrinking or expanding according to the control voltage.

[0057] The device in FIG. **7** performs inner intermolecular changes at the cluster level driven by the external voltage. The nano-material is formed from the substrate **700** and the active layers **701** and **702**. When the voltage is applied in one direction **705** in the adaptor module **703** the incident radiation **704** is deflected in the direction **706**, shown in FIG. **7**A. When the applied voltage is modified as **707** the incident radiation will be deflected in direction **708** as showed in FIG. **7**B.

[0058] The advantage is that the radiation may be controllable driven making a radiation electric shutter.

[0059] FIG. **8**—shows a main embodiment of the present invention called the "miu" radiation switch with digital control that is mainly a radiation gyrator, based on molecular wave-guides.

[0060] The material is in a planar micrometric construction having conductive layers **816** usable to apply the voltage **814** to control the inner channel gate mechanism. The input layer **800** is creating a rarefied electronic structure based on fulerenes or metallic spheres, able to create a resonance cavity to trap radiation inside, in the wave guide made by the molecular orbital **805** The incident wave **808** having the Poynting vector **809** towards the material is reaching a input structure **805**, **800** that guides it inside on a resonant path **806**. The changes of the molecular distribution from the material **800** to **801** and **802** makes the molecular wave-guide turn driving the wave back outside by slight interaction with electronic charges, and being resonantly trapped into the middle of the wave guide isopotential electronic orbital surfaces **804**.

[0061] The material **801** is implanted over the interface **800**-**802** modifying the cluster end in order to produce the wave-guide bending driving the wave inside **815** towards outside **811** traveling in opposite direction **810**. The material **802** is deposited on a structural resistance material **803** that may be a polymer, fabric or metal-ceramic sheet.

[0062] The total depth of the channels remains small in the domain of 50 nm to several hundred nanometers making that the total impulse transfer due to radiation direction change to be taken by several thousands atomic structures the total energy taken from the radiation being small.

[0063] The slight interaction with the electronic structures and hard interaction with the nuclear structures keeps the wave on track changing the direction in small steps. The generation along the channel of orbital magnetic moments is welcomed for neutrons gyration creating a focusing defocusing molecular structure similar to particle accelerators. The resonance between neutron spin turning and the magnetic orbital moment alternating is generating the turning force. For practical reasons a 90 deg. Gyration seems enough for most of the shielding purposes.

[0064] For nuclear reaction control purposes up to 180 deg. Gyration angle seems appropriate to keep the radiation in a specific location. The application of the voltage over the piezo-structure or ferroelectrics enhanced structured by nano-engineered makes the switch of the channels from turning around **806** to direct transfer **817** allowing the radiation to pass through without attenuation. The control voltage **814** may be applied in digital or analogical manner.

[0065] FIG. **9**—shows a monolayer "miu" switch schematics with emphasis on operation mode. The material is at the minimal approximation tri-layered. The intermediary layer **902** caring the switch function **905**, **915** is separated from the input layer **901** by a conductive interface **906** applying the voltage between **901** and **902** relative to the backing layer **903** grounded by the plot **914**. The voltage applied on **902** by the plot **912** induced a displacement in the structure **905**, **915** such all the parallel channels initially opened to gyration **909** are moving narrowing the gyration channel but opening the direct pass channel **910**. Such as the radiation, gamma, neutron, X coming from **907** direction entering the admittance resonant chamber **907** is voltage **906**,**912**, **914** voltage switched from complete gyration to **908** direction exiting on **904** exit chamber, to the transmission channel **910** exiting on **911** direction forward. This represents the development of a voltage controlled variable albedo shielding reflector.

[0066] FIG. **10**—shows the application of the voltage-controlled reflectors a embodiment of the present invention in the nuclear reactor control by variable transmission "miu" switch shielding application. This is an important stage of the invention as allows the drastic reduction of the shielding dimensions and mass.

[0067] The nuclear reactor structure **1008** operating in direct conversion mode delivering directly the electric power at the plots **1009**, **1010** or thermal conductivity heat extraction for which the plots **1009** and **1010** represents the cooling agent exit and input in the reactor critical volume. The criticality is controlled by the transmission of the nano-shielding such as to maintain the required power level. When the power have to be increased the transmission through the shield **1000** is increased. The released neutrons are used for the fuel breeding **1001** or fission products **1006** burning purposes. There are numerous plots to control the sector shielding as **1011** for the outer layer, while **1012** controls the top shielding. The escape neutrons are hitting the shielding **1000** in the point **1003** and dependent of the applied voltage applied on **1011** they can reflect back in the reactor or be released interacting with the breeding fuel being absorbed in the point **1005** or scattered hitting further the nuclear reactor external shield **1004** reflecting back. Here they may be funneled placing them tangent to breeding structure or being allowed on a radial path inside the nuclear reactor. In the upper side the escaped neutrons may cross through the shielding in the point **1014** depending on the voltage preset applied at plots **1012** and ent transmuting a fission product **1006** in the point **1013**. The entire structure is introduced in an external case **1007** with multiple functional roles.

[0068] This represents an important advancement as makes the nuclear power accessible on vehicles, few MWDay structures being possible of being produced in cubes of 2 feet lateral powering a car, house, residence for several years continuous driving.

[0069] FIG. **11**—Shows another application, the use of a radiation funneling shielding to shield plasma focused fission device being an embodiment of the present invention. Shows an application related to colider fusion device based on two opposite direction beams, for which the center of mass of the colliding particles is in repose overlapping the center of the harvesting geometry.

[0070] The colider may be also achieved with a fixed perpendicular thin target and a down flow harvesting structure. In the drawing the role of the nano-shield **1102** is to funnel the secondary radiation **1104** coming from the harvesting element **1103** such as to maximize its path in the absorbing element **1105** until it hits the outer nano-shielding **1101** with reflects it back tangentially **1106**. The fusion assembly **1100** may have the fusion reactions of Boron **1108** proton **1107** giving a Helium particle and a 8Be that instantly decays **1109** in two Helium particles, or Lithium **1111** deuteron **1112** or proton giving two Helium **1110** particles. The Helium particles carrying the fusion energy as kinetic energy interacts with the direct conversion structure **1103** that takes their energy and transforms it into electricity.

[0071] FIG. **12**—shows another application as embodiment of the present invention in the application of the nano-layered funneling shield as a space-shuttle radiation-shielding device for charged particles and X, gamma rays. In this case the outer frame structure **1200** that protects the payload inside is shielded laterally by nano-foils **1201**. This foil is funneling the radiation **1204** by controlled tunneling reflection **1203** to the harvesting elements **1202**. For charged particles **1205** specialized inertial spinning magnetic coils **1206** are driving the charged particles to specialize or universal harvesting elements **1202**. In this way a cosmic ray protection similar to that of the earth may be achieved.

[0072] FIG. **13**—shows another embodiment of the present invention that is a multi-focusing multi-layer device operating as gamma, X, n, charged particle imager. Various layers **1301** having narrow admittance angle and narrow directive output create the material **1300**. A radiation wave coming from the direction **1392** is transmitted on the direction **1303** towards a point in space **1304** where a detector is placed. The same happens to radiation **1305**, transmitted on the direction set **1306** towards the point **1307** with the appropriate detector. The radiation **1308** is also transmitted on the directions set **1309** towards the point **1310** with the appropriate detector. The radiations **1302**, **1305** and **1308** may be different and come under the same incidence angle, or may be the same class, and the detectors may be different. The selectivity choices are multiple and are construction and materials type particularizations.

[0073] FIG. **14** shows the space-imaging device for terrestrial and outer space applications. It is mainly a 2-3 PI imaging device, with angular selectivity. A plurality of such devices may generate a 3D image in spherical coordinates. The sensitive cylinder or prism **1400** contains a multitude of planar or bended layers as shown in FIG. **13** concentrating the radiation to imaging points set on the hyper-surface **1401**, equipped with the appropriate transducers, with some symmetry and access shape **1402**. A ray **1404** is directed inside the set angles **1405** to a specific concentrator/imaging point. The same happens with the ray **1406** poised on the direction set **1407** towards the detector **1403**. The shape, detector types, radiation selectivity criteria are buildup elements and may vary in a wide margin.

[0074] FIG. **15**—shows how the adapted nano-tube wave-guide works as an example for the buildup of the molecular wave-guides. The material **1500** is made of a plurality of layers from which the figure shows only three. The admittance-exit layer **1501**, is followed by the channeling-in nano-structure layer **1502**, placed on a substrate layer **1503**. A control voltage may be applied between the extreme layers or control layers **1501** and **1503**, having as effect the displacement of the atom **1507** that interferences with the admittance path, and resonator trapping device **1506** made from a nano-cluster of various materials and various geometries. The incident radiation coming from the direction **1511** or **1512** is trapped in the structure **1506** and injected in the nano-wave-guide **1508**.

[0075] The radiation interacts slightly with the nuclei in the nano-tube that are seen at the grazing angle, being driven with almost no energy exchange towards the exit device **1504**. This device matches the radiation determining the direction **1517** and the cardioid's **1518** shape or exit angular distribution. The admittance cardioids **1510** are determined by the input adapting structure **1506** that makes the oscillation inside the nano-cluster **1514** adapted to be injected **1515** in the molecular drive.

[0076] After channeling inside the structure **1505** the wave gets into the exit adapter **1504** having a matching **1516** oscillation before departure. It is possible that passing through these structure the shape of the photons to be modified as well the energy. The selectivity between the rays X, X' and X" is a constructive details. The structure is reversible if the input and output matching structures are properly arranged.

[0077] FIG. **16** shows the complete shielding structure section **1600**. This is achieved from a plurality of layers with various functions in radiation **1607** propagating towards the shield **1608** denial or control. The first layer **1601** is design of harvesting the energy from low penetrating radiation like charged particles up to MeV domain and electromagnetic field with energy less than few eV delivering it at the electric plots **1611**. It also acts as a protection for the next layer depleting the radiation **1610** of its low penetration components and may be replaced by an anti-chemical protective layer.

[0078] The next layer **1602** is made of a plurality of layers containing nano-tubes or organized nano-clusters **1621**, **1622** adjusted for various particles and various angles controlled by the voltage applied to the plots **1623**. In this layer the radiation **1610** is back-reflected **1624** by gyrating inside the molecular wave-guides leaving a small amount of being transmitted **1625**.

[0079] The layer **1603** has mainly separation and resistance functions. The layer **1604** is based on atomic absorption enhanced by nuclear resonance cascade. The absorptive layers **1641**, **1642** have various nano-micro layers of various isotopic enriched materials eliminating resonant bands from the gamma, n radiation spectrum. The layer **1606** is the last resort of protection being based on mass absorption in degradation lattice, being mainly a usual shielding. The remnant radiation **1660** is supposed to be very low, with orders of magnitude. The dashed line **1605** is a symmetry line for the case when the shielding arrangement is bi-directional. The symmetry line may be also build on the **1603** layer for nuclear radiation control applications.

[0080] FIG. **17** shows another embodiment of the invention related to the atomic level radiation channeling through an atomic structure presented in a window **1700**. The picture shows several atoms **1701** connected through chemical bounds at the 2p **1714** orbital level—like Carbon—but that is not an issue, is just for simplicity of the example. The lattice, a cluster, nano-tube has a cell dimension. The electric potential curve **1702** starts at the nucleus **1701** where it has a high value decreasing fast with the distance, and being partially shielded by the electrons placed on atomic orbital 1s, and 2s **1721**, 2p **1711** and 2p-bound **1714**.

[0081] The atomic channel given by the atoms alignment **1704** is bended left by a gap **1705** determining the radius of curvature of the structure by using the equation:

$$\alpha = \frac{\Delta y}{A} = \frac{A}{R} \Rightarrow R = \frac{A^2}{\Delta y} \rightarrow 2$$

[0082] If keeping a smaller than 2 degrees for an inter-atomic distance of 3 Angstroms=A, (sp^2 bound in CNT is 1.41 A) we get a radius R=20 nm. Of course this looks very small but is the lower limit a molecular wave-guide effect may occur. In reality the radiation wave **1703** has a finite length of several [nm] up to hundreds of [nm], depending on the production source, with a E;B profile wearing the signature of the primary source and the environment it passed through. In our example it has also a width and an envelope **1732** with the Poynting vector Y **1731** centered in the channel. The image resembles a ship in a strait. In normal environments between 250 and 400 Kelvin degrees the atoms have molecular vibrations at THz frequencies. Thou the atoms have not fixed locations as figured by the alignment axes **1704** but likelihood places figured by the rectangles **1706** where in plain they describe a combined oscillatory movement similar to Lisajoux trajectories, under the action of the figured in plane oscillations **1717** on z axis, **1718** on y axes and **1712** on xz. In reality these movements have to be treated in volume and a plurality of specific eigen-frequency in THz domain, specific to all molecular vibrations. These movements may make the wave-guide impractical above a certain temperature, because the atoms may interpose with the wave driving to a nuclear collision effect known under the name of Doppler broadening.

[0083] This effect generates Compton recoil electrons **1708** that stops far in the lattice by generating a cascade **1709** accompanied by X rays and energy and direction modification going astray.

[0084] This imposes the following requirements:

[0085] The nanowire to be pretty straight and long free of sudden curls, while the gap on the rotational axis to be a rational number so during a twist around its symmetry axis the molecules to cover all the space.

[0086] The nano-structure has to be as compact as possible and with high Z number so the fields constrain to be big enough to bend the radiation wavelet and keep on the channel.

[0087] There is possible to vary the isotope in such a manner to create a funnel and control the exit from the channel.

[0088] The chemical stability and the molecular strength have to be high so that the amplitude of the molecular vibration to be small enough to require no cryogenics.

[0089] The development of organized structures have also to have a high fill factor, that possible may not be higher than 10% so a 20 layers structure might be necessary.

[0090] FIG. **18**—shows another embodiment according to the invention said radiation selective extractor/gyrator **1800**.

[0091] A beam **1802** of composed radiation reaching the target **1801** comes, and is separated on types and extracted from the hot area by specialized guiding tubes **1804**, **1808**, driving it to receivers.

[0092] The radiation may be a mixture of n, gamma becoming p, e, and gamma for travel times greater than ½ hour due to n disintegration. The n emitter modulation carries a fake signal while gamma caries the true signal. Their overlap on target makes the decoding hard due to physical properties of the signal that have to be extracted from the high-energy radiation background.

[0093] This kind of communicator is also usable in high radiation environment where the noise **1805** distinctly extracted may be separated from the real information-carrying signal **1807**. The system is transparent to the radiation not matching the extraction conditions **1806**.

[0094] The nano-structured entry interface **1801** takes inside all the radiation that is focused **1803** to the input filters of the specialized extraction guides. This device may use the signal decoders for imaging and communication purposes. The radiation modulation might be done with the electro-sensitive radiation transport device shown in FIG. **9**.

[0095] In FIG. **19** as a whole body protective coat **1900**, formed by the upper body coat **1907** and pans **1908** with protective shoes or boots **1909**.

The coat **1901**, **1907** may include helmet or hood **1903** and a backpack **1902** for survival and instrumentation. The face protection may have a face protection shield **1904** that may be transparent for eyes or completely opaque equipped with complex orientation system **1905**, giving the images of the terrain in various bands and radiation. The gloves **1906** may have various degrees of flexibility and protection. The advantage of this suit is that it may exhibit attenuation coefficients up to ppm level and weight by 100 times lower than it would be fabricated by the mass attenuation materials.

[0096] Some flexibility degree will be possible in the suit. The suit may be used in various configurations and circumstances for individual protection as military suit, security first intervention, hazmat environments, outer space for astronaut suit or for outposts shielding, for shelter in place, portable emergency vehicles, etc.

[0097] FIG. **20** shows an accomplishment of these active shields **2000** in lightening and miniaturizing the nuclear power sources as fission, fusion and hybrids. The entire assembly is contained into a technologic case that has mechanical resistance purposes and shielding purposes as electric, radiation, etc, containing pressure and temperature. The total reflection external shield **2002** is reflecting all the particles coming from the hot area towards inside, keeping the radiation together I a smaller confinement zone. Immediately near the absorber is placed a multipurpose cooled absorber material making a sealed structure able to confine pressure and temperature, up to a limit where it has a controlled release. A direct conversion layer and gamma absorber material form the absorber. It also exhibits chemical stabilization materials. The breeding control adjustable reflection shield **2004** is driving the neutrons to the absorption layer mainly having the function of breeding and transmutation, when it is electrically polarized and transparent to the total reflection, reflecting them inside for power production. Breeding nanomaterial **2005** contains ^{232}Th, ^{238}U, or may contain other materials for transmutation and radioisotopes production. To keep a constant reactivity in this area the transmutation products will be removed from the production area in a storage cooling compartment. Power control adjustable reflection shield **2006** is made form the active material, whose transmittance and reflection also called albedo is done by using a control system for criticality **2007**, that together with the Breeding control system **2008** assure the neutron **2009** flux management establishing their trajectories **2010** and range. All the functions are automatically controlled in order to balance the power output **2011** produced with the power demand of the system this part is integrated.

[0098] FIG. **21** represents an example of mobile portable nuclear power source **2101**, based on reflective Nano-Shielding **2102** that may drive to super-critical nuclear sources, as an example 239 Pu based reactor reaching the criticality with less than 50 g of fissile material. The produced power is transmitted to wheels electric motors **2103** making part of the integrated vehicle system **2100**.

[0099] Other examples as trains, ships, planes, superplanes space shuttles and underwater devices are also possible.

BRIEF DESCRIPTIONS OF INVENTION

[0100] The invention refers to a new type of active nanostructured material to be used for X, gamma and neutrons shielding and control. The main idea behind the patent comes from the actual super-mirror used in synchrotrons X ray focusing and cold neutron transport at spallation sources. The other idea used in the patent approach was the fact that the interaction between high-energy radiation and materials is very weak except for nuclear resonances. Such resonant materials may have small thickness but they may generate high absorption rates.

[0101] The equation 1 is characterizing the process:

$$I(E_j)=I_0(E_j)\exp(\mu_i x^i+\delta_j^i\mu^j x^j) \qquad \text{Eq.1}$$

where I is the intensity in a point x on the axis for an energy belonging to the energy group j.

[0102] The group width is set to be equal with the resonance's effective width (something like nσ where n is a reasonable value usually smaller than 3). μ is the liniar absorption coefficient absorbing the value

$$\frac{\mu}{\rho}\rho_i$$

where μ is the material specific absorption density while ρ is the material mass density and ρ_i is the specific material density spanning the length x_i.

[0103] Using this concept there is possible to make arrangements of various materials resonantly absorbing the incident radiation, activating the internal nuclear channel and dezexciting by following the nuclear branching paths. There are very few cases when the excited nucleus is emitting a higher energy than it absorbed, therefore the new material becomes a new source of radiation in that bandwidth backscattering theoretically 50% of the primary radiation. If consider two repetitive layers separated by a distance they theoretically cut down 75% of the radiation by backscattering. The disadvantage of these materials is that the resonance band is very narrow, so a sandwich is required to cut down most of the energetic groups, but the nature did not provided so many stable isotopes as we may need to make resonant shielding. Radiation buildup is also important but is considered a secondary effect for this approach.

[0104] The usage of the first concept about radiation reflection at grazing angles together with the fact that the radiation interaction with the surface is local at few tens of atoms driven the conclusion that a nano-tube slightly bending, see FIG. **17** may offer the same conditions, and more it may contain the radiation and slightly center in the tube hole. The nano wires are naturally bending and so the radiation. One of the problems to be solved is the small admittance for the radiation inside the molecular wave-guides that is solved by growing fulerene like structures that will divert the radiation inside sa described in FIG. **15**.

[0105] FIG. **1** describes the 3 types of shielding, from which the patent brings as new the nuclear resonance enhanced absorption and the molecular wave-guides radiation gyration.

[0106] If the resonance enhanced radiation absorption and reemission described by FIG. **3** may brining a passive shield with maximum 1-2 orders of magnitude thinner than the classical mass absorption actual shielding described generically in FIG. **2**, the radiation gyration by molecular waveguides described by FIG. **4** opens new perspectives.

[0107] As FIG. **5** shows there is necessary to build organized nano-structures, that to create the so-called molecular structures. These structures may be build in many ways, but for simplicity one way to build is by starting from a Si, Diamond substrate, building by beam-annealed Au self organized nano-clusters, and building a layer of carbon nanotubes, slowly bended in about 500 nm to 1 micron. Over this layer a new conductive micro layer is deposited as TiO and W, or WC follows by pulsed laser deposition than by Au, Ag deposition. This substrate will create the germination for the new set of C nano-tubes deposited by CVD, slightly tilted than the first.

[0108] By this way a plurality of substrates may be build. Another modality of building the organized structure is to perform a combined CVD and Laser Pulsed Deposition, assisted by an interfered ion bean on a 10 nm pattern to create the thermal spikes to induce the nucleation of the nano-clusters and separation of the depositions. In this structure the organized layers of nano-clusters will float in an insertion material also partially crystallized. The insertion of a piezo material as BaTiO4 by LPD or a ferro-electric material as TGS brings the possibility of the electric control of the radiation direction by obtaining the molecular wave-guide switches.

[0109] As already resulted from FIG. **5** and in the molecular switch version presented in FIG. **8** there is difficult to achieve this effect by using few atoms. A collective action with the participation of few thousands atoms is needed to completely gyrate MeV n or gamma rays as detailed in FIG. **17**.

[0110] In the case og the gyration by 180° of the radiation of few MeV on 1000 atoms, an energy exchange of several tens of eV will be transferred to lattice due to impulse transfer. This is enough to warm-up that channel and the structure to require cooling.

[0111] The main formula is:

$$p = 2\frac{E}{c} = nMv \rightarrow v = \frac{2E}{cnM} \Rightarrow \Delta E = \frac{2E^2}{c^2nM} = nk_BT \quad (3)$$

that in the case of 1 MeV radiation turned by 1000 atoms gives about 2.5 eV that drives to a 3° K temperature increase per particle.

[0112] This is not so bad showing that high doses may be handled by this mechanism without significant radiation damage effects. To calculate the radiation damage the isotopic specific interaction cross-sections have to be considered. Without doing this we observe that in the radiation admission interface small cross-section materials have to be used to channel the radiation. The particularity of the channeling process exploited in the present invention consists in the fact that the radiation quanta interacts mainly with the collective atomic electric field and not directly with the nuclei, making the interactions small.

[0113] The application of the material in communication in FIG. **18** uses the selectivity and electric control that makes possible the modulation as emitter and the direct conversion systems with fast response detection and demodulation. The high sensitivity makes possible the data and signal transmission through shielding materials and high absorbers.

[0114] The usage of these materials inside nuclear reactors is making possible the replacement of the mechanical control rods by electric controlled albedo materials, increasing the n usage and making an optimal management of breeding, transmutation and partitioning. The waste and contamination will be drastically removed The drastically change in the nuclear reactor structure. Same structure might be used to fusion structures, accelerator driven structures and hybrid structures.

What is claimed is:

1. A radiation guiding material according to the main embodiment made of:

a plurality of layers containing nanostructures, said nano-channels, pores, clusters, nano-tubes and nanowires and a combination of these with the role to trap and guid the nuclear radiation

a plurality of conductive and insulator layers coat or insert with piezo or ferro electro magnetic properties with the capability of changing the guided nuclear radiation channeling direction

a plurality of layers having the absorption increased by the presence of nuclear resonance in the energy domain of interest placed in a predefined order

a plurality of layers, fabrics and inserts with the purpose of increasing mechanical, chemical and heat and other radiation resistance

2. A radiation guiding material according to claim **1** made by a nano-structure that traps radiation and is steering it inside, driving it in a controlled direction.

3. A radiation guiding material according to claim **1** said nuclear reflective layer made from a plurality of molecules forming nano-cluster structures connected in a predetermined order forming an internal charged space similar to a wave-guide able to channel and guide the high frequency electromagnetic field, neutral waves and charged particles along the channel gyrating it in a controlled manner.

4. A radiation guiding material according to claim **1** made by a symmetrical atomic structure, offering a hollow cavity able to trap and resonate with the incident waves increasing the incidence admittance angle.

5. A radiation guiding material according to claim **1** comprising an assembly of molecular wave-guide channels, grabbing the radiation from a large incidence angles and sending it in a controlled angle.

6. A radiation guiding material according to claim **1** said a material sheet offering channeling properties for a preferred direction and normal attenuation properties for all other incidence angles.

7. A radiation guiding material according to claim **1**, used to create human radiation shielding similar to raincoats.

8. A radiation guiding material according to claim **1**, made of a plurality of layers used to shield a glove-box or hot-cell or individual radiation protective raincoat shielding for HAZMAT or space suits.

9. A radiation guiding material according to claim **1** comprising a structure bordered by electro sensitive layers able to change its shape according to an applied voltage said control to its extremities offering the traveling wave alternate exit possibilities depending on the control voltage

10. A radiation guiding material according to claim **1** made of an assembly of molecular wave-guide channels that grabs the radiation from a large incidence angles and is sending it in a controlled angle to concentrate or focus it for energy harvesting, propulsion, active interrogation or medical applications.

11. A radiation guiding material according to claim **1** made of an assembly of nano-channeled structure driving the radiation in different directions switched by a control voltage

12. A radiation guiding material according to claim **1** made of an assembly of neutrons channeling device made by sectors with transmission/reflection controlled by voltage surrounding a nuclear reactor structure and adjusting the criticality

13. A radiation guiding material according to claim **1**, made of an assembly of directive structures, used to funnel the radiation from a narrow admittance angle towards a single point called focal point used for imaging.

14. A radiation guiding material according to claim **1**, fabricated as a material sheet, offering channeling properties for a preferred direction and normal attenuation properties for all other incidence angles.

15. A radiation guiding material according to claim **1** used in a combination as panel elements a to create a multi-layer conic gamma, n imaging device.

16. A radiation guiding material according to claim **9** said controlled shielding panel applied in to control the flux and energy harvesting in fission, fusion and mixed reactors, as in energy generation by nuclear means as annihilation.

17. A controlled radiation guiding material according to claim **9** made as a multi-nanostructured-layer device used in communication by X and gamma, particle ray modulation demodulation communication, imaging and probing systems.

18. A radiation guiding material according to claim **9** mounted to form a combined structure of radiation funneling and nano-focusing for atomic microscopy and quantum-devices manufacturing.

19. A radiation guiding material according to claim **1** mounted in a repetitive microstructure to be used for space shielding, of space shuttles, outposts, nuclear power generators on board

20. A controlled radiation guiding material according to claim **9** mounted in a combination of active passive structures used to replace the nuclear reactors criticality control mechanical rods and to make the neutron management is ultra-small portable nuclear reactors on terrestrial vehicles.

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