



(11)

EP 3 509 085 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
06.10.2021 Bulletin 2021/40

(51) Int Cl.:
H01J 43/06^(2006.01) H01J 43/10^(2006.01)

(21) Application number: **17854332.8**

(86) International application number:
PCT/CN2017/071996

(22) Date of filing: **21.01.2017**

(87) International publication number:
WO 2018/058871 (05.04.2018 Gazette 2018/14)

(54) AUTOMATIC EXPANSION FOCUSING ELECTRODE FOR PHOTOMULTIPLIER AND PHOTOMULTIPLIER

FOKUSSIERUNGSELEKTRODE MIT AUTOMATISCHER EXPANSION FÜR
PHOTOVERVIELFACHER UND PHOTOVERVIELFACHER

ÉLECTRODE DE CONCENTRATION À EXPANSION AUTOMATIQUE POUR
PHOTOMULTIPLICATEUR ET PHOTOMULTIPLICATEUR

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **28.09.2016 CN 201610855953**

(43) Date of publication of application:
10.07.2019 Bulletin 2019/28

(73) Proprietor: **North Night Vision Technology Co., Ltd
Kunming, Yunnan 650217 (CN)**

(72) Inventors:
• **SUN, Jianning
Kunming
Yunnan 650217 (CN)**
• **SI, Shuguang
Kunming
Yunnan 650217 (CN)**
• **WANG, Zhihong
Kunming
Yunnan 650217 (CN)**
• **ZHANG, Qindong
Kunming
Yunnan 650217 (CN)**
• **REN, Ling
Kunming
Yunnan 650217 (CN)**

- **LI, Dong
Kunming
Yunnan 650217 (CN)**
- **WANG, Xingchao
Kunming
Yunnan 650217 (CN)**
- **XU, Haiyang
Kunming
Yunnan 650217 (CN)**
- **SHAO, Aifei
Kunming
Yunnan 650217 (CN)**
- **ZHANG, Zhengjun
Kunming
Yunnan 650217 (CN)**

(74) Representative: **Roman, Alexis
SPE Roman-Andre
35 rue Paradis
B.P. 30064
13484 Marseille (FR)**

(56) References cited:
**EP-A1- 0 713 243 WO-A1-2015/139344
CN-A- 105 570 750 CN-U- 203 863 575
US-A- 4 855 642 US-A- 4 855 642**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 3 509 085 B1

Description

Field of the Invention

[0001] The Invention relates to the technical field of microchannel plate type photomultiplier tube, and particularly to an automatic expansion type focusing electrode for photomultiplier tube and a photomultiplier tube thereof.

Background of the Invention

[0002] Photomultiplier tube is a photodetector which can convert weak light signals into electrical signals for output. It can be divided into dynode type photomultiplier tube and microchannel plate type photomultiplier tube based on the category of multiplier. Various types of photomultiplier tubes are widely used in the fields of basic physics, high-energy gamma ray detection, telescope observation cosmic ray on the ground, double beta decay experiment, proton decay experiment, dark matter detection, neutrino detection experiment and so on.

[0003] From prior art one should refer to WO2015139344 A1 (Institute of High Energy Physics of the Chinese Academy of Sciences (CAS) et al.) disclosing a photomultiplier of electrostatic focusing micro-channel plates.

[0004] References should also be made to CN105570750 A (Southeast university), regarding a table lamp with an illumination range capable of being adjusted and controlled.

[0005] Furthermore references should be made to JPH02288145 A (Burle Technologies) regarding an optoelectronic multiplier

[0006] Finally, from prior art one should also refer to EP0713243 A (Hamamatsu Photonics KK), regarding a Electron multiplier.

[0007] At present, the technical scheme of photomultiplier tubes, especially those with large size, are mostly of dynode type, which have complex structure and relatively weak time response. Meanwhile, microchannel plate photomultiplier tubes have better time response, and the parameters such as TTS can be further improved with expandable focusing electrode. However, due to various technical conditions, especially the limitation on the size of the focusing electrode, it is difficult to obtain higher collection efficiency.

Summary of the Invention

[0008] The purpose of the Invention is to provide an automatic expansion type focusing electrode for photomultiplier tube with superior time response and a photomultiplier tube with the focusing electrode.

[0009] The above purposes of the Invention are realized through the technical features of the independent claims, and the dependent claims develop the technical features of the independent claims in alternative or favorable

manner.

[0010] To achieve the above purposes, the Invention provides an automatic expansion type focusing electrode for photomultiplier tube according to claim 1 to 4, comprising a fixed hold-down mechanism, expandable blades, a trigger pedal, a trigger wire and a trigger ring, wherein:

The fixed hold-down mechanism comprises an annular bottom plate and torsion springs and rotating shafts arranged on the bottom plate, wherein the torsion springs are wound around the rotating shafts; The multiple expandable blades are arranged along the edge of the bottom plate and are mounted around the rotating shafts in a rotating manner; the multiple expandable blades are fixed vertically over the bottom plate in the initial state, held down by the trigger ring to be folded together in an annular shape and to present in a folded condition;

The torsion springs are arranged one-to-one with the expandable blades, with one end of each torsion spring fixed to the expandable blade and the other end to the bottom plate, and the torsion springs are arranged to make the expandable blades expand towards the radial dimension of the focusing electrode and to provide a pretightening force;

The trigger pedal, the trigger wire and the trigger ring constitute an automatic trigger mechanism;

One end of the trigger wire is fixed to the trigger pedal and the other end to the trigger ring;

The trigger pedal is arranged to drive the trigger wire to move when being triggered so as to release the multiple expandable blades from the folded condition due to being held down by the trigger ring and to enter into an expanded condition by the pretightening force from the torsion springs.

[0011] In an embodiment, the trigger pedal is located close to the bottom plate and stretches outward and is arranged to be blocked by the edge of the spherical glass shell when the focusing electrode is sealed with indium into the spherical shell to make it move in the opposite direction of the moving direction of the focusing electrode and drive the trigger wire to move synchronously to release the fastener on the trigger ring and further release the multiple expandable blades from being folded by the trigger ring, so as to make the expandable blades enter into releasable condition and rotate and position along the rotating shaft on the edge of the fixed hold-down mechanism in the presence of the pretightening force of the torsion springs and make the focusing electrode enter into an expanded condition.

[0012] In another embodiment, the external diameter of the focusing electrode is smaller than 90mm when the expandable blades are in the folded condition in the initial state.

[0013] In another embodiment, the external diameter of the focusing electrode is greater than 175mm when

the expandable blades are in the expanded condition after being released.

[0014] In another embodiment, the bottom plate is a metal plate.

[0015] According to the disclosure of the present invention, it further provides a photomultiplier tube according to claims 5 to 8.comprising:

a high-vacuum sealed shell composed of a spherical part and a transitional sealing part, with the interior of the shell under an ultra-high vacuum condition;
a high quantum efficiency photocathode placed on the inner surface of the high-vacuum sealed shell;
an automatic expansion type focusing electrode according to the present invention, arranged to collect photoelectrons generated by the high quantum efficiency photocathode, the automatic expansion type focusing electrode being located in the interior of the high-vacuum sealed shell;
an electron multiplier placed under the automatic expansion type focusing electrode and arranged to multiply the photoelectrons collected by it;
a lead wire system placed under the electron multiplier and passing through the transitional sealing part of the high-vacuum sealed shell is arranged to extract electrical signals.

[0016] In another embodiment, the automatic expansion type focusing electrode is located in the interior of the high-vacuum sealed shell and between the high quantum efficiency photocathode and the electron multiplier and is arranged to collect photoelectrons generated by the high quantum efficiency photocathode.

[0017] In another embodiment, the high-vacuum sealed shell is made of high temperature insulating materials with high transmittance and low reflectance, with the shape of spherical structure, ellipsoidal structure with smooth transition of multiple circular arcs or cylindrical structure.

[0018] In another embodiment, the high quantum efficiency photocathode is constructed as a semiconductor film plated by evaporation on the inner surface of the high-vacuum sealed shell that is arranged to convert photons into electrons.

[0019] In another embodiment, the electron multiplier uses two microchannel plates as its multiplier elements, the two microchannel plates being connected in series and under superposition, and the working voltage being loaded respectively.

[0020] According to the above technical scheme, the automatic expansion type focusing electrode and the photomultiplier tube of the Invention have significant beneficial effects compared with the prior art:

1) By adopting the automatic expansion type focusing electrode as the electron collector of the photomultiplier tube, it is able to effectively increase the radial dimension of the electron collector, thus sig-

nificantly improving the time response of the photomultiplier tube, especially the transit time spread (TTS);

2) By adopting the automatic expansion type focusing electrode as the electron collector of the photomultiplier tube, it is able to effectively improve the collection ability of electron collector to the electron generated by the high quantum efficiency photocathode, thus improving the detection efficiency of the sample tube;

3) The electron multiplier is used in conjunction with the automatic expansion type focusing electrode to multiply the electron it collects and the microchannel plate is used as the core multiplier to realize ultra-high efficiency, greatly simplify the complexity of structure and reduce the costs of lead wire system and voltage loading system;

4) The photomultiplier tube based on automatic expansion type focusing electrode adopts the axisymmetric design scheme, exhibiting good uniformity, including cathode uniformity and anode uniformity.

[0021] It should be understood that all combinations of the above ideas and the additional ideas described in more detail below may be considered as part of the subject matter of the present disclosure provided that such ideas are not contradictory. Moreover, all combinations of the subject matter being claimed for protection are considered as part of the subject matter of the present disclosure.

[0022] The above and other aspects, embodiments and features of the present invention can be better understood from the following description with reference to the drawings. Other additional aspects of the Invention, such as the features and/or beneficial effects of exemplary embodiments, will be apparent in the following description or will be understood through practice of the specific embodiments in accordance with the present invention.

Brief Description of the Drawings

[0023] The drawings are not prepared in proportion. In the drawings, the same or nearly the same components shown in each drawing may be represented by the same symbols. For clarity, not every component is marked in the drawings. Embodiments of various aspects of the present invention will be described by examples and with reference to the drawings, wherein:

Fig. 1 is the structural diagram of the photomultiplier tube based on the automatic expansion type focusing electrode according to the present invention.

Figs. 2A-2B are the structural diagrams of the automatic expansion type focusing electrode according to the present invention, wherein Fig. 2A is the diagram of the focusing electrode under folded condition and Fig. 2B under the expanded condition.

Fig. 3 is the diagram for the connection between the electron multiplier and the automatic expansion type focusing electrode according to the present invention.

Fig. 4 is the diagram for the connection between the electron multiplier and the connecting system and the lead wire system according to the present invention.

Fig. 5 is the diagram for the process of indium sealing according to the present invention.

Detailed Description of the Preferred Embodiments

[0024] In order to better understand the technical content of the present invention, specific embodiments in combination with accompanying drawings are described below.

[0025] In the present disclosure, various aspects of the present invention are described with reference to the drawings, which show multiple illustrative embodiments. The embodiments of the present disclosure are not necessarily intended to cover all aspects of the Invention. It should be understood that the multiple ideas and embodiments described above as well as those ideas and embodiments described in detail below, may be implemented in any of multiple ways, which is because that the ideas and embodiments disclosed in the Invention are not limited to any embodiment. Moreover, some aspects of the Invention may be used alone or in any appropriate combination with other aspects of the Invention.

[0026] In conjunction with Fig. 1, the Invention provides a photomultiplier tube with automatic expansion type focusing electrode comprising a high-vacuum sealed shell 101, an automatic expansion type focusing electrode 102, a high quantum efficiency photocathode 103, an electron multiplier 104 and a lead wire system (including connecting structure) 105.

[0027] The high-vacuum sealed shell 101 keeps the interior of the photomultiplier tube under ultra-high vacuum condition and acts as the attached substrate for the photocathode 103.

[0028] High quantum efficiency photocathode 103 is plated by evaporation on the specific area (for example, the upper part) of the inner surface of the high-vacuum sealed shell 101. When the photon from outside is incident onto the surface of the glass shell with a high quantum photocathode plated inside by evaporation, the photocathode converts the photon into electrons.

[0029] The automatic expansion type focusing electrode 102 acts as the collector of the photomultiplier tube and is used to collect and multiply the electrons generated by the high quantum efficiency photocathode to the electron multiplier.

[0030] The automatic expansion type focusing electrode 102 is in the folded condition in the initial state (i.e., before expansion), and the focusing electrode is triggered by the high-vacuum sealed shell 101 (i.e. the glass shell) at the final sealing to expand within the glass shell,

so as to realize the expansion of the focusing electrode towards the radial dimension, and further improve the collection ability of the focusing electrode to electrons and the time response.

[0031] The electron multiplier 104 is connected to the bottom of the focusing electrode 102 to multiply and output the electrons collected by the focusing electrode 102. The electron multiplier 104 adopts a multiplier mechanism with at least two microchannel plates connected in series.

[0032] The lead wire system 105 acts as the supporting part of the automatic expandable focusing electrode and the electron multiplier, and simultaneously extracts the electrons multiplied by the electron multiplier.

[0033] As shown in Figs. 1, 2A and 2B, the high quantum efficiency photocathode 103, the automatic expansion type focusing electrode 102 and the electron multiplier 104 are all placed in the glass vacuum vessel, i.e. the high-vacuum sealed shell 101.

[0034] The high-vacuum sealed shell 101 is made of high temperature insulating materials with high transmittance and low reflectance, with the shape of spherical structure. The present embodiment illustrates the Invention in detail with a glass vacuum vessel 101. The interior of the shell is under ultra-high vacuum condition and is composed of a spherical part and a transitional sealing part.

[0035] The high quantum efficiency photocathode 103 is a semiconductor film plated by evaporation on the inner surface of the high-vacuum sealed shell that converts photons into electrons.

[0036] The automatic expansion type focusing electrode 102, the electron multiplier 104 and the lead wire system 105 are connected into a whole, which is then sealed into the glass vacuum vessel 101 through indium sealing. After sealing, the automatic expansion type focusing electrode 102 is on the central axis of the glass vacuum vessel 101 and under the center of the ellipsoid, and the electron multiplier 104 is under the automatic expansion type focusing electrode 102, which are connected together through welding. The lead wire system 105 runs through the electron multiplier 104 to extract the electrodes to be loaded with voltage to the outside of the glass vacuum vessel 101 to facilitate the loading of voltage.

[0037] The electron multiplier 104 uses microchannel plates as its multiplier elements and the two microchannel plates are connected in series and under superposition, and the working voltage is loaded respectively.

[0038] As shown in Fig. 1, voltage is loaded onto the photomultiplier tube in accordance with the operation requirements when the whole photomultiplier tube is in operation. When weak photons irradiate on the high quantum efficiency photocathode 103, the photocathode converts the photon into electron. At this time, the automatic expansion type focusing electrode 102 collects the converted electrons onto the electron multiplier 104, which multiplies the electrons. The multiplied electrons are ex-

tracted to the outside of the photomultiplier tube through the connection and the lead wire system 105. After reading and processing of the signals, it is possible to detect the weak photon.

[0039] In conjunction with Figs. 1, 2A and 2B, as a preferred embodiment, the automatic expansion type focusing electrode 102 is used for collecting photoelectrons generated by the high quantum efficiency photocathode and is located in the interior of the high-vacuum sealed shell.

[0040] The automatic expansion type focusing electrode 102 is automatically triggered to expand towards the radial dimension when sealed with indium to the transitional sealing part. The automatic expansion type focusing electrode 102 has multiple expandable blades 201 which can expand after being triggered; the multiple expandable blades 201 have two conditions: the folded condition in an annular shape with blades being held down and the expanded condition with blades expanding towards the radial dimension of the focusing electrode; in the expanded condition, the multiple expandable blades are tensioned and positioned with help of the torsion springs. In conjunction with Figs. 2A and 2B, the automatic expansion type focusing electrode 102 comprises multiple expandable blades 201, a fixed hold-down mechanism 202, a trigger pedal 203, a trigger wire 204 and a trigger ring 205.

[0041] The fixed hold-down mechanism 202 comprises an annular bottom plate 202A and torsion springs 202B and rotating shafts 202C arranged on the bottom plate, wherein the torsion springs are wound around the rotating shafts.

[0042] The expandable blades 201 are arranged along the edge of the bottom plate and can be mounted around the rotating shafts in a rotating manner. The expandable blades 201 are fixed vertically over the bottom plate in the initial state, held down by the trigger ring 205 to be folded together in an annular shape and to present in a folded condition. The torsion springs 202B are arranged one-to-one with the expandable blades 201, with one end of each torsion spring fixed to the expandable blade and the other end to the bottom plate. Each torsion spring has the tendency to make the expandable blades expand towards the radial dimension of the focusing electrode and can provide a pretightening force.

[0043] The trigger pedal 203, the trigger wire 204 and the trigger ring 205 constitute an automatic trigger mechanism.

[0044] One end of the trigger wire 204 is fixed to the trigger pedal 203 and the other end to the trigger ring 205.

[0045] The trigger pedal 203 is arranged to drive the trigger wire 204 to move when being triggered so as to release the multiple expandable blades 201 from the folded condition due to being held down by the trigger ring 205 and to enter into an expanded condition by the pretightening force from the torsion springs 202B.

[0046] In conjunction with Figs. 2A and 2B, the trigger pedal 203 is located close to the bottom plate and stretch-

es outward and is arranged to be blocked by the edge of the spherical glass shell when the focusing electrode is sealed with indium into the spherical shell (i.e. the glass vacuum vessel 101) to make it move in the opposite direction of the moving direction of the focusing electrode and drive the trigger wire 204 to move synchronously to release the fastener on the trigger ring 205 and further release the multiple expandable blades 201 from being folded by the trigger ring, so as to make the expandable blades enter into releasable condition and rotate and position along the rotating shaft on the edge of the fixed hold-down mechanism in the presence of the pretightening force of the torsion springs 202B and make the focusing electrode enter into an expanded condition.

[0047] Preferably, the external diameter of the focusing electrode is smaller than 90mm when the expandable blades are in the folded condition in the initial state.

[0048] Preferably, the external diameter of the focusing electrode is greater than 175mm when the expandable blades are in the expanded condition after being released.

[0049] As shown in Figs. 2A and 2B, the working process of the automatic expansion type focusing electrode 102 is as follows:

The automatic expansion type focusing electrode 102 has two conditions: folded condition (as shown in Fig. 2A) and expanded condition (as shown in Fig. 2B). In the folded condition, the expandable blades 201 are folded by the trigger ring 205 and are fixed vertically over the fixed hold-down mechanism 202. At this time, the external diameter of the automatic expansion type focusing electrode 102 is smaller than 90mm. When indium sealing is carried out for the photomultiplier tube, the automatic expansion type focusing electrode 102 rises and passes through the neck of the glass vacuum vessel 101. At this time, the bottom end of the glass vacuum vessel 101 will touch the trigger pedal 203, and the trigger pedal 203 will pull down the trigger wire 204 connected with it, thereby unlocking the fastener of the trigger ring 205. At this time, the expandable blades 201 are released from being folded by the trigger ring 205, and the expandable blades 201 are made to rotate and position along the rotating shaft on the edge of the fixed hold-down mechanism 202 in the presence of the force of the torsion springs on the fixed hold-down mechanism 202, thus making the automatic expansion type focusing electrode 102 to enter into an expanded condition. In the expanded condition, the external diameter of the automatic expansion type focusing electrode 102 is greater than 175mm.

[0050] Fig. 3 is the diagram for the connection between the electron multiplier 104 and the automatic expansion type focusing electrode 102 according to the present invention. As shown in Fig. 3, the electron multiplier 104 is mainly composed of a multiplier element and an electron collecting structure. The embodiment illustrates the invention in detail with two microchannel plates under superposition as a multiplier element, but it does not act as the limitation to the implementation of the invention.

Wherein, the microchannel plate 1301 is located at the center under the automatic expansion type focusing electrode 102, the microchannel plate 2302 is located under the microchannel plate 1301, and the two microchannel plates are used under superposition to achieve a gain above 1×10^7 . The electrons converge on the anode strip 303 after being amplified by the two microchannel plates, thereby facilitating the extraction, reading and processing of subsequent signals. The position of the electron multiplier 104 and the automatic expansion type focusing electrode 102 is shown in Fig. 3. The electron multiplier 104 is under the automatic expansion type focusing electrode 102, and the two components are connected together through spot welding. At this time, the multiplier element is in the lower central of the automatic expansion type focusing electrode 102, which facilitates to converge and multiply the electrons collected onto its upper surface.

[0051] Fig. 4 is the diagram for the connection between the electron multiplier 104 and the lead wire system 105 according to the present invention. As shown in Fig. 4, the lead wire system 105 is primarily used to extract the relevant electrodes to be loaded with voltage of the electron multiplier 104 and the automatic expansion type focusing electrode 102 and at the same time to extract the signals on the anode strip 303.

[0052] Wherein, the lead wire system 105 mainly comprises the following: the input electrode 401 of the microchannel plate 1, the output electrode 402 of the microchannel plate 1, the input electrode 407 of the microchannel plate 2, the output electrode 408 of the microchannel plate 2, the anode output electrode 403, the output electrode 406 of the expandable focusing electrode, the transitional fastener 404 and the indium sealed lower kovar disc 405. Voltage can be loaded separately to each electrode extracted. These input and output electrodes can be realized by adopting existing ways and will not be described in the present invention.

[0053] Fig. 5 is the diagram for the process of indium sealing according to the present invention. The process of indium sealing is to seal the indium sealed upper kovar disc 501 and the indium sealed lower kovar disc 405 by using indium-tin alloy 502 as the sealing solder, so as to ensure that the interior of the glass vacuum vessel 101 is in a high-vacuum condition.

[0054] Wherein, the whole indium sealing process of the photomultiplier tube in the present invention is carried out automatically in the chamber of ultra-high vacuum equipment. Before sealing, the automatic expansion type focusing electrode 102, the electron multiplier 104 and the lead wire system 105 are connected into a whole, which is located under the glass vacuum vessel 101. At this time, the automatic expansion type focusing electrode 102 is in the folded condition. The automatic expansion type focusing electrode 102, the electron multiplier 104 and the lead wire system 105, as a whole, is called as the tube-core assembly. When the indium sealing process starts, the tube-core assembly begins to rise.

When the automatic expansion type focusing electrode 102 gets in touch with the bottom of the glass vacuum vessel 101, expansion is triggered and the tube-core assembly continues to rise until the indium sealed upper kovar disc 501 and the indium sealed lower kovar disc 405 get in touch and are compressed tightly. During the whole process of indium sealing, the indium-tin alloy 502 is in molten condition all the time.

[0055] Meanwhile, as shown in Figs. 2A and 2B, the tube-core assembly and the high-vacuum sealed shell 101 are sealed together in vacuum equipment in a fully automatic manner. During the sealing process, the trigger mechanism of the automatic expansion type focusing electrode 102 is triggered, thus realizing the expansion of the automatic expansion type focusing electrode 102 as well as the expansion towards the radial dimension of the focusing electrode.

[0056] Although the present invention has been disclosed through the preferred embodiment as described above, they are not intended to limit the invention. Changes and variations may be made by those who have common knowledge in the field of the invention. Therefore, the protection scope of the invention shall be as defined in the claims.

Claims

1. An automatic expansion type focusing electrode (102) for photomultiplier tube, comprising a fixed hold-down mechanism (202), expandable blades (201), a trigger pedal (203), a trigger wire (204) and a trigger ring (205), wherein:

the fixed hold-down mechanism (202) comprises an annular bottom plate (202A) and torsion springs (202B) and rotating shafts (202C) arranged on the bottom plate (202A), wherein the torsion springs (202B) are wound around the rotating shafts (202C);

the multiple expandable blades (201) are arranged along the edge of the bottom plate (202A) and are mounted around the rotating shafts (202C) in a rotating manner; the multiple expandable blades (201) are fixed vertically over the bottom plate (202A) in the initial state, held down by the trigger ring (205) to be folded together in an annular shape and to present in a folded condition;

the torsion springs (202B) are arranged one-to-one with the expandable blades (201), with one end of each torsion spring fixed to the expandable blade (201) and the other end to the bottom plate (202A), and the torsion springs (202B) are arranged to make the expandable blades (201) expand towards the radial dimension of the focusing electrode and to provide a pretightening force;

- the trigger pedal (203), the trigger wire (204) and the trigger ring (205) constitute an automatic trigger mechanism;
 one end of the trigger wire (204) is fixed to the trigger pedal (203) and the other end to the trigger ring (205);
 the trigger pedal (203) is arranged to drive the trigger wire (204) to move when being triggered so as to release the multiple expandable blades (201) from the folded condition due to being held down by the trigger ring (205) and to enter into an expanded condition by the pretightening force from the torsion springs (202B).
2. An automatic expansion type focusing electrode (102) for photomultiplier tube according to Claim 1, wherein, the trigger pedal (203) is located close to the bottom plate (202A) and stretches outward and is arranged to be blocked by an edge of a spherical glass shell when the focusing electrode is sealed with indium into a spherical shell to make it move in the opposite direction of the moving direction of the focusing electrode and drive the trigger wire (204) to move synchronously to release the fastener on the trigger ring (205) and further release the multiple expandable blades (201) from being folded by the trigger ring (205), so as to make the expandable blades (201) enter into a releasable condition and rotate and position along the rotating shaft (202C) on an edge of the fixed hold-down mechanism (202) in the presence of the pretightening force of the torsion springs (202B) and make the focusing electrode enter into an expanded condition.
3. An automatic expansion type focusing electrode (102) for photomultiplier tube according to Claim 1, wherein, the external diameter of the focusing electrode is less than 90 mm when the expandable blades (201) are in the folded condition in the initial state.
4. An automatic expansion type focusing electrode (102) for photomultiplier tube according to Claim 1, wherein, the external diameter of the focusing electrode is greater than 175 mm when the expandable blades (201) are in the expanded condition after being released.
5. A photomultiplier tube comprising:
 a high-vacuum sealed shell (101) composed of a spherical part and a transitional sealing part, with the interior of the shell under an ultra-high vacuum condition;
 a photocathode (103) placed on the inner surface of the high-vacuum sealed shell (101);
 an automatic expansion type focusing electrode (102) according to any one of claim 1 to 4, arranged to collect photoelectrons generated by the high quantum efficiency photocathode (103), the automatic expansion type focusing electrode (102) being located in the interior of the high-vacuum sealed shell (101);
 an electron multiplier (104) placed under the automatic expansion type focusing electrode (102) and arranged to multiply the photoelectrons collected by it;
 a lead wire system (105) placed under the electron multiplier (104) and passing through the transitional sealing part of the high-vacuum sealed shell (101) is arranged to extract electrical signals.
6. A photomultiplier tube according to claim 5, wherein, the automatic expansion type focusing electrode (102) is located in the interior of the high-vacuum sealed shell (101) and between the photocathode (103) and the electron multiplier (104) and is arranged to collect photoelectrons generated by the high quantum efficiency photocathode (103).
7. A photomultiplier tube according to claim 5 or 6, wherein, the photocathode (103) is constructed as a semiconductor film plated by evaporation on the inner surface of the high-vacuum sealed shell (101) that is arranged to convert photons into electrons.
8. A photomultiplier tube according to claim 6 or 7, wherein, the electron multiplier (104) uses two microchannel plates as its multiplier elements, the two microchannel plates being connected in series and under superposition, and the working voltage being loaded respectively.

Patentansprüche

1. Fokussierelektrode (102) eines automatischen Expansionstyps für eine Photovervielfacherröhre, umfassend einen feststehenden Niederhaltemechanismus (202), expandierbare Flügel (201), ein Auslösepedal (203), einen Auslösedraht (204) und einen Auslösering (205), wobei:

der feststehende Niederhaltemechanismus (202) eine ringförmige Bodenplatte (202A) und Torsionsfedern (202B) und rotierende Wellen (202C), die an der Bodenplatte (202A) angeordnet sind, umfasst, wobei die Torsionsfedern (202B) um die rotierenden Wellen (202C) gewickelt sind;
 die mehreren expandierbaren Flügel (201) entlang der Kante der Bodenplatte (202A) angeordnet sind und um die rotierenden Wellen (202C) in einer rotierenden Weise angebracht sind; wobei die mehreren expandierbaren Flü-

- gel (201) im Ausgangszustand vertikal über der Bodenplatte (202A) fixiert sind, wobei sie durch den Auslösering (205) so niedergehalten werden, dass sie in einer ringförmigen Form zusammengefaltete sind und sich in einem gefalteten Zustand präsentieren;
- die Torsionsfedern (202B) eins-zu-eins mit den expandierbaren Flügeln (201) angeordnet sind, wobei ein Ende jeder Torsionsfeder an dem expandierbaren Flügel (201) und das andere Ende an der Bodenplatte (202A) fixiert ist, und die Torsionsfedern (202B) so angeordnet sind, dass sie die expandierbaren Flügel (201) veranlassen, hin zu der radialen Abmessung der Fokussierelektrode zu expandieren und eine Vorspannkraft bereitzustellen;
- das Auslösepedal (203), der Auslösedraht (204) und der Auslösering (205) einen automatischen Auslösemechanismus bilden;
- ein Ende des Auslösedrahts (204) an dem Auslösepedal (203) und das andere Ende an dem Auslösering (205) fixiert ist;
- das Auslösepedal (203) angeordnet ist, bei Auslösen den Auslösedraht (204) anzutreiben, sich so zu bewegen, dass die mehreren expandierbaren Flügel (201) aus dem gefalteten Zustand aufgrund des Niedergedrücktwerdens durch den Auslösering (205) gelöst werden und durch die Vorspannkraft von den Torsionsfedern (202B) in einen expandierten Zustand eintreten.
2. Fokussierelektrode (102) eines automatischen Expansionstyps für eine Photovervielfacherröhre nach Anspruch 1, wobei sich das Auslösepedal (203) nahe zu der Bodenplatte (202A) befindet und nach außen erstreckt und angeordnet ist, durch eine Kante einer Glaskugelschale blockiert zu werden, wenn die Fokussierelektrode mit Indium in einer Kugelschale versiegelt ist, um es zu veranlassen, sich in die entgegengesetzte Richtung zu der Bewegungsrichtung der Fokussierelektrode zu bewegen und den Auslösedraht (204) anzutreiben, sich synchron so zu bewegen, dass das Befestigungselement an dem Auslösering (205) gelöst wird und ferner die mehreren expandierbaren Flügel (201) aus dem Gefaltetsein durch den Auslösering (205) gelöst werden, um die expandierbaren Flügel (201) zu veranlassen, in einen lösbaren Zustand einzutreten und zu rotieren und sich entlang der rotierenden Welle (202C) an einer Kante des feststehenden Niederhaltemechanismus (202) in Gegenwart der Vorspannkraft der Torsionsfedern (202B) zu positionieren und die Fokussierelektrode zu veranlassen, in einen expandierten Zustand einzutreten.
 3. Fokussierelektrode (102) eines automatischen Expansionstyps für eine Photovervielfacherröhre nach Anspruch 1, wobei der Außendurchmesser der Fokussierelektrode kleiner als 90 mm ist, wenn sich die expandierbaren Flügel (201) in dem gefalteten Zustand im Ausgangszustand befinden.
 4. Fokussierelektrode (102) eines automatischen Expansionstyps für eine Photovervielfacherröhre nach Anspruch 1, wobei der Außendurchmesser der Fokussierelektrode größer als 175 mm ist, wenn sich die expandierbaren Flügel (201) in dem expandierten Zustand nach einem Auslösen befinden.
 5. Photovervielfacherröhre, umfassend:
 - eine versiegelte Hochvakuumchale (101), die aus einem Kugelteil und einem Übergangsversiegelungsteil besteht, wobei sich das Innere der Schale in einem Ultra-Hochvakuumzustand befindet;
 - eine Photokathode (103), die an der Innenfläche der versiegelten Hochvakuumchale (101) platziert ist;
 - eine Fokussierelektrode (102) eines automatischen Expansionstyps nach einem der Ansprüche 1 bis 4, die angeordnet ist, durch die Photokathode (103) mit hoher Quantenausbeute erzeugte Photoelektronen aufzunehmen, wobei sich die Fokussierelektrode (102) eines automatischen Expansionstyps im Inneren der versiegelten Hochvakuumchale (101) befindet;
 - einen Elektronenvervielfacher (104), der unter der Fokussierelektrode (102) eines automatischen Expansionstyps platziert und angeordnet ist, die durch sie aufgenommenen Photoelektronen zu vervielfachen;
 - wobei ein Anschlussdrahtsystem (105), das unter dem Elektronenvervielfacher (104) platziert ist und durch den Übergangsversiegelungsteil der versiegelten Hochvakuumchale (101) verläuft, angeordnet ist, elektrische Signale zu extrahieren.
 6. Photovervielfacherröhre nach Anspruch 5, wobei sich die Fokussierelektrode (102) eines automatischen Expansionstyps im Inneren der versiegelten Hochvakuumchale (101) und zwischen der Photokathode (103) und dem Elektronenvervielfacher (104) befindet und angeordnet ist, durch die Photokathode (103) mit hoher Quantenausbeute erzeugte Photoelektronen aufzunehmen.
 7. Photovervielfacherröhre nach Anspruch 5 oder 6, wobei die Photokathode (103) als ein Halbleiterfilm ausgestaltet ist, der durch Verdampfung auf die Innenfläche der versiegelten Hochvakuumchale (101) plattiert ist, die angeordnet ist, Photonen in Elektronen umzuwandeln.
 8. Photovervielfacherröhre nach Anspruch 6 oder 7,

wobei der Elektronenvervielfacher (104) zwei Mikrokanalplatten als seine Vervielfacherelemente nutzt, wobei die zwei Mikrokanalplatten in Reihe und unter Überlagerung verbunden sind, und die Arbeitsspannung entsprechend gespeist wird.

Revendications

1. Électrode de focalisation de type à agrandissement automatique (102) pour tube photomultiplicateur, **caractérisée en ce qu'elle** comprend un mécanisme de retenue fixe (202), des lames agrandissables (201), une pédale de déclenchement (203), un fil de déclenchement (204) et une bague de déclenchement (205), dans laquelle :

le mécanisme de retenue fixe (202) comprend une plaque inférieure annulaire (202A) et des ressorts de torsion (202B) et des arbres rotatifs (202C) agencés sur la plaque inférieure (202A), dans laquelle les ressorts de torsion (202B) sont enroulés autour des arbres rotatifs (202C) ; les multiples lames agrandissables (201) sont agencées le long du bord de la plaque inférieure (202A) et sont montées autour des arbres rotatifs (202C) de manière rotative ; les multiples lames agrandissables (201) sont fixées verticalement sur la plaque inférieure (202A) dans l'état initial, retenues par la bague de déclenchement (205) pour être pliées ensemble en une forme annulaire et pour se présenter dans une condition pliée ; les ressorts de torsion (202B) sont agencés un-à-un avec les lames agrandissables (201), avec une extrémité de chaque ressort de torsion fixée à la lame agrandissable (201) et l'autre extrémité à la plaque inférieure (202A), et les ressorts de torsion (202B) sont agencés pour faire en sorte que les lames agrandissables (201) s'agrandissent vers la dimension radiale de l'électrode de focalisation et pour fournir une force de préserrage ; la pédale de déclenchement (203), le fil de déclenchement (204) et la bague de déclenchement (205) constituent un mécanisme de déclenchement automatique ; une extrémité du fil de déclenchement (204) est fixée à la pédale de déclenchement (203) et l'autre extrémité à la bague de déclenchement (205) ; la pédale de déclenchement (203) est agencée pour forcer le fil de déclenchement (204) à se déplacer lors du déclenchement afin de libérer les multiples lames agrandissables (201) à partir de la condition pliée due à l'état retenu par la bague de déclenchement (205) et pour entrer dans une condition agrandie grâce à la force de

préserrage provenant des ressorts de torsion (202B).

2. Électrode de focalisation de type à agrandissement automatique (102) pour tube photomultiplicateur selon la revendication 1, dans laquelle la pédale de déclenchement (203) est située près de la plaque inférieure (202A) et s'étire vers l'extérieur et est agencée pour être bloquée par un bord d'une enveloppe en verre sphérique lorsque l'électrode de focalisation est scellée avec de l'indium dans une enveloppe sphérique pour faire en sorte qu'elle se déplace dans la direction opposée de la direction de déplacement de l'électrode de focalisation et forcer le fil de déclenchement (204) à se déplacer de façon synchrone pour libérer le dispositif de fixation sur la bague de déclenchement (205) et en outre libérer les multiples lames agrandissables (201) à partir de l'état plié par la bague de déclenchement (205), afin de faire en sorte que les lames agrandissables (201) entrent dans une condition libérable et entrent en rotation et se positionnent le long de l'arbre rotatif (202C) sur un bord du mécanisme de retenue fixe (202) en présence de la force de préserrage des ressorts de torsion (202B) et de faire en sorte que l'électrode de focalisation entre dans une condition agrandie.
3. Électrode de focalisation de type à agrandissement automatique (102) pour tube photomultiplicateur selon la revendication 1, dans laquelle le diamètre externe de l'électrode de focalisation est inférieur à 90 mm lorsque les lames agrandissables (201) sont dans la condition pliée dans l'état initial.
4. Électrode de focalisation de type à agrandissement automatique (102) pour tube photomultiplicateur selon la revendication 1, dans laquelle le diamètre externe de l'électrode de focalisation est supérieur à 175 mm lorsque les lames agrandissables (201) sont dans la condition agrandie après avoir été libérées.
5. Tube photomultiplicateur, comprenant :
 - une enveloppe scellée sous vide poussé (101) composée d'une partie sphérique et d'une partie de scellage transitionnelle, avec l'intérieur de l'enveloppe dans une condition sous ultravide ;
 - une photocathode (103) placée sur la surface intérieure de l'enveloppe scellée sous vide poussé (101) ;
 - une électrode de focalisation de type à agrandissement automatique (102) selon l'une quelconque de la revendication 1 à 4, agencée pour collecter des photoélectrons générés par la photocathode à haut rendement quantique (103), l'électrode de focalisation de type à agrandissement automatique (102) étant située à l'intérieur

de l'enveloppe scellée sous vide poussé (101) ;
un multiplicateur d'électrons (104) placé sous
l'électrode de focalisation de type à agrandisse-
ment automatique (102) et agencé pour multi-
plier les photoélectrons collectés par celle-ci ; 5
un système de fil de sortie (105) placé sous le
multiplicateur d'électrons (104) et passant à tra-
vers la partie de scellage transitionnelle de l'en-
veloppe scellée sous vide poussé (101) est
agencé pour extraire des signaux électriques. 10

6. Tube photomultiplicateur selon la revendication 5,
dans lequel l'électrode de focalisation de type à
agrandissement automatique (102) est située à l'in-
térieur de l'enveloppe scellée sous vide poussé 15
(101) et entre la photocathode (103) et le multiplica-
teur d'électrons (104) et est agencée pour collecter
des photoélectrons générés par la photocathode à
haut rendement quantique (103).

20

7. Tube photomultiplicateur selon la revendication 5 ou
6, dans lequel la photocathode (103) est construite
sous forme de film semi-conducteur plaqué par éva-
poration sur la surface intérieure de l'enveloppe scel-
lée sous vide poussé (101) qui est agencée pour 25
convertir des photons en électrons.

8. Tube photomultiplicateur selon la revendication 6 ou
7, dans lequel, le multiplicateur d'électrons (104) uti-
lise deux plaques à micro-canaux en tant que ses 30
éléments multiplicateurs, les deux plaques à micro-
canaux étant connectées en série et sous superpo-
sition, et la tension de fonctionnement étant chargée
respectivement.

35

40

45

50

55

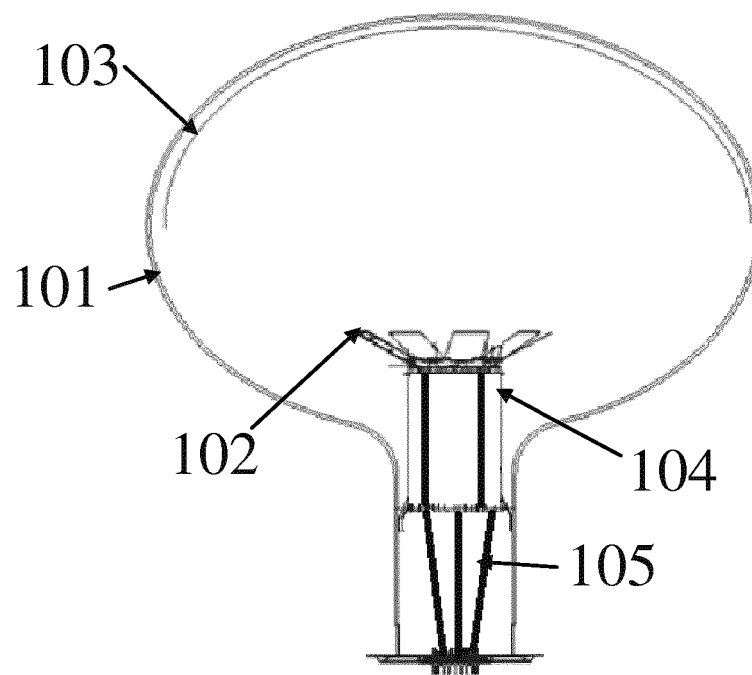


Fig. 1

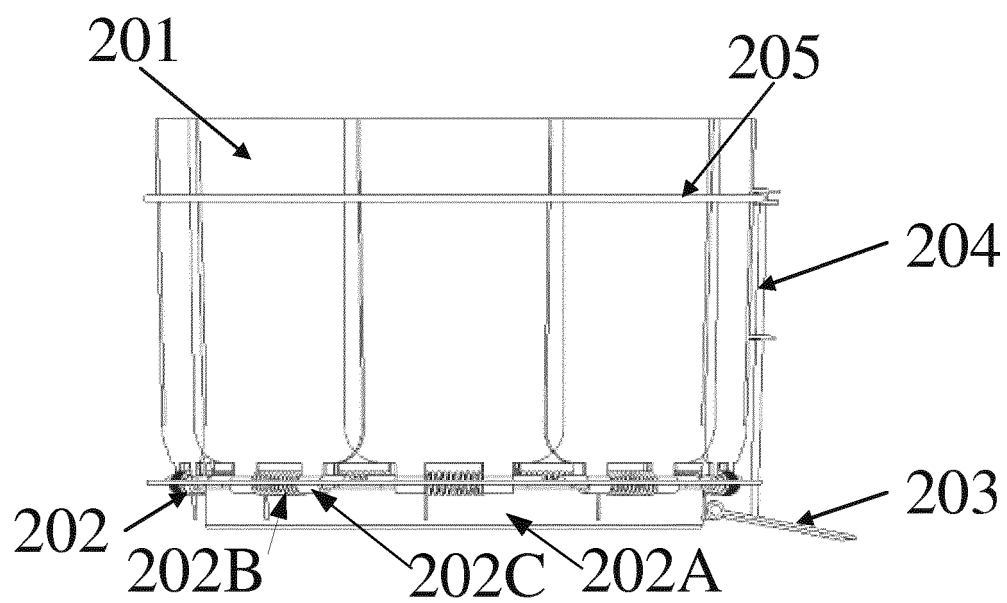


Fig. 2A

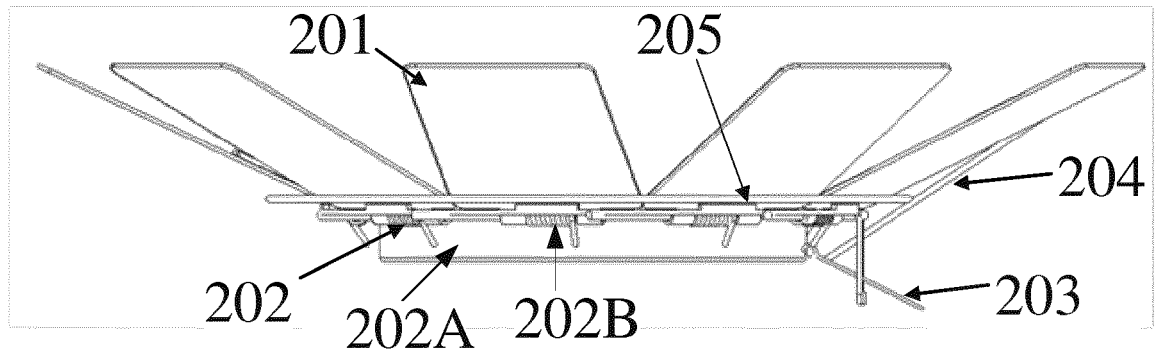


Fig. 2B

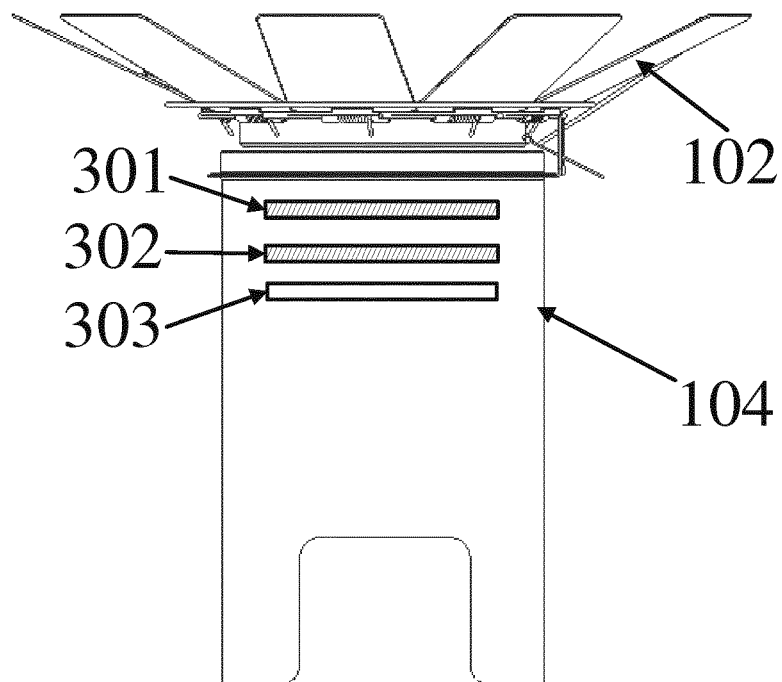


Fig. 3

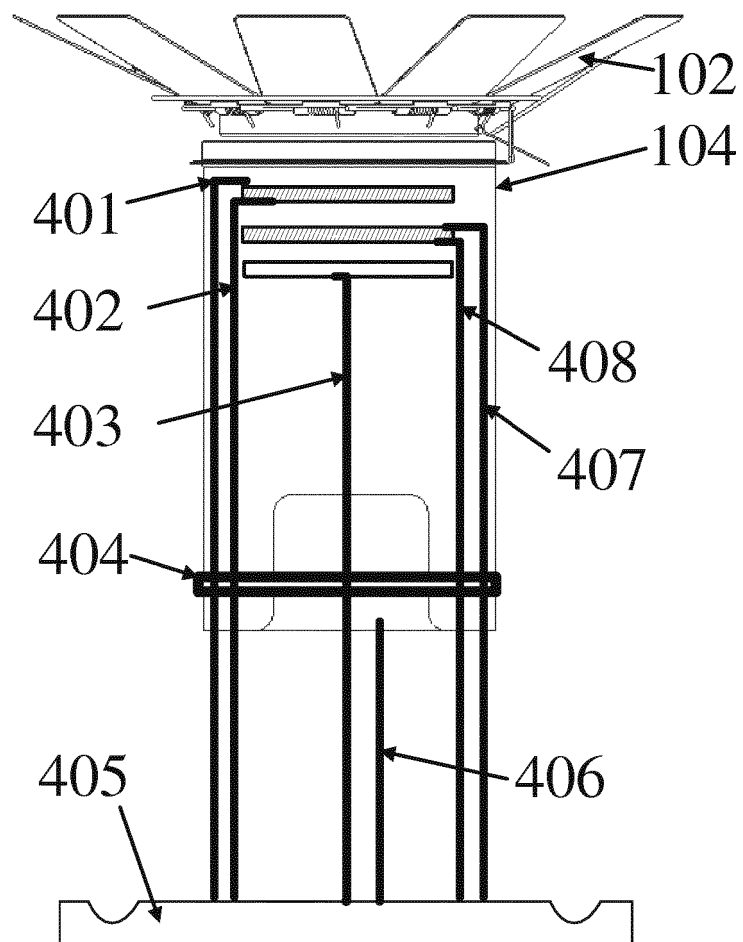


Fig. 4

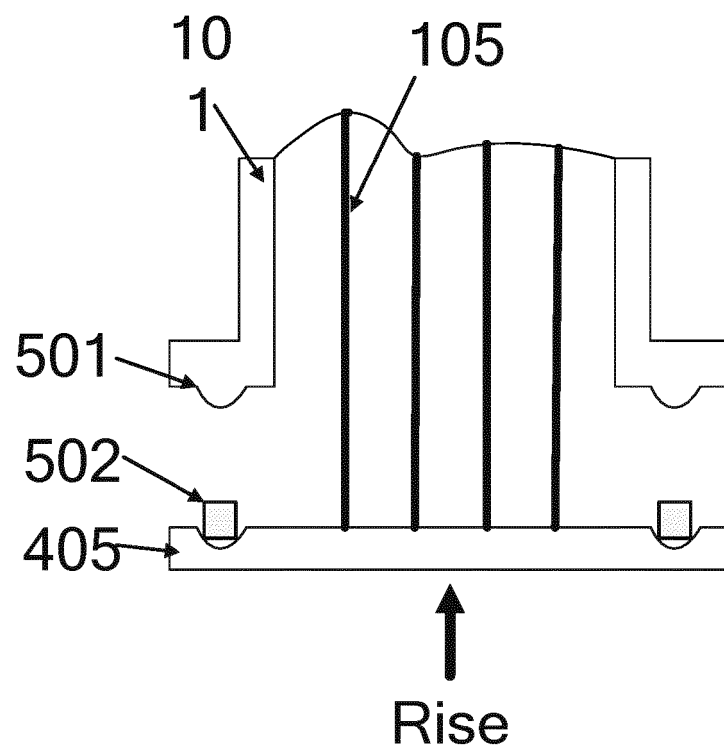


Fig. 5

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2015139344 A1 [0003]
- CN 105570750 A [0004]
- JP H02288145 A [0005]
- EP 0713243 A [0006]