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(54) PHOTO-ELECTRON AMPLIFYING DEVICE

(71) We, N.V. PHILIPS' GLOEILAMPENFABRIEKEN, a limited liability Company, organised and established under the laws of the Kingdom of the Netherlands, of Emmasingel 29, Eindhoven, the Netherlands do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

The invention relates to a photo-electron amplifying device and to an image intensifier tube.

Devices of this kind are used, for example, in medical X-ray apparatus, scintography and X-ray analysis apparatus. In such devices, an image-carrying radiation beam, for example a beam of X-ray or gamma radiation, is incident on an entrance screen of an image intensifier tube. At the entrance screen of the image intensifier tube, the image-carrying beam is converted into an image-carrying beam of photoelectrons. The electron beam is focussed onto a luminescent exit screen of the image intensifier tube by means of an electron-optical system included in the tube. A problem is encountered in that the quality of the electron optical image-forming process in the image intensifier tube is adversely affected by external magnetic fields. Examples of disturbing magnetic fields are: the terrestrial magnetic field and magnetic fields originating from deflection coils, power supply equipment for the radiation source, electrically driven motors, magnetic braking devices etc.

German Offenlegungsschrift No. 2306575 (Schiegel 14.8.1974) describes an X-ray image intensifier tube including a ferromagnetic foil which is arranged in front of the entrance screen. This foil is magnetically integral with a cylinder of ferromagnetic material which is arranged around the image intensifier tube. The object is to reduce the effect of disturbing magnetic fields. However, a foil of this kind has the drawback that besides the absorption of stray radiation, part of the image-forming radiation is also absorbed by the foil; the foil moreover causes additional scattering of the image-forming beam. A reduction of this effect by choosing the foil to be comparatively thin, has the drawback that the magnetic screening is then insufficient.

The invention has for an object to provide an improved device in which suitable magnetic screening can be provided. According to the invention there is provided the combination of a photo-electron amplifying device in which input radiation directed onto an input screen provides a corresponding flow of photo-emissive electrons the effect of which is intensified or amplified by said device, and a grid-like element arranged adjacent said input screen and formed at least partly from magnetic screening material, the arrangement being such that said grid-like element can function, optionally together with a conventional magnetic screening jacket applied about said photo-electron amplifying device, to reduce the magnitude of an ambient magnetic field in the region in said device in which the process of intensifying or amplifying the electron flow takes place, when compared with said magnitude in the absence of said grid-like element. Because the screening material is arranged in the form of a gird such a grid can be located to provide a comparatively large amount of magnetic screening material in front of the entrance screen, so that ample screening can be provided without an undesirable amount of absorption or dispersion of the image-carrying radiation beam occuring.

In a preferred embodiment of the invention, laminations of a stray radiation grid consist completely of ferromagnetic material, the grid forming a substantially continuous magnetic screen with a ferromagnetic jacket which surrounds the image intensifier tube.

In respect of the grid structure, laminations are to be understood herein to mean thin plates, in general spaced apart, to form the grid structure and arranged substantially edge-on to radiation which it is desired to pass through the grid.

In a further embodiment, the laminations of a stray radiation grid are formed partly of a commonly used grid material, such as lead, and partly of ferromagnetic material, such as, for example, mu-metal. Both requirements to be imposed, i.e. an adequate amount of magnetic screening and an adequate degree of collimation, can be optimally satisfied by a suitable choice of the relative amounts of each kind of material and of the geometry. In this case the stray ray grid can also form the magnetic screening grid and no additional magnetic grid need be provided. A stray radiation grid in such an embodiment of the invention may be constructed, as desired, to be integral with the image intensifier tube, or to be a detachable independent element, or to be a part of the image-forming device. In a further preferred embodiment of the invention, the magnetic screening material forms part of an element included in the image intensifier tube. Notably ferromagnetic material is included in the image intensifier tube. Notably ferromagnetic material is included in the channel amplifier plate of an image intensifier tube comprising a channel amplifier plate.

In order that the invention may be clearly understood and readily carried into effect various embodiments of the invention will now be described by way of example, with reference to the accompanying drawing, the single figure of which shows diagrammatically an image-forming device embodying the invention which is constructed as an X-ray examination device.

The drawing shows the following parts of an X-ray examination device: an X-ray source 1, with a high voltage power supply 2, a patient table 3 for a patient 4 to be examined, and X-ray image intensifier tube 5, an output objective 6, a semi-transparent mirror 7, a film camera 8, a television camera tube 9, with beam deflection coils 10, and a television monitor 11. Apart from the terrestrial magnetic field, the following magnetic fields can also disturb electron-optical image formation in the X-ray image intensifier tube 5 magnetic fields caused respectively by the high voltage power supply 2, by the deflection coils 10 of the camera tube 9, by the deflection coils of the monitor 11, and by magnetic braking devices (not shown) which are often included in a patient table or stand forming part of the device. The X-ray image intensifier tube 5 comprises an entrance window 12 on the inner surface of which is formed an X-ray phosphor screen, preferably of CsI forming an entrance screen and a photocathode (not separately shown), an exit window 14 provided on the inner surface with an exit screen 13, and an electron-optical system which includes, apart from the photocathode on the entrance window 12 and an electrically conducting layer forming part of the exit screen 13, one or more intermediate focussing electrodes 15. An incident radiation beam 16 irradiates the patent 4 and a transmitted, image-carrying X-ray beam 17 is incident on the entrace screen of the intensifier tube 5. The X-ray beam 17 incident on the entrance screen, is converted into an image-forming beam of photoelectrons 18 which is accelerated by a potential difference of, for example, 25 kV and forms a corresponding electron image display on the exist screen 13. An image-carrying light beam 19 is emitted *via* the exit window 14, and this can be used, as desired, to expose a photographic plate or to form a television image.

That part of the image-forming process which is situated inside the image intensifier tube and involves an electron beam, will be susceptible to deflection by stray magnetic fields and will be distorted thereby, because the image transfer is effected by electrons at this point. Notably in the vicinity of the entrance screen, where the electrons have only a comparatively low velocity, a magnetic field will tend to have a comparativley large effect on the direction of the electrons and hence on image formation. Between the patient and the image intensifier tube there is arranged a stray radiation grid 20. In this grid, X-rays whose propagation direction deviates considerably from the general propagation direction of the beam 17, for example, due to the effect of scattering within the patient, will be intercepted. A stray radiation grid of this kind, therefore, preferably consists of laminations of a comparatively heavy element such as lead. A single grid comprises laminations having a thickness of, for example, 50μm which are arranged at a distance of, for example, 250μm from each other. The function or the shape of the grid is not relevant to the present invention and any grid normally used in the corresponding system can be used. For example, use is also made of cross-hatch girds which are formed, for example, by arranging two single grids one behind the other, the plates of one grid being rotated through 90° about the system axis. In an embodiment of the invention, at least a portion of the stray radiation grid is made of ferromagnetic material, such as, for example, mu-metal. The ferromagnetic material may replace all the normally used grid material. Alternatively the laminations of the grid structure may be arranged so that alternate laminations in the stacking sequence are respectively formed of ferromagnetic material and of a heavy metal, or in a sequence with fewer ferromagnetic laminations than heavy metal laminations. Alternatively, each of the grid laminations can also be made partly of a heavy metal and partly of a ferromagnetic material. This can be effected by forming each grid plate either as a double-layered structure or as an alloy of a heavy metal and a ferromagnetic material. Alloys for this purpose can be formed, for example, by sintering a powder comprising a mixture of both metals in a mixture ratio which can be selected as desired, the hot mass being quickly cooled, for example, while rolling into the form of a foil. Alloys are thus obtained which are sometimes also referred to as amorphous metals. When two grids are employed in tandem, one of the grids can be made of a heavy metal and the other of a ferromatnetic material. When the laminations of one grid are arranged parallel to the laminations of the other grid, the laminar structure of both grids must have exactly the same pitch.

Following the said state of the art, it has been proposed to use a foil of "Mumetal" (Trade Mark), having a thickness of from 10 to 70 μm, arranged in front of the entrance window of an image intensifier tube. Calculations performed on known X-ray image intensifier tubes reveal that a "Mumetal" (Trade Mark) foil thickness of approximately 50μm represents a reasonable compromise between the degree of screening and the degree of absorption and dispersion, but the amount of screening is far from optimum. In a device embodying the invention, however, a thickness equivalent of, for example, 300 μm "Mumetal" (Trade Mark) can be readily provided without giving rise to any additional absorption or dispersion of the image forming X-ray beam. In the described embodiment, a suitable magnetic connection is preferably ensured between the stray radiation grid embodying the invention and a ferromagnetic jacket 21 which is usually arranged around the image intensifier tube. To provide this, the jacket 21 may be slightly extended towards the front, the stray radiation grid being adapted thereto. Normally, at the exit end of the tube the magnetic screening jacket 21 of the image intensifier tube will extend as far as possible towards the output window or even to the output objective lens 6. The penetration of disturbing magnetic fields *via* the exit window can thus be sufficiently reduced.

For the described embodiment, it is assumed that an X-ray examination device is concerned in which an already present stray radiation grid is replaced by a grid embodying the invention. In an alternative arrangement a grid embodying the invention is added to a device which already includes a stray radiation grid or in which a stray radiation grid is not required. If a stray radiation grid is already present, the additional magnetic screening grid is prefereably arranged at an angle of 90° with respect thereto. A preferred position for the magnetic screening grid is again situated as near as possible to the entrance window of the image intensifier tube. In devices in which a stray radiation grid is arranged in a position spaced in fron of the image intensifier tube, for example, in order to enable large pictures to be made, the stray radiation grid is then mounted at a comparatively large distance from the image intensifier tube and it is then advantageous to provide an additional grid formed as a magnetic screening grid. When a magnetic screening grid embodying the invention is used in a device where the image intensifier tube is not provided with a ferromagnetic jacket, the grid is preferably provided with a glange of ferromagnetic material which extends rearward around at least a part of the image intensifier tube.

In one form of a magnetic screening grid embodying the invention, the laminations are made of a strip-like core of ferromagnetic material which is provided with a covering layer of heavy metal either on both major surfaces or on all surfaces. Preferably, a tin-lead solder is used as the heavy metal.

Besides applications in X-ray examination devices, a device embodying the invention can also be advantageously used in, for example, a gamma camera in which an image intensifier tube is used for the recording of scintillations. A gamma camera includes a stray radiation grid in the form of a collimator. An adapted screening grid embodying the invention can be added to this collimator, or ferromagnetic material can be included in the collimator.

A substantial improvement in image formation can be achieved in infrared viewers including a light intensifier tube, by the use of a screening grid embodying the invention. Even though stray radiation grids are not often used in such viewers, the use of a transverse screening foil of ferromagnetic material is not possible due to its complete absorption of infrared radiation. A screening grid embodying the invention, adapted to the resolution of the entrance screen, can provide significant advantage in this case, especially with respect to the terrestrial magnetic field which can have a strongly disturbing effect, if such screening is not used, due to the frequently changing orientation of the device during measurement.

In some modern image intensifier tubes, notably light intensifier tubes, the electron-opical system includes a channel amplifier plate. Because an image-carrying electron beam also occurs therein, an embodiment of the invention can include a magnetic screen formed by including ferromagnetic material in the channel amplifier plate or by making the channel plate at least partly of ferromagnetic material.

WHAT WE CLAIM IS:-

1. The combination of a photo-electron amplifying device in which input radiation directed onto an input screen provides a corresponding flow of photo-emissive electrons the effect of which is intensified or amplified by said device, and a grid-like element arranged adjacent said input screen and formed at least partly from magnetic screening material, the arrangement being such that said grid-like element can function, optionally together with a conventional magnetic screening jacket applied about said photoelectron amplifying device, to reduce the magnitude of an ambient magnetic field in the region in said device in which the process of intensifying or amplifying the electron flow takes place, when compared with said magnitude in the absence of said grid-like element.

2. The combination claimed in Claim 1, wherein said photo-electron amplifying device is an image intensifier tube including a channel amplifier plate and said grid-like element is formed by said channel amplifier plate.

3. The combination claimed in Claim 1, wherein said grid-like element is arranged in the path of input radiation directed at said photo-

electron amplifying device so as to provide radiation transparent regions through which said input radiation can pass freely to said input screen.

4. The combination claimed in Claim 3, wherein said grid-like element is formed as a stray-radiation grid, the structure of which includes ferromagnetic material.

5. The combination claimed in Claim 4, wherein said grid-like element comprises interspersed laminations of ferromagnetic material and radiation-transparent laminar regions.

6. The combination claimed in Claim 4, wherein said grid-like element comprises interspersed radiation absorbing laminations, ferromagnetic laminations and radiation-transparent laminar regions.

7. The combination claimed in Claim 4, wherein said grid-like element comprises a plurality of spaced multi-layer laminations each formed by at least a respective layer of ferromagnetic and of radiation absorbing material.

8. The combination claimed in Claim 4, wherein the structure of said grid-like element includes a mixture of radiation absorbing material and ferromagnetic material.

9. The combination claimed in any one of the preceding Claims and including a magnetic screening jacket arranged about at least that portion of said photo-electron amplifying device adjacent said input screen and said grid-like element is arranged to form a substantially continuous magnetic screen with said magnetic screening jacket.

10. A gamma camera including the combination claims in Claim 1 or in any one of Claims 3 to 9, wherein said photo-electron amplifying device comprises a photomultiplier tube.

11. The combination of an X-ray image intensifier tube, and a magnetic screening grid arranged in the vicinity of an entrance window of the X-ray intensifier tube.

12. An image forming device, including an image intensifier tube, wherein a magnetic screening material is included in a grid-like element which is arranged in the vicinity of an entrance window of the image intensifier tube.

13. An image-forming device as claimed in Claim 12, wherein the grid-like element is constructed as a stray radiation grid the structure of which includes ferromagnetic material.

14. An image-forming device as claimed in Claim 13, wherein the grid-like element is formed by interspersed laminations of ferromagnetic material and laminations of radiation-transparent material.

15. An image-forming device as claimed in Claim 13, wherein the grid-like element comprises, interspersed radiation transparent laminations, ferromagnetic laminations and radiation absorbing laminations.

16. An image-forming device as claimed in Claim 13, wherein the grid-like element comprises spaced multi-layer laminations each formed by at least a respective layer of ferromagnetic and of radiation absorbing material.

17. An image-forming device as claimed in Claim 13, wherein the structure of said grid-like element includes a mixture of radiation absorbing material and ferromagnetic material.

18. An image-forming device as claimed in any one of Claims 12 to 17, wherein said screening jacket arranged about at least the adjacent portion of the image intensifier tube.

19. An image-forming device as claimed in any one of Claims 12 to 18, in which said image intensifier tube is an X-ray image intensifier tube and including an X-ray source arranged to project a radiographic image of an object *via* said grid-like element onto said entrance window.

20. An image-forming device as claimed in any one of Claims 12 to 18, constructed as a gamma camera which comprises a light intensifier tube with a screening grid.

21. A gamma camera including scintillation means, a collimator formed by a stray radiation grid and an image-forming device as claimed in any one of Claims 12 to 18, in which said image intensifier means is arranged to sense scintillations occurring in said scintillation means.

22. An image-forming device substantially as herein described with reference to the accompanying drawing.

R.J. BOXALL.
Chartered Patent Agent
Berkshire House
168-173 High Holborn
London WC1V 7AQ
Agent for the Applicants

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