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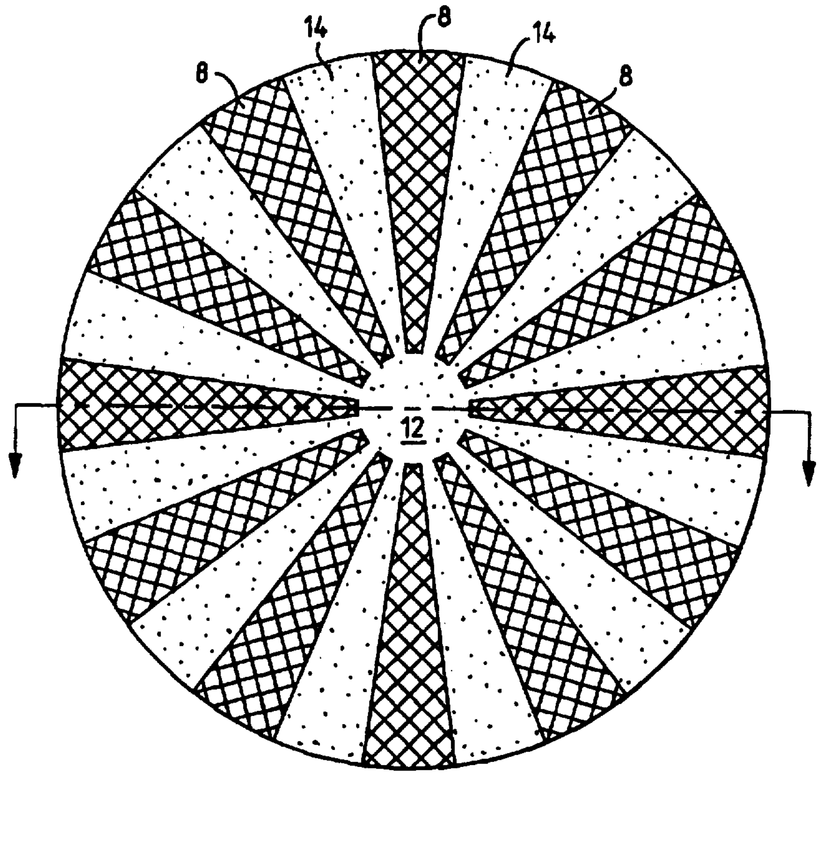
(57) Abstract

An X-ray beam attenuator includes an attenuator plate (2) for location between an X-ray source (3) and an X-ray detector (5). The attenuator plate comprises a central window (12) of low beam attenuation and, radiating from the central window (12), a plurality of alternating segments of high and low X-ray attenuation (8, 14). During use, the attenuator plate (2) is rotated at speeds exceeding several hundred revolutions per minute. Beams passing through the central window provide a high quality, highly contrasting image, for imaging a region of interest, with the remaining incident beams providing an image of adequate quality and contrast. The invention reduces the exposure of a patient to X-rays, whilst not altering the characteristics of the X-ray beam. Thus, for example, image enhancement is rendered simple.



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AN X-RAY BEAM ATTENUATOR

This invention relates to an X-ray beam attenuator. More particularly, but not exclusively, the invention relates to an X-ray beam attenuator which is suitable for use in apparatus for the X-ray imaging of objects and more particularly of humans or other animals.

X-ray beams and X-ray sensitive detectors are widely used to image humans, animals and objects. Within the whole image field of view there is often a sub-portion of the image which is of particular interest. In this specification, this sub-portion is referred to as the "region of interest" (ROI). The highest image quality is required within the region of interest, whilst outside the region of interest, poorer image quality may be tolerated in some circumstances.

When recording X-ray images, it is desirable to obtain a high quality image whilst using the lowest possible X-ray exposure. This is due to the possible harmful effects of prolonged or repeated exposure upon a subject.

The prior art includes beam attenuators which aim to meet these objectives, but which modify the X-ray beam spectrum between the region of interest and the remainder of the image. This variation of the X-ray beam spectrum is detrimental, since it causes a loss of image contrast in the area outside the region of interest. Furthermore, such attenuators do not enable the accurate and simple matching of modified images inside and outside the region of interest, for example those as obtained with prior art systems. Thus when presenting a modified image for viewing, enhancement or digital analysis, complex and/or lengthy image enhancement procedures may be required. These can be difficult to implement and may require additional computer processing facilities.

An example of one type of X-ray beam attenuator is described in United Kingdom Patent Application GB-A-2132460 (Grady). The arrangement described has a slotted mask which opens but appears to limit radiation by scattering between an X-ray source and a patient. The mask rotates synchronously with a matched mask between the patient and an image detector. The arrangement reduces detrimental scattered radiation, but does not reduce the radiation dose received by the patient. It produces only one region of intensity of X-rays. Compared to the present invention, the arrangement is also large and cumbersome.

Another arrangement is described in a paper by Rudin and Bednarek in Medical Physics Vol. 19 No.5. Sept/October 1992 at pages 1183 to 1189. The arrangement discusses the problem of real time imaging, it discloses a compensator which provides an observer effectively with a compensated image. Two sub-regions A and B have different X-ray transmissivities in order to produce an enhanced image in region A with an acceptable image in region B, and with an overall dose reduction due to reduced X-ray transmission through region B. A problem with the arrangement was that the means of reducing X-ray transmission in region B also altered the characteristics of the X-ray beam, specifically by altering the X-ray energy spectrum compared to the beam incident upon the region, whereas the X-ray spectrum is unaltered in region A. This is important since it is the X-ray energy spectrum which determines the transmission of an X-ray beam through a given object, and in particular it determines the contrast observed between different structures within that object.

A similar arrangement is described by Labbe *et al.* in Medical Physics, Vol. 21, No. 3 (1994) at pages 471-481. Labbe's arrangement also suffered from similar drawbacks to those described by Rudin.

The arrangements described by Rudin *et al.* and Labbe *et al.* therefore alter the fundamental X-ray beam transmission properties across the whole field of view between regions A and B. This creates a practical problem for image restoration since the restoration multiplication factor is affected by the change in X-ray energy spectrum and the particular object (thickness, composition) being imaged. The value of any correction factor therefore depends upon the object, and so is therefore subject to approximation in any automatic or semi-automatic image restoration procedure.

The present invention sets out to provide an X-ray beam attenuator which :-

(i) Improves image quality (specifically, image contrast) within the region of interest of an image;

(ii) Provides adequate image quality in the remainder of the image outside of the region of interest, in particular preserving image contrast through the provision of an X-ray beam having an X-ray energy spectrum that is approximately constant over the whole image field of view;

(iii) Reduces radiation exposure to the subject being imaged;

(iv) Allows variation in the location and size of the region of interest relative to the whole image; and

(v) Allows variation in the exposure reduction.

According to a first aspect of the invention there is provided an attenuator plate for an X-ray attenuator comprising first and second regions, the first region having a relatively higher X-ray transmissivity than the second region, means provided to displace at least said first region with respect to an X-ray detector such that X-rays from an X-ray source incident on the first region are attenuated by it thereby reducing the average X-ray exposure to an object placed between the attenuator plate and the imaging surface is reduced.

According to a second aspect of the invention there is provided an X-ray attenuator comprising an attenuator plate adapted to be inserted between an X-ray source and an object to be imaged, the plate comprising first and second regions of differing X-ray transmissivity, characterised in that, in use, the first region is substantially transparent to X-rays which illuminate the object at a region of interest and the second region is substantially X-ray opaque, said second region being disposed on at least a portion of said plate and being displaced relative to the object so that alternate first and second regions intercept the X-ray beam thereby providing a time varying flux on the surface of an object adjacent or surrounding that part of the object viewed within the region of interest, the integral value with respect to time of the time varying flux is less than the integral value with respect to time of the flux impinging the surface of an object viewed within the region of interest.

Preferably there is no variation of X-ray beam energy spectrum characteristics during operation of the invention. Thus only the average X-ray dose is reduced, in the region adjacent or surrounding the region of interest.

Preferably the attenuator plate is adapted to rotate, with the second regions being disposed in a radial form thereon. However, it will be appreciated that the second regions may be in the form of shutters which may open and close. What is important is that during one time interval the attenuator plate is effective to attenuate X-rays and that during a subsequent interval the X-ray beam is able to pass along the same axis unattenuated.

In the present invention the X-ray beam spectrum is constant between the two regions of transmissivity. This is achieved by having one of the regions subdivided into sub-regions with either completely transmitting or completely opaque (or effectively opaque), and then by moving these sub-regions with respect to the object to achieve uniform transmission of X-rays through the second region during the X-ray image formation time.

Use of the present invention allows control of the percentage reduction in a region of transmissivity due to the ability to have sub-regions of size and alignment which are changed under the operator's control.

According to a third aspect of the invention there is provided an X-ray attenuator comprising a body for transmitting X-rays; the said body including a first region having a first transmissivity to X-rays and a second region having a second transmissivity to X-rays; and positioning means for positioning the body relative to an X-ray source in such a manner as to enable transmission of X-rays via at least one of the said first region and the said second region, to provide an image, including a region of interest, at a detector.

According to a third aspect of the invention there is provided a method of X-ray imaging an object comprising directing a beam of X-rays at the object and spatially pulsing part of the beam, in order to reduce the average X-ray exposure at a particular location at which that part of the beam is incident.

Preferably, the method comprises interrupting part of the beam repeatedly to cause it to pulse. Relative motion between the attenuator and image detector produces an averaging of the absorption along an X-ray path for the X-ray focus through the second region and its moving sub-region such that within an image exposure time the average transmission of X-ray through the second region is reduced.

In a preferred embodiment the method comprises:

(i) generating an X-ray beam;

(ii) directing the beam at a first X-ray beam attenuator body;

(iii) displacing the X-ray beam attenuator body in a plane transverse to the X-ray beam so as to produce a first region having a first transmissivity and a second region having a second average transmissivity;

(iv) transmitting the X-ray beam via the X-ray beam attenuator; and

(v) detecting the transmitted X-ray beam using a detector. wherein one of the first and second regions transmits X-rays for imaging a region of interest.

A preferred embodiment of the invention will now be described by way of example and with reference to the accompanying drawings in which:-

Figure 1 is a schematic view, showing a positional relationship between a beam attenuator in accordance with the invention, an X-ray source and an X-ray detector;

Figure 2 is a plan view of the attenuator plate of the arrangement of Figure 1 with a top layer removed for clarity;

Figure 3 is a cross-section along the line III-III of Figure 2;

Figure 4 is a schematic partially perspective view showing details of the arrangement of Figure 1;

Figure 5 shows a partial section of an X-ray attenuator, held within a mounting and drive device, for installation between an X-ray source and an object;

Figure 6 is a graph of Scatter to Primary Ratio against beam stop diameter;

Figure 7 is a graph of pixel values against pixel number from images of a contrast filled catheter image with and without the X-ray attenuator, showing the improvement in contrast obtained when the attenuator is used; and

Figure 8 is a graph showing differential fluence photons of incident and attenuated spectra against photon energy.

Referring to Figure 1, an X-ray imaging system comprises an X-ray generating device 3, which may be of any conventional type; and an X-ray beam attenuator, which comprises a mounting unit 1, which is fitted over the exit window of the X-ray generating device 3; and an attenuator plate 2, mounted in and held in position by the mounting unit 1. The mounting unit 1 positions the attenuator plate 2 in X-ray beam 6 and thereby attenuates the X-ray beam before it is transmitted to an object 4 which is to be imaged. The system further comprises an imaging X-ray sensor 5, which may have an output in either a digital or analogue electronic form or an X-ray film or another detector.

During use, the object 4 which is to be imaged is positioned between the attenuator 2 and the imaging X-ray sensor 5 as shown diagrammatically in Figure 1.

Figure 2 is a plan view of an embodiment of an attenuator plate 2 of the present invention, wherein one layer of the plate has been removed for purposes of explaining the invention. It can be seen that the attenuator plate 2 is in the form of a circular disc, with alternating regions of high (ideally totally absorbing) X-ray attenuation 8 and low (ideally totally transparent) X-ray attenuation 14, which extend radially from a generally circular central window 12 of low attenuation. This arrangement is realised by providing a circular low attenuation mounting plate 14 and affixing the highly X-ray attenuating segments 8 upon its surface. In the present case, a further layer 14 of low attenuation material is placed on top of the highly attenuating segments 8, to provide a sandwich-like arrangement. This can be viewed more clearly in Figure 3, which is a cross-section along the line III-III of Figure 2.

The second layer of low attenuation material may be omitted, if convenient. However, it improves integrity of the attenuator plate and provides a conveniently planar surface, as described further below.

Furthermore, other arrangements are envisaged. For example, the segments 8 may be moulded in a suitable matrix, such as a plastics material, which would subsequently define the regions of low attenuation. In such a case, the matrix material may cover as much or as little of the intermediate highly attenuating segments 8 as the circumstances require. Furthermore, if the attenuating segments were made of a mechanically rigid material (such as tungsten), then there would be no need for the light supporting material. The attenuator plate would then effectively comprise a "fan-like" arrangement. Therefore for the purposes of this invention the term plate is intended to include this construction.

In the present case, the highly attenuating segments 8 are made from lead, which is chosen to provide a high absorption of X-rays relative to transmission or scatter. The central window 12 contains no high attenuation material, but may be covered by the supporting structure of either or both plates 14 or may be filled with the low attenuation material in a moulded arrangement. Alternatively, this window may be left completely open, as an aperture.

The attenuator plate 2 is initially arranged perpendicular to the X-ray beam axis 16, but may be moved 'off axis' or obliquely, for example as shown in Figure 4.

Figure 4 schematically shows the relationship between the X-ray source 3, the attenuator plate 2 and the sensor 5.

During use, the attenuator plate 2 is motor-driven for circumferential rotation about the axis of the attenuator plate 2 at a rate of at least several hundred revolutions per minute.

1000 revolutions per minute has been found particularly effective; however different X-ray exposure times will benefit from different speeds of rotation. In particular, the plate must rotate at a sufficient speed to avoid an image of the plate segments appearing in the final image. Electronic synchronisation of the rotation with a pulsed X-ray beam may be advantageous. Alternatively a high speed shutter arrangement (not shown) may be used in a non-rotating embodiment. This could be incorporated into a pulsed X-ray system.

Thus, due to the lack of high attenuation material in the central window 12 provided in the plate 2, the projected flux of X-rays through the window 12 is higher than that through the remainder of the attenuator plate 2, in which X-rays are intercepted by the highly attenuating segments 8. The X-rays passing through the central window 12 fall upon the sensor 5, so as to correspond with the region of interest (ROI) 18.

Because the X-rays passing through the attenuator plate outside the window region 12 are interrupted by the highly attenuating segments 8, the level of flux in this region is reduced. Therefore the rotation of the attenuator plate 2 effectively causes effective attenuation along an X-ray path to be an average of the attenuation of the two sub-regions (8 and 14), of attenuating fins and less attenuating material, at one or more regions of the detector. Thus the level of radiation incident on the object is decreased, without altering the energy spectrum due to the use of effectively totally attenuating and totally transparent materials for the two regions.

The speed of rotation is controlled such that by having an average of approximately totally absorbing, or totally transmitting sub-regions, the intensity averaged over the X-ray beam exposure period is equal for all locations within the region outside the central window. This region surrounds or is adjacent to the ROI.

Accordingly, the X-ray energy spectrum of the incident beam can be constant over the whole field of view. Although outside the ROI the total energy delivered per unit area is less than inside the ROI. Thus a patient is subjected to a lower dose of X-rays.

The level of flux passing through the region surrounding the ROI is controlled by the ratio of the respective areas of the high attenuation segments and the low attenuation segments.

An example of a mounting device 100 is shown in Figure 5 and is described in detail below. It consists of supports and mechanical drives that direct the attenuator plate 2 so as to be perpendicular to a line drawn from the origin of the X-ray beam to the centre 10 of the attenuator plate. The mounting device 100 also includes mechanical drives and controls which allow the attenuator plate to be moved such that the window 12 of the plate 2 moves over the surface of a virtual sphere, which has its centre situated at the origin of the X-ray beam and which has a radius that is equal to the distance between the origin of the X-rays and the centre 10 of the attenuation plate. This radius is variable by a mechanical drive in the mounting device 100. The possible adjustments are indicated in Figure 4, where "d" corresponds to the radius of the virtual sphere and "e" shows the movement of the unattenuated beam 16, resulting from movement of the window 12 over the surface of the virtual sphere.

By these adjustments, the position and projected size of the region of interest falling upon the detector may be varied. Of course, any part of an object intercepting the X-ray beam transmitted by the central window 12 and falling upon the region of interest 18 will be the subject of certain of the benefits of the invention. Specifically, that part of the object will be represented on the detector 5 by a high quality image, with good image contrast. The image of the object as a whole, i.e. that intersecting the attenuated beam, will be of an at least adequate image quality, with an at least adequate image contrast, whilst experiencing an overall relatively low exposure to X-ray radiation of the same beam characteristics of that part of the object within the ROI.

If desired, variable attenuation may be achieved by concentrically mounting two attenuator plates, one in front of another along the path of the X-ray beam. In such an arrangement, a mechanism may be provided to enable one plate to be set at a fixed circumferential angle relative to the other. Both plates are then mechanically rotated (or displaced with respect to the object) together about their joint centre at the same speed of at least several hundred revolutions per minute. To achieve an apparently increased relative motion of the sub-regions it is possible to overlie two attenuator plates and rotate them in opposite directions. This may be advantageous to achieve shorter image exposure times. When two plates are used in this manner, one may have a larger central window, so as to reduce alignment errors at the narrow ends of the highly attenuating regions near the centre region.

An example of a mounting and drive device is now described with reference to Figure 5 in which the dimensions of the attenuator plate 10 are also as follows: the central region 12 is approximately 0.04m in diameter and the plate 2 is approximately 0.32m in diameter. The attenuator plate 2 has 12 lead attenuating fins 8. The fins 8 are glued between carbon fibre discs 20 (epoxy resin fill the inter-lead fin space). The dimensions of the lead fins 11 and the attenuator plate were selected such that the attenuator 2 was capable of being positioned for test purposes at about 30cm from a focal spot 21 of an X-ray tube. An embodiment designed for clinical use may have the attenuator plate 2 located closer to the X-ray focus, with an appropriate scaling of disc diameters to account for the diverging nature of the X-ray beam.

The attenuator plate 2 is rotated by a belt driver 22 which rotates supporting perimeter rings 24a and b. The perimeter rings 24a and b have metal rims which sandwich the attenuator plate 2, and whose exterior rubber edges 28 press against roller bearings 30 on a support frame. A spacer 26 is interposed between plate 2 and perimeter ring 24a.

The bearings 30 press against a hard rubber track 3 on the perimeter rings 24a and b, and the angled bearing arrangement allows high speed rotation with little free motion perpendicular to the axis 10 of rotation of the attenuator plate 2.

Alternative drive mechanisms may incorporate the attenuator plate 2 as part of the rotor of an electric motor. Alternatively motors 22' having drive rollers may impinge on an angled or bevelled rim, to drive the plate directly as shown in ghost lines on Figure 5.

In order to assess its effects on the spectrum of X-ray beam spectrum, on a patient and on an operator dose rate and final image quality, measurements were made. Figure 8 shows the measured X-ray spectra before and after transmission through the attenuator plate 2. It is apparent from Figure 8 that the attenuator plate 2 has a negligible effect on the beam spectrum. This is important because it is highly undesirable to have beam quality which differs in different regions of the image. If beam spectrum varied then identical objects would appear with different image contrast depending upon whether they were being imaged inside or outside the ROI. Also, if the beam spectrum varies between the ROI and the surrounding or adjacent region, restoration of the image is not simple and cannot be accurately implemented.

Radiation dose rates were measured on the surface of tissue equivalent material of 20cm thick. A reduction in The Roentgen-area-product (RAP) of approximately 50% was measured. Operator dose reduction was estimated by measuring dose at 1m from a phantom (not shown), with a 50% reduction due to use of the attenuator compared to the unattenuated beam.

Image quality was assessed in the centre of the ROI (maximum exposure rate), by measuring scatter-to-primary ratio, and the contrast across a catheter and radiological guide wire.

The scatter-to-primary ratio with no attenuator was 43%, whilst with the attenuator it was 32% as shown in the graph Figure 6. Contrast across the catheters and guidelines was improved by up to 30% by use of the attenuator as shown in Figure 7.

Image restoration to compensate for the visually distracting bright central circular region was performed. An edge detection algorithm followed by an automatic circle localising procedure was used to automatically identify the central circular region which was then multiplied by an empirically determined factor in order to reduce the discontinuity in brightness across the image. Details of this are described briefly below. The image thus processed were judged to be acceptable, with images of an anthropomorphic chest phantom being used in the evaluation.

The invention produces an X-ray flux on the object and the detector of different intensities in the ROI region and that region surrounding or adjacent to the ROI. The resulting image therefore has these two regions of different intensity superimposed upon variations in intensity due to variations in the object density. This produces an image which is different to an image which the observer (e.g. radiologist) is used to seeing from systems without the invention. Sometimes it is desirable to manipulate the image brightness levels such that the image appears as if it was produced by a beam having a uniform intensity across the imaged field. This manipulation is known as "Image restoration".

Three different forms of image restoration are considered below. These are:

1. A digital image with detected X-ray flux represented by a digital value;
2. A video image, with X-ray flux represented by a voltage level of a video signal; and

3. A film or other hardcopy image in which detected X-ray flux is represented by the optical density of the film at a point.

There are numerous ways in which digital image image-restoration may be performed. One way is to have a fixed or calibrated geometry for the system such that the Central Region of Interest always lies in the same part of the final image. A look-up table of values may then be referred to to restore apparent uniform illumination.

Another way is when the geometry is not fixed, the geometry may be precisely read-out and used to calculate the size, shape and position of the regions on the final image, and then to apply correction factors to the image. Another way to achieve image restoration is to locate the region of interest by digital image processing.

Firstly it is necessary to apply a local gradient operator to the image (i.e. replace each pixel value by the local pixel intensity gradient). Next a Hough transform is applied to the gradient image. Then a search is made in the "Hough space" for the signature of a circle of radius r, centre (x,y). Finally all pixels outside of the circle r, (x,y) are multiplied by a factor f (x,y); f is set from the characteristics of the system, that is the X-ray and detector performance and the intensity reduction selected in the outer region. This may be found empirically by imaging uniform blocks of tissue equivalent material of similar thickness to a body and observing the ratio of intensity between the two regions.

A smooth transition from the region of interest image intensity to the surrounding image intensity may be made by making f (the image correction function) a function of the distance R from the centre of region A. This function reflects the fact that there is not a sharp transition in image intensity at the edge of region A due to X-ray scatter and image un-sharpness.

It may be desirable to give the operator an on-line control of the degree of restoration, since it may be useful to use brightness differences to identify the region of interest a knob/control could then vary f (x,y) - or alternatively to allow the user to fine-tune the restoration to be visually pleasing.

Other digital image processing may be used, such as identifying the regions by identifying average brightness in areas. All methods are subject to some error due to the superimposition of complex bodily structures altering the intensity levels.

An analogue video signal may be manipulated to carry out image restoration. This is straightforward if a fixed geometry is used (see above). With a variable geometry, an operator may control the analogue restoration by controls which vary the centre, diameter and restoration factor f. One test image can be taken, the user uses controls to obtain a pleasing result, and then live imaging could proceed with these factors.

If X-ray film is used as the detector a means of illumination for film viewing may also be provided whereby illumination regions C, D have different relative brightnesses. Placing the film over regions C and D and varying the position and brightness of C and D can be used to present an apparently uniform image.

Many further modifications and variations will suggest themselves to those versed in the art upon making reference to the foregoing description, which is given by way of illustrative example only and which is not intended to limit the scope of the monopoly, which is determined by the appended claims.

CLAIMS

1. An X-ray attenuator comprising an attenuator plate adapted to be inserted between an X-ray source and an object to be imaged, the plate comprising first and second regions of differing X-ray transmissivity, characterised in that, in use, the first region is substantially transparent to X-rays which illuminate the object at a region of interest and the second region is substantially X-ray opaque, said second region being disposed on at least a portion of said plate and being displaced relative to the object so that alternate first and second regions intercept the X-ray beam thereby providing a time varying flux on the surface of an object adjacent or surrounding that part of the object viewed within the region of interest, the integral value with respect to time of the time varying flux is less than the integral value with respect to time of the flux impinging the surface of an object viewed within the region of interest.

2. An attenuator plate according to Claim 1, comprising a plurality of first regions.

3. An attenuator plate according to Claim 1 or 2, comprising a plurality of second regions.

4. An attenuator plate according to Claim 3 when dependent on Claim 2, wherein the first and second regions are arranged in an alternating pattern.

5. An attenuator plate according to Claim 4, wherein the regions radiate from a central region and alternate in a circumferential direction.

6. An attenuator plate according to any preceding claim wherein the or each second region includes a layer of lead corresponding to its incident surface area.

7. An attenuator plate according to any preceding claim, formed from a sheet of a first material having the said first transmissivity to X-rays and one or more sheets of a second material, located upon the said first sheet, the or each sheet of second material corresponding in configuration and location to a respective second region and having the said second transmissivity to X-rays less the said first transmissivity to X-rays.

8. An attenuator plate according to Claim 7, comprising a further sheet of material situated upon the or each sheet of second material on a side opposite to that of the said first material.

9. An attenuator plate according to any one of Claims 1 to 5, formed from a sheet of material having the said first transmissivity to X-rays and one or more sheets of second

material embedded in the first material, the or each sheet of second material corresponding in configuration and location to a respective second region and causing the resultant total transmissivity to X-rays in that second region to be equal to the said second transmissivity to X-rays.

10. An X-ray attenuator comprising a body for transmitting X-rays, the said body including a first region having a first transmissivity to X-rays, and a second region having a second transmissivity to X-rays; and positioning means for positioning the body relative to an X-ray source in such a manner as to enable transmission of X-rays via at least one of the said first region and the said second region, to provide an image, including an image of interest, at a detector.

11. An X-ray attenuator according to Claim 10, wherein the positioning means is adjustable, so as to enable alteration of the size and location of a region of interest of an image provided at a detector by means of the said X-ray attenuator.

12. An X-ray attenuator according to Claim 11, wherein the positioning means is adapted to position the said body at any selected one of a plurality of locations upon the surface of a virtual sphere which has the origin of an X-ray beam as its centre.

13. An X-ray attenuator according to Claim 12, wherein the positioning means is adapted to alter the radius of the said virtual sphere.

14. An X-ray attenuator according to any one of Claims 10 to 13, wherein the said body is an attenuator plate in accordance with any one of Claims 1 to 9.

15. An X-ray attenuator according to Claim 12, wherein the means for causing the attenuator plate to rotate is adapted to cause the attenuator plate to rotate at speeds of one hundred revolutions per minute or greater.

16. An X-ray attenuator according to Claim 15, comprising an additional attenuator plate in accordance with Claim 5 or any claim dependent thereon; wherein the attenuator plates are arranged concentrically along a direction of X-ray propagation and both attenuator plates are caused to rotate about a common central axis.

17. An X-ray attenuator according to Claim 16, wherein the plates are caused to rotate with their respective second regions mutually out of phase.

18. An X-ray attenuator according to Claim 15 or 16, wherein the attenuator plates have central regions of different sizes.

19. A method of imaging an object comprising directing a beam of X-rays at the object comprising:

(i) generating an X-ray beam;

(ii) directing the beam at a first X-ray beam attenuator body;

(iii) rotating the X-ray beam attenuator body in a plane transverse to the X-ray beam, so as to produce a first region having a first transmissivity and a second region having a second transmissivity;

(iv) transmitting the X-ray beam via the X-ray beam attenuator and the object to be imaged: and

(v) detecting the transmitted X-ray beam using a detector, wherein one of the first and second regions transmits X-rays for imaging a region of interest.

20. A method according to Claim 19, comprising aligning a central region of the said attenuator body for transmitting X-rays for imaging a region of interest.

21. A method according to Claim 19 or 20, comprising rotating a second, concentric attenuator body simultaneously with the said first attenuator body, but out of phase with the said first attenuator body.

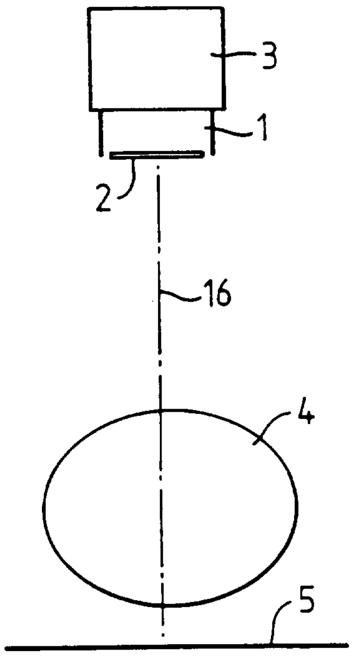

Fig. 1

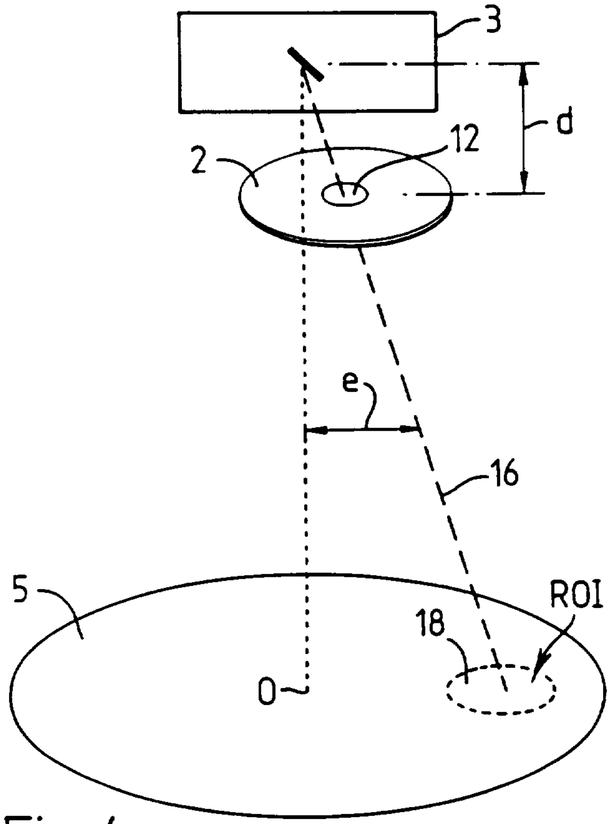

Fig. 4

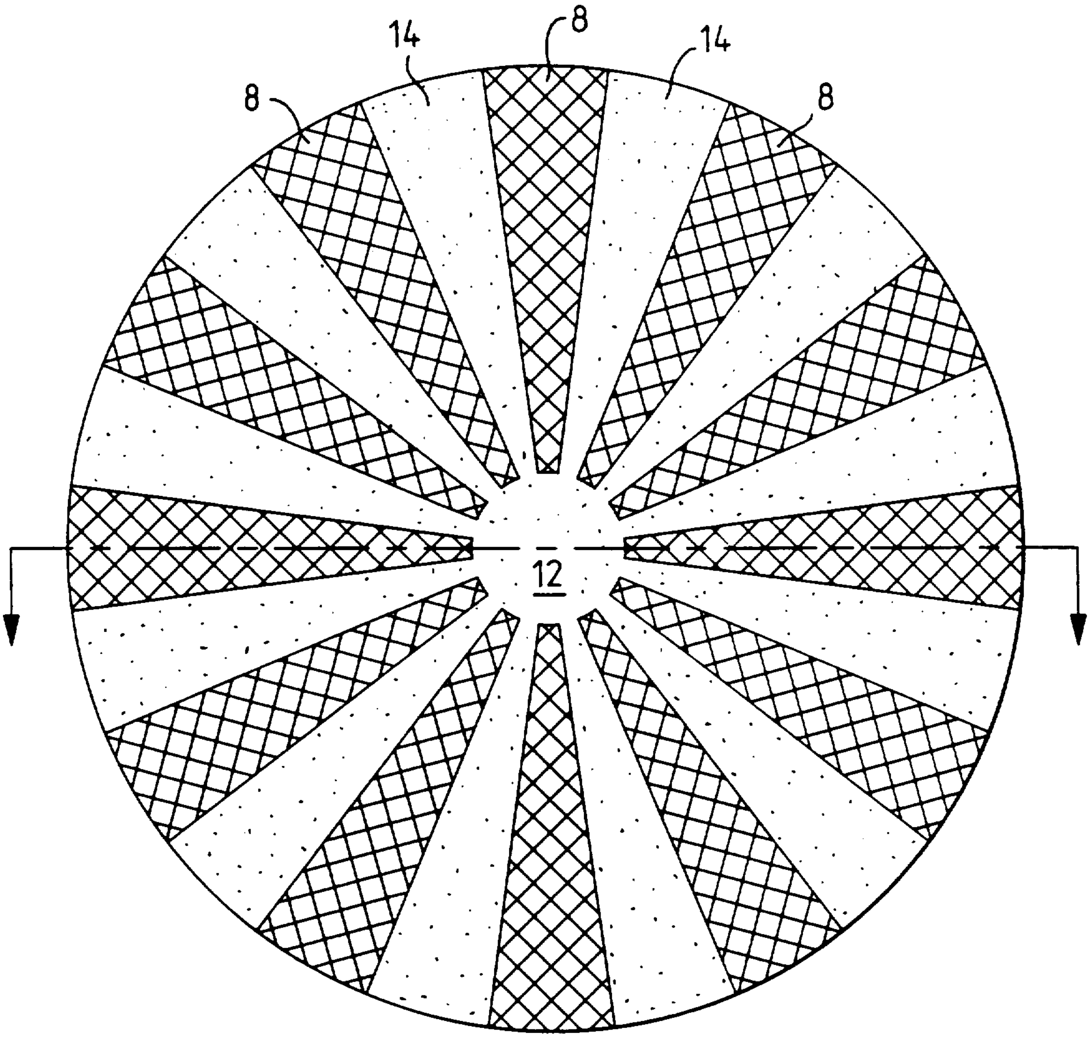

Fig. 2

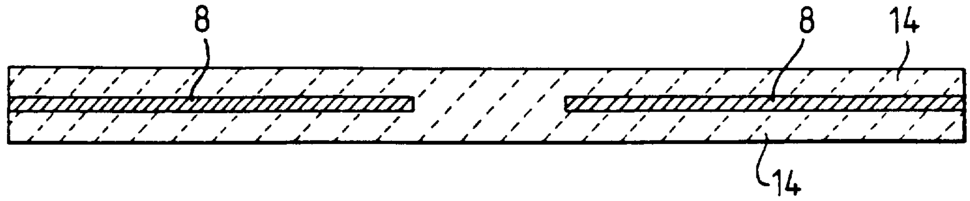

Fig. 3

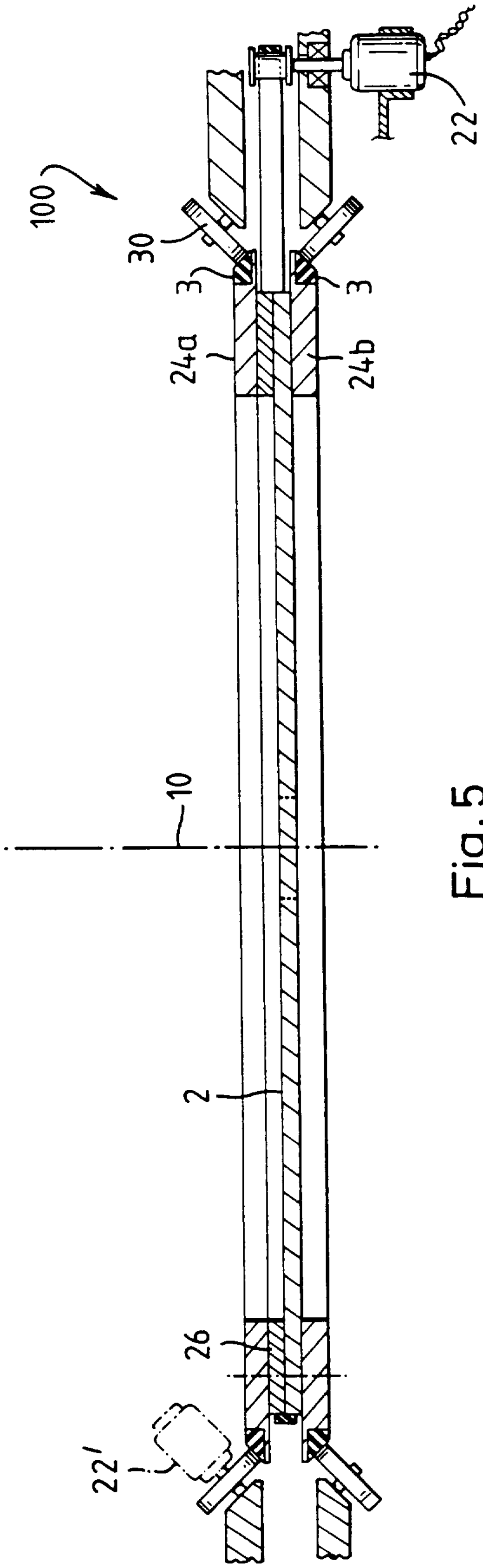

Fig.5

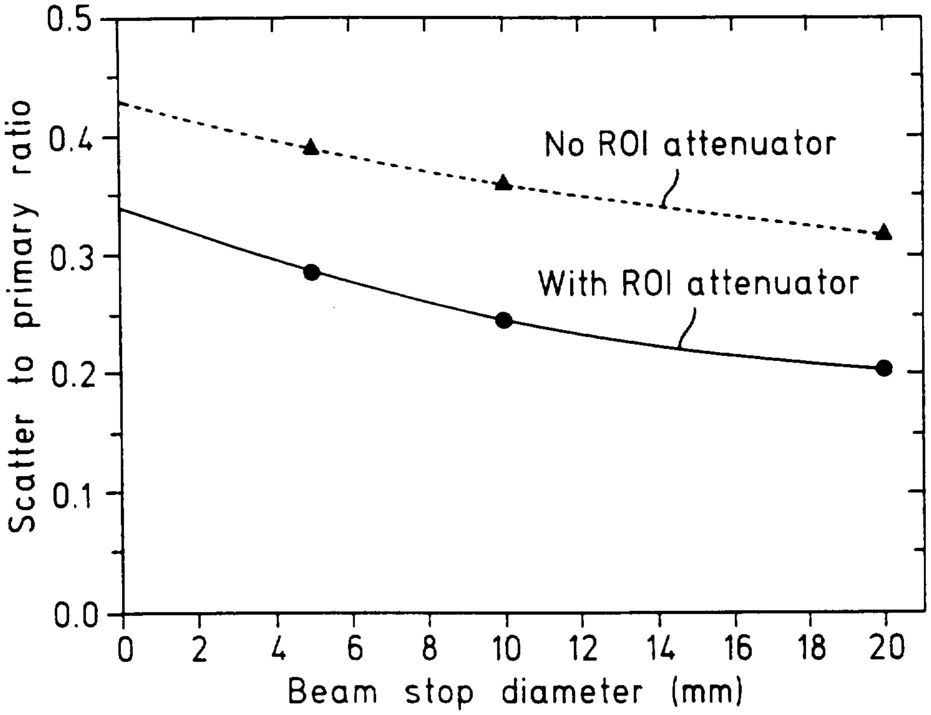
0.5
0.4
0.3
0.2
0.1
0.0
Scatter to primary ratio
No ROI attenuator
With ROI attenuator
0
2
4
6
8
10
12
14
16
18
20
Beam stop diameter (mm)

Fig. 6

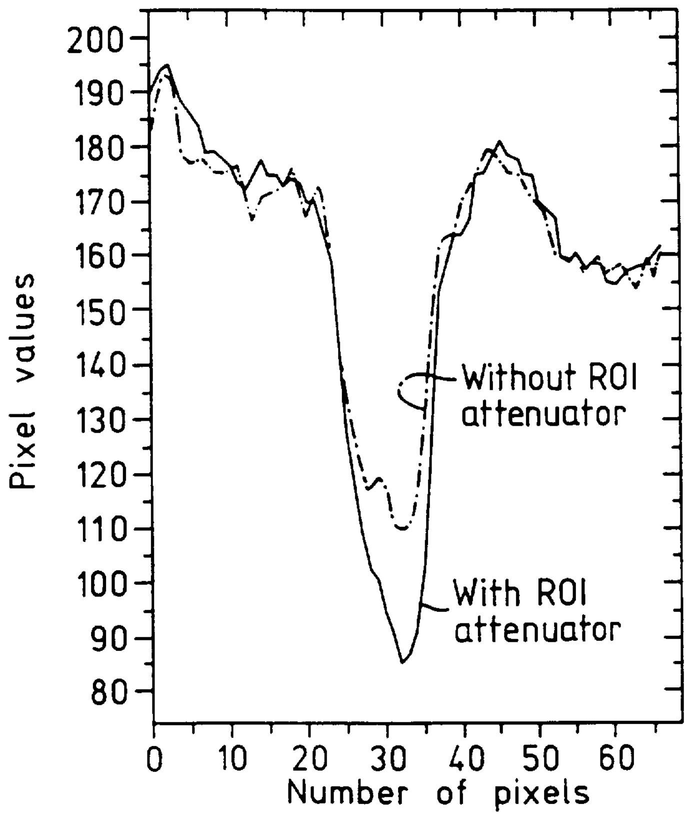
200
190
180
170
160
150
140
130
120
110
100
90
80
Pixel values
Without ROI attenuator
With ROI attenuator
0
10
20
30
40
50
60
Number of pixels

Fig. 7

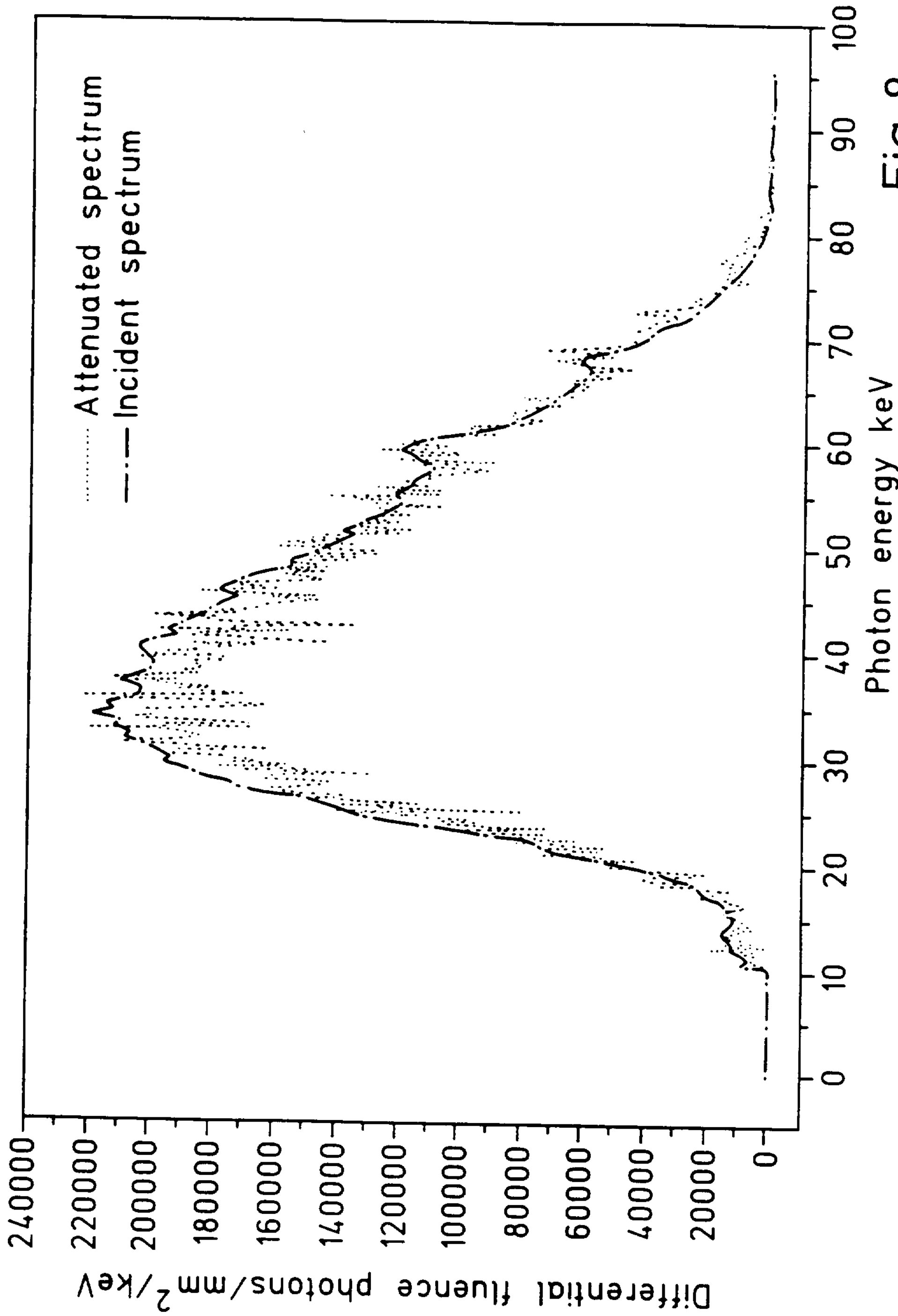
Attenuated spectrum
Incident spectrum
Photon energy keV
0
10
20
30
40
50
60
70
80
90
100
Differential fluence photons/mm2/keV
240000
220000
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0

Fig.8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/00485

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G21K1/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G21K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 251 407 (OPTISCHE IND DE OUDE DELFT NV) 7 January 1988 see column 1, line 1 - line 15 see column 2, line 6 - line 15 see column 3, line 38 - line 43 see column 10, line 44 - column 11, line 24 see column 11, line 37 - line 47 see claims 37,39,41; figures 1,13,15 ---	1-6,10, 11,14,19
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 143 (P-459), 27 May 1986 & JP,A,60 262084 (YOKOKAWA HOKUSHIN DENKI KK), 25 December 1985, see abstract --- -/--	1-5,10, 14,19

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
3 June 1996	12. 06. 96

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCI/GB 96/00485

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 086 (E-1039), 28 February 1991 & JP,A,02 302020 (MATSUSHITA ELECTRON CORP), 14 December 1990, see abstract ---	2,3,7
A	US,A,5 314 768 (SETHI RAKESH B) 24 May 1994 see column 1, line 44 - line 54 see column 3, line 44 - column 4, line 13 see figure 4C ---	9
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A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 486 (E-695), 19 December 1988 & JP,A,63 202021 (SANYO ELECTRIC CO LTD), 22 August 1988, see abstract ---	8
A	US,A,4 260 898 (M. ANNIS) 7 April 1981 see claims 1,4-6; figure 2 ---	1-3,10
A	OPTICAL ENGINEERING, vol. 19, no. 1, January 1980, BELLINGHAM US, pages 132-138, XP000567947 S. RUDIN: "Rotating aperture wheel (RAW) device for improving radiographic contrast" cited in the application -----	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 96/00485

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		US-A-	4916723	10-04-90
		US-A-	4996701	26-02-91
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		FR-A-	2538240	29-06-84
		NL-A-	8303263	16-07-84
US-A-4260898	07-04-81	NONE		