

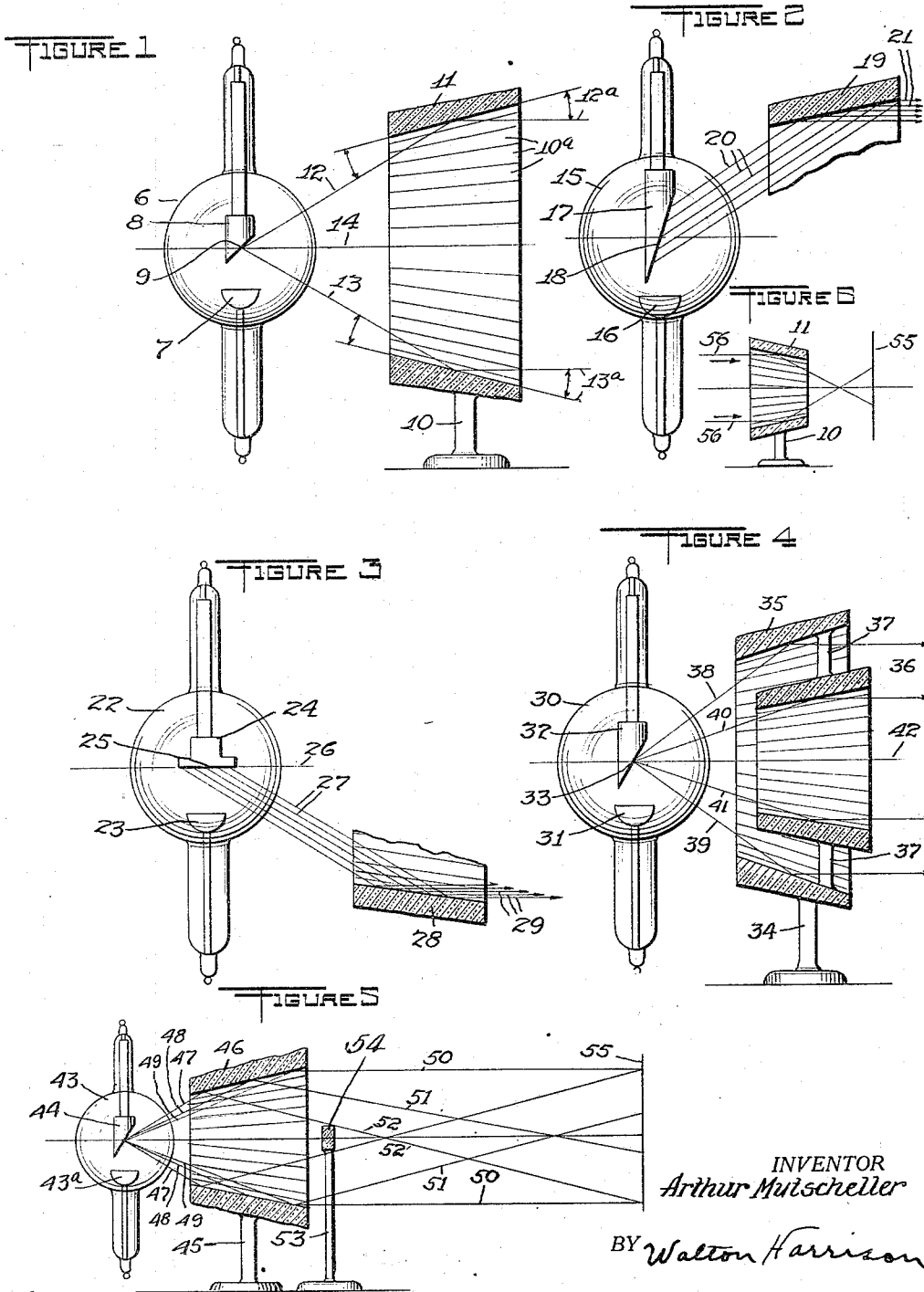
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A. MUTSCHELLER

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METHOD OF AND APPARATUS FOR CONTROLLING THE DIRECTION OF X-RAYS

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INVENTOR
Arthur Mutscheller

BY *Walton Harrison*

his ATTORNEY,

WITNESS
W. B. Lavin

UNITED STATES PATENT OFFICE

ARTHUR MUTSCHELLER, OF NEW YORK, N. Y., ASSIGNOR TO WAPPLER ELECTRIC COMPANY, INC., OF LONG ISLAND CITY, NEW YORK

METHOD OF AND APPARATUS FOR CONTROLLING THE DIRECTION OF X-RAYS

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My invention relates to a method of and apparatus for controlling the direction of X-rays in order to improve their efficiency for various purposes, and to extend their uses in a number of different ways.

My invention is based upon the fact that X-rays, though incapable of being either refracted or reflected to any material extent according to ordinary conceptions, may be virtually or actually reflected, within certain limits, by the action of certain crystals and crystalline substances, or substances having a regular arrangement of the atoms, and may thus be projected along lines substantially parallel with each other, or brought to a focus, or concentrated upon a particular area or within a particular path.

More particularly stated, my invention contemplates a method and apparatus whereby the X-rays may be projected in large quantities and to great distances, and thus may be used for purposes of signalling; or may be used to better advantage than has heretofore been done in deep therapy for the treatment of deep seated and malignant diseases, and also in fluoroscopy and photography, and in many other relations.

My invention further comprehends means to be so used, in connection with the above-mentioned crystals and crystalline substances, as to dispense with the necessity for X-ray filters; or in other words, so employed as to get rid of a large percentage of soft rays, which for most purposes do more harm than good.

In the use of ordinary light rays, that is, the rays of the so-called visible spectrum, for signalling over long distances upon the principle of the heliograph, the rays are rendered as far as practicable parallel with each other or formed into a bundle, and thus retain uniformity of intensity over long distances. However, if these rays be projected through air containing fog, dust, smoke screens or vapors, the rays are either dispersed or stopped altogether, so that the use of ordinary light in this relation is limited considerably.

On the other hand X-rays have great penetrative power, and are scattered but little in

passing through fog, dust, smoke or vapor. Up to the present time, however, it has not been practicable to impart to the X-rays any desired limited or single direction of propagation, or to form them into a bundle or parallel rays.

By my invention I can so divert the X-rays as to concentrate them in practically the form of a bundle, in which the rays are substantially parallel with each other, in a manner more or less analogous to that whereby the visible rays are handled as in a heliograph.

Reference is made to the accompanying drawing forming a part of this specification, and in which like reference characters indicate like parts throughout all of the figures.

Figure 1 is a view partly a section and partly an elevation, showing a simple form of my invention as used with an ordinary X-ray tube.

Figure 2 is a view, partly a fragmentary section and partly an elevation, showing a form of my invention as used with an X-ray tube having a large focal spot, the parts being so arranged as to utilize a large proportion of the X-rays generated.

Figure 3 shows a form of my invention as used with an X-ray tube having a large target of rather unusual form, a large proportion of the X-rays being utilized.

Figure 4 is a view partly a section and partly an elevation of a form of my device using more than one crystal or crystalline substance in order to increase the number of rays projected in a particular direction.

Figure 5 shows a form of my invention so constructed and arranged as to do away with a large proportion of the soft rays, and so as to focus the rays between certain limits of wave lengths upon a surface located at a fixed distance from the crystals.

Figure 6 is a vertical section, showing my invention used as a receiver for indicating signals by X-rays transmitted from a distance.

An X-ray tube of ordinary form appears at 6, and is provided with a cathode 7 and an anode 8. This anode serves as a target, and for this purpose is provided with an in-

clined face 9, from the center of which the X-rays are propagated.

Mounted upon a base 10 is a ring 11 of substantially frusto-conical form, and made up of slabs 10^a, of crystals or crystalline substances, capable of virtually or actually reflecting the X-rays.

The slabs 10^a may be composed of rock salt, calcite, gypsum, zinc blende or the like. The crystals of each of the substances mentioned are adapted to reflect a particular wave length at a certain angle, this wave length and angle being different for the different substances and probably dependent upon the arrangement of the atoms, or their distance apart, within the crystal. No effort is here made to illustrate the atomic arrangement or condition thus contemplated, or even to show the physical characteristics of the crystals. The slabs 10^a are so grouped together as to give the ring 11 a frusto-conical form, adapted to virtually or actually reflect the X-rays, as indicated by the lines 12, 12^a, 13, 13^a. The angle of incidence being equal to the angle of reflection, it is an easy matter to thus render the X-rays parallel with each other, as indicated by the lines 12^a, 13^a. For this purpose the ring may be moved toward or from the X-ray tube, and its distance therefrom thus adjusted. The axis of the bundle of rays is indicated by the line 14.

The ring 11 must be so constructed and positioned that the angle of inclination of the inner surface of each slab 10^a, relatively to the line 14, shall be so fixed as to confer upon the X-rays the desired direction of propagation. The angle to be thus determined depends in part upon the nature of the substance of which the slabs are composed and in part upon the particular wave length of the X-rays which the operator wishes to control. The angle for this purpose may be calculated by means of a formula as follows:

$$n\lambda = 2d \sin \theta$$

in which

n is the order of the spectrum,

λ is the wave length,

d is the distance between the atoms of the crystal, and

θ is the angle of reflection.

In the form shown in Figure 2 the X-ray tube appears at 15, the cathode at 16, and the anode, serving as a target, at 17. The face 18 of the target is in this instance rather large, and has a large focal spot or surface from which the X-rays emanate. The reflecting member 19 is made up of crystals or crystalline substances, as above described with reference to the frusto-conical ring 11, so as to give the X-rays the direction indicated by the lines 20, 21. Thus a larger proportion of rays of the same wave length are formed into a bundle and rendered substantially parallel with each other, and as a result a very much larger proportion of the

total output of radiation is utilized, as indicated by the lines 21. It follows that a large number of the rays, from a relatively large focal spot, are made into a bundle of parallel rays and their aggregate intensity is greatly enhanced.

In the form shown in Figure 3 the X-ray tube appears at 22, and is provided with a cathode 23 and with an anode 24 of rather unusual form. This anode has a large face 25, directly facing the cathode, and coinciding with the direction of the minor or cross axis of the X-ray tube, indicated by a line 26. The X-rays from the face 25 pass as indicated by the lines 27 to the member 28 which is crystalline as above described with reference to the members 11 and 19, and so arranged as to reflect the X-rays and form them into a bundle, as indicated by the lines 29.

In the form of my device illustrated in Figure 4 the X-ray tube is shown at 30, the cathode at 31 and the anode at 32, with its target face at 33. A base 34 supports two rings 35, 36, each made up like the ring 11 as above described, but in which the crystals reflect, at different angles X-rays, of a particular wave length. The ring 36 is properly spaced relatively to the ring 35 by means of small spacing bars 37. The X-rays from the target face diverge along straight lines 38, 39, 40, 41, and upon striking the inner surfaces of the rings 35, 36 are rendered substantially parallel and thus formed into a bundle, as above described with reference to other figures. The axis of the bundle is indicated by a line 42, which is also the minor axis of the X-ray tube.

In the form shown in Figure 5 the X-ray tube appears at 43, its cathode at 43^a, and its anode at 44. A base 45 carries a ring 46 like the ring 11 above described, as to its outward form. However, the ring 46 is made up of crystals and is somewhat broader, so that X-rays of more widely different wave lengths are picked out and formed into a bundle. This may be understood from a study of the lines 47, 48, 49, leading to the ring 46, and the lines 50, 51, 52, leading from this ring to the right according to Figure 5. The X-rays are projected toward a surface 55, which may be some deep seated region within the human body, and into which the projection of the rays is for the treatment of disease, or the ascertainment of pathological conditions. A stand 53 carries a shield 54, made preferably of lead or some other substance of high atomic number, and thus relatively opaque to the passage of X-rays. In the particular device here illustrated, the shield is so proportioned and arranged relatively to other parts, as to cut off all X-rays of longer wave lengths than those represented by the two lines 52, 52; in other words, the screen tends to stop the X-rays of relatively long wave lengths—rays of the kind which for most

purposes are harmful. As may also be noted from Figure 5, the X-rays which succeed in reaching the surface 55 include rays of different wave lengths, ranging from the shortest to those of the greatest length which may be desired; and the rays which succeed in reaching the surface 55 are distributed uniformly.

The form of my apparatus illustrated in Figure 5 and just described enables the X-rays to be used without a filter for removing the rays of longer wave-length. Filters, at least of the kind heretofore known, cause very substantial reductions in the intensity of the radiation, and the correct thickness required for a filter suitable for use with them is rather difficult to ascertain. I use the simple screen 54, which is essentially a stationary fixture, instead of a carefully matched fixture.

My invention has a large variety of uses. In fact, its uses are commensurate with practically all uses for X-rays of great penetrative power. It is especially well adapted for deep therapy, and to some extent for deep fluoroscopy and photography, and also, as above set forth, for signaling over relatively great distances as in heliography. When used for this kind of signalling, it is of course necessary to use some appropriate receiving mechanism, sensitive to the action of X-rays, for registering the indications, and the signals may be made by rendering the rays intermittent, and modulating their intensity as in the use of ordinary light. These are mere details, and have little or no bearing upon the spirit of my invention. As instances of detecting mechanisms, however, I mention fluorescent screens, selenium cells, ionization chambers, especially such as contain gases of heavy atomic weight, besides the various detecting devices of other kinds heretofore used in connection with X-ray, for rendering the latter perceptible to the senses. Thus the signals transmitted can be detected, during either the day or night.

In Figure 6 I show a form of my device adapted for use as a receiver, or in other words for registering indications of X-rays transmitted from a distance in signalling. For this purpose the ring above described may be employed, as shown in this figure; and in connection with this ring is an indicating member 55, in this particular instance a fluorescent screen. However, any equivalent device, capable of being acted upon by X-rays and sensitive thereto for the purpose of making an indication, may be substituted for the fluorescent screen.

The incoming X-rays are indicated by the lines 56 and 57, and these X-rays are by action of the ring 11 virtually reflected and thrown upon the indicating member 55. The incoming signals may thus be read off.

For the treatment of malignant diseases, and especially such diseases as are seated deeply within the body, I am by my invention

enabled to increase the depth dose very greatly. This does away with the necessity of using two or more areas at each treatment. Heretofore it has been customary to arrange the X-ray tubes so that from several angles and thus through several portals of entry the rays play upon the same diseased part or region, by the method known as cross-firing, as to give the required dose but without unduly burning the skin of the patient by means of the incident rays. By my invention a heavy depth dose of the X-rays may be used, without burning the skin.

Moreover, in treating deep-seated regions of the body in the manner heretofore used, there is a very rapid decrease in the intensity of the rays as they penetrate deeply into the tissues, due to the fact that owing to the divergence of the rays they rapidly decrease in intensity as they reach tissues further and further removed from the X-ray tube. This necessitates either an overdosing of the skin of the patient or the complication above mentioned in connection with cross firing.

As may be readily understood from the foregoing description, my invention may be so used as to develop X-rays of only a predetermined wave length, and thus may be employed for rendering homogeneous the radiation employed. This is simply because no rays need be utilized except such as have a predetermined penetrative power.

As may be further understood from the foregoing description when an X-ray exposure is made by means of diverging rays, the image or picture formed by rays will always be slightly larger than the object sought to be reproduced, whereas if the exposure is made by means of converging rays, the image or picture will be smaller.

I do not limit myself to the particular features here illustrated and described, as variations may be made therein without departing from my invention, the scope of which is commensurate with my claims.

I claim:

1. A device comprising an X-ray tube and a reflecting member for the purpose of reflecting X-rays from said tube, said reflecting member being made up of a crystalline substance capable of reflecting the X-rays and having the form of a cone frustum.

2. A device comprising a source of X-rays from which the rays diverge, and a plurality of different reflecting members each in the proximate form of a cone frustum for gathering said rays into the form of a bundle.

3. A device comprising a source from which X-rays are thrown off to diverge, and a crystalline substance provided with a plurality of reflecting surfaces arranged circumferentially relative to each other and positioned relatively to the source of X-rays to reflect them into a predetermined path, in

which some of said X-rays are parallel with others.

4. A device of the character described comprising in combination with means for producing a beam of X-rays, of means comprising a hollow member, said member being formed of crystalline material, said last mentioned means reflecting X-rays impinging thereon in the form of a concentrated beam.

5. A device of the character described comprising in combination with a diverging beam of X-rays of means surrounding said beam of X-rays adjacent the source thereof, said means comprising a crystalline deflecting material for concentrating said beam.

6. A device of the character described comprising in combination with means for producing a beam of X-rays of means comprising a hollow member, said member being formed of a crystalline material, said last mentioned means reflecting X-rays impinging thereon in the form of a concentrated beam, and a shield positioned in the path of the beam of X-rays to prevent X-rays of undesired wave lengths from being included in said concentrated beam.

Signed at New York city, in the county of New York, and State of New York, this 2nd day of August, 1923.

ARTHUR MUTSCHELLER.