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[54] **X-RAY IMAGE CONVERTER USING A HIGH PERFORMANCE FOLDED OBJECTIVE LENS**
8 Claims, 3 Drawing Figs.

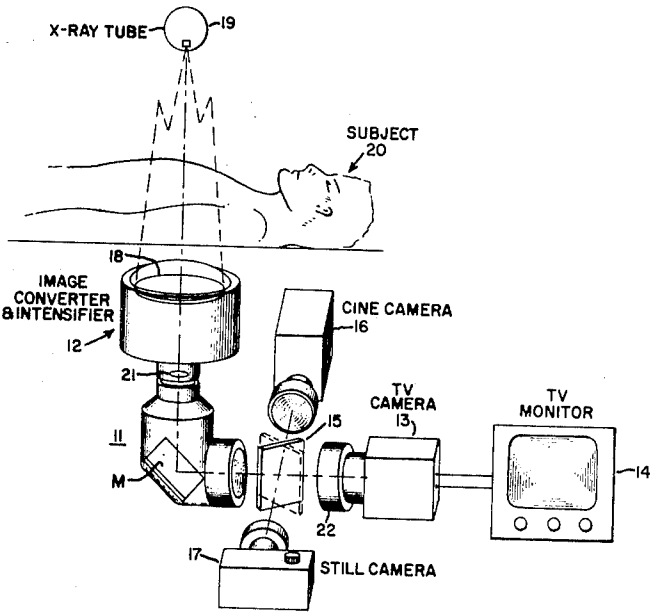
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[50] Field of Search 250/77, 71.5, 71.55, 213; 350/202, 171

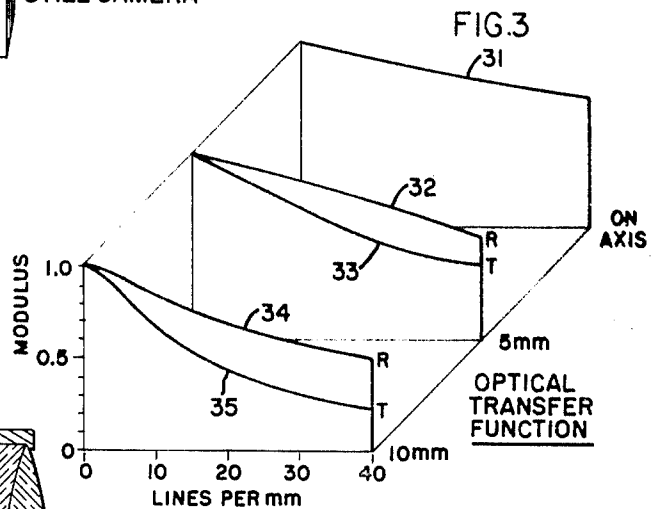
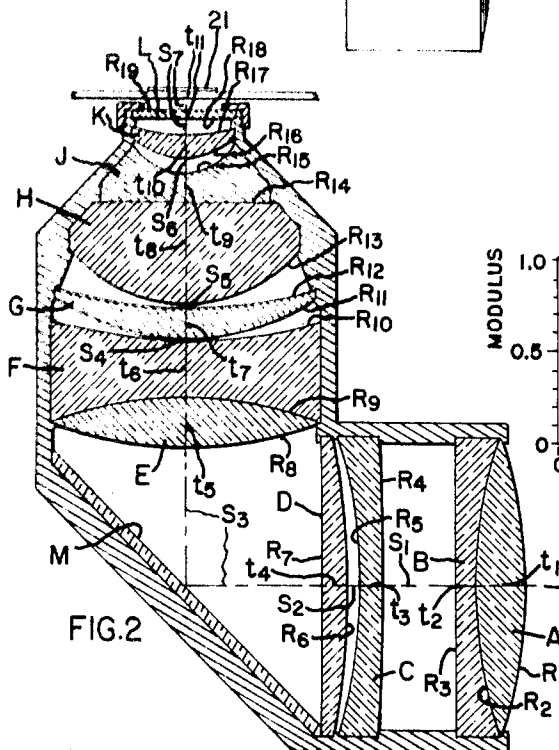
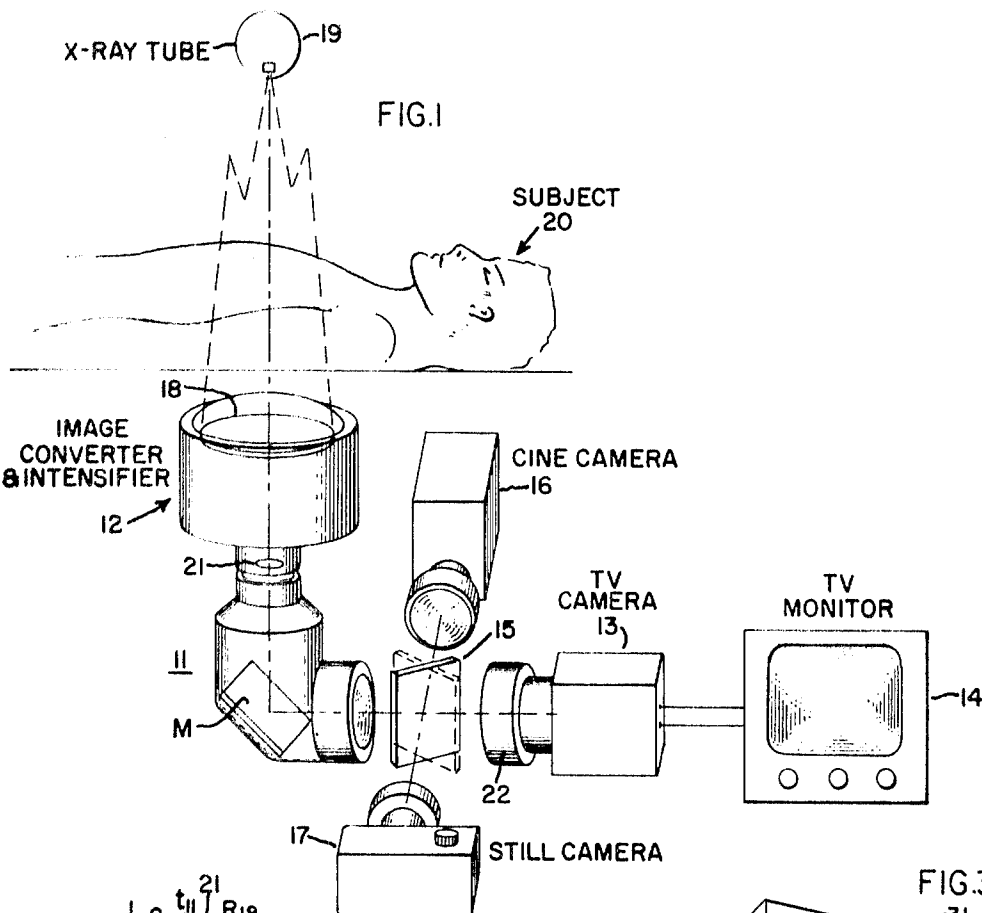
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ABSTRACT: A high performance folded objective lens and a compact fluoroscopic apparatus incorporating the lens are disclosed. The objective lens has a relative aperture of $f/1.0$ and its performance has been optimized for use with an X-ray image intensifier tube. The lens consists of two spaced groups with a fold of 90° introduced between the two groups. The first group, which consists of four elements, is of relatively low power. The second group which consists of six elements is of relatively high power, designed particularly to have a short physical length. Provision has been made for makeup glass in the back focal region. The fluoroscopic apparatus, of which the lens is a part, achieves compactness measured along the axis of the X-ray beam by folding the optical axis. In a preferred application, this feature permits location of the fluoroscopic apparatus in the limited vertical dimensions available beneath an examination table without reduction in the efficiency of optical coupling to the conventional multiple output devices.





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X-RAY IMAGE CONVERTER USING A HIGH PERFORMANCE FOLDED OBJECTIVE LENS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to high performance lens designs of high relative apertures (typically $f/1.0$) and is specially characterized by having a good low frequency response. A compact fluoroscopic apparatus is also disclosed.

2. Description of the Prior Art

There is a need for a lens optimized for use in a fluoroscopic system employing an X-ray tube and an image intensifier with television or film camera outputs. In fluoroscopic systems for hospital use there is the prime requirement that patient exposure be minimized and to this end it is desirable that the lens be of large aperture. In systems of this type, where the image intensifier output screen provides the input source for the visual image, the limiting resolution occurs in the image intensifier whose line resolution maybe on the order of 20 to 25 line pairs/mm. In the design of optical components to relay the image from the intensifier tube to the various output devices, the customary emphasis on high performance at higher spatial frequencies, will not insure a good low frequency response where the information content of the image is largely concentrated. Additionally, when location of the exit pupil is not optimized in respect to the application of the lens or where nonoptimal placement of the exit pupil is tolerated in order to use previously executed lens designs, there are often rather substantial losses in off-axis illumination of the image, i.e. vignetting.

A further degradation in lens performance may also occur if due to variations in image tube glass thickness the input image must proceed through additional layers of glass without compensation in the design.

In a typical application where the fluoroscopic system is employed for examination of a patient upon an examination table, it is desirable that the table be of conventional height from the floor. Assuming that the X-ray source is disposed over the patient with its beam projecting downward along a vertical axis, then under the patient and within the space between the under surface of the examination table and the floor, one should be able to locate the remaining elements of the fluoroscopic system. If for instance, an image intensifier, an objective lens, a beam splitter permitting a plurality of optical take-offs, and a television camera, which are the conventional components of a fluoroscopic system, are arranged along a vertical axis under the table, their vertical extension would substantially exceed the available vertical, under-the-table dimension. Assuming a necessity to keep the vertical dimension of the fluoroscopic system to a value compatible with conventional table heights, a fold in the axis of the fluoroscopic system is dictated. While folding the axis of the system will achieve a major reduction in the vertical dimensions of the under-the-table components, it does not completely solve the problem. Since a substantial amount of the under-the-table vertical dimension is taken up by the image intensifier, it is desirable that any optical elements coupled to the image intensifier be of minimum vertical dimensions. This arrangement and these dimensional requirements should be achieved in a manner not adversely affecting the optical performance of the system.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved fluoroscopic apparatus in which the axis of the optical output is folded with respect to the axis of the X-ray beam.

It is another object of the present invention to provide an improved high performance, folded lens for use in a fluoroscopic system.

It is a further object of the invention to provide an improved high performance, folded lens for use with an input image device of low spatial frequency such as an image intensifier.

It is still another object of the present invention to provide a folded lens arranged to couple an image in a fluoroscopic system to plural output optical devices with a minimum of vignetting.

It is a further object of the invention to provide a folded lens adapted to use with varying amounts of glass in the back focal region without degradation of the optical performance.

These and other objects of the invention are achieved in a fluoroscopic apparatus having a fold in the optical portions of the apparatus. The fluoroscopic apparatus includes an X-ray source, an image intensifier placed on the axis of the X-ray source beyond the object under examination and a novel folded objective lens coupled to the image intensifier which folds the optical axis orthogonally to the axis of the X-ray source. The folded lens is then arranged through a beam splitter to couple light selectively to a plurality of optical output devices such as a cine camera, still camera, and a closed circuit television camera. The folded objective lens is of novel design and consists of two groups separated by a mirror. The front group consists of four elements in a Tessar type lens and is of a relatively long focal length. The second group consists of six element resembling an infinite conjugate lens. Midway between the two lens groups a mirror is arranged to achieve a fold in the optical axis of the lens. The folded lens has a make-up glass provision in the back focal region to accommodate a plurality of glass thicknesses in the cover glass of the image intensifier. The exit pupil of the folded objective lens is placed well in front of the front group. The plural optical output elements may be arranged about a beam splitter with their entrance pupils at this exit pupil, which reduces vignetting to a minimum.

BRIEF DESCRIPTION OF THE DRAWING

The novel and distinctive features of the invention are set forth in the claims appended to the present application. The invention itself, however, together with the further objects and advantages thereof may best be understood by reference to the following description and accompanying drawings, in which:

FIG. 1 is an illustration partially in perspective of a folded objective lens in accordance with the invention and disposed in a compact fluoroscopic apparatus;

FIG. 2 is a more detailed illustration of the lens itself; and

FIG. 3 is a graph illustrating the lens performance in an example having a 90-mm. focal length.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, the folded objective lens is shown at 11 in a novel television aided fluoroscopic apparatus. The folded objective lens 11 couples an image produced by an X-ray image intensifier tube 12 to a television camera 13 and monitor 14 and optionally through a mirror system or "beam splitter" 15, to a cine camera 16 or still camera 17. The X-ray image is initially formed on an input screen 18 of the image converter and intensifier tube 12 located under the subject 20. As illustrated, the X-ray beam is projected from an X-ray tube 19 downwardly through the subject and emergent rays, modulated in intensity by the variable opacity of the subject, impinge on the input screen 18. The image converter and intensifier tube 12 forms an optical image of the X-ray image on its output screen 21.

The image converter and intensifier tube 12 provides the optical input for the folded objective lens 11. The image converter and intensifier tube 12 is a vacuum device which converts a relatively large X-ray image formed on its input screen 18 to a relatively small, more intense optical image at its output screen 21. Common image intensifiers have input screens of from 6 to 12 inches and have an output screen usually of 1 inch or less (15 to 20 mm. in typical systems) in diameter. Brightness may be increased by a factor of 3,000-10,000 and the output is usually of a yellow-green hue.

The image at the image intensifier output screen 21 is coupled by the objective lens 11 to the above-mentioned output optical devices. As illustrated in FIG. 1, these devices, including the television camera 13, the cine camera 16, the still camera 17, and the mirror system or "beam splitter" 15, which provides an output selection function, are arranged in a horizontal plane passing through the output axis of the folded objective lens 11. This physical arrangement minimizes the below-patient height of the fluoroscopic apparatus.

The optical functions of the beam splitter 15 are performed by a glass plate having a reflective coating which reflects a portion of the impinging light and transmits another portion. The division is a function of receiver sensitivity, generally in the range of 50/50 to 90/10 depending on application (90 percent reflected). The glass plate is translatable (by means not shown) to one of two mutually orthogonal positions. In the illustration, the plane of the beam splitter is vertical in both positions and by means of the reflective surfaces, the beam splitter optionally couples either to the cine camera 16 or to the still camera 17. In either position, however, light is transmitted directly through the beam splitter to the television camera 13. One may optionally translate the glass plate to mutually orthogonal positions where one position is rotated about a horizontal axis from the other position. This will permit one of the optical output devices to be disposed above rather than to one side of the beam splitter. In either disposition, the camera is ordinarily oriented along its axis so that the patient's head is up in the pictures.

It should be noted that in the illustration of FIG. 1, the output elements 13, 16, 17 and the objective lens 11 are shown in a slightly expanded view for clarity in illustration. In practice, the beam splitter may be regarded as occupying a space which is cubical with the edge dimension of the cubic space being equal to the distance from the front group of the objective lens to it exit pupil (100 mm. in a 90 mm. example). The objective lens and each of the output lenses are then disposed at each of the lateral or upper faces of this cube for a minimum vignetting position. This optimal disposition of the lenses reduces vignetting to approximately 25 percent. For certain output devices, optimal positioning is not essential but is available when desired.

One may now consider the optical aspects of the objective lens 11 in relation to the output optical devices. An input lens 22 of the television camera 13 and input lenses of the cine and film cameras 16 and 17 are arranged with respect to the objective lens 11 so as to have an "infinity" conjugate ratio. That is to say, the image intensifier output screen 21 is placed at the focal plane of the objective lens 11 so as to produce essentially parallel light between the objective lens 11 and the television camera lens 22 and similarly, the television camera lens 22 is arranged such that the camera pickup tube target (not shown) within the television camera 13 is in the focal plane of the lens 22, permitting the lens 22 to be focused to infinity. This is an optimum design position for all three optical output devices 13, 16 and 17. The provision of an infinity conjugate ratio creates a parallel wave front between the lens 11 and the three optical output devices, and permits greater latitude in adjustment of the spacing between the respective lenses. At the same time, the interposition of an optically flat beamsplitting device 15 between the lenses for switching in the cine or still cameras 16, 17, introduces a minimum of lens error.

The lenses 11 and 22 should be in relatively close mutual proximity to avoid the loss of light from off-axis image points, i.e. vignetting. The lens 11 has its exit pupil in front of its front element (100 mm. being typical for a lens of 90-mm. focal length). The combination, in one practical example, exhibits a maximum of 25 percent vignetting when the entrance pupil of lens 22 is located at this position. Preferably the entrance pupils of lens 22 and of the other optical output devices are placed at the exit pupil of the lens 11 with the penalty for greater separations being increased vignetting.

The performance requirements of the folded objective lens 11 are established by the following system components. To

minimize patient exposure to X-ray radiation the lenses 11 and 22 should have relatively large apertures and should be efficiently coupled. One example of the objective lens 11 has a 90-mm. focal length and an aperture of $f/1.0$ corresponding to a lens diameter of 90 mm. Similarly, the television camera lens 22 should have a relatively large aperture, typically from $f/0.75$ to $f/1.0$ and provide an entrance pupil diameter of the same approximately 90 mm. to intercept the image beam.

In the event that an interlens spacing exceeding the desired figure is required, it may be desirable that the output lens (22) have a smaller entrance pupil. Although this arrangement results in some reduction in optical efficiency, it produces a more uniform illumination of the image.

The maximum useful resolution in the system is ordinarily set by the image intensifier tube 12, which in a typical case, has a resolution of 20 line pairs/mm. in the plane of the output screen 21. The X-ray tube itself may be capable of at least twice this resolution and the optical elements are ordinarily of about four times this quality. The output monitoring requirements, assuming a standard 525 line television viewing system, establish a resolution requirement of approximately 25 line pairs/mm. at the output screen 21, while a camera output system (such as 16 or 17) may be capable of as great resolution as the optics themselves. The foregoing resolution requirements thus place a premium on objective lenses having good low frequency response and to achieve this end, the objective lens is designed to provide an image having substantial contrast at all spacial frequencies between 0-40 line pairs/mm. The resulting cut-off frequency in this particular design varies from 150 line pairs/mm. on axis to 80 line pairs/mm. at the edge of the image. A graph of this performance property obtained from actual test data on a 90-mm. example is illustrated in FIG. 3.

The lens 11 has been designed with 5,200 Angstrom units as the nominal center of the spectral range. This corresponds to a common value for image intensifier tubes. The color correction of the lens however is maintained over any reasonable broad bandwidth (approximately 2,000 Angstrom units) within the visible spectrum suiting the lens for use in a wide variety of practical applications.

A final system requirement which this lens has been designed to meet is that it be fully corrected for differing amounts of glass in the face plates of the various kinds of image intensifier tubes with which it is likely to be used.

The folded objective lens 11 is illustrated in detail in FIG. 2. It is a 10 element lens having four elements (A, B, C, and D) in a first or front group separated by a mirror M from six element (E, F, G, H, J, K) forming a second or back group. The function of the mirror is to provide a 90° fold in the axis of the lens. Both the first group (A, B, C, and D) and the second group (E, F, G, H, J, K) are convergent, with the first group having relatively low power and functioning primarily to refract the outer most ray of the off-axis bundle sufficiently to get it within the transverse dimensions of the following lens assembly. Associated with the second group is a final plane member L of make-up glass.

Considering the lens elements one at a time, the elements A, B form a crown-flint doublet while the meniscus C, which has a negative power, and the meniscus D are crown elements. In the second group, element E, F, and H, J are both double flints and the menisci G and K are also flints. The mirror M is disposed at 45° with respect to the axes of the front and back groups of the objective lens and is conventionally a first surface mirror having an aluminum reflecting layer. The mirror is optically flat and is suitably coated to avoid deterioration and to enhance optical efficiency. Since minimum overall dimensions of the objective lens are desirable the first and second groups of lenses closely abut the cube which the mirror occupies.

As mentioned above, the front group is of relatively low power being of approximately 1,000-mm. focal length while total lens may have a focal length of 90 mm. (in a 90-mm. example). The front group is of relatively low speed ($f/10.0$) and

has the relatively small field angle of $6\frac{1}{4}^\circ$ half field. The clear aperture diameters of the elements, as will be explained below, are optimized to assist in placing the exit pupil some 100 mm. (in the 90-mm. example) in front of the front element of the lens in order to reduce vignetting.

In a lens of two widely spaced groups, chromatic aberrations are the most difficult to correct. One may regard the front group as a Tessar type lens with the achromatization of the front element representing a refinement of a triplet.

The second lens group contains the principal power within the lens. It is of approximately 90-mm. focal length (in the 90-mm. example) and has a relative aperture of $f/1.0$. It resembles a corresponding infinite conjugate lens having the further limitation that its maximum overall length not greatly exceed its focal length. The requirement of such short physical dimensions eliminates the possibility of using most conventional lens design approaches.

Because of this dimensional requirement, the second group is designed with the general philosophy of using all positive elements and of following each of the stronger elements with immediate correction. Approximately half the power is assigned to the first doublet (EF) a double flint which is followed by a meniscus G for correction. A second double flint (HJ) having substantial power is also provided. It is followed by a meniscus K for correction of both aberrations introduced by the second doublet and in order to balance accumulated system aberrations. Measured from the face of element E to the image plane, the physical length of second group is approximately 102 units for a 110-unit focal length.

The final element shown in FIG. 2 is a planoparallel window L, which functions as a sheet of make-up glass. It may be treated as a part of the lens proper since retaining rings are ordinarily provided to support it integrally with the other elements. It has a "design" thickness of 6.7 units (6.0 mm.). This dimension represents the maximum dimension of intensifier tube face plate thicknesses that can be accommodated without degradation. When the lens is used with such a tube of maximum thickness, no make-up glass is included in the lens assembly. If a tube having a lesser face plate thickness is used, a sheet of make-up glass is provided of such thickness as is required to make the total thickness of glass between last element K and the image equal to the original "design" thickness.

The foregoing elements provide a highly corrected folded objective lens having an aperture of $f/1.0$ suitable for use in the fluoroscopic system so far described. In the example referred to, where the focal length of the lens is 90 mm., the lens has an image format of 20 mm. in diameter and an exit pupil 90 mm. in diameter located 100 mm. in front of the front element. The overall vignetting factor is significantly reduced due to the strategic placement of the exit pupil of objective lens 11 close to the entrance pupil of the television camera lens 22. In the case of a normal design, the pupil would be located within the lens and for a given positive off-axis point, the upper portion of the light bundle from the image would be vignetted within the lens 11. When this light bundle encounters the television camera objective lens 22, the lower portion of the bundle will ordinarily be additionally vignetted, resulting in a total vignetting factor on the order of 60 percent. Having the exit pupil remote from the lens as is the case for the objective lens 11 herein considered, results in the unusual condition wherein vignetting occurs at the lower portion of the light bundle from the lens 11. This vignetted loss in the objective lens 11 is largely coincident with the vignetted loss the TV objective, which also vignettes the lower portion of the bundle. Thus by a super position of the exit pupil of the lens 11 upon the entrance pupil of the TV lens 22, the overall vignetting is reduced to 25 percent.

In order to place the exit pupil of the objective lens 11 well in front of the lens in the interest of reducing vignetting, certain additional conditions are imposed upon the lens design. In particular, several of the lens elements are made considerably larger in clear aperture diameter than in conventional designs. Secondly, the lens performance is optimized with reference to

those rays which pass through the remote exit pupil rather than those which pass through an exit pupil internal to the lens assembly.

A table of the final lens design at a standardized equivalent focal length of 100 and a relative aperture of $f/1.0$ is given below:

Lens	Radius	Thickness	Air space	Nd	ed	Clear aperture (in.)
A.....	$R_1=126.4$	$t_1=17.2$		1.498	65.1	100.0
B.....	$R_2=-207.8$	$t_2=5.56$		1.788	47.4	100.0
	$R_3=\infty$		$S_1=26.4$			100.0
C.....	$R_4=432.5$	$t_3=5.56$		1.517	64.2	90.0
	$R_5=-158.0$		$S_2=3.8$			90.0
D.....	$R_6=275.5$	$t_4=8.9$		1.620	60.3	90.0
	$R_7=651.0$		$S_3^a=111.0$			90.0
E.....	$R_8=150.5$	$t_5=15.8$		1.689	49.5	90.0
F.....	$R_9=-126.4$	$t_6=18.6$		1.755	27.6	90.0
	$R_{10}=211.0$		$S_4=.11$			90.0
G.....	$R_{11}=81.5$	$t_7=10.0$		1.744	44.8	83.0
	$R_{12}=196.0$		$S_5=.11$			83.0
H.....	$R_{13}=51.2$	$t_8=33.4$		1.784	43.9	75.0
J.....	$R_{14}=\infty$	$t_9=9.7$		1.785	26.1	57.0
	$R_{15}=20.8$		$S_6=3.9$			35.0
K.....	$R_{16}=20.8$	$t_{10}=8.34$		1.744	44.8	35.0
	$R_{17}=90.5$		$S_7^c=5.5$			35.0
L.....	$R_{18}=\infty$	$t_{11}=6.67^b$		1.517	64.2	30.0
	$R_{19}=\infty$					30.0

^a Mirror is placed in S_3 .

^b Face plate and make-up glass.

^c S_7 is the total air space included between R_{17} and image plane. Image format = 22.2 units diameter.

Full field angle = $12\frac{1}{2}$ degrees.

The tabulated figures are nominal dimensions for use in manufacturing and are subject to conventional manufacturing tolerances. The actual tested performance of the lens in a 90-mm. focal length example is illustrated in FIG. 3 where the modulation transfer function is plotted along a three-coordinate axis. The modulation transfer function whose modulus is the vertical coordinate in FIG. 3 is a representation of the ability of the lens to reproduce an object at varying spatial frequencies whose intensity varies in a sinusoidal fashion. The ability to reproduce such sinusoidal variations, which is graphed in FIG. 3, is a ratio of the modulation of the image relative to the modulation of the object. It might be spoken of as the contrast ratios between the image and the object. This property has been plotted against spatial frequency and radial position along the object. In FIG. 3, the line 31 corresponds to an on-axis position; the lines 32 and 33 to a position 5 mm. off axis; and the lines 34 and 35 to an off-axis position of 10 mm. The symbols "R" and "T" illustrated on the line traces 32-35 show disparate treatment for radial and tangentially oriented lines. This difference in treatment is an indication of nonsymmetrical point images. The modulus is plotted at each of the given object positions against the third coordinate, namely the spatial frequencies in line pairs/mm. It may be seen that the graph illustrates measurement through the range of from zero to 40 line pairs/mm.

From a consideration of this graph, it will be seen that the modulus of the optical transfer function is 1 at the origin (on the object axis, at zero spatial frequency) and remains close to

unity at low spatial frequencies irrespective of the radial position on the object. As the spatial frequency increases from zero to 40 lines/mm., the function decreases, the decrease tending to becoming more marked as one moves off axis along the object. If one takes the particular line frequency of 40 lines/mm., the modulus falls from a value of approximately 0.70 to approximately 0.50 at the 5-mm. off-axis position and 0.35 at the 10-mm. position (averaging the R and T plots).

In FIG. 3, the lateral chromatic aberration accounts for the reduction of the modulus for the tangential characteristic (33, 35) with respect to the radial characteristic (32, 34). The lateral chromatic aberration is a radial aberration which has no effect on the modulus for radially oriented lines, but does have an effect on tangentially oriented lines. In the case of a small off-axis image, the lateral color error appears as a small radial smear of progressively changing hue. If the line structure of the image is radially oriented the modulus is unaffected, while if the line structure of the image is tangentially oriented, successive lines blur into one another and the modulus is reduced.

In the performance characteristic in FIG. 3, the radial characteristic (32) has a modulus value of approximately 0.57 at the 5-mm. object position at a spatial frequency of 40 lines/mm. At the 10-mm. object position at the same spatial frequency the radial characteristic (34) continues to have a modulus value of approximately 0.5, while the tangential characteristic (33) is now reduced to approximately 0.24. Taking the tangential line performance by itself, the performance of 0.24 at 40 lines/mm. is still well in excess of the 0.10 figure which is usually regarded as marginal. At 20 lines/mm. the tangential resolution is approximately 0.43, indicating that the design is quite conservative at the intended upper spatial frequency limit of 20 lines/mm. Since most subject matter contains lines of random orientation, the subjective effect is ordinarily viewed as a composite one, approximating an average of the two individual radial and tangential properties.

The curves illustrated in FIG. 3 describe a lens having good low frequency performance whose cut-off frequency generally exceeds 80 lines/mm. throughout the object positions and which has a very substantial modulus at 40 lines/mm. While the cutoff region is not graphed in FIG. 3, it represents the point at which the modulus falls below a useful level (usually approximately 0.10 as noted above). The curves in FIG. 3 thus denote a lens design emphasizing extremely good low frequency response not only throughout the design region of from 0 to 20 lines/mm., but throughout the region of from 0 to 40 lines/mm.

The values indicated in FIG. 3 represent good performance from a lens design standpoint and are in excess of those observed in competitive lenses of equal focal lengths and apertures. Typical values for the modulus encountered in comparable lenses measured at a spatial frequency of 20 lines/mm., vary from 0.4 to 0.3 on the object axis to from 0.46 to 0.0 at the 10-mm. object position. The comparable values for the present lens of 0.85 on the object axis and approximately 0.57 (averaging R and T characteristics) at the 10-mm. object position, thus represent a substantial improvement.

The above table provides the design data for a lens incorporating the invention. Since the table is given in arbitrary units it is intended for the design of lenses over a range of focal lengths, of which a typical example is the 90-mm. focal length lens previously discussed. The lens design retains its high quality over a range of locations of the exit pupil. Consequently, one may employ the tabular values of the clear diameters of the elements wherein a number of the elements are oversized to place the exit pupil well in advance of the lens to achieve a minimum of vignetting in the present coupled optics application. If such an application is not contemplated, however, and a more conventionally located internal exit pupil is desired, the oversized elements may be reduced to

conventional values.

The lens design contemplates 6.7 units of the indicated variety of glass in the back focus of the lens between the last doublet and the object plane. The actual placement of the makeup glass, when such glass is necessary, is variable within the rather small limits of space remaining between the surface of the last doublet and the object plane.

In a fluoroscopic apparatus, the foregoing folded lens permits the optical axis to be conveniently folded with respect to the axis of the make-up beam. Since the X-ray beam is downwardly directed, the requisite elements of the fluoroscopic system required to be arranged under the patient along the vertical axis are now reduced to the image intensifier which ordinarily requires about 15 inches and the folded objective lens, which in a 90-mm. example occupies about 200 mm. (8 inches) of vertical space to achieve the fold. The remaining optical elements, such as the beam splitter 15, the cine camera 16, the still camera 17, and the television camera 13, may be arranged horizontally in the region of or above the folded objective lens. Thus, they need not extend very much below the lower extreme of the objective lens. The same spatial advantage is also achieved when the objective lens is used with simpler optical systems, such as those involving only direct coupling to a television system. By this arrangement, the under-the-patient fluoroscopic apparatus is conveniently arranged under an examination table of conventional height.

What is claimed as new and desired to be secured by Letters Patent in the United States is:

1. In a fluoroscopic apparatus adapted for use with an X-ray beam, the combination comprising:
 - a. an image converter and intensifier coaxially oriented along said beam;
 - b. a folded objective lens having two groups with a mirror interposed between; one of said groups being a back group of relatively high power coaxially arranged with said image intensifier and optically coupled thereto, and a second, front group of relatively low power, whose axis is folded to a position orthogonal to that of said rear group, said mirror providing said fold in said axis, the exit pupil of said folded lens being a substantial distance in front of said front group; and
 - c. output optical means including at least one lens having the entrance pupil thereof coupled to said folded lens at said exit pupil.
2. The combination set forth in claim 1 wherein said back group consists of all positive doublet and singlet elements to achieve minimum physical length, said physical length approximating the focal length thereof.
3. The combination set forth in claim 1 wherein means are provided for reflecting the output of said objective lens orthogonal to the horizontal axis thereof, to one of said output means.
4. The combination set forth in claim 3 wherein at least one of the orthogonal positions is displaced from said axis in a horizontal plane.
5. The combination set forth in claim 3 wherein one of the orthogonal positions is vertically displaced above said axis.
6. The combination set forth in claim 3 wherein said reflective means is a beam splitter partially reflecting the light coupled thereto to at least one output means and partially transmitting the light coupled thereto to a second output means coaxial with said horizontal axis.
7. The combination set forth in claim 6 wherein the minimum transmissive path length through said beam splitter from said front group to said output means approximates said substantial distance to permit said output means to be arranged substantially at said exit pupil to minimize vignetting.
8. The combination set forth in claim 3 wherein the minimum reflective path length via said reflecting means from said front group to said output means approximates said substantial distance to permit said output means to be arranged substantially at said exit pupil to minimize vignetting.

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