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(54) **Apparatus for the transmission  
and distribution of light radiation**

(57) An apparatus for the transmission  
and distribution of light radiation com-  
prising at least one source (1) of light  
radiation and an optical mixer in the  
form of a prism (3) made with para-  
meters enabling multiple reflection of  
light radiation of each source from the  
side faces of the prism (3) which is  
optically coupled with one end face to  
the output of each light radiation source  
(1, 2) and with the other end face to the  
input of a distributing light guide (4).

The invention is particularly de-  
scribed with reference to series con-  
nected thyristors.

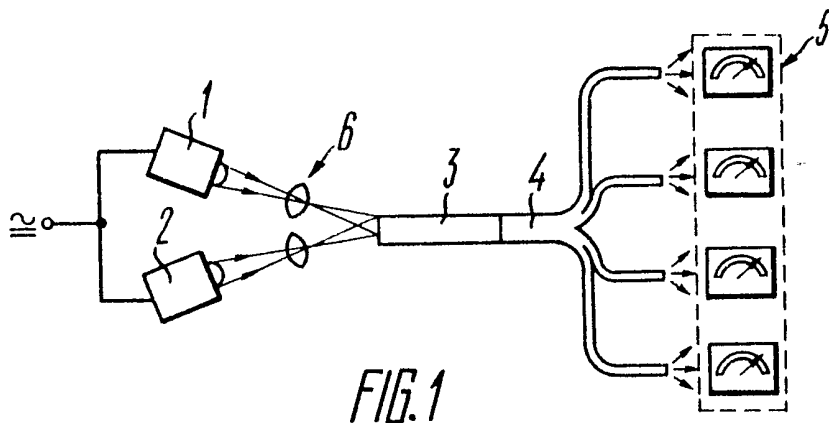
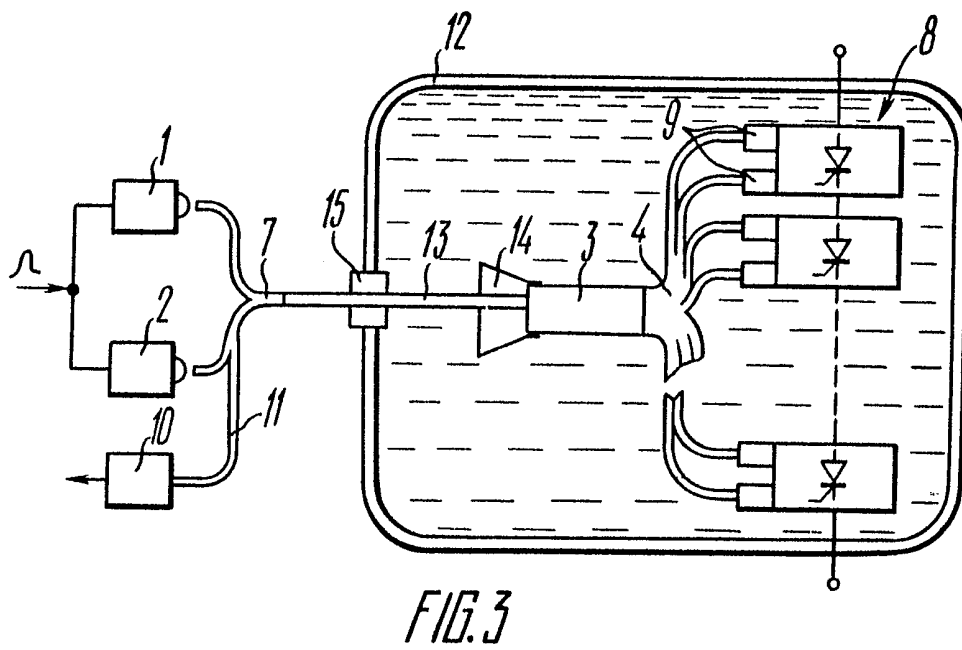
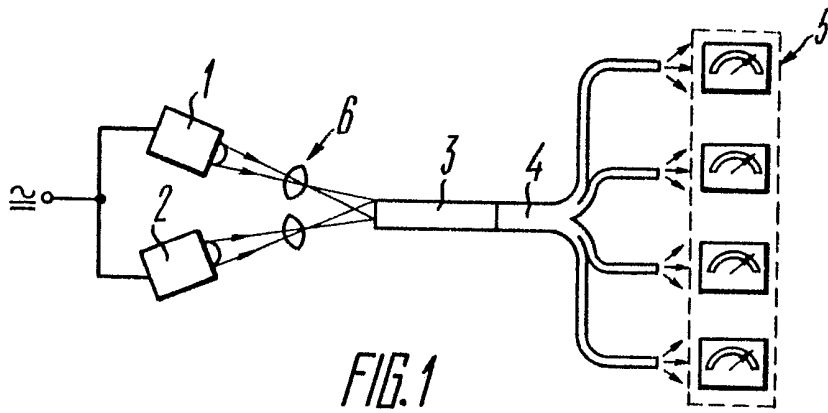
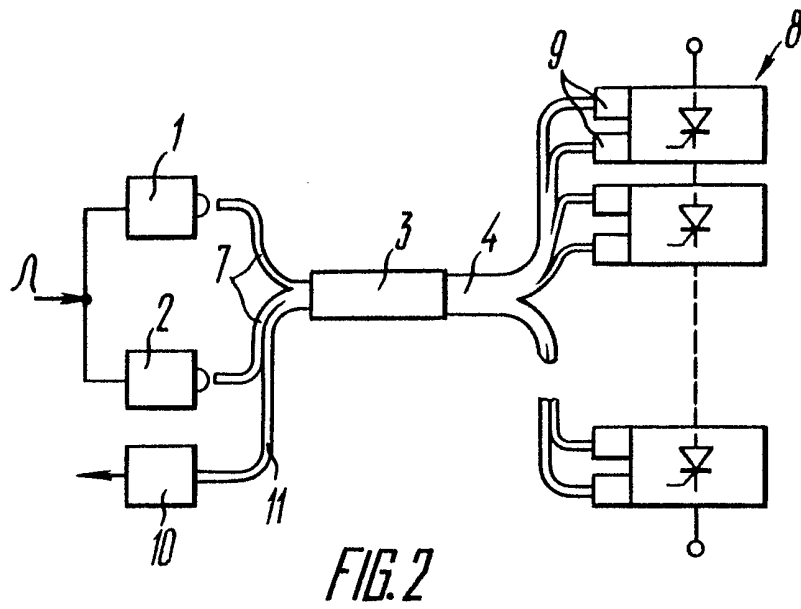


FIG. 1





## SPECIFICATION

**Apparatus for the transmission and distribution of light radiation**

5 The invention relates to high-voltage conversion equipment and deals with optical control systems for controlling series connected thyristors, and more particularly, the invention relates to apparatus for  
10 the transmission and distribution of light radiation.

An apparatus for the transmission and distribution of light radiation may be used in converting bridge circuits of direct current power transmission lines, in static compensators for reactive power, as well as in  
15 various vehicles and in the mechanical engineering equipment for illuminating the scales of instruments and for light indication of light display boards.

It is an object of the invention to provide an apparatus for the transmission and distribution of  
20 light radiation which ensures uniform distribution of radiation over the illuminated surface or among photocells of receivers, hence an improved reliability of the receivers.

Another object of the invention is to provide an  
25 apparatus for the transmission and distribution of light radiation which ensures simplified methods of assembly when used in a high-voltage thyristor rectifier optical control system.

Still another object of the invention is to provide  
30 an apparatus for the transmission and distribution of light radiation wherein the life of radiation sources is prolonged.

These objects are accomplished by that an apparatus for the transmission and distribution of light  
35 radiation, comprising at least one source of light radiation having an output which is optically coupled to an input of a distributing light guide, according to the invention, comprises an optical mixer in the form of a prism which is made with parameters enabling  
40 multiple reflection of light radiation of each source from the side faces of the prism which is optically coupled with one end face to the output of each light radiation source and with the other end face to the input of the distributing light guide.

45 In case light radiation-to-electric signal converters are used having their inputs optically coupled to respective outputs of the distributing light guide and accommodated in a sealed casing filled with a liquid or gaseous insulating material, the prism is preferably  
50 installed in the casing, and the apparatus comprises a rigid light guide in the form of a rod for optically coupling each light radiation source to the prism, the cross-sectional area of the rod being equal to, or smaller than, the area of the end face of  
55 the prism, and the prism is provided with a guide member installed on its end face facing the rod, the end of the rod moving along the guide member when the rod is installed in the casing.

In case a light radiation control circuit is used  
60 which has an input optically coupled to the output of the light guide for sampling a part of the radiation, the input of the light guide is preferably optically coupled to the end face of the prism facing the light radiation source.

65 The apparatus for the transmission and distribu-

tion of light radiation according to the invention is simple in structure and makes it possible to obtain in the practice high uniformity of distribution of radiation from one or several sources among outputs of  
70 the distributing light guide so as to improve the efficiency of utilization of the sources. Moreover, this makes it possible to use identical converters at the outputs of the apparatus, with a simplified electrical configuration forming substantially identical electric  
75 signals so as to ensure high reliability of optical control system. The apparatus also ensures identical brightness and illumination of illuminated portions of display boards and panels in display and illumination systems, respectively.

80 The invention will now be described with reference to specific embodiments illustrated in the accompanying drawings, in which:

*Figure 1* is a diagrammatic view of an apparatus for the transmission and distribution of light radiation according to the invention in a system for  
85 illuminating the scales of instruments;

*Figure 2* is a diagrammatic view of an apparatus for the transmission and distribution of light radiation according to the invention in a system for  
90 optical control of a high-voltage thyristor rectifier, having a control circuit provided with a light guide directly connected to the end face of a prism, and a collector-type light guide for optically coupling sources to the prism;

95 *Figure 3* is an embodiment of an apparatus for the transmission and distribution of light radiation according to the invention, having a prism, a distributing light guide, and actuator elements enclosed in a sealed casing, and a control circuit having a light  
100 guide which is optically coupled to the prism by means of a rigid light guide in the form of a rod.

An apparatus for the transmission and distribution of light radiation comprises at least one source of light radiation: sources 1, 2 (*Figure 1*) in this  
105 embodiment, and an optical mixer in the form of a prism 3 having an end face optically coupled to the outputs of the sources 1, 2. The prism 3 is made with parameters enabling multiple reflection of light radiation of the sources 1, 2 from the side faces of  
110 the prism. The other end face of the prism 3 is coupled to the input of a distributing light guide 4.

It is preferred to use a rectangular square-section prism made of an optical glass as the optical mixer. The side face of the prism may be with or without  
115 light-insulating coating. In the latter case the surface should have minimum area of optical contact with a protective casing (not shown), and the index of refraction of the prism material should be greater than the index of refraction of the ambient medium.

120 In this embodiment the prism 3 is made of an optical glass with the index of refraction  $n = 1.52$  and with polished faces. The ratio of the edge length of the prism 3 to the length of the base side is 20:1. When the input end face of the prism 3 is illuminated  
125 with a conical light beam with the spot diameter on the end face 2 mm and with an angle at the vertex  $40^\circ$ , independent of the position of the spot on the input end face, illumination with non-uniformity of maximum 5% is obtained at the output end face of  
130 the prism.

This property makes it possible to use such prism for adding light radiations from several sources and for uniform distribution of radiation over the illuminated surface, in particular, for illuminating the scales

5 of instruments 5.

Sources 1, 2 of light radiation may comprise incandescent lamps, gas-discharge lamps light-emitting diodes, lasers.

Optical coupling of such sources of light radiation to the end face of the prism 3 may be effected in various ways. Thus, in this embodiment of the apparatus the use is made of a lense optical system conventionally shown in biconvex lenses 6. Light flux from the sources 1, 2 is focused by means of the

15 lenses 6 through an electrically insulating air gap directly at the input end face of the prism 3. Optical coupling of the prism 3 to the input of the distributing light guide 4 is effected through their direct contact. The light guide 4 and the prism 3 may be made in the form of an integral structure as an element of the optical system. Their coupling may be effected in any manner so as to ensure adequate light transmission and mechanical strength. The number of outputs in the form of output strands of the light guide 4 is chosen depending on specific

25 application, and the length thereof should be minimum and sufficient for wiring. Optical coupling of the light radiation sources 1, 2 to the input end of the prism 3 may be effected by means of a collector-type light guide 7 (Figure 2) which is more preferable compared to the above-described lense optical system. The cross-sectional area of strands of the light guide 7 is chosen in such a manner as to focus all radiation from the sources

35 1, 2 at their end faces. The length and design of the light guide 7 should be chosen in such a manner as to ensure a reliable electrical insulation of a high-voltage thyristor rectifier 8 which is controlled by means of the apparatus according to the invention. The output end face of the collector light guide 7 may be of round or square section and is coupled to the end face of the prism 3 by means of a detachable connector.

For forming a signal for controlling the high-voltage thyristor 8, the radiation sources 1, 2 used in the apparatus may comprise gas-discharge lamps, light-emitting diodes, semiconductor lasers such as an injection-type gallium arsenide lasers functioning on the pulse basis, and there are provided light

50 radiation-to-electric signal converters 9. The end faces of the output strands of the distributing light guide 4 are optically coupled each to a respective converter 9 which may be built around photodiode, phototransistor or photothyristor. In such case the cross-sectional area of strands of the light guide 4, the coupling of the strands to the converters 9, and parameters of light radiation sources 1, 2 should be chosen in such a manner that the coefficient of transmission of light radiation to a sensitive area of each converter 9 be at maximum and that radiation power at the end faces of the output strands be sufficient for reliable functioning of the converter 9.

In order to ensure reliable operation of the high-voltage thyristor rectifier 8, redundant converters 9

65 are provided at each module of the rectifier 8.

In the apparatus for the transmission and distribution of light radiation there is provided a circuit 10 for controlling light radiation, e.g. by radiation power, and a light guide 11 is provided for sampling a part of the light radiation. Output and input of the light guide 11 are optically coupled to an optical window of a photoreceptor at the input of the circuit 10 and to the output end face of the prism 3, respectively. Optical coupling is effected by means of optical connectors (not shown).

70 Sampling a part of light radiation for controlling radiation power is effected owing to the backward reflection of a part of the radiation from the output end face of the prism.

80 In case the collector light guide 7 is used for optically coupling the sources 1, 2 to the prism 3, the light guide may comprise a strand serving as the light guide 11 for sampling a part of the light radiation.

85 It follows from the properties of the prism 3 that the circuit 30 can ensure a general control with the use of one or several sources of light radiation. Owing to the multiple reflection of radiation from the side faces of the prism 3 with forward and backward beams, high degree of proportionality of radiation sampled for radiation control is ensured both with respect to total radiation of one or several sources and to the radiation at the output strands of the light guide 4. Consequently, the control circuit 10 may be

95 adjusted both to the total radiation of the sources and to the radiation from the output of the apparatus. The latter capability of the circuit is due to the uniform distribution of the light radiation among the output strands of the light guide 4.

100 Independent of what kind of control (general or output) is effected, the control circuit 10 remains unchanged and may have a configuration known to those skilled in the art. In case the high-voltage thyristor rectifier 8 is accommodated in a sealed casing 12 (Figure 3) filled with a liquid or gaseous insulating material such as transformer oil, the prism 3, distributing light guide 4, and converters 9 are also installed in the casing 12. Optical coupling of the light radiation sources 1, 2 to the prism 3 is effected by means of a rigid light guide in the form of a rod 13 with the cross-sectional area equal to, or smaller than, the area of the input end face of the prism 3. For an optical coupling of the rod 13 to the prism 3 installed in the casing 12, the prism

115 3 has a guide member 14 installed on the input end face thereof, and for the insertion of the rod 13 into the casing 12, there is provided a sealing bushing 15. The rod 13 has a cross-section identical with the cross-section of the output end of the collector light guide 7 but equal to, or smaller than, the cross-section of the prism 3.

120 It is most preferred to make the guide member 14 with the inner working surface in the form of the surface of truncated pyramid. When the rod 13 is installed, the bushing 15 ensures a rough guiding toward the prism 3 and so that the end of the rod will necessarily get into the zone defined by the guide member 14. When the rod 13 is pushed home, the end of the rod 13 moves

130 along the guide member 14 so as to ensure its

optical contact with the end face of the prism 3.

The distributing light guide 4, prism 3, rod 13, and converters 9 should be designed for operation in oil.

In case the rod 13 is provided, a part of light  
5 radiation is sampled for the control circuit 10 by means of the light guide 11 by the direct contact of its input end with the end face of the rod 13.

In operation of the apparatus for the transmission and distribution of light guide, e.g. in a system for  
10 illumination of the scales of instruments, the light radiation sources 1, 2 (Figure 1) such as incandescent lamps are turned on by feeding electric supply thereto. The radiation from the sources 1, 2 is focused by means of the optical lense system in the  
15 form of biconvex lenses 6 at the input end face of the prism 3. High focusing accuracy is not required. Thus, when the focused radiation spot takes an area smaller than the area of the end face of the prism 3 a considerable unfocusing and displacement of the  
20 spot over the end face are permitted, provided that the focused radiation is within the area of the end face of the prism 3.

The light radiation incident upon the prism 3 subjected to multiple reflection from its side faces  
25 passes from the input end face toward the output face and gets to the input of the distributing light guide 4 which is in the direct contact with the prism 3. Uniform illumination from each source 1, 2 is obtained at the input end face of the distributing  
30 light guide 4 with any non-uniformity of radiation by area and angle at the input end face of the prism within the limits of the aperture of the prism 3. Owing to this, equal power of radiation from each source 1, 2 is achieved at the output strands of the  
35 distributing light guide 4 with equal cross-sectional areas and transmission coefficients of the strands.

This uniform radiation from the output strands of the light guide 4 is fed for illumination of the scales of instruments 5, each strands illuminating an  
40 individual scale.

In case the output strands of the light guide 4 are of different length in accordance with design considerations, coefficients of transmission of the strands may be substantially different. In each case,  
45 in order to provide for identical radiation power at the output of the strands of the light guide 4, each strand should have the cross-sectional area inversely proportional to its coefficient of transmission.

The apparatus for the transmission and distribution of light radiation in a system for controlling a  
50 high-voltage thyristor rectifier functions substantially similarly to the above-described apparatus.

The apparatus is started by electric starting pulses which are fed simultaneously to the input of the  
55 sources 1, 2 (Figure 1) such as semiconductor pulse lasers. Laser radiation is focused at the end faces of strands of the collector light guide 7 and is fed along the light guide 7 to the end face of the prism 3. When the radiation from the sources 1, 2 passes through  
60 the prism 3 it is partly reflected from the output end face of the prism 3 toward its input end. A part of this reflected radiation gets into the light guide 11 for sampling a part of the light radiation and is fed to the photoreceptor of the control circuit 10 controlling,  
65 e.g. radiation power. A signal from control circuit 10

is fed to a control board of the high-voltage thyristor rectifier (not shown in the drawing).

The amount of sampled radiation fed to the control circuit 10 depends on the coefficient of  
70 reflection of the output end face of the prism 3 on the cross-sectional area of the light guide 11 and its coefficient of transmission (for the coated end face the coefficient of reflection is about 0.5% and for uncoated end face this coefficient is about 4%).

75 Light signals of radiation of both sources 1, 2 uniformly distributed among the output strands of the light guide 4 are fed to the sensitive areas of the converters 9. Light signals of radiation are converted into electric control pulses in the converter 9 to be  
80 fed to the high-voltage thyristor rectifier 8.

Redundant converters 9 are provided at each module of the rectifier 8, and the sensitivity of the converters 9 is such as to work normally in case of the two sources 1, 2 fails. This system of redundancy  
85 of the sources 1, 2 and converters 9 cross-redundancy makes it possible to ensure high reliability of the high-voltage thyristor rectifier optical control system.

The embodiment of the apparatus according to the  
90 invention works along the same lines as the system shown in Figure 2 and described above in a system of optical control of a high-voltage thyristor rectifier enclosed in the sealed casing 12 (Figure 3) filled with a liquid or gaseous insulating material such as  
95 transformer oil. The only difference resides in that in operation of the apparatus the coefficient of transmission of the rod 13 should be taken into account since the rod 13 will somewhat lower both radiation fed to the converters 9 from the light radiation  
100 sources 1, 2 and radiation reflected from the output end face of the prism 3 and fed to the control circuit 10.

In all three above-described embodiments of the apparatus according to the invention the structure  
105 and manufacture of the optical mixer in the form of a prism are much simpler compared to the fiber matrix disclosed in the prior art. At the same time, better uniformity of light splitting is achieved, uniform illumination of the input end faces of strands of the collector light guide is not required, the requirements to the sources of light radiation and to their coupling to the light guide strands are lower.

As differed from the concentrator described in the analogous art, the optical mixer made in the form of  
115 a prism ensures guaranteed uniformity of splitting of light radiation.

The employment of the apparatus according to the invention makes it possible to improve reliability of optical control of high-voltage thyristor rectifiers  
120 owing to a necessary degree of redundancy achieved by simple means; eliminate the influence of exposure and dust deposits on working surfaces of elements of the optical path based on light-emitting diodes installed in the direct optical contact  
125 with the prism, radiation sources and converters. Moreover, the possibility of disruption of adjustment of the optical path is eliminated, first, owing to the above-mentioned direct contact between elements of the optical path; second, because the light spot can move within the input and face of the prism;  
130

third, owing to the use of a mechanical means (guide member) for ensuring complete optical contact of the rod with the input end face of the prism.

Reliability of optical control is also improved  
5 owing to uniform distribution of light signal among the converters and absence of special adjustment of the elements of optical path which, in addition, makes it possible to simplify the maintenance of the apparatus, especially in high-voltage thyristor recti-  
10 fier control system.

In addition, the apparatus has a prolonged service life without preventive maintenance.

#### CLAIMS

15

1. An apparatus for the transmission and distribution of light radiation, wherein at least one light radiation source has an output optically coupled to an input of a distributing light guide, and there is  
20 provided an optical mixer in the form of a prism made with parameters enabling multiple reflection of light radiation of each source from the side faces of the prism which is optically coupled with one end face to the output of each light radiation source and  
25 with the other end face to the input of the distributing light guide.

2. An apparatus for the transmission and distribution of light radiation as claimed in claim 1, wherein, in case there are provided light radiation-  
30 to-electric signal converters having their inputs optically coupled to respective outputs of the distributing light guide and accommodated, together with the light guide, in a sealed casing filled with a liquid or gaseous insulating material, the prism is also  
35 installed in the casing and is optically coupled to each light radiation source by means of a rigid light guide in the form of a rod having a cross-sectional area which is equal to, or smaller than the area of the end face of the prism, the prism having a guide  
40 member installed on the end face thereof facing the rod, the end of the rod moving along the guide member when installed in the casing.

3. An apparatus for the transmission and distribution of light radiation as claimed in one of claims  
45 1, 2, wherein, in case a light radiation control circuit is used which has an input optically coupled to the output of a light guide for sampling a part of light radiation, the input of the light guide is optically coupled to the end face of the prism facing the light  
50 radiation source.

4. An apparatus for the transmission and distribution of light radiation substantially as hereinabove described with reference to, and as shown in the accompanying drawings.