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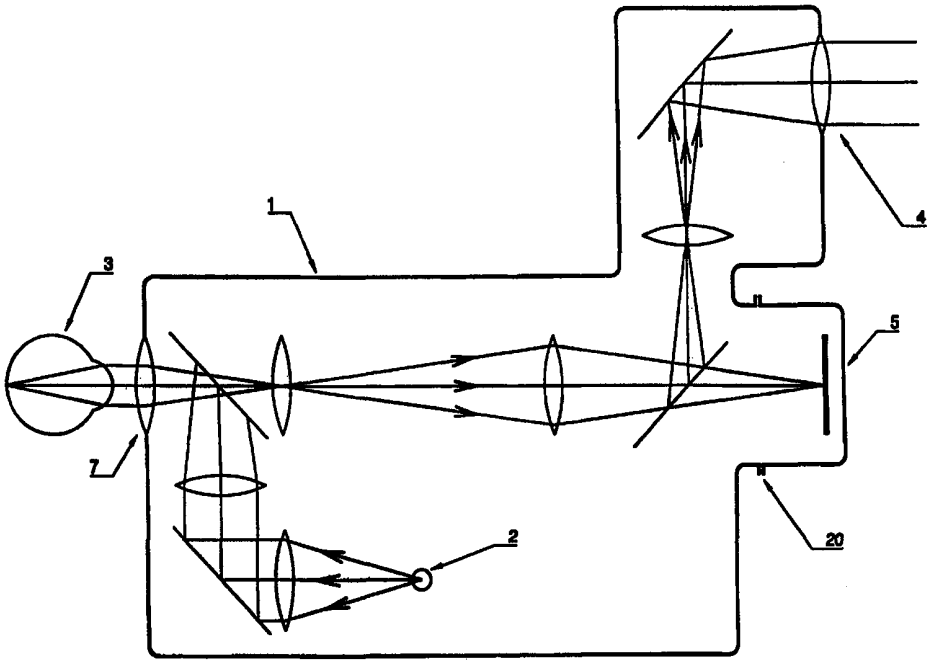
(54) Title: MEDICAL LASER GUIDANCE APPARATUS



(57) Abstract

A laser guidance apparatus comprises a laser light source and laser light directing means for directing light from the laser light source into the optical path of a retina viewing apparatus at its optical output. Laser light positioning means moves the position of laser light from the laser light source within said optical path, and control means control the laser light source and positioning means in order to apply, in use, laser light to specific points or areas in the retina of an eye.

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MEDICAL LASER GUIDANCE APPARATUS

This invention relates to a medical laser guidance apparatus.

In recent years laser light has been used to assist in the treatment of a number of ailments. One particular application of laser light has been in the treatment of eye disease by the application of laser light to the retina of an eye. Traditionally, such treatment has involved preliminary inspection of the eye using a fundus camera, slit lamp or similar optical viewing device followed by movement of the patient to a separate location for laser treatment of the eye. With such treatment, the laser is often applied days or weeks after the initial inspection, in view of the need to develop photographs taken by the fundus camera and the time required to analyse such photographs. Furthermore, once laser treatment is started, a number of sessions may be required, as the treatment is time consuming and traumatic for the patient, due to the need to compare the retina to be treated with earlier photographs. This, in turn, leads to the operator and patient tiring, making lengthy treatment sessions difficult to tolerate.

In order to overcome some of the above problems, it has been proposed to incorporate a laser treatment apparatus within a fundus camera. Such a system, whilst enabling the laser treatment of the retina to be performed at the same time as initial inspection, is extremely expensive in view of the large number of components required to provide a combined camera and laser application device. This means that treatment centres have been reluctant to replace existing fundus cameras, slit lamps or similar devices with these new, combined treatment devices.

The present invention is directed towards solving some of the above problems.

According to the present invention there is provided a laser guidance apparatus comprising:

a laser light source;

laser light directing means for directing light from the laser light source into the optical path of a retina viewing apparatus at its optical output;

laser light positioning means for moving the position of laser light from the laser light source within said optical path; and,

control means for controlling the laser light source and positioning means in order to apply, in use, laser light to specific points or areas in the retina of an eye.

With the apparatus according to the present invention, existing retina viewing apparatus need not be replaced, as the apparatus can be attached externally to the viewing apparatus. An operator can view the position of low level laser light emitted by the laser light source by viewing the retina through the eye piece of the fundus camera, slit lamp or similar viewing apparatus, and can apply a treatment level of laser light to a selected point or area of a patient's retina by appropriate application of commands to the control means.

Alternatively, a video camera may be attached to the eyepiece of the viewing apparatus. The video camera output can be displayed on a video monitor for ease of viewing. With either arrangement points on the retina may be selected for laser treatment by simple operation of a mouse, trackball or the like with an output connected to the control means. With such an arrangement, semi-automated control of the laser is also possible by providing real time or near real time image recognition means which receives selected point or area data from an operator and then tracks the retina using video data from a camera and outputs treatment level laser light as required. This semi-automated arrangement has the advantage that it can compensate for movements of the retina by the patient at a speed and accuracy that is not within the ability of a human operator.

A diffractive optical element may be placed within the optical path of the guidance apparatus in order to produce, from a single primary laser beam, an array of secondary treatment beams, which can thus be used to speed up treatment over a selected area, in order to reduce treatment time and patient discomfort.

The laser light source may be a tube laser, solid state laser or a diode laser, which has the advantages of reduced weight, size, and power consumption. The laser light positioning means may be a galvanometer and mirror arrangement, or may include acousto-optical devices. The laser light positioning means may be employed to modulate the light emitted by the laser light source by directing it away from the viewing apparatus optical path in a pulsed manner. Alternatively the laser light source may be pulsed.

One example of apparatus according to the present invention will now be described with reference to the accompanying drawings, in which:-

Fig. 1 is a schematic diagram of a known fundus camera;

Fig. 2 is a schematic diagram of a guidance apparatus according to the present invention;

Fig. 3 is a schematic block diagram of a computer control guidance apparatus according to the present invention;

Fig. 4 is a diagram showing the operation of a diffractive optical element that may be employed in the present invention;

Fig. 5 is a diagram of a treatment template for an apparatus employing the diffractive optical element shown in Figure 4; and,

Fig. 6 is a schematic diagram showing an example image recognition technique that may be employed with the present invention.

Fig. 1 shows a known fundus camera 1 which is employed to inspect the retina of an eye 3 which is to be treated.

An illuminating light source 2 provides illuminating light to the eye 3, which light is then reflected back towards a viewing eyepiece 4 and camera 5. When a photograph of the retina is to be taken, a flash light 2 is activated and a photograph taken with a camera 5 attached to a further optical output 20. A focusing system 7 is provided to focus the image of the retina for clear viewing by both the camera 5 and through the eyepiece 4.

Fig. 2 shows an example of the present invention being operated in conjunction with the known fundus camera 1 of Fig. 1. Corresponding components are identically numbered. It will be appreciated that this example could be adapted to operate in conjunction with a slit lamp or similar retina viewing apparatus. Attached to the optical output 20 of the fundus camera 1 is an optical extension 9. The optical extension 9 comprises a half-silvered mirror 10 and lenses 11. The mirror 10 is arranged to direct light from a laser light source 12 into the optical path of the fundus camera 1 and on to the retina of the eye 3 and also to allow light from the fundus camera 1 to transmit through to the cameras attached to the optical extension 20.

In this example, the laser light source 12 comprises a target laser light source 12a and a main pulse laser light source 12b. It will be appreciated, however, that a single laser light source, operating at two different power levels could be employed. In this example, the target laser light source may be a HeNe or red diode laser, and the main pulse laser light source an argon or NdYg laser. An optional power level meter 21 monitors laser light levels to ensure only safe light levels are applied to the eye 3.

Light from the laser light source 12 is directed via a dichroic mirror 13 to a laser light positioning means 14 which is under the control of a control means 15, in the example a computer, and comprises two X Y galvo mirrors 14a, 14b. This arrangement may be substituted by an acousto-optical device placed in the light path. The light

positioning means 14 operates to position light from the laser light source 12 within the optical path of the fundus camera 1 and to control the light's position on the retina of the eye. The laser light source 12 in this example comprises a treatment light source 12a and target light source 12b. An optional diffractive element 16 is placed in the path of the light from the laser light source 12. The operation of this optional diffractive element 16 will be described later.

Light from the laser light source 12 passes, in use, via the optical extension 9, through the camera 1 on to the retina of the eye 3 and back into the fundus camera 1 via the objective lens 8. The light is then passed out, via the eyepiece 4 or optical extension 9, to a video camera 5. The output of the video camera 5 is, in this case, connected to the control means 15 via a computer system, although it may alternatively simply be output to a display.

Referring to Fig. 3, the overall operation of the apparatus according to the invention will now be described. Again, components corresponding to those described with reference to Figs. 1 and 2 are identically numbered. In this example, a monitor 18 is provided to receive outputs from the control means 15 and hence to display images received by the video camera 5. User input means 19, 20 are provided, and may be components such as a keyboard 19 and/or mouse 20, a joystick or foot pedal. The example shown in Fig. 3 provides a number of treatment options. The first option is complete control of the treatment by the control means 15. With this option, control means receives data about the treatment, and controls the output of the laser light source 12, together with the laser positioning means 14 to apply laser light to the retina of the eye 3. The control means 15 is adapted, using appropriate real time image recognition software to monitor the position of light from the laser light source relative

to features on the retina of the eye, and to track the retina's position accordingly.

This example also enables a semi-automated process, in which particular points or areas on the retina are selected for treatment by an operator selecting points or areas displayed on the monitor 18. Once selection has been completed, the control means 15 then proceeds to treat the selected points or areas by application of the required level of laser light from the laser light source 12.

A further option is also possible with this example apparatus. This option provides for the individual point or area selection of the retina by an operator, followed by actual positioning of the laser light by direct control of the laser positioning means 14, and pulse application of the laser light source 12 as required.

Fig. 4 shows the optional diffractive optical element 16 shown in Fig. 2. This light diffractive element 16 diffracts a single laser beam 30 into a laser beam array 31 which, in this case, is a three-by-three matrix. It will be appreciated that matrices of other sizes could also be produced. The provision of this diffractive optical element 16 enables the application of laser light to multiple points in a single application, speeding up the treatment process, and reducing discomfort to the patient. As can be seen from Fig. 5, with a three-by-three diffractive optical element 16, the application of eight separate pulses, providing eight arrays of application points A to H, which can cover a large area of the retina 3 when the diffractive optical element 16 is provided.

The apparatus may incorporate a laser control algorithm which spatially and or temporarily randomises or disperses application of light to selected treatment parts.

Fig. 6 shows an example of one image recognition process that may be used in conjunction with the apparatus of the present invention. This process, performed by the control means 15, employs the outline of the optic nerve as a reference point on the retina (although an alternative

reference may be employed by an operator), and searches through the output of the video camera 17 until a match is produced. The control means 15 can then track the position of the retina 3 through both voluntary and involuntary eye movements by locking into and following the optic nerve position, or another topographical feature of the retinal image such as a blood vessel, for example. The process which may be employed with the invention, or may be employed in any combined retina viewing device employing laser treatment and appropriate image capturing, processing and laser control circuitry. The process of this example employs a cross-correlation function of the type

$$R_{ft}(u,v) = \sum_{x=-M}^{M} \sum_{y=-N}^{N} f(x,y).t(x-u,y-v)$$

where an image F(F,Y) and template T(Y), are captured and generated respectively. It will be appreciated that alternative functions may be employed.

This function is at a maximum when a portion of image F which is under template T as exactly the same as T. This can then form a simple goodness-fit measure, having a range from 0 to 1 by computing paragraph R_{ft} (u,v)/R_{tt} (u,v).

Where R_{tt} is computed once, before any matching has to be done.

The deviation of the current captured image from a reference image (and its corresponding template) yields a number in X and Y dimensions which is essentially an estimate of deviation. This number can then be employed to drive laser light deflecting means to correctly align the laser beam to a selected target.

This process is particularly useful if an automated or pre-stored treatment data course of treatment is required.

It will be appreciated that the overall control of the present invention can be provided by a control means 15 which is any suitable computer or microprocessor base system. For example a PC, Apple MacIntosh or other work station system with appropriate software and control

interfaces. This means that control of the system can be realised with high reliability and at relatively low cost.

CLAIMS

1. A laser guidance apparatus comprising:

a laser light source;

laser light directing means for directing light from the laser light source into the optical path of a retina viewing apparatus at its optical output;

laser light positioning means for moving the position of laser light from the laser light source within said optical path; and,

control means for controlling the laser light source and positioning means in order to apply, in use, laser light to specific points or areas in the retina of an eye.

2. An apparatus according to the present invention, wherein a video camera is attached to the eyepiece of the viewing apparatus.

3. An apparatus according to claim 1 or claim 2, further comprising a use input device for allowing selection of points on a retina by a user.

4. An apparatus according to claim 2 or claim 3, further comprising:

image recognition means; and

retina tracking means for tracking the position of the retina based upon the image recognition means.

5. An apparatus according to any preceding claim, further comprising a diffractive optical element within the optical path of the guidance apparatus.

6. An apparatus according to any preceding claim, wherein the laser light source is a diode laser.

7. An apparatus according to any preceding claim, wherein the laser light positioning means comprises a galvanometer driven mirror.

8. An apparatus according to any of claims 1 to 6, wherein the laser light positioning means includes an acousto-optical device.

9. An apparatus according to any preceding claims, wherein the laser light positioning means is arranged to enable pulsing of the light applied to a retina in use.

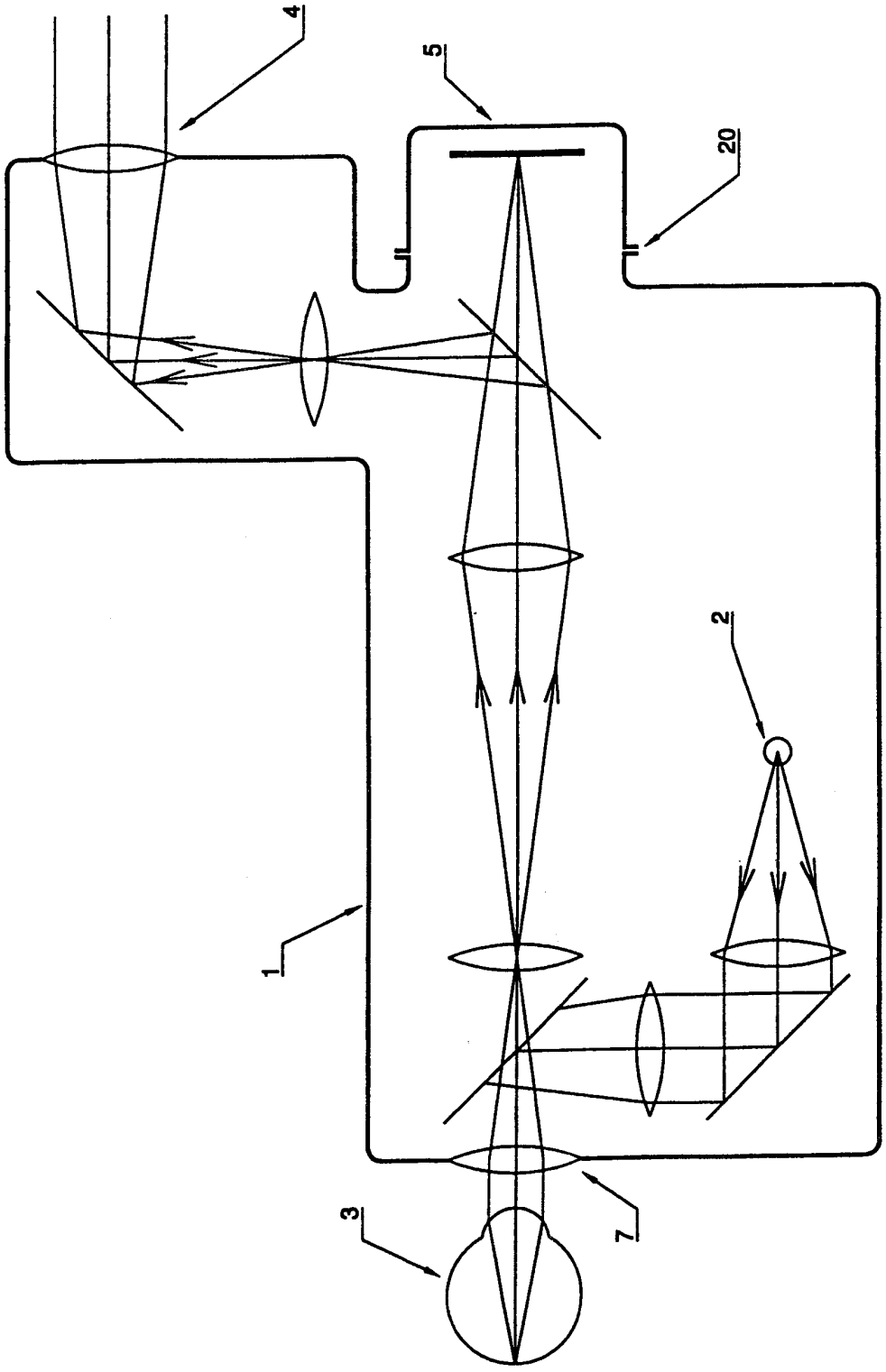


FIGURE 1

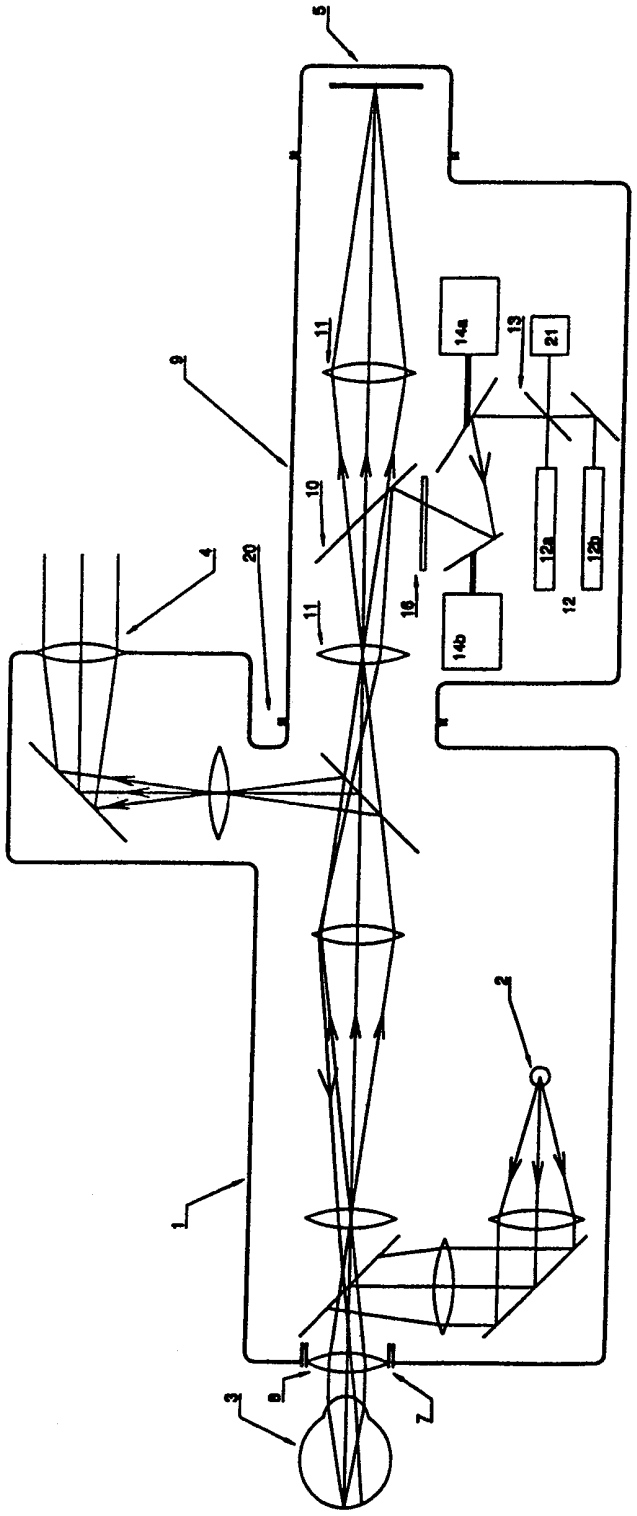


FIGURE 2

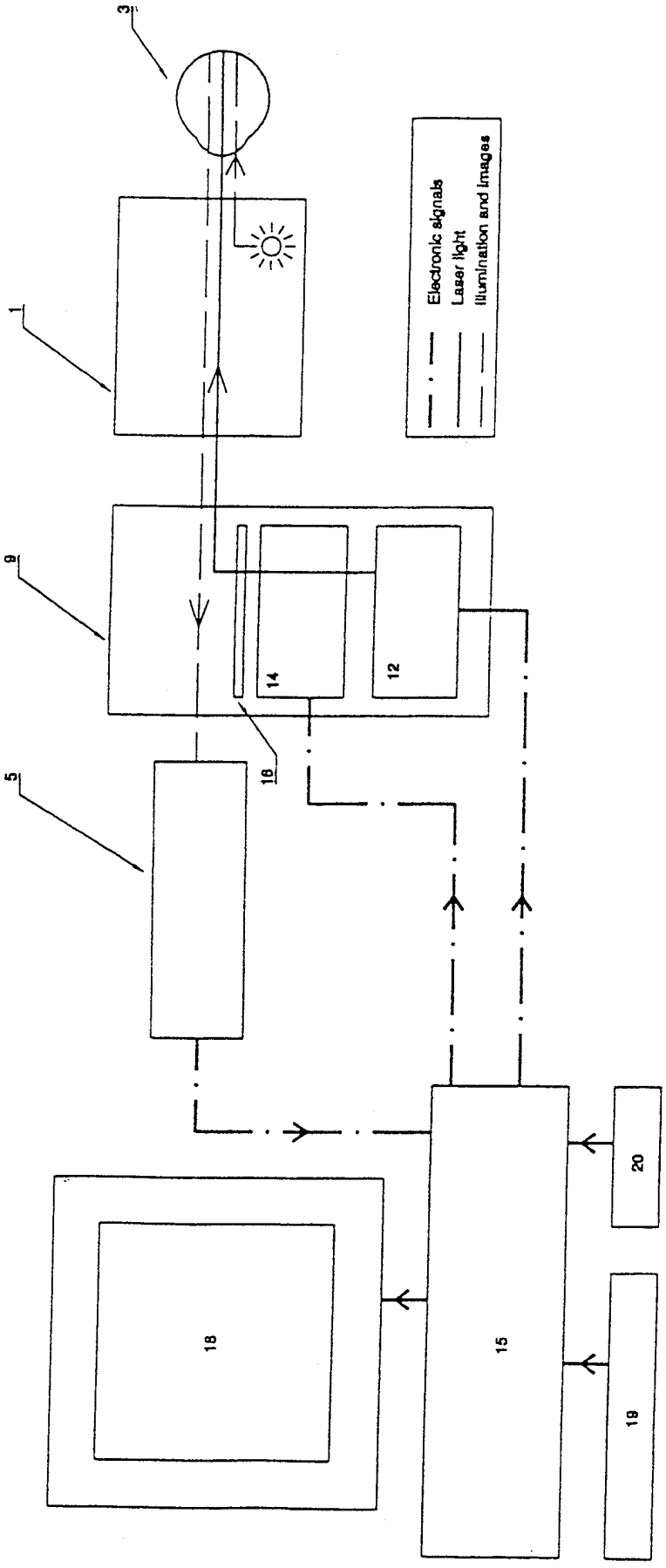

3
1
9
14
12
16
5
18
15
20
19
Electronic signals
Laser light
Illumination and images

FIGURE 3

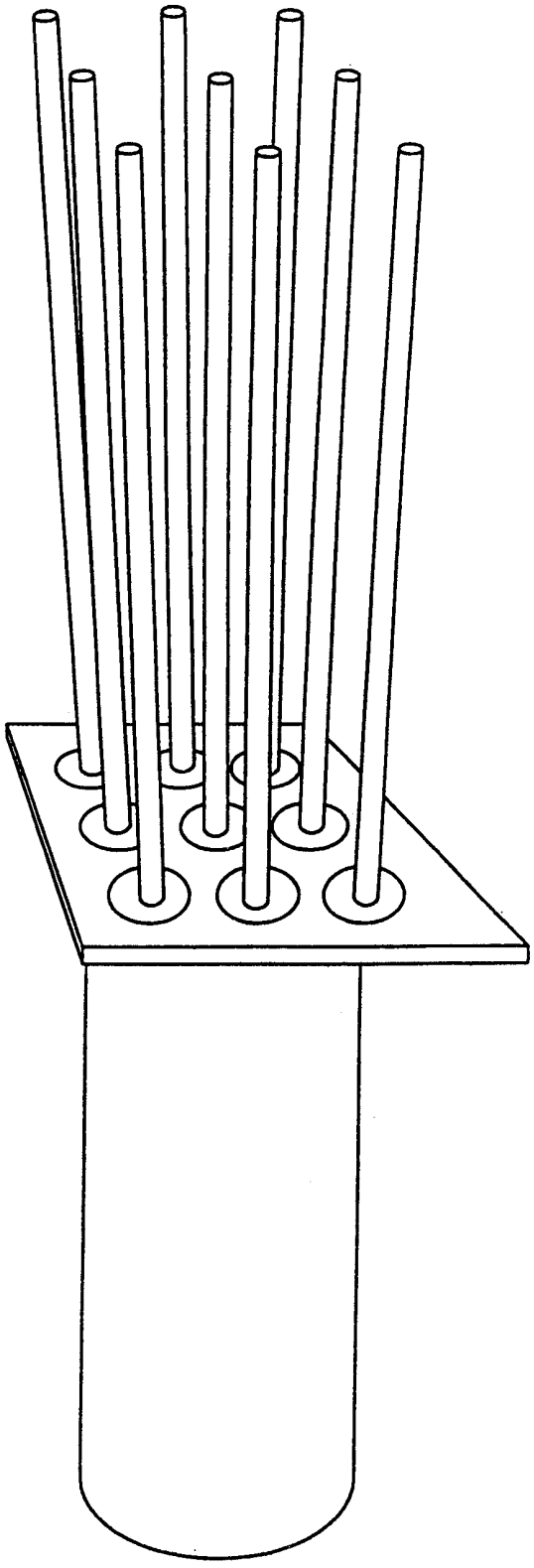
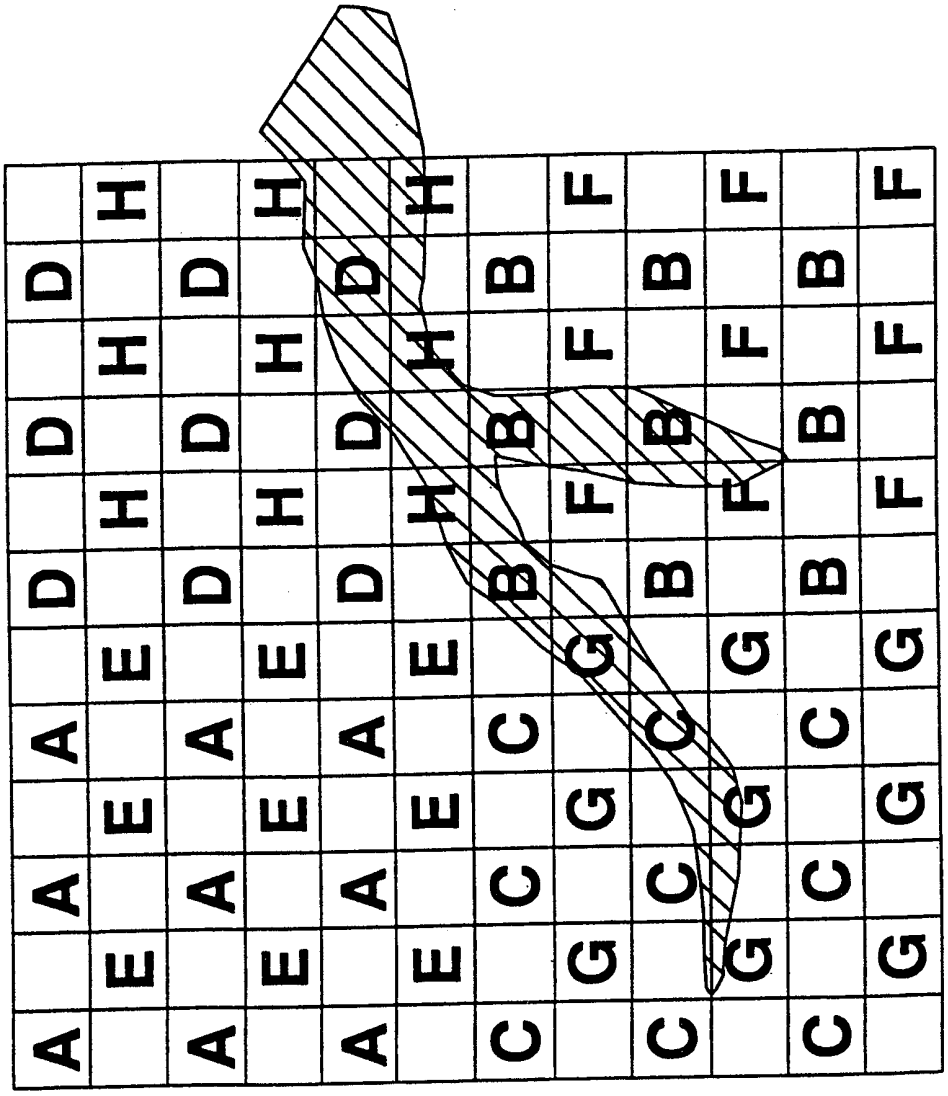


FIGURE 4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D E D E D E B G B G B G
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D E D E D E B G B G B G
A H A H A H C F C F C F
D E D E D E B G B G B G
A H A H A H C F C F C F
D E D E D E B G B G B G
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D E D E D E B G B G B G
A H A H A H C F C F C F

FIGURE 5

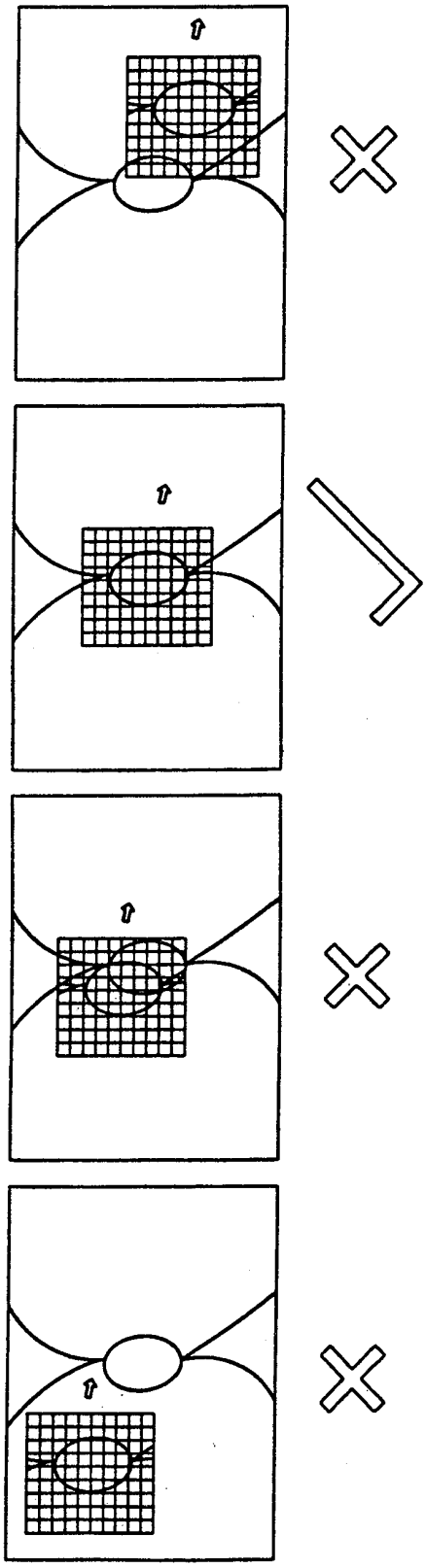

FIGURE 6

INTERNATIONAL SEARCH REPORT

Inte .ional Application No
PCT/GB 98/02204

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61F9/007

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 A61F

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.
X Y	US 5 029 220 A (JUDAY) 2 July 1991 see column 8, line 9 - line 30; claim 5; figure 4 ---	1,3,4 2,5-9
Y	EP 0 589 825 A (OPTIKO SCIENTIFIC) 30 March 1994 see column 3, line 26 - line 34 see column 6, line 55 - column 7, line 5 see claim 10; figure 9 ---	2
Y	US 5 376 086 A (KHOOBEHI ET AL.) 27 December 1994 see column 2, line 35 - line 60 ---	5
Y	WO 91 01703 A (SCIENTIFIC GENERICS) 21 February 1991 see page 6, line 17 - page 7, line 19 --- -/--	6

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

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 October 1998	05/11/1998

Name and mailing address of the ISA	Authorized officer
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PCT/GB 98/02204

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 326 760 A (INTELLIGENT SURGICAL LASERS) 9 August 1989 see column 6, line 29 - column 9, line 22; claim 7	7
Y	WO 87 00748 A (ARON-ROSA) 12 February 1987 see page 8, line 34 - line 38 see page 14, line 5 - line 9 see claim 2; figure 1	8
Y	US 3 769 963 A (GOLDMAN ET AL.) 6 November 1973 see column 6, line 28 - column 8, line 39	9
X	WO 93 16631 A (PHOENIX LASER SYSTEMS) 2 September 1993 see claim 1	1,3,4

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte .onal Application No
PCT/GB 98/02204

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5029220 A	02-07-1991	NONE	
EP 589825 A	30-03-1994	IL 103290 A	18-06-1996
		DE 69318501 D	18-06-1998
		JP 6205744 A	26-07-1994
		US 5450144 A	12-09-1995
US 5376086 A	27-12-1994	US 5571107 A	05-11-1996
WO 9101703 A	21-02-1991	AU 6061090 A	11-03-1991
		EP 0485450 A	20-05-1992
		JP 5500315 T	28-01-1993
EP 326760 A	09-08-1989	US 4901718 A	20-02-1990
		AU 2630188 A	03-08-1989
		JP 1262836 A	19-10-1989
		JP 1724927 C	24-12-1992
		JP 4012976 B	06-03-1992
WO 8700748 A	12-02-1987	FR 2585558 A	06-02-1987
		FR 2591097 A	12-06-1987
		EP 0232347 A	19-08-1987
US 3769963 A	06-11-1973	NONE	
WO 9316631 A	02-09-1993	AU 3781193 A	13-09-1993
		CA 2130999 A	02-09-1993
		EP 0630205 A	28-12-1994