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PHOTO-CAUTERIZER WITH COHERENT LIGHT SOURCE

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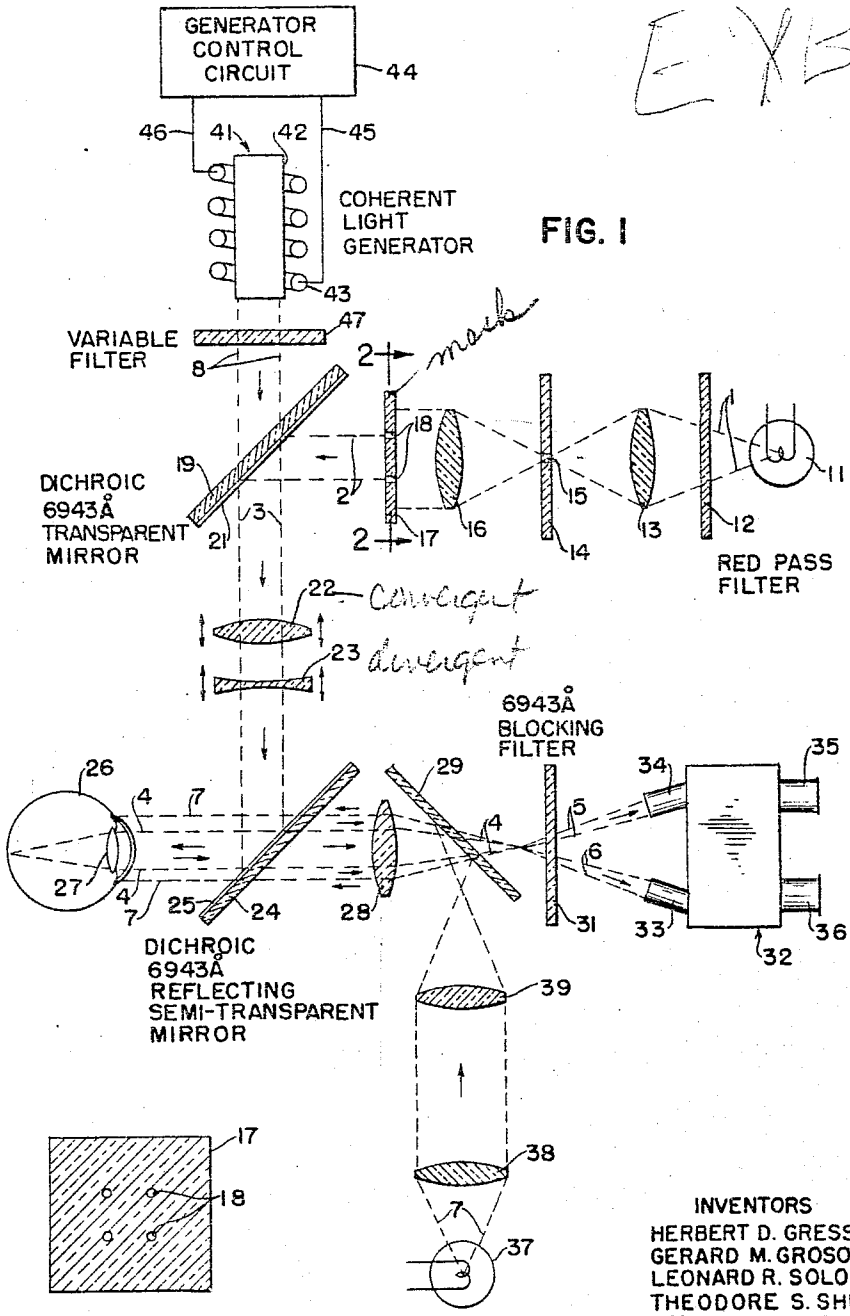

FIG. 1

FIG. 2

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PHOTO-CAUTERIZER WITH COHERENT LIGHT SOURCE

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The present invention relates to medical apparatus utilizing high intensity electromagnetic radiation to produce cauterizing or similar effects in the human body (or in other animals). More particularly, the invention relates to such apparatus using a coherent light source (such apparatus is variously known as an optical maser, laser, or coherent light generator).

Apparatus for photo-cauterizing which utilizes as a cauterizing energy source a source of incoherent light, such as an arc or discharge lamp, has previously been known and used with some degree of success. One important use of photo-cauterizing apparatus is in the attachment of detached retinas in the human eye. This not infrequent cause of blindness obviously is not of a character which is suitable for ordinary surgical treatment, due to the delicate nature of the human eye. It is possible, however, by burning a tiny point on the retina, to reattach it to the chorioid in its proper position due to the adhesion of the lesion or scar tissue at the burned area.

It is obviously desirable that the point or points which are cauterized to, in effect, weld the retina in place should be small relative to the area of the retina, as they will likely be destroyed with the resulting blind spots on the retina. Previous photo-cauterizing apparatus was incapable of producing a sufficiently tiny focal spot to avoid damaging a substantial area of the retina and thus the success of the photo-cauterizing technique was limited.

By the present invention a coherent light source is utilized which has, among other properties, an exceptionally high degree of parallelism in the rays emitted from the source. This allows the light to be concentrated on a much smaller area than heretofore possible, so that a high intensity spot of substantially less than one millimeter in diameter, for example, can be produced. Such high degree of concentration of the light energy also obviously allows greater local intensity for the same total amount of light power. This allows the cauterizing operation to be performed in a shorter interval of time. This is advantageous due to the fact that when the cauterizing temperature must be built up by integration of the heating effect over a period of several seconds, there is undesirable heat transfer tending to enlarge the lesion produced by the photo-cauterizing beyond the area of the focal spot. There is also the apparent advantage in speed of operation that the area to be cauterized need be immobilized for a shorter period of time and the danger of injury from accidental movement during the period of cauterization is minimized.

While the most promising present use for the photo-cauterizing apparatus according to the present invention is in treatment of detached retinas, or other diseases or malformations in the eye, the apparatus is by no means limited to such treatment, and photo-cauterization of other external or internal parts of the human body is also within contemplation of the invention.

In addition to providing the foregoing features and advantages, it is a further object of the present invention to provide a photo-cauterizing apparatus utilizing a coherent light source to provide the cauterizing energy.

It is another object of the invention to provide apparatus of the foregoing type where an auxiliary incoherent light source is provided and arranged to have a beam coincident with coherent light source beam for preliminary focussing and positioning of the optical system to produce photo-cauterization at the desired point.

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It is another object of the present invention to provide apparatus of the foregoing type wherein the incoherent light source is provided with a filter or other means to limit its final light output to a region of the light spectrum in proximity to the wavelength of the coherent light source to substantially avoid problems of chromatic aberration.

It is still another object of the present invention to provide apparatus of the foregoing type wherein the beams from the coherent and incoherent light sources are directed onto a coincident path by means of a dichroic mirror.

It is still another object of the present invention to provide apparatus of the foregoing type wherein means is provided for viewing the subject to which the photo-cauterizing process is to be applied and including means for blocking the light from the coherent light source from the user of the viewing apparatus in order to protect the operator from possible damage due to such light.

Other objects and advantages will be apparent from a consideration of the following description in conjunction with the appended drawings, in which:

FIGURE 1 is a partially schematic diagram of optical apparatus according to the present invention; and

FIGURE 2 is a sectional view taken along the line 2—2 in FIGURE 1.

Referring now to the drawing, a focusing light source **11** is provided which is illustrated as a conventional incandescent lamp. The form of light source **11** is not critical since the auxiliary light source **11** does not furnish the energy for cauterization, but merely provides light beams for initially indexing and focusing the optical system.

A red filter **12** may be provided to cause the light output from source **11** to be in approximately the same portion of the light spectrum as that produced by the coherent light generator. In the illustration given here, it is assumed that a ruby type coherent light generator will be utilized, having an output of 6,943 Angstroms wavelength. In such case, preferably the filter **12** will substantially limit the output from source **11** to a range of approximately 0–10% less than the 6,943 Angstrom output of the coherent light generator. (Longer wavelengths would in this specific case tend to extend beyond the visible spectrum into the infra red.)

An optical system comprising lens **13**, diaphragm **14**, and lens **16** is provided to collimate the light beam from source **11**. Diaphragm **14** is provided with a small aperture **15** so that the light rays indicated by dashed lines **1** from source **11** reach lens **16** as if from a nearly point source represented by the aperture **15**. Lens **16** is spaced from diaphragm **14** by a distance equal to its focal length thus substantially collimating light rays **1** originating at source **11**.

A mask **17** is provided having openings **18** therein which, for example, may be placed in a rectangular array as illustrated in FIGURE 2. As will later be more fully explained, the provision of the mask **17** facilitates focusing the collimated beam emerging from openings **18** and indicated by dashed lines **2** in FIGURE 1.

A dichroic mirror **19** is placed in the path of light rays **2** at an angle (for example 45°) with respect thereto. The dichroic mirror **19** may be provided with a coating **21** of the multi-layer interference type in order to provide a surface which is transparent to light of wavelength 6,943 Angstroms (and of course in the immediate vicinity of that wavelength), but which will substantially reflect most of the light rays **2** from the source **11**. It

should be pointed out that the dichroic mirror 19 is much more selectively transparent than the red filter 12, so that most of the light passing through filter 12 will not be transmitted but rather be reflected by the dichroic mirror 19. It should also be noted that throughout FIGURE 1, only the rays which are useful in the operation of the system are illustrated, and those which are not utilized by virtue of being reflected or transmitted out of the designed optical path have been omitted in FIGURE 1 (and in the apparatus would be absorbed by suitable non-reflective internal coating, or the like).

The path of rays from dichroic mirror 19 is indicated by dashed lines 3. The dashed lines 3 indicate the path of rays from auxiliary light source 11, and as later will be seen, also indicate the coincident path of rays from the coherent light generator.

A variable focal length optical system is schematically illustrated by lenses 22 and 23 in FIGURE 1. The former is a convex lens and the latter is a concave lens. Movement of respective lenses 22 and 23 (or their counterparts in an equivalent optical system) will allow control of various parameters associated with the focal spot obtaining at the end of the optical train, such as its position along the direction of propagation, the angle of convergence, and the size of the spot in the focal plane.

It should be noted at this point that in the illustration of FIGURE 1 the subject of the cauterization process is a human eye 26 and the lens 27 of the eye 26 is in effect a part of the optical train. In fact, in the illustration of FIGURE 1, lens 27 is assumed to provide the primary converging effect to produce the focal spot, and lenses 22 and 23 provide relatively fine focusing adjustment to correct for failure of lens 27 to focus parallel rays on the retina.

Where the apparatus is used to cauterize other areas than within the eye, an auxiliary lens or focusing means may be provided to contribute the focusing effect provided by the lens 27 of the eye 26 in FIG. 1.

A dichroic mirror 24 is located in the path of rays 3 to direct these rays as they emerge from lenses 22 and 23 to the subject of the cauterization process, which is illustrated as a human eye 26 having a lens 27. The dichroic mirror 24 is different from mirror 19 with essentially the opposite color discrimination characteristic, that is, it reflects light of 6,943 Angstroms while transmitting approximately one-half of other wavelengths. The dichroic mirror 24 may also be made with a coating 25 of the multilayer interference type according to known optical techniques.

Rays directed from mirror 24 to the eye 26 are indicated by dashed lines 4 (which also represent the path of light reflected back from the eye which is seen by the operator and enables him to properly position and focus the beam originating at auxiliary light source 11). Accordingly, the beam emerging from lens 23 may diverge or converge to compensate for the characteristics of lens 27, and variable focal length will thus be understood to include negative and positive focal lengths.

As has been previously seen, light rays originating at auxiliary light source 11 may be focused by means of the apparatus thus far described. Accordingly, a pattern of light will fall on the retina of the eye, for example, and if the light beam is not focused on the retina the pattern will resemble the pattern in the mask as shown in FIGURE 2. However, when the beam is focused the dots 18 will appear to merge in the light pattern projected on the retina. Light from this pattern is visible by virtue of light reflected out through the lens 27 of the eye and along a path indicated by dashed lines 4. The light reflected from the eye passes in part through dichroic mirror 24 which, as previously explained, is partially transparent to a light other than that of wave-length 6,943 Angstroms or at least to light from source 11.

An imaging lens 28 is provided to form an image of the pattern projected on the retina by converging the reflected rays as indicated by dashed lines 4, which pass through an obliquely oriented partially transparent mirror 29 and thence through a 6,943 Angstrom blocking filter 31, to binocular viewing apparatus 32. Two sets of optics indicated at 33 and 34 together with separate eye pieces 36 and 35 are provided for binocular viewing of the eye. Filter 31 is an optional added protection against the possibility of light from the coherent light generator reaching the eyes of the operator or viewer which could obviously be very injurious.

Since the light from the focusing source 11 is directed into the eye in a restricted pattern by reason of the mask 17, it is desirable to provide other general illumination for the eye to facilitate viewing thereof and location of the spot to be cauterized. Partially reflecting mirror 29 provides means for reflecting light provided by general illumination source 37. This light is collimated by lens 38 and further directed by field lens 39 into the eye. General illumination light source 37 is preferably a white light and partially reflecting mirror 29 may be a partially transmissive mirror with little or no color selectivity. As may be seen from FIGURE 1, the light from source 37 passes along the path indicated by dashed lines 7 through mirror 29, thence to the left through lens 28 and through dichroic mirror 24 to illuminate the eye 26. Dichroic mirror 24 will partially transmit all except a narrow band of frequencies in the vicinity of 6,943 Angstroms, thus causing relatively little attenuation of the light from source 37.

The reflected light from the eye due to source 37 will return along the path indicated by the dashed lines 7 to dichroic mirror 24 and lens 28. A portion of the reflected light will pass through partially reflecting mirror 29 and filter 31 to the binocular viewing apparatus 32. Separate optical paths indicated by dashed lines 5 and 6, respectively, are associated with each of the optic systems of the binocular viewing apparatus 32.

The apparatus thus far described allows the viewer utilizing binocular viewing apparatus 32 to view the eye 26 as illuminated by general illumination source 37 and also to locate and focus a spot or pattern of spots produced by focusing source 11 and the optical system associated therewith. As will now be seen, a coherent light generator 41 is provided and arranged to produce a beam of light which is effectively coincident with the beam from focusing source 11 along the path indicated by dashed lines 3. The coherent light generator 41 comprises a volume of working medium 42 which may, for example, be a ruby crystal as in the present example. A gaseous discharge lamp 43 is provided for "optically pumping" the ruby crystal. Electrical energy for the discharge lamp 43 is provided by leads 45 and 46 connected to a generator control circuit 44 which may include provision for timing the duration or number of pulses from the generator and also their intensity. The design and operation of coherent light generators is known and will not be explained here. Information concerning such generators will be found in the literature in various places including:

"Physical Review," vol. 112, No. 6, page 1940, December 15, 1958, "Infrared and Optical Masers" by A. L. Schawlow and C. H. Townes;

"Nature" vol. 187, page 493 (1960) article by T. H. Maiman;

"Physical Review Letters," vol. 5, page 303 (1960), article by R. J. Collins et al.

Coherent light generators are also commercially available, for example from TRG, Incorporated, Syosset, New York.

It will be understood that other than ruby light generators of the coherent type may be utilized in apparatus according to the present invention and in particular it may be desirable in some instances to utilize coherent light generators employing gaseous working mediums rather than a solid working medium such as ruby. The ruby light

generator has one advantage in that it produces red light which is a color and wave-length more readily transmitted by human tissue, both in the eye and elsewhere.

As indicated in FIGURE 1, the coherent light generator **41** is arranged to transmit light along a path indicated by dashed lines **8** through dichroic mirror **19** which is transparent to such light (in the example illustrated 6,943 Angstroms wavelength) so that it becomes coincident with a beam from focusing source **11** along a path indicated by dashed lines **3**.

As previously explained, the light from source **11** is passed thruogh a collimating optical system so that the beam from source **11** is substantially collimated along path **3**. The light from the coherent light generator emerges therefrom inherently collimated, that is with a high degree of parallelism of the rays of light. The coherent light generator beam from a ruby type apparatus may, for example, have rays parallel to within less than .005 radian of angle (compared to an angle of about ½ degree for light from the sun). It is this characteristic of the coherent light which is principally responsible for its being susceptible of being focused into a very small (and thus very intense) spot.

It will be obvious that since the beam from the focusing source **11** and the beam from the coherent light generator **41** are coincident along the path **3** and are both parallel (they are also nearly the same wavelength, within approximately 10%) they will be focused at the same spot by the optical train comprising lens **22**, lens **23** and the lens of the eye **27**. Accordingly, it is possible to determine the location and focus of the coherent light generator beam spot indirectly by means of the spot pattern produced by the focusing source **11**. This will normally be accomplished with the coherent light generator **41** inoperative.

Once the desired location, focus and spot size are set the coherent light generator **41** is actuated for a predetermined time interval and a predetermined power to produce the desired cauterizing effect. Variable filter **47** provides a means for controlling the amount of energy in the beam, which could also be controlled within limits by the amount of power provided by generator control circuit **44**. Ruby-type coherent light generators typically operate in pulsed fashion with a pulse of approximately 1 millisecond. In a single such pulse an energy of .1 Joules is readily obtainable, which is quite adequate to produce cauterization of a spot approximately one millimeter in diameter. Obviously, higher energy generators could be utilized and may be desirable in the event that it is desired to cauterize below the surface of body areas more opaque than the human eye. The variable filter **47** could, of course, be replaced by any other means for wasting or attenuating part of the light generator beam, such as an adjustable iris, for example.

It should be understood that the illustration of the apparatus as being used for photo-cauterization of the eye is only one of many uses of the apparatus, some of which would be facilitated by slight modifications in the apparatus within the ability of those of ordinary skill in the art.

For example, the intensity of light available from coherent light generators is such that it would readily be possible to penetrate a few millimeters or more of the skin on portions of the body other than the eye for the eradication of undesirable growths or other treatments. In such a case, it may be desired that the optical system be arranged so that the focusing spot from focusing source **11** be longitudinally displaced a predetermined or a controllable distance from the spot produced by the coherent light generator.

It should further be understood that the use of the apparatus is not limited to the exterior of the body, but that rigid or articulated optical trains may be utilized to convey the light beams of the apparatus into the interior of the body through natural or surgical openings within the scope of the invention.

It should also be noted that the present invention admits of the utilization of fiber optics in addition to or in place of the conventional lens optics shown by way of illustration.

It will be apparent that in addition to the various alternatives and modifications suggested that numerous other variations of the present invention will be apparent to those of ordinary skill in the art. Accordingly, it is intended that the scope of the present invention not be limited to those alternatives, modifications and variations shown or suggested but that it be limited solely by the appended claims.

What is claimed is:

1. Photo-cauterizing apparatus comprising a coherent light generator for producing a beam of light with rays having a high degree of parallelism, a variable focal length optical system for controlling the position of the focal point of said beam and the angle of convergence of said beam to cauterize a small area of matter, a focusing light source, means for directing a beam from said focusing light source along a path substantially coincident with the beam of light from said generator passing through said optical system, with the rays of said focusing light beam respectively parallel with the rays of said coherent light generator beam, the last said means including a reflector element for at least partially reflecting one of said two beams and for at least partially transmitting the other of said two beams along said coincident path whereby a spot to be cauterized may accurately be determined by observation of the beam from said focusing light source and thereafter cauterized by energy from said generator, the coincidence of the focal spot of said coherent light generator beam with the focal spot of said focusing light beam being assured by the parallelism of the respective rays of said beams.

2. Apparatus as claimed in claim 1 wherein said reflector element is a dichroic reflector.

3. Apparatus as claimed in claim 1 wherein said light from said focusing light source is limited substantially to a range of wave-lengths between 0.9 times and 1.1 times the wave-length of said generator.

4. Apparatus as claimed in claim 1 further including a mask with a plurality of apertures placed in the path of the beam from said focusing light source to facilitate fine focusing of said beam.

5. Apparatus as claimed in claim 1 further including an observer's position and means for blocking light of the wave-length of said generator from reaching said position to prevent injury to the observer.

6. Photo-cauterizing apparatus comprising a coherent light generator for producing a beam of light with rays having a high degree of parallelism, a variable focal length optical system for controlling the position of the focal point of said beam and the angle of convergence of said beam, a focusing light source having a range of output of wavelengths within approximately 10% of the wave-length of said generator output, means for directing a beam from said focusing light source along a path substantially coincident with the beam of light from said generator passing through said optical system, said means comprising a dichroic mirror substantially transmitting one of said beams and substantially reflecting the other of said beams, means for collimating the light from said focusing light source arranged between said source and said dichroic mirror, a mask having a plurality of apertures placed in the collimated beam from said focusing light source between said dichroic mirror and said collimating means, beam splitting means for directing to an observer's position a portion of the light from said focusing light source after reflection from the subject being cauterized, and means for blocking direct or reflected light of the wave-length emitted by said generator from said observer's position.

7. Photo-cauterizing apparatus comprising a coherent light generator for producing a beam of light with rays having a high degree of parallelism, a variable focal length optical system for controlling the position of the focal point of said beam and the angle of convergence of said beam, and a dichroic beam splitter for directing said beam to the subject being cauterized while simultaneously allowing observation of said subject from a position substantially unexposed to said beam.

References Cited in the file of this patent

UNITED STATES PATENTS

2,929,922 Schawlow ---------- Mar. 22, 1960
2,930,379 Dopp ---------- Mar. 29, 1960

OTHER REFERENCES

Mann: Popular Science, pp. 25, 26, Oct. 1960.
Colyear: American Journal of Ophthalmology, pp. 474–479, Oct. 1961.