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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A61N 5/06

A1

(11) International Publication Number: WO 99/58195

(43) International Publication Date: 18 November 1999 (18.11.99)

(21) International Application Number: PCT/IL99/00210

(22) International Filing Date: 20 April 1999 (20.04.99)

(30) Priority Data:
09/076,098 12 May 1998 (12.05.98) US

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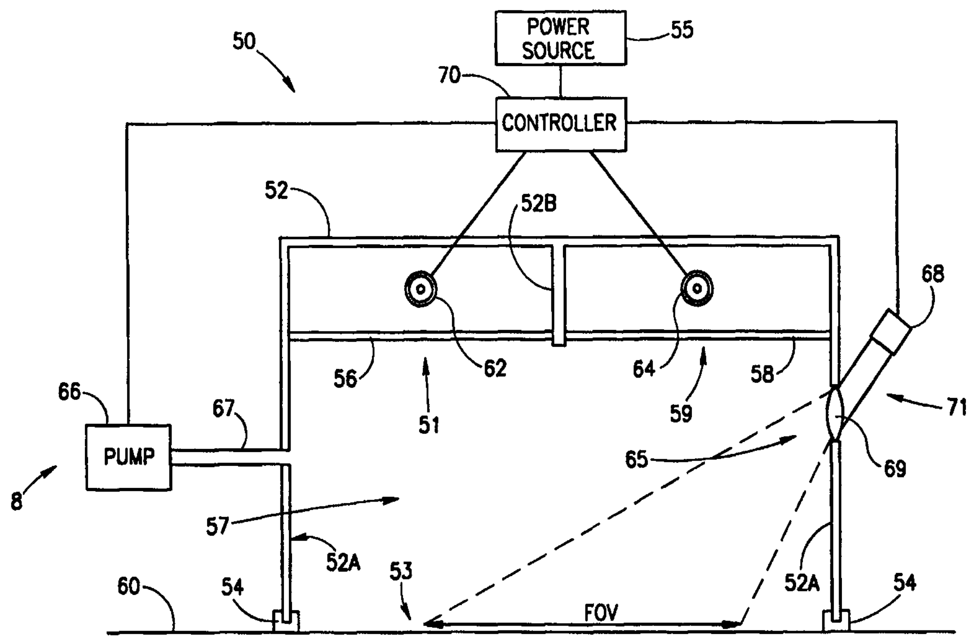
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: SELECTIVE PHOTOTHERMOLYSIS OF THE SKIN



(57) Abstract

Apparatus for selective photothermolysis of a target tissue within the skin, the apparatus comprising: a housing having an opening therein, said housing forming a cavity enclosing a volume of air when said opening is placed in contact with said skin; a pulsable heat source disposed within said housing which heats the volume of air, such that heat is transferred to the skin by the heated air; and a pulsable source of narrow band electromagnetic radiation disposed in the cavity which irradiates the skin with narrow band electromagnetic radiation to selectively heat said target tissue.

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SELECTIVE PHOTOTHERMOLYSIS OF THE SKIN

FIELD OF THE INVENTION

The present invention relates to dermatological surgery and, more specifically, to apparatus and a method of selective photothermolysis that allows the destruction of targets, such as varicose veins, that are too large to be destroyed by presently known methods without damaging the surrounding healthy tissue, and targets such as plaque psoriasis.

BACKGROUND OF THE INVENTION

Selective photothermolysis is a surgical method, introduced by Anderson and Parrish in 1983 ("Selective Photothermolysis: Precise Microsurgery by Selective Absorption of Pulsed Radiation", Science, Vol. 220, pp. 524-527), for destroying certain diseased or unsightly tissue, on or near the skin, with minimal damage to the surrounding healthy tissue. The tissue to be destroyed must be characterized by significantly greater optical absorption at some wavelength of electromagnetic radiation than the surrounding tissue. The method consists of irradiating the target and the surrounding tissue with pulsed electromagnetic radiation, usually visible radiation, that is preferentially absorbed by the target. The energy and duration of the pulses is such that the target is heated to between about 70^{o}C and about 80^{o}C, at which temperature the proteins of the target coagulate. Because the target absorbs the incident radiation much more strongly than the surrounding tissue, the surrounding tissue is heated negligibly.

Usually, the radiation source is a laser, for example a flashlamp-pulsed dye laser. A laser source has the advantage of being inherently monochromatic. Other sources include broad band sources used in conjunction with narrow band filters, as described, for example, by Gustaffson in Patent publication. WO 91/15264. A similar device, called the "Photoderm-VL", is manufactured by ESC Medical Systems.

Suitable targets for selective photothermolysis include birthmarks, port-wine stains, spider veins, and varicose veins, all of which tend to be much redder than the surrounding tissue because of their higher concentration of oxyhemoglobin-containing red blood cells. Anderson and Parrish used light of a wavelength of 577 nanometers, corresponding to the 577 nanometer oxyhemoglobin absorption band. It was subsequently determined (Tian, Morrison, and Kurban, "585 nm for the Treatment of Port-Wine Stains", Plastic and Reconstructive Surgery, vol. 86 no. 6 pp. 1112-1117) that 585 nanometers is a more effective wavelength to use.

One constraint on the pulse duration is that the surrounding tissue must not be heated to the point that it, too, begins to coagulate. As the target is heated, heat begins to diffuse from the target to the cooler surrounding tissue. To keep the surrounding tissue from being heated to the point of damage, the pulse length must be kept on the order of the target's thermal relaxation time. For relatively small targets, such as birthmarks, port-wine stains, and spider veins, typical pulse lengths are on the order of hundreds of microseconds. For varicose veins, pulse lengths on the order of milliseconds should be used.

A complication arises in the treatment of varicose veins by selective photothermolysis. The normal tissue surrounding varicose veins typically includes other blood vessels, notably capillaries, that also absorb the incident radiation but, being much smaller than the varicose veins, have much shorter thermal relaxation times. Therefore, heat diffusing from these other blood vessels into the surrounding tissue tends to heat the surrounding tissue to the point of damage, thereby causing scarring. Recently, selective photothermolysis also has been used to treat psoriatic skin tissue.

Psoriasis is a non contagious skin disorder that most commonly appears as inflamed swollen skin lesions covered with silvery white scale. This most common type of psoriasis is called "plaque psoriasis".

Psoriasis comes in many different variations and degrees of severity. Different types of psoriasis display characteristics such as pus-like blisters (pustular psoriasis), severe sloughing of the skin (erythrodermic psoriasis), drop-like dots (guttate psoriasis) and smooth inflamed legions (inverse psoriasis). The degrees of severity of psoriasis are divided into three important categories: mild, moderate and severe.

Skin cells are programmed to follow two possible programs: normal growth or wound healing. In a normal growth pattern, skin cells are created in the basal cell layer, and then move up through the epidermis to the stratum corneum, the outermost layer of the skin. Dead cells are shed from the skin at about the same rate as new cells are produced, maintaining a balance. This normal process takes about 28 days from cell birth to death.

When skin is wounded, a wound healing program, also known as regenerative maturation, is triggered. Cells are produced at a much faster rate, theoretically to replace and repair the wound. There is also an increased blood supply and localized inflammation. In many ways, psoriatic skin is similar to skin healing from a wound or reacting to a stimulus such as infection.

Lesional psoriasis is characterized by cell growth in the alternate growth program. Although there is no wound at a psoriatic lesion, skin cells, also referred to as keratinocytes, behave as if there is. These keratinocytes switch from the normal growth program to regenerative maturation. Cells are created and pushed to the surface in as little as 2-4 days, and the skin cannot shed the cells fast enough. The excessive skin cells build up and form elevated, scaly lesions. The white scale (called "plaque") that usually covers the lesion is composed of dead skin cells, and the redness of the lesion is caused by increased blood supply to the area of rapidly dividing skin cells.

SUMMARY OF THE INVENTION

According an aspect of some preferred embodiments of the present invention there is provided a method and apparatus of selective photothermolysis of a target within surrounding tissue, comprising: (a) heating the target and the surrounding tissue above normal body temperature; and (b) heating the target to between about 70°C and about 80°C.

According to an aspect of some preferred embodiments of the present invention there is provided a device for selective photothermolysis of a target within surrounding tissue. Preferably the device comprises: (a) a heater which heats the surrounding tissue to a first temperature by convection or conduction; and (b) an electromagnetic pulse generator that generates at least one pulse of narrow band or substantially monochromatic electromagnetic radiation, each of said at least one pulse being substantially simultaneous with said broad-band electromagnetic radiation.

The method and apparatus of the present invention is based on the fact that the rate of heat diffusion from a warm body to a cold body is proportional to the thermal gradient between the bodies. Therefore, heating the surrounding tissue to a temperature higher than normal body temperature, but not high enough to cause damage, and only then heating the target to the point of coagulation, creates an environment in which the thermal gradient between the target and the surrounding blood vessels, on the one hand, and the other surrounding tissue, on the other hand, is sufficiently small that the surrounding tissue is not damaged. In the context of the present invention, "higher than normal body temperature" means a temperature of at least about 40°C, but preferably between about 55°C and about 65°C. Furthermore, the pulse of narrow band light used to heat the target may be of lower power and shorter duration than in the prior art, because the target is heated from a higher initial temperature.

The device of the present invention accomplishes this end primarily by heating the surrounding tissue using heat conducted or transmitted by convection from a source of heat. The preferred device for generating the heat is a high intensity lamp such as a xenon arc lamp. The device preferably includes a mechanism for pulsing the light (heat) from the lamp. Preferably, the heat from the lamp heats the air surrounding the surface of the skin to a first temperature. In general this will cause a temperature gradient between the heat source and the skin which will cause a ramped increase in the temperature of the skin. When the skin has reached a desired temperature, the narrow band radiation is turned on to preferentially heat the tissue being treated.

There are two preferred means for generating the substantially radiation used to heat the target. The first is a laser that operates at the desired wavelength, preferably a wavelength between about 570 nanometers and about 610 nanometers. The second is to pass light from a high intensity lamp through a suitable wavelength selection device, such as a narrow band filter or a monochromator.

The device of the present invention synchronizes the narrow band pulses with the heating, to ensure that the surrounding tissue has been heated sufficiently before the radiation pulse is turned on to heat the target further, and to ensure that the target is heated further before the surrounding tissue has a chance to cool down. In general terms, this means that, if the broad-band electromagnetic radiation is pulsed, then each radiation pulse is substantially simultaneous with a broad-band pulse. As used herein "substantially simultaneous" means that the radiation pulse is turned on either while the broad-band pulse is on, or substantially immediately after the broad-band pulse is turned off.

Preferably, the heated air is then removed from the vicinity of the body and optionally the skin is cooled, to avoid overheating of the skin.

There is thus provided, in accordance with a preferred embodiment of the invention, apparatus for selective photothermolysis of a target tissue within the skin, the apparatus comprising:

a housing having an opening therein, said housing forming a cavity enclosing a volume of air when said opening is placed in contact with said skin;

a pulsable heat source disposed within said housing which heats the volume of air, such that heat is transferred to the skin by the heated air; and

a pulsable source of narrow band electromagnetic radiation disposed in the cavity which irradiates the skin with narrow band electromagnetic radiation to selectively heat said target tissue.

Preferably, the pulsable heat source forms a temperature gradient in the air between the source and the skin.

Preferably, the apparatus includes a sensing unit attached to said housing for sensing the temperature of said skin. Preferably, the sensing unit includes at least one optical sensor for sensing the temperature of said skin, said at least one optical sensor receives infra-red radiation emanating from an area of said skin positioned under said housing through an optical element preferably attached within an aperture in said housing, senses the intensity of said infra-red radiation and provides signals indicative of said intensity to said controller. In a preferred embodiment of the invention the at least one optical sensor includes an infra-red light sensitive photo-diode. Alternatively or additionally, the sensor unit includes at least one contact temperature sensor for contacting said skin to sense the temperature of said skin, and for providing said controller with signals indicative of said temperature. Preferably the at least one contact temperature sensor comprises a thermistor.

In a preferred embodiment of the invention, the apparatus includes:

a controller unit which controls said heat source and said source of electromagnetic radiation, for coordinating the sequence of activation of said heat source and said source of electromagnetic radiation responsive to said sensed temperature.

Preferably, the controller unit has a data input capable of receiving data determining at least one treatment parameter selected from a plurality of treatment parameters for coordinating the timing and the duration of activation of any of said heat source and said source of narrow band electromagnetic radiation.

In a preferred embodiment of the invention the apparatus includes: a pump attached to said housing and controlled by said controller for controllably pumping a cooler gas into said housing to displace said volume of air heated by said heat source with air having a temperature lower than the temperature of said volume of air, to prevent overheating of said skin. Preferably, the pump is activated by said controller when said skin has reached a predetermined temperature after said heat source is energized. Preferably, controller unit is capable of determining at least one treatment parameter selected from a plurality of treatment parameters for coordinating the timing and the duration of activation of said heat source and said source of narrow band electromagnetic radiation.

In a preferred embodiment of the invention, the controller unit includes a removable storage device on which said plurality of treatment parameters are stored, said removable storage device is capable of being disconnected and removed from said controller for changing the value of at least one of said plurality of treatment parameters, prior to reconnecting said storage device to said controller. Preferably, the storage device is selected from a flash memory device, a magnetic bubble memory device, an EPROM memory device, an EEPROM memory device, an optical memory device, an opto-magnetic memory device and a magnetic memory device.

In a preferred embodiment of the invention, the apparatus includes a cooling unit suitably attached to said housing and controlled by said controller for controllably cooling said skin, to prevent overheating of said skin. Preferably, the cooling unit is activated by said controller when said skin has reached a predetermined temperature after said heat source is energized.

In a preferred embodiment of the invention, the heat source and said source of narrow band radiation are activated substantially simultaneously.

In a preferred embodiment of the invention, the source of narrow band radiation is activated by the controller when the skin temperature reaches a predetermined temperature, which predetermined temperature is above 40°C. Preferably, the predetermined temperature is between about 55°C and 65°C.

In a preferred embodiment of the invention, the controller interrupts said source of narrow band radiation when the target temperature reaches between about 70°C and about 80°C.

Preferably, the apparatus includes: at least one power source for energizing said heat source, said source of electromagnetic radiation and said controller. Preferably, the at least one power source is an electrical power source. Preferably, the at least one power source comprises at least one battery, at least one capacitor and an electronic control circuit. Alternatively, the least one power source comprises a mains operated direct current supply, at least one capacitor and an electronic control circuit.

In a preferred embodiment of the invention, the cavity is a sealed cavity, except for the opening to the skin.

In a preferred embodiment of the invention, the heat source also provides pulsed light for irradiating said region of skin. Preferably, the housing further includes a reflector for reflecting said pulsed broad band light and said narrow band electromagnetic radiation. Preferably, at least part of said housing is coated by a layer of material having a high reflectivity for reflecting said pulsed broad band light and said narrow band electromagnetic radiation. Preferably, the pulsed light is broad band pulsed light.

In a preferred embodiment of the invention, the heat source is a flash lamp or an arc discharge lamp. In a preferred embodiment of the invention, the flash lamp is a glass xenon lamp.

In a preferred embodiment of the invention, flash lamp is a quartz xenon lamp and wherein said apparatus further includes a filter attached to said housing and disposed between said flash lamp and said opening for absorbing a pre-selected portion of said pulsed broad band light, said pre-selected portion including radiation in the ultra-violet light range which may be harmful to said skin.

Preferably, the flash lamp is disposable.

In a preferred embodiment of the invention, the source of narrow band electromagnetic radiation includes a flash lamp or an arc discharge lamp and a filter attached to said housing and disposed between said flash lamp and said opening for absorbing a pre-selected portion of said pulsed broad band light, to produce narrow band electromagnetic radiation selectively absorbed by said target tissue.

In a preferred embodiment of the invention, the source of narrow band electromagnetic radiation emits radiation between the wavelengths of 550 to 610 nanometers.

In a preferred embodiment of the invention, the housing further comprises a sealing gasket attached to said housing along the circumference of said opening for forming a sealed air cavity disposed between said skin and said heat source. Preferably, the apparatus includes an extension, said extension having a first end attachable to said opening and a second end placeable on said skin, said extension has an aperture therethrough defining an area for treating said skin.

Preferably, the housing is made of a heat insulating material.

Preferably, the apparatus fits into the palm of a hand.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, in which like components are referred to by like reference numerals wherein:

Fig. 1 is a schematic diagram of a preferred embodiment of the device of the present invention in which the source of monochromatic light is a laser;

Fig. 2 shows an exemplary pulse schedule for the device of Fig. 1, in accordance with a preferred embodiment of the invention;

Fig. 3 is a schematic diagram of a preferred embodiment of the device of the present invention in which the source of monochromatic light is the same as the source of the broad-band light;

Fig. 4 shows an exemplary pulse schedule for the device of Fig. 3, in accordance with a preferred embodiment of the invention;

Fig. 5 show an alternative embodiment of the device of Fig. 3, in accordance with a preferred embodiment of the invention;

Fig. 6 shows an exemplary pulse schedule for the device of Fig. 5, in accordance with a preferred embodiment of the invention;

Fig. 7 is a schematic cross sectional view illustrating apparatus for selective photothermolysis, having a heat source and a source of narrow band electromagnetic radiation, in accordance with another preferred embodiment of the device of the present invention;

Fig. 8. is a schematic diagram illustrating an exemplary pulse schedule for the device of Fig. 7, in accordance with a preferred embodiment of the invention;

Fig. 9 is a schematic cross sectional view illustrating apparatus for selective photothermolysis, including a glass-xenon flash lamp, in accordance with yet another preferred embodiment of the device of the present invention;

Fig. 10 is a schematic cross sectional view illustrating apparatus for selective photothermolysis, having contact temperature sensors, in accordance with yet another preferred embodiment of the device of the present invention;

Fig. 11 is a schematic cross section illustrating an apparatus for selective photothermolysis adapted for use with a plurality of differently shaped extenders, in accordance with yet another preferred embodiment of the present invention; and

Figs. 12 -14 are schematic isometric views of three differently shaped extenders useful for selective photothermolysis when used with the apparatus of Fig. 11; and

Fig. 15 is a schematic functional block diagram illustrating a programmable system including the apparatus for selective photothermolysis of Fig. 7, in accordance with still another preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of a method and device for selective photothermolysis of relatively large surgical targets. Specifically, the present invention can be used to remove varicose veins and similar diseased or unsightly tissue with minimal damage to the surrounding healthy tissue. The present invention can also be used for treatment of psoriasis.

The principles and operation of a method and device for selective photothermolysis according to the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, Fig. 1 is a schematic diagram of a preferred embodiment of the device of the present invention. A high intensity lamp 10 functions as a source of broad-band (white) light 14. Because lamp 10 emits light in all directions, a parabolic reflector 12 and a concave lens 16 are provided to collimate broad-band light 14, so that substantially all of the energy emitted by lamp 10 is directed at the target and the surrounding tissue. A laser 20 emits substantially monochromatic light 24, preferably at a wavelength of 585 nanometers, also towards the target and the surrounding tissue. A control system 30 supplies power to lamp 10 and laser 20, and also turns lamp 10 and laser 20 on and off in accordance with the pulse schedule shown in Fig. 2.

Preferably, lamp 10 is a xenon arc lamp. Preferably, laser 20 is a flash lamp-pulsed dye laser, for example the ScleroLASER manufactured by Candela Corporation of Wayland MA.

Fig. 2 shows a pulse schedule for the device of Fig. 1. The solid line in Fig. 2 represents the duration and intensity of a pulse of broad-band light 14. The dashed line in Fig. 2 represents the duration and intensity of a pulse of monochromatic light 24. Broad-band light 14 is turned on at time T_0 and is kept on long enough, until time T_2, to heat the target and the surrounding tissue to about 60°C. As the temperature of the surrounding tissue approaches the desired final value, monochromatic light 24 is turned on at time T_1, and is kept on until time T_3, long enough to cause coagulation of the target but not long enough to damage the surrounding tissue. Preferably, the duration of the monochromatic pulse is between about 0.1 milliseconds and about 10 milliseconds.

Fig. 3 is a schematic diagram of another preferred embodiment of the device of the present invention. In this embodiment, lamp 10 serves as the source of both the broad-band radiation and the monochromatic radiation that are incident on the target and the surrounding tissue. In this embodiment, a mechanical shutter 32 serves to alternately block and pass broad-band light 14, thus causing the light emerging from the device to be pulsed. A rotating circular filter 34 having two sections, a white section 36 and a colored section 38, serves to filter the broad-band pulses passed by shutter 32. White section 36 attenuates all wavelengths to substantially the same degree, thereby providing a broad-band pulse of the proper intensity and duration to heat the target and the surrounding tissue to about 60°C. Colored section 38 attenuates all but a narrow spectral band of light centered on a wavelength of 585 nanometers. Control system 30 synchronizes the movement of shutter 32 and filter 34 to provide light pulses according to the pulse schedule of Fig. 4.

Note that lamp 10 must be much more powerful in the embodiment of Fig. 3 than in the embodiment of Fig. 1, because in the embodiment of Fig. 3, lamp 10 must provide enough spectral power in the vicinity of 585 nanometers to coagulate the target. It is for this reason that white section 36 of filter 34 is required in this embodiment.

Fig. 4 shows a pulse schedule for the device of Fig. 3. As in Fig. 2, a solid line represents a broad-band pulse and a dashed line represents a monochromatic pulse. At time T_0, with filter 34 positioned so that white section 36 is in the optical path of broad-band light 14, shutter 32 is opened, allowing broad-band light 14 to pass through, and to be attenuated by, white section 36. Filter 34 is rotated, until, at time T_1, colored section 38 begins to intercept broad-band light 14. At time T_2, all of broad-band light 14 is passing through colored section 38, so that the light emerging from the device is substantially monochromatic. At time T_3, shutter 32 is closed, terminating the monochromatic pulse.

Fig. 5 is a schematic diagram of a variant of the device of Fig. 3. In the device of Fig. 5, a movable mirror 40 is provided to deflect light passed by shutter 32 to a fixed mirror 41 and a monochromator 42. The device of Fig. 5 generates pulses according to the pulse schedule of Fig. 6, in which, again, the solid line represents a broad-band pulse and the dashed line represents a monochromatic pulse. At time T_0, with mirror 40 withdrawn, shutter 32 is opened, allowing broad-band light 14 to pass through an attenuation filter 44 and thence to the target and the surrounding tissue. Like white region 36 of filter 34, attenuation filter 44 attenuates all wavelengths to substantially the same degree, to provide a broad-band pulse of the proper duration and intensity to heat the target and the surrounding tissue to about $60^{o}C$. At time T_1, mirror 40 is moved into place, terminating the broad-band pulse, and, deflecting broad-band light 14 so that it passes, via mirror 41, through monochromator 42, thereby initiating the monochromatic pulse. Thus, the monochromatic pulse starts substantially immediately after the termination of the broad-band pulse. Monochromator 42 passes on to the target only a narrow spectral band of light preferably centered on a wavelength of 585 nanometers. At time T_2, shutter 32 closes, terminating the monochromatic pulse.

It is noted that the embodiments of Figs. 1-6 have been described in US Patent 5,759,200, issued June 2, 1998.

Additional embodiments of the present invention may be constructed for treating varicose veins and psoriasis skin at considerably less expense than that associated with presently known methods.

Reference is now made to Fig. 7 which is a schematic cross sectional view illustrating an apparatus 50 for selective photothermolysis, having a heat source and a source of narrow band electromagnetic radiation, in accordance with another preferred embodiment of the device of the present invention

Apparatus 50 preferably includes a housing 52 made of a thermally insulating material such as high temperature plastic, a ceramic material or any other suitable thermally insulating material. Housing 52 has an opening 53 which can be placed on the surface of the tissue to be treated, for example, on the surface of skin 60. Inner surface 52A of housing 52 is preferably coated with a diffusely reflective coating of near-perfect reflectivity, such as finely divided titanium dioxide. Alternatively or additionally, a suitably shaped reflector (not shown) may be attached to the housing 52 for reflecting electromagnetic radiation produced within the housing as disclosed in detail hereinbelow, towards the skin 60.

Apparatus 50 preferably includes a sealing gasket 54 made from soft rubber or the like for sealing the contact with skin 60 when opening 53 of apparatus 50 is placed on the skin. When housing 52 is lightly pressed onto the skin, a sealed cavity 57 is formed. Sealed cavity 57 includes a volume of air which is enclosed between skin 60 and housing 52.

The upper part of the housing 52 preferably includes a heat source 51 and a source of narrow band electromagnetic radiation 59. A separator 52B extending from housing 52 separates heat source 51 from radiation source 59. Heat source 51 and radiation source 59 may be rectangular or ellipsoidal in cross section or may have any other suitable cross section or shape. Heat source 51 preferably includes a lamp 62 preferably attached to housing 52, and a filter 56 preferably attached to housing 52 and to separator 52B.

Lamp 62 may be any suitable flash lamp or gas discharge arc lamp such as the quartz-xenon flash lamp model G5109, commercially available from The Electronic Goldmine, AZ, USA. Filter 56 may be any filter suitable for filtering the harmful ultra violet radiation which is produced by flash lamp 62 while passing through the non-harmful portion of the broad band radiation produced by pulsing flash lamp 62. For example, filter 56 may be the long wave pass filter model 450FH90-25, commercially available from Andover Corporation, NH, USA.

Radiation source 59 preferably includes a lamp 64 preferably attached to housing 52 and a filter 58 preferably attached to housing 52 and to separator 52B. Lamp 64 may be any suitable flash lamp or gas discharge arc lamp such as the quartz-xenon flash lamp model G5109, commercially available from The Electronic Goldmine, Az, USA Filter 58 is any suitable band pass filter which absorbs a substantial part of the electromagnetic radiation produced by the lamp 64 while passing therethrough only a suitable narrow band of the electromagnetic radiation which is selectively absorbed by the target tissue. For example, for the treatment of psoriatic skin, the target tissue is the blood vessels within the skin, therefore the filter 64 should selectively pass a narrow band of radiation around the absorption maximum of oxyhemoglobin.

Preferably, filter 58 includes a combination of two filters, a visible long wave pass filter such as model 550FH90-25 filter, and the near infrared short wave pass filter model 600FL07-25 which are commercially available from Andover Corporation. This filter combination passes only wavelengths in the range 550 to 600 nanometers. It is noted that, other suitable narrow band filters or filter combinations may also be used provided that they transmit the required narrow band radiation which can be selectively absorbed by the target tissue without being substantially absorbed by the tissue surrounding the target tissue.

It is noted that, the use of an interference filter in the apparatus of the present invention is not recommended because the light from flash lamp 64 is spread at a large angle of incidence on the filter.

Apparatus 50 preferably includes a cooling unit 8 which includes a pump 66 connected to the housing 52 by a suitable tube 67 for pumping air into cavity 57. This avoids overheating of the skin, since the temperature of the air at the skin surface will continue to increase with time.

It is noted that while cooling unit 8 of apparatus 50 includes a pump 66, other embodiments of the present invention may include other types of cooling devices as disclosed below.

Apparatus 50 preferably includes a sensing unit 71, for sensing the skin temperature, attached to the housing 52. In a preferred embodiment thereof sensing unit 71 includes a sensor 68 and a collimating optical element 69. Preferably, optical element 69 is attached within an aperture 65 in housing 52. Optical element 69 and optical sensor 68 are aligned such that the field of view of sensor unit 71 represented by a double headed arrow labeled FOV, covers a substantial portion of the skin under opening 53 but preferably does not include any part of the housing 52.

Preferably, sensing unit 71 is an infra-red (IR) sensing unit such as the model A 53,367 Infrared thermometer, commercially available from Edmund Scientific Company, NJ, U.S.A. However, any other suitable optical sensing unit can be used provided that it has sufficient sensitivity in the relevant range of temperatures (roughly 30° - 80°C). The lens 69 is an infra-red lens substantially transparent to infra-red radiation.

It is noted that, while in the preferred embodiment of the invention illustrated in Fig. 7 the optical element is a collimating infra-red lens 69, other preferred embodiments of the present invention may be constructed that include other optical elements such as an optical window, a holographic lens, a composite lens, a micro-lens array or any other optical element suitable for collimating infra red radiation in the spectral band necessary for sensing of the temperature of the skin surface within the field of view FOV.

It is further noted that, while the preferred embodiment of the invention illustrated in Fig. 7 has only one sensing unit 71 including one optical sensor 68, other preferred embodiments of the present invention may be constructed to include more than one optical unit. This may be required to include a wider portion of the surface of the skin 60 or for other alignment and or other manufacturing considerations. In such a case, additional apertures are made within the housing 52.

Apparatus 50 also includes preferably includes a controller 70 and a power source 55. Power source 55 is suitably connected to controller 70 for providing power to the controller. Controller 70 is preferably suitably connected to the lamps 62 and 64 for controlling the energizing thereof. Controller 70 is also preferably connected to the sensing unit 71 for receiving signals therefrom, the signals representing the temperature of the surface of the portion of the skin which is included in the field of view, FOV. Controller 70 is also preferably connected to pump 66 for controlling the operation thereof.

In a preferred embodiment of the invention, power source 55 is, an electrical power source such as a DC power supply connectable to a mains AC power socket. However, it can also be one or more disposable batteries, one or more rechargeable batteries, or any other suitable electrical power source.

Additionally, power source 55 may be included within controller 70 or may be comprised of a plurality of power sources (not shown) each capable of providing different voltage and/ or current levels. For example, one power source (not shown) may be used for powering controller 70 while another power source capable of delivering higher current densities may be used for energizing lamps 62 and 64, and pump 66.

To use apparatus 50 of Fig. 7, the user places opening 53 adjacent to skin 60 to be treated and lightly presses apparatus 50 against the skin to achieve sealing of the air volume within cavity 57 by sealing gasket 54. The user then activates the treatment sequence by pressing a button or a suitable switch (not shown) and controller 70 activates flash lamp 62, producing a pulse of 1 to 3 milliseconds duration that irradiates the skin tissue with broad band light having an energy density of approximately 0.5 to 5 Joule/cm^2. Filter 56 filters out most of the radiation within the ultra-violet range, preventing it from reaching the skin. The skin tissue under opening 53 and the target therewithin are thus heated to a temperature which is well below the tissue coagulation temperature, and below the desired temperature. Immediately after the pulse, flash-lamp 62 reaches a temperature of approximately 600°C to 800°C. The exact temperature of flash lamp 62 depends, *inter alia*, on the type of flash lamp chosen, the operating voltage and the current flowing through the flash lamp. The flash lamp 62 heats the air surrounding it and filter 56, and creates a temperature gradient in the volume of air enclosed within the sealed cavity 57, forcing heat to flow along the gradient into the skin and further heating the skin and target. In general, this heat conduction or diffusion causes the skin to be heated to the desired temperature.

Optical sensor 68 preferably senses the intensity of infra-red radiation emitted from the skin 60 within the field of view and sends signals to controller 70, which processes the signals to determine the temperature of the skin within the field of view FOV. When the temperature of the skin within the field of view reaches a certain predetermined temperature, preferably about 65°C, controller 70 activates flash lamp 64, producing a pulse having a duration of preferably approximately 0.5 to 5 milliseconds, irradiating the target with narrow band light having a power density of 0.75 to 3.0 Joule/cm^2. The narrow band radiation is selectively absorbed by the target tissue, for example, the blood vessels and capillaries within the psoriatic skin, thus selectively heating and coagulating the blood vessels and capillaries without damaging the surrounding skin tissue.

Preferably, almost all of the energy from flash lamps 62 and 64 that passes filters 56 and 58 heats the skin and the capillaries therein because inner surface 52A of housing 52 is almost perfectly reflective, and because housing 52 is thermally insulating.

After the coagulation of the blood vessels and capillaries is achieved controller 70 activates pump 50 which pumps air at room temperature into cavity 53 of housing 52 through tube 67 in order to cool the skin and to prevent the skin from reaching the temperature of coagulation due to the continued heat conduction along the temperature gradient within the volume of air enclosed within cavity 57. Controller 70 activates pump 66 when the temperature of the skin, determined by controller 70 from the signals of optical sensor 68, reaches a predetermined temperature value. The rate of pumping of relatively cold air by pump 60 is high enough to cool the skin fast enough so as to prevent burns or coagulation of the skin. Alternatively, controller 70 may activate pump 66 at the termination of the narrow band light pulse of flash-lamp 64. The time of the activation of pump 66 by controller 70 may also be done at a predetermined time after the termination of the narrow band light pulse of flash-lamp 64. An optimum time of pump activation may be determined empirically.

It is noted that apparatus 50 should have an opening 53 which is of a sufficient area in order to increase the ratio between the heated volume to the surface thus decreasing the loss of heat to the surrounding tissue and increasing the optical coupling to the target tissue.

Reference is now made to Fig. 8 which is a schematic diagram illustrating a pulse schedule for the device of Fig. 7.

The vertical axis of Fig. 8 represents an arbitrary pulse intensity and the horizontal axis represents time. The solid line curve 80 represents the duration and intensity of the first pulse of broad band radiation of flash lamp 62. The dashed line curve 82 represents the duration and intensity of the pulse of narrow band radiation of the flash lamp 64. The flash lamp 62 is turned on at time T_5, and is kept on until time T_6 to heat the target and the surrounding skin tissue above normal body temperature. At time T_6 the flash lamp 62 is turned off and heat flows from flash lamp 62 and filter 56 towards the skin.

As the temperature of the target tissue and the surrounding tissue approaches the desired final value of about 65°C, the flash lamp 64 is turned on at time T_7, and is kept on until time T_8, producing a pulse of narrow band radiation which irradiates the skin for a duration sufficient to cause coagulation of the target tissue without substantially damaging the surrounding tissue. Preferably, the duration of the narrow band radiation pulse is in the range of approximately 0.5 to 5 milliseconds.

In accordance with one preferred embodiment of the present invention, the controller 70 activates pump 66 at the time T_8 to pump fresh air at room temperature into housing 52 in order to prevent the skin from reaching the temperature of coagulation.

In accordance with another preferred embodiment of the present invention, controller 70 activates pump 66 when the temperature of the skin, sensed by sensing unit 71 reaches a predetermined value.

Preferably, this predetermined temperature value is in the range of approximately 70°-75° C. However, the predetermined temperature value may somewhat vary depending, *inter alia*, on the rate of rise of the skin temperature and of the attainable efficiency of the cooling of the skin by the cooling unit such as pump 66.

It is noted that, while apparatus 50 of Fig. 7 includes a quartz-xenon lamp which has an extended useful lifetime, it is also possible to use glass-xenon flash lamps or other types of gas arc discharge lamps which do not emit high intensities of UV light. The use of such lamps may obviate the need for a UV filter such as filter 56 of Fig. 7.

Reference is now made to Fig. 9 which is a schematic cross sectional view illustrating apparatus for selective photothermolysis, including a glass-xenon flash lamp, in accordance with yet another preferred embodiment of the present invention. Apparatus 100 is similar to apparatus 50 of Fig. 7 except that instead of heat source 51 of Fig. 7, apparatus 100 includes a heat source 61 which comprises a glass-xenon flash lamp 63 such as model A1033 glass-xenon flash lamp, commercially available from The Electronic Goldmine, Az, U.S.A., or any other suitable flash lamp or gas discharge lamp that does not emit substantial energy in the ultraviolet range harmful to living tissue. Heat source 61 does not need to include a UV filter because the glass envelope of flash lamp 63 absorbs most of the harmful UV radiation emitted in the arc discharge.

Reference is now made to Fig. 10 which is a schematic cross sectional view illustrating an apparatus 150 for selective photothermolysis, having contact temperature sensors, in accordance with yet another preferred embodiment of the present invention. Apparatus 150 includes a housing 102 which is similar to the housing 52 of Fig. 7, except that it does not include an aperture such as the aperture 65 of the housing 52 of Fig. 7. Furthermore, in contrast to apparatuses 50 and 100 of Figs. 7 and 9, respectively, which include a pump 55, apparatus 150 does not include a pump. The apparatus 150 also includes a controller 110 and two contact temperature sensors 115 and 120 which are suitably connected to controller 110. Apparatus 150 further includes a power source 55 suitably connected to controller 110.

Apparatus 150 also includes flash lamps 62 and 64, filters 56 and 58, and sealing gasket 54 as illustrated in Fig. 7 and disclosed in detail for apparatus 50 hereinabove.

The method of operation of apparatus 150 of Fig. 10 is somewhat different from that of apparatuses 50 and 100 disclosed hereinabove. The manner and the sequence of operating the heat source 51 and the narrow band radiation source 59 is similar to that disclosed in detail for the apparatus 50 of Fig. 7. However, in contrast with the optical sensing of temperature in the apparatuses 50 and 100 of Figs. 7 and 9, respectively, the sensing of the temperature of the skin is performed in apparatus 150 by the two contact sensors 115 and 120 which are placed in contact with the skin as the apparatus 110 is placed in contact with the skin. Contact sensors 115 and 120 generate signals representing the temperature of the skin at the contact point of the contact sensors with the skin 60. The signals are received by controller 110 which processes the signals to determine the temperature of the skin therefrom.

Similar to the method of use of apparatus 50, in which when the average skin temperature, as determined by controller 110 from the signals received from sensors 115 and 120, approaches about 65°C after the activation of flash lamp 62 by controller 110, flash lamp 64 is turned on by controller 110 to produce a pulse of narrow band radiation as disclosed above. However, in contrast to the method of use of apparatus 50, the user of apparatus 150 terminates the heating of the skin after the coagulation of the target tissue (not shown) by manually lifting apparatus 150 off the skin to enable air at room temperature to reach the skin and gradually cool it.

It is noted that, while apparatus 150 of Fig. 10 includes two contact sensors 115 and 120 for determining an average temperature of the skin, other preferred embodiments of the present invention can be constructed in which a single contact sensor is used to monitor the temperature of the skin at a single contact point. Alternatively, more than two contact sensors may be used for obtaining a better average of the temperature of the skin.

It is further noted that in the cases where multiple contact sensors are used, the analog signals of all the sensors may be averaged prior to being further processed by the controller 110 in order to simplify the determination of the averaged skin temperature.

It is still further noted that, contact temperature sensors 115 and 120 must have a fast response time, so as to sense the temperature of the surface of the skin fast enough as the temperature of the skin rises to enable controller 110 to timely activate pulse 82 (Fig. 8) and/or cooling unit 8 (Fig. 7). This can be achieved by using thermistors or other suitable temperature contact sensors having a minimal thermal mass.

It is further noted that various methods for determining the temperature of a surface using optical Infra-red sensors or one or more contact sensors are well known in the art. Such methods are also usable in the present invention. However, as they are well known, they are not described herein in detail.

Reference is now made to Fig. 11 which is a schematic cross section illustrating an apparatus 200 for selective photothermolysis adapted for use with a plurality of differently shaped extenders, in accordance with yet another preferred embodiment of the present invention. In contrast to the apparatus 50 of Fig. 7, apparatus 200 includes a housing 252 having a raised collar 217.

Apparatus 200 further includes flash lamps 62 and 64, filters 56 and 58, a controller 70 and a power source 55, a pump 66 and a tube 67, and a sensing unit 71 constructed and operative as disclosed in detail above for apparatus 50 of Fig. 7. Apparatus 200 further includes an extender 263 which is detachably attached to housing 252. The attaching of extender 263 to housing 252 is performed by forcing extender 263 over raised collar 217.

Extender 263 is a hollow extender having a first end 263A attachable to the raised collar 217 and a second end 263B for contacting the skin. Extender 263 has an aperture 219 therethrough defining an area for treating the skin. In one preferred embodiment, extender 263 is a metal extender. However, the extender 263 may also be made of a thermally insulating material such as a plastic or a ceramic material. Apparatus 200 is operated by pressing aperture 219 against the skin and operating the apparatus for treating the skin as disclosed for apparatus 50 of Fig. 7 hereinabove.

It is noted that many different forms of extender 263 can be made, each having an aperture of a different shape and/or size for adapting apparatus 200 to be used for photothermolytic treatment of different regions of skin or of different organs such as different limbs, torso, and the like.

Reference is now made to Figs. 12 -14 which are schematic isometric views of three differently shaped extenders 265, 267 and 269 useful for performing photothermolysis when used with apparatus 200 of Fig. 11. Fig. 12 illustrates an extender 265 having a rectangular aperture 275. Fig. 13 illustrates an extender 267 having an ellipsoidal aperture 277. Fig. 14 illustrates an extender 269 having a circular aperture 279. Each of extenders 265, 267 and 269 may be used with apparatus 200 for photothermolytic treatment of various skin regions.

It is noted that, extenders 263, 265, 267 and 269 of Figs. 11 -14, respectively, may also include a sealing gasket (not shown) attached to the end of the extender distal from apparatus 200 and made from a soft resilient material such as soft rubber, or any other suitable sealing material, for better sealing of the contact region with the skin (not shown). Extenders 263, 265, 267 and 269 of Figs. 11 -14, respectively, may or may not be internally coated with a diffusely reflective coating (not shown) for improving transmission of light through apertures 219, 275, 277 and 279, within each of the corresponding extenders.

In accordance with a preferred embodiment of the present invention, flash lamps 62, 63 and 64 may be disposable to allow convenient replacement of the lamp once it is burnt out.

It is noted that, while the preferred embodiments of apparatuses 50, 100, 150 and 200 of Figs. 7, 9, 10, and 11, respectively, have a housing shaped generally as a substantially rectangular open box, other embodiments are possible in which the housings have other shapes such as a cylindrical shape, a triangular prism shaped open box, a truncated triangular prism shaped open box or any other suitable shape having an open side and capable of forming a sealed cavity when suitably placed on the skin.

Reference is now made to Fig. 15 which is a schematic functional block diagram illustrating a programmable system including apparatus 50 for selective photothermolysis of Fig. 7, in accordance with still another preferred embodiment of the present invention. The system 250 includes apparatus 50 of Fig. 7 and a programming device 245. Programming device 245 includes a computer 246 connected to a printer 247. Controller 70 includes a central processing unit (CPU) 255 connected to a memory device 252, an interface 256 and a removable memory device 260. Interface 256 can be a standard RS-232 interface or any other suitable serial or parallel interface device. Controller 70 is suitably connected to power supply 55 and to sensor unit 71 for sensing the temperature of the surface of the skin as disclosed in detail above. Memory device 252 is preferably a read only memory integrated circuit, but can also be any other suitable type of electrical, magnetic, optical and magneto-optic storage or memory device.

Controller 70 is also suitably connected to cooling unit 8 and to flash lamps 62 and 64 and controls their activation. It is noted that controller 70 includes all the additional circuitry necessary for interfacing with sensing unit 71 and for controlling and energizing cooling unit 8 and flash lamps 62 and 64.

A program for operation of controller 70 is stored, preferably, in memory device 252. Treatment parameters, such as the skin temperature value at which the second pulse 82 (Fig. 8) is started, and the predetermined value of skin temperature at which the activation of cooling device 8 is initiated, the pulse duration of pulses 80 and 82 (Fig. 8), or (where relevant to the specific embodiment of the apparatus which is used) the time for switching on the pump, or any other parameters necessary for the operation of controller 70, are, preferably, stored in flash memory 260.

In accordance with one preferred embodiment of the present invention, controller 70 can be programmed by a physician in his office based on a test treatment made by the physician on the patient. Based on the results of the test treatment, the physician programs the treatment parameters to the necessary values by connecting computer 246 to controller 70 through interface 256 and downloading the treatment parameters into memory 252 or into flash memory 260. The physician may additionally store the programmed treatment parameters, for future reference, on a storage device included in computer 246 such as a hard disk drive or any other suitable storage device. The physician may also generate a hard copy of the programmed treatment parameters, for example by printing a report on printer 247.

Alternatively, flash memory 260 can be physically removed from controller 70 and the physician may program the treatment parameters by using a suitable programming interface connected to a communication port of the computer 246.

In accordance with another preferred embodiment of the present invention, system 250 may be also used for remote programming of the treatment parameters by a physician. In this embodiment the user uses a video camera (not shown) or a digital camera (not shown) to remotely send a digital photograph of the treated area to his physician over the Internet using video-conferencing in real time or by sending a digital photograph as a data file using the Internet or any other suitable data communication method. The physician receives the data or the digital photograph showing the results of the treatment and by examining the treatment results he may decide to change the treatment parameters. The physician then sends the new treatment parameters to the user over the Internet, or by any other suitable data communication method, such as using a modem, as a data file. The user may then load the new parameters from the data file into controller 70 erasing the previously stored parameters from and storing the new parameters on flash memory 260. The advantage of this preferred embodiment of the invention is that the patient may obtain a treatment at home under the supervision of a doctor without having to physically visit the physicians office.

It is noted that while the embodiments disclosed hereinabove teaches the use of flash memory 256 as a preferred programmable and/ or removable memory in controllers 70 and 110, other types of memory devices such as eraseable programmable read only memory (EPROM), electrically eraseable programmable read only memory (EEPROM), magnetic bubble memory, or any reprogrammable and/ or removable type of magnetic, optical, or magneto-optical memory devices may also be used instead of flash memory 256.

It is noted that while pump 66 of apparatuses 50, 100, and 200 preferably operates by pumping air into the cavity overlying the skin for cooling the skin, the pump may also be adapted to pump another coolant. The coolant may be other gases such as CO_2 or a liquid coolant such as ethyl-chloride or any other suitable liquid coolant supplied from a suitable coolant container (not shown).

It is further noted that, pump 66 of any of apparatuses 50, 100, and 200 may be replaced by a reservoir (not shown) containing a coolant and having a valve (not shown) which is controlled by one of controllers 70 or 110. The coolant may be a compressed gas or a liquid coolant. When one of controllers 70 or 110 provides a suitable signal to the valve, the valve opens, and some the coolant exits the reservoir, expands, and enters the air cavity of apparatus 50, 100, or 200, respectively. The expansion of the compressed coolant lowers the coolant's temperature below ambient temperature and the coolant cools the skin. The coolant in the reservoir may be a compressed CO_2 gas or any other suitable compressed gas. Alternatively, the coolant in the reservoir may be a liquid coolant such as ethyl-chloride or any other suitable liquid coolant.

It is noted that, the apparatuses 50, 100, 150 and 200, may be hand held, portable devices and/or directed for use by the user himself. Preferably, the apparatuses have a size which allows them to fit into the palm of a hand. However, other preferred embodiments of the apparatus of the present invention are possible which are larger and do not fit in the palm of the hand.

It will be appreciated by the person skilled in the art that the invention is not limited to what has been disclosed hereinabove and illustrated in the drawings. While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made. For example, while the invention is particularly adapted for use in the treatment of psoriasis it may also be used with some modification to the treatment of varicose veins, port wine stains or any other treatment of humans or other animals which is amenable for treatment by selective photothermolysis methods. In addition, while the narrow band source of Figs. 5-15 is a suitable lamp and filter, a laser or other monochromatic source may be substituted for the lamp.

Furthermore, each of the described embodiments has a plurality of features which differ from embodiment to embodiment. It should be understood that features from one embodiment may be added to or may replace features in a second embodiment. Furthermore, some of the features, while desirable, are not essential and may be omitted in some preferred embodiments of the invention.

The terms "comprise", "include" or their conjugates as used herein mean "including but not necessarily limited to."

CLAIMS

1. Apparatus for selective photothermolysis of a target tissue within the skin, the apparatus comprising:

a housing having an opening therein, said housing forming a cavity enclosing a volume of air when said opening is placed in contact with said skin;

a pulsable heat source disposed within said housing which heats the volume of air, such that heat is transferred to the skin by the heated air; and

a pulsable source of narrow band electromagnetic radiation disposed in the cavity which irradiates the skin with narrow band electromagnetic radiation to selectively heat said target tissue.

2. Apparatus according to claim 1 wherein the pulsable heat source forms a temperature gradient in the air between the source and the skin.

3. Apparatus according to claim 1 or claim 2 and including:

a sensing unit attached to said housing for sensing the temperature of said skin.

4. Apparatus according to claim 3 wherein said sensor unit includes at least one optical sensor for sensing the temperature of said skin, said at least one optical sensor receives infra-red radiation emanating from an area of said skin positioned under said housing, senses the intensity of said infra-red radiation and provides signals indicative of said intensity to said controller.

5. Apparatus according to claim 4 wherein the sensor receives the infra-red radiation through an optical element attached within an aperture in said housing

6. Apparatus according to claim 4 or claim 5 wherein said at least one optical sensor includes an infra-red light sensitive photo-diode.

7. Apparatus according to any of claims 3-6 wherein said sensor unit comprises at least one contact temperature sensor for contacting said skin to sense the temperature of said skin, and for providing said controller with signals indicative of said temperature.

8. Apparatus according to claim 7 wherein said at least one contact temperature sensor comprises a thermistor.

9. Apparatus according to any of claims 3-8 and including:

a controller unit which controls said heat source and said source of electromagnetic radiation, for coordinating the sequence of activation of said heat source and said source of electromagnetic radiation responsive to said sensed temperature.

10. Apparatus according to claim 9 wherein the controller unit is a programmable controller.

11. Apparatus according to claim 9 or claim 10 wherein said controller unit is a controller unit having a data input capable of receiving data determining at least one treatment parameter selected from a plurality of treatment parameters for coordinating the timing and the duration of activation of any of said heat source and said source of narrow band electromagnetic radiation.

12. Apparatus according to claim 11 further including a pump attached to said housing and controlled by said controller for controllably pumping a cooler gas into said housing to displace said volume of air heated by said heat source with air having a temperature lower than the temperature of said volume of air, to prevent overheating of said skin.

13. Apparatus according to claim 12 wherein said pump is activated by said controller when said skin has reached a predetermined temperature after said heat source is energized.

14. Apparatus according to claim 12 or claim 13 wherein said controller unit is a controller unit capable of determining at least one treatment parameter selected from a plurality of treatment parameters for coordinating the timing and the duration of activation of said heat source and said source of narrow band electromagnetic radiation.

15. Apparatus according to any of claims 11-14 wherein said controller unit includes a removable storage device on which said plurality of treatment parameters are stored, said removable storage device is capable of being disconnected and removed from said controller

for changing the value of at least one of said plurality of treatment parameters, prior to reconnecting said storage device to said controller.

16. Apparatus according to claim 15 wherein said storage device is selected from a flash memory device, a magnetic bubble memory device, an EPROM memory device, an EEPROM memory device, an optical memory device, an opto-magnetic memory device and a magnetic memory device.

17. Apparatus according to claim 9 or claim 10 and including a cooling unit suitably attached to said housing and controlled by said controller for controllably cooling said skin, to prevent overheating of said skin.

18. Apparatus according to claim 17 wherein said cooling unit is activated by said controller when said skin has reached a predetermined temperature after said heat source is energized.

19. Apparatus according to any of claims 9-18 wherein said heat source and said source of narrow band radiation are activated substantially simultaneously.

20. Apparatus according to any of claims 9-19 wherein said source of narrow band radiation is activated by the controller when the skin temperature reaches a predetermined temperature, which predetermined temperature is above $40^{o}C$.

21. Apparatus according to claim 20 wherein said predetermined temperature is between about $55^{o}C$ and $65^{o}C$.

22. Apparatus according to any of claims 9-21 wherein said controller interrupts said source of narrow band radiation when the target temperature reaches between about $70^{o}C$ and about $80^{o}C$.

23. Apparatus according to any of claims 9-22 and including:

at least one power source for energizing said heat source, said source of electromagnetic radiation and said controller.

24. Apparatus according to claim 23 wherein said at least one power source is an electrical power source.

25. Apparatus according to claim 23 or claim 24 wherein said at least one power source comprises at least one battery, at least one capacitor and an electronic control circuit.

26. Apparatus according to claim 23 or claim 24 wherein said at least one power source comprises a mains operated direct current supply, at least one capacitor and an electronic control circuit.

27. Apparatus according to any of the preceding claims wherein said cavity is a sealed cavity except for the opening to the skin.

28. Apparatus according to any of the preceding claims wherein said heat source also provides pulsed broad band light for irradiating said region of skin.

29. Apparatus according to claim 28 wherein said housing further includes a reflector for reflecting said pulsed broad band light and said narrow band electromagnetic radiation.

30. Apparatus according to claim 28 or claim 29 wherein at least part of said housing is coated by a layer of material having a high reflectivity for reflecting said pulsed broad band light and said narrow band electromagnetic radiation.

31. Apparatus according to claim 28 wherein said pulsed light is broad band pulsed light.

32. Apparatus according to any of he preceding claims wherein said heat source is a flash lamp or an arc discharge lamp.

33. Apparatus according to claim 32 wherein said flash lamp is a glass xenon lamp.

34. Apparatus according to claim 32 wherein said flash lamp is a quartz xenon lamp and wherein said apparatus further includes a filter attached to said housing and disposed between

said flash lamp and said opening for absorbing a pre-selected portion of said pulsed broad band light, said pre-selected portion including radiation in the ultra-violet light range which may be harmful to said skin.

35. Apparatus according to any of claims 32-34 wherein said flash lamp is disposable.

36. Apparatus according to any of the preceding claims wherein said source of narrow band electromagnetic radiation includes a flash lamp or an arc discharge lamp and a filter attached to said housing and disposed between said flash lamp and said opening for absorbing a pre-selected portion of said pulsed broad band light, to produce narrow band electromagnetic radiation selectively absorbed by said target tissue.

37. Apparatus according to any of the preceding claims wherein said source of narrow band electromagnetic radiation emits radiation between the wavelengths of 550 to 610 nanometers.

38. Apparatus according to any of the preceding claims wherein said housing further comprises a sealing gasket attached to said housing along the circumference of said opening for forming a sealed air cavity disposed between said skin and said heat source.

39. Apparatus according to any of the preceding claims and including an extension, said extension having a first end attachable to said opening and a second end placeable on said skin, said extension has an aperture therethrough defining an area for treating said skin.

40. Apparatus according to any of the preceding claims wherein said housing is made of a heat insulating material.

41. Apparatus according to any of the preceding claims which fits into the palm of a hand.

42. Apparatus according to any of the preceding claims wherein the source of narrow band radiation is a laser.

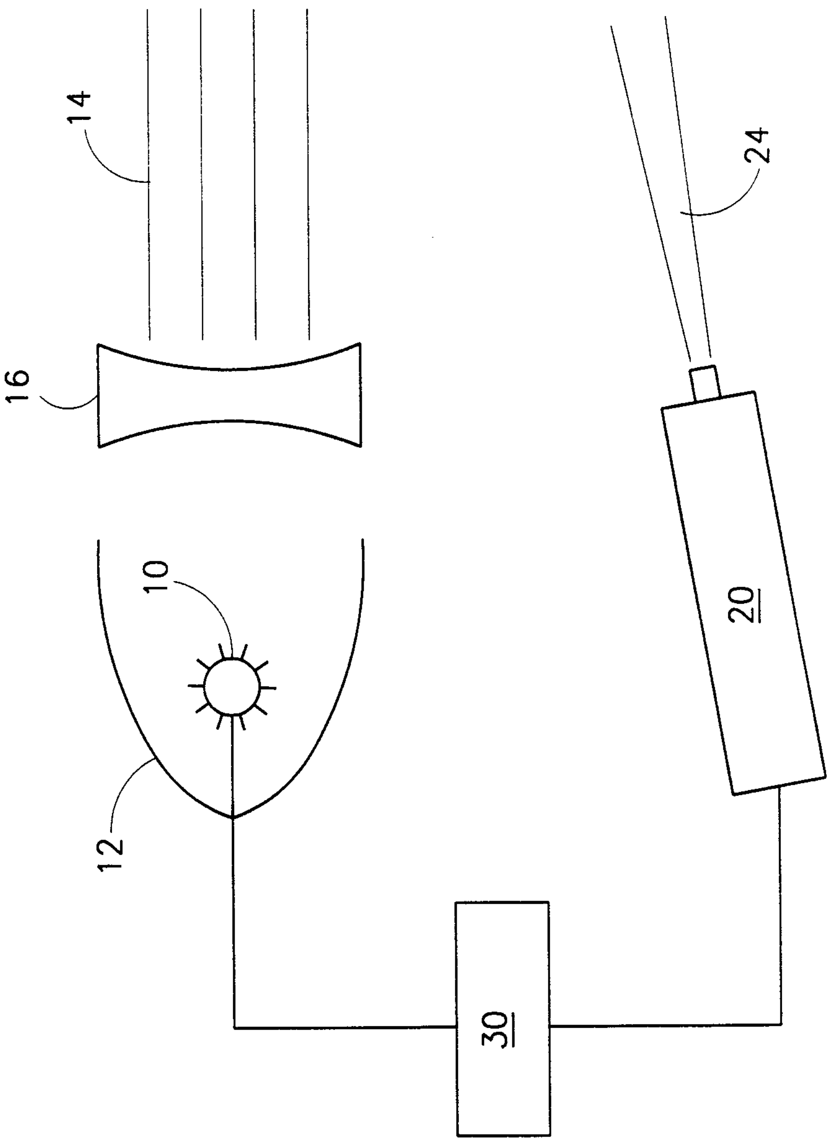

FIG.1

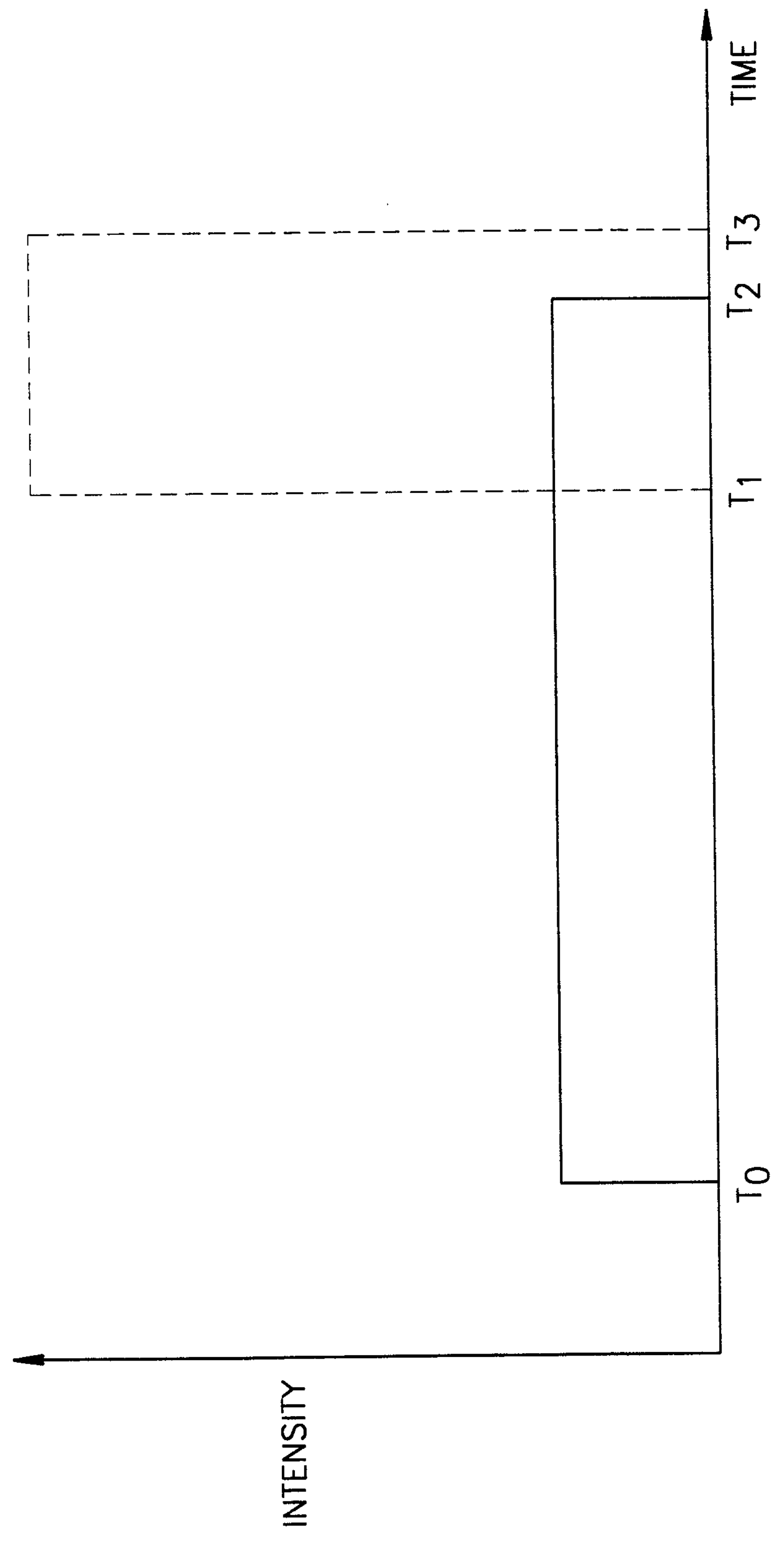

FIG.2

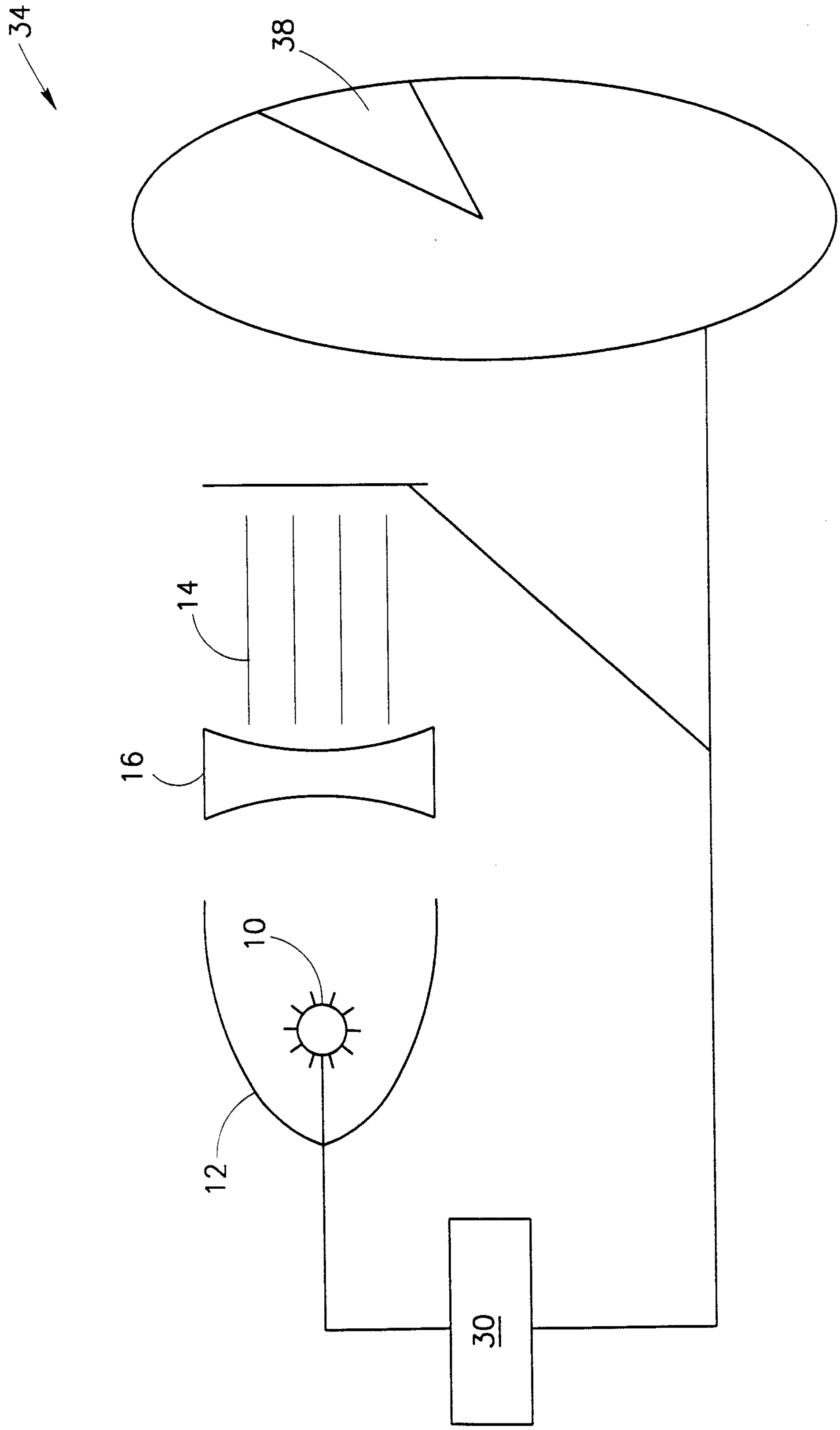

FIG.3

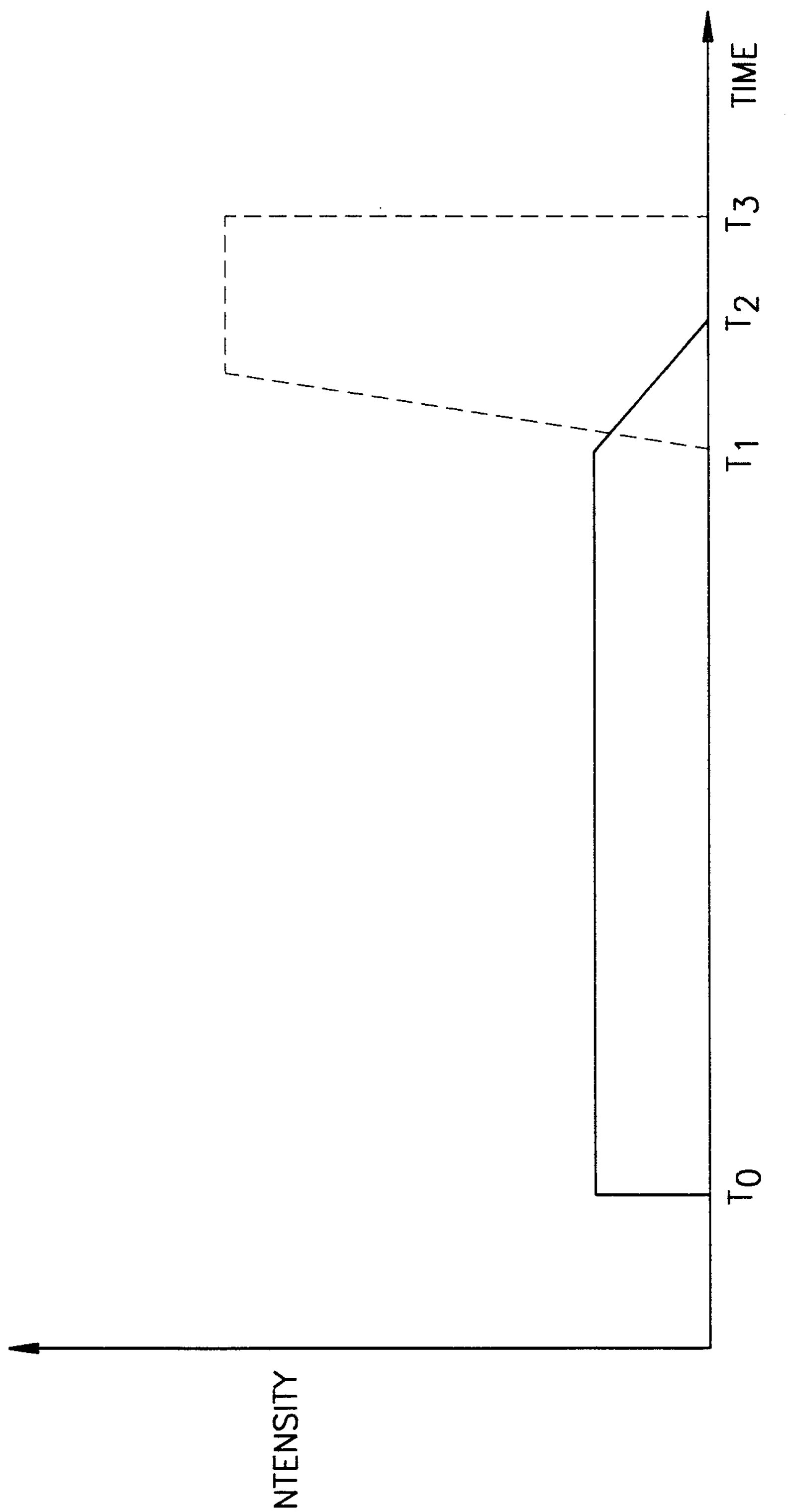

FIG.4

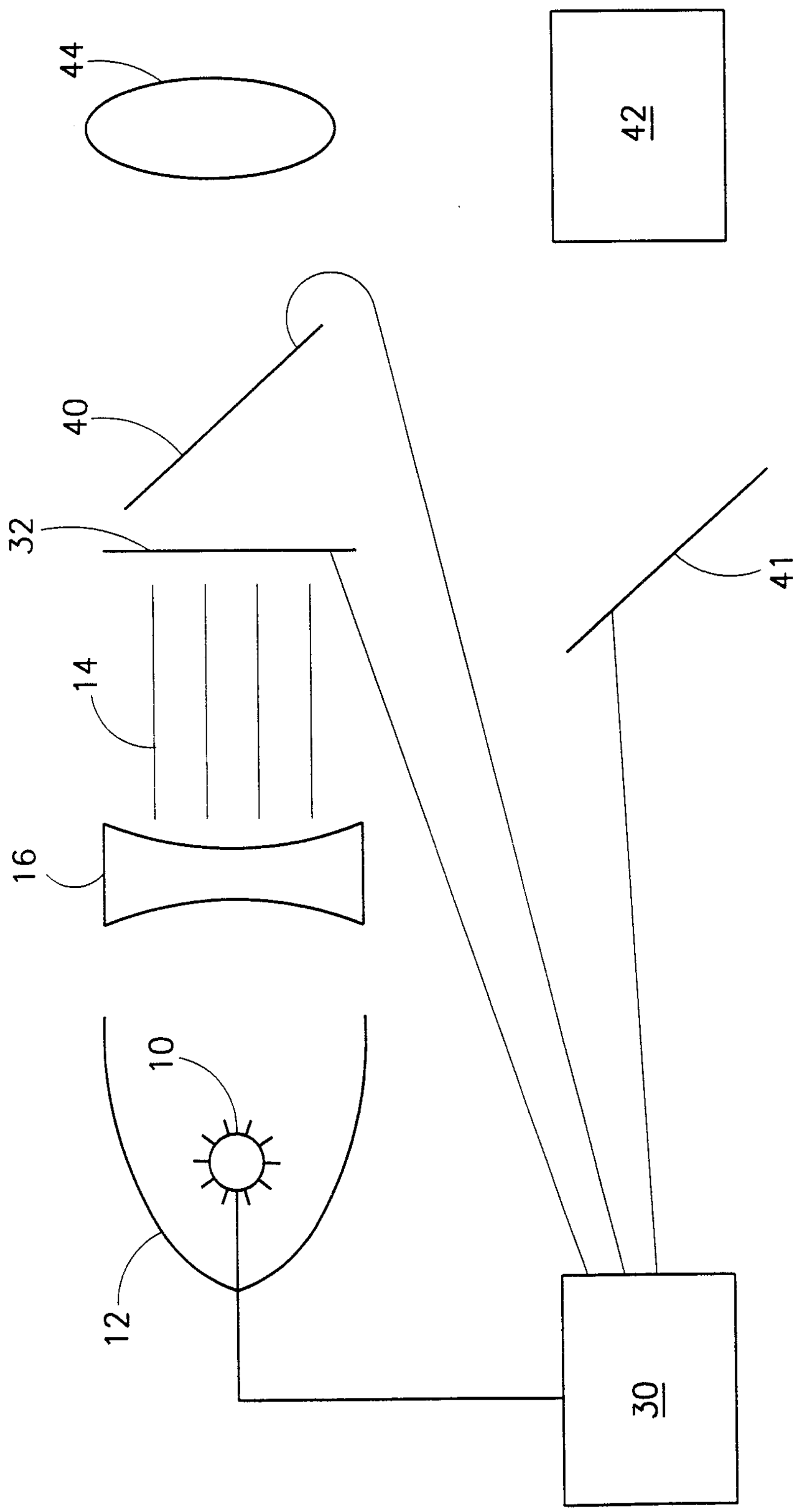

FIG.5

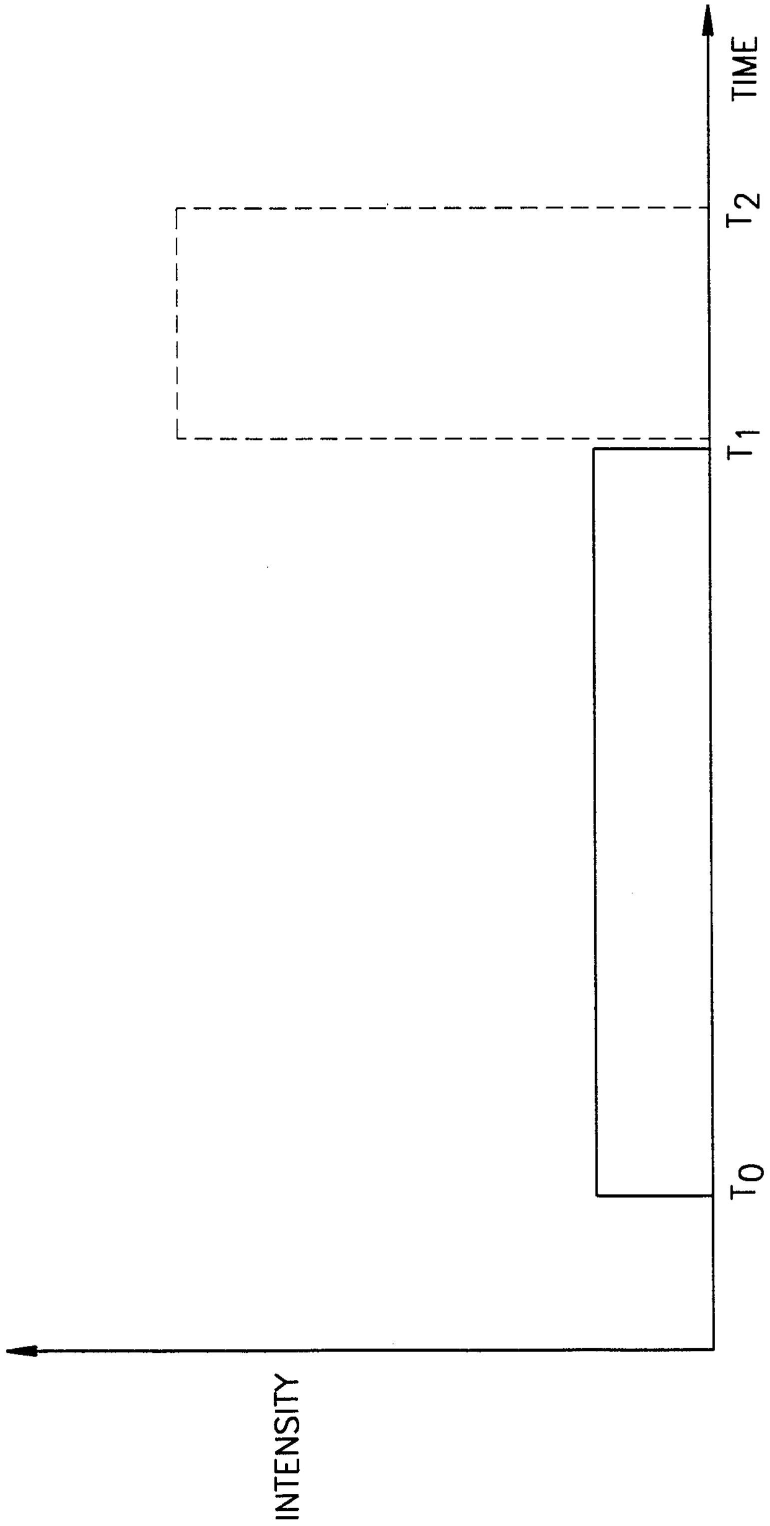

FIG.6

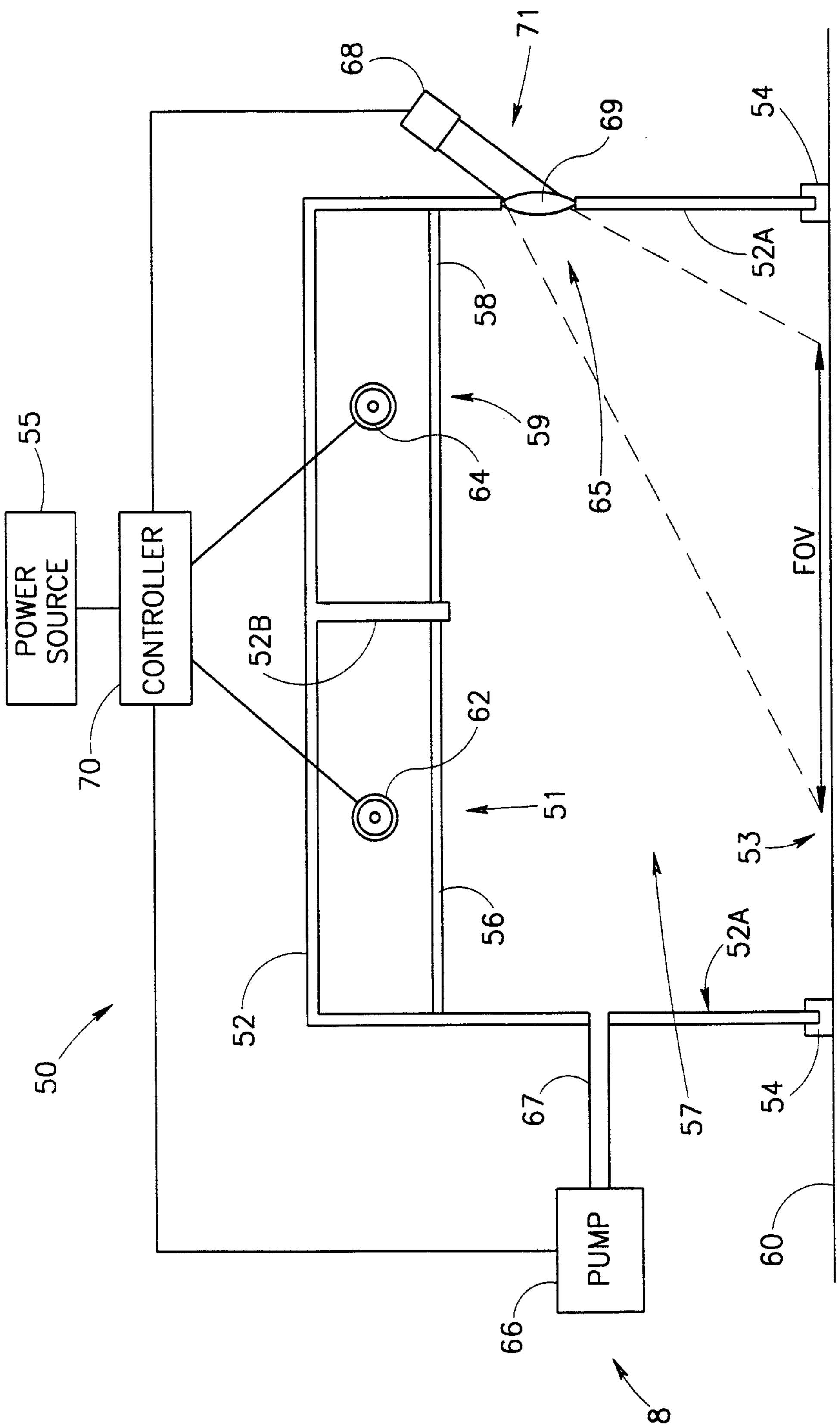
POWER SOURCE
CONTROLLER
PUMP
FOV
50
51
52
52A
52B
53
54
55
56
57
58
59
60
62
64
65
66
67
68
69
70
71
8

FIG.7

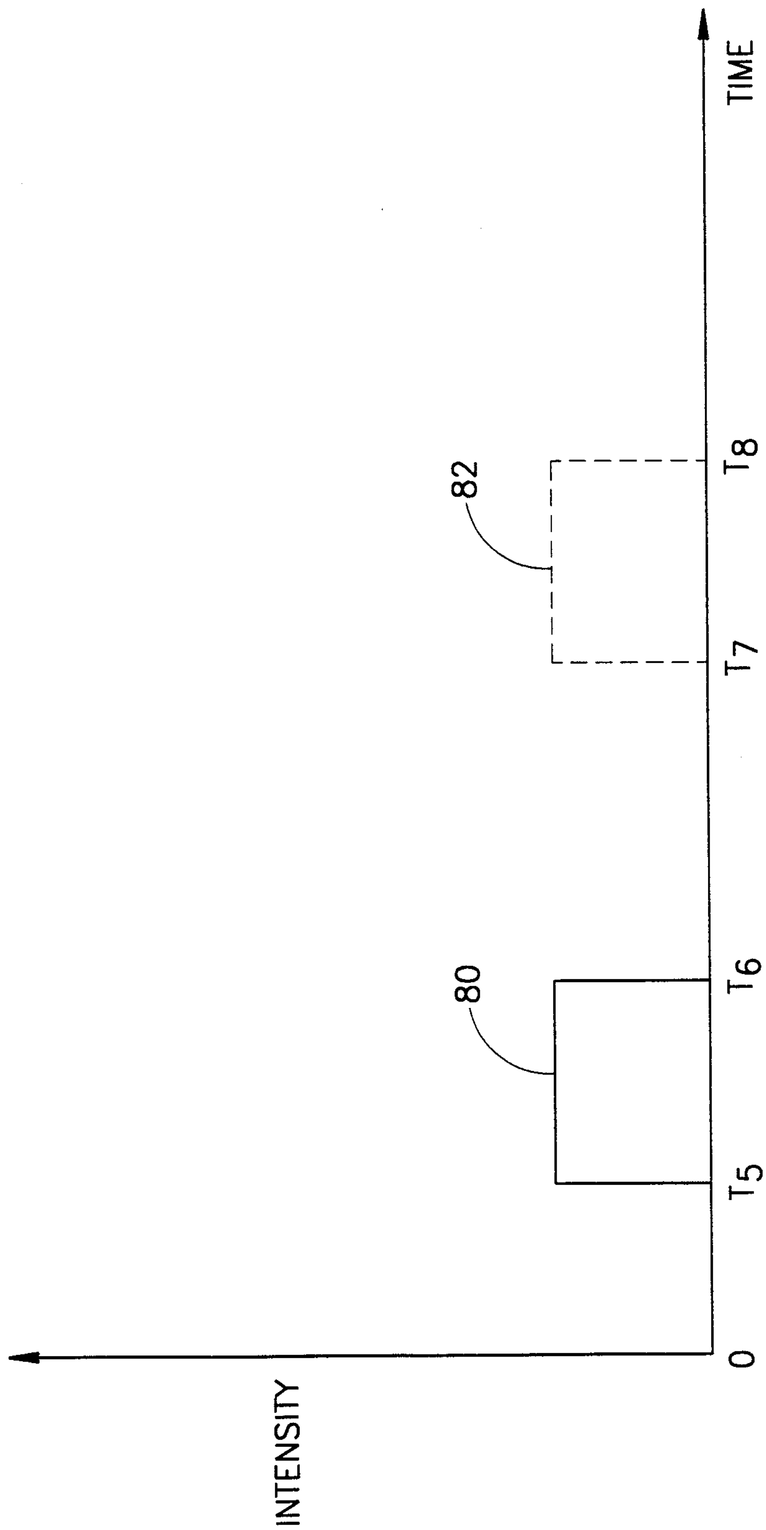

FIG.8

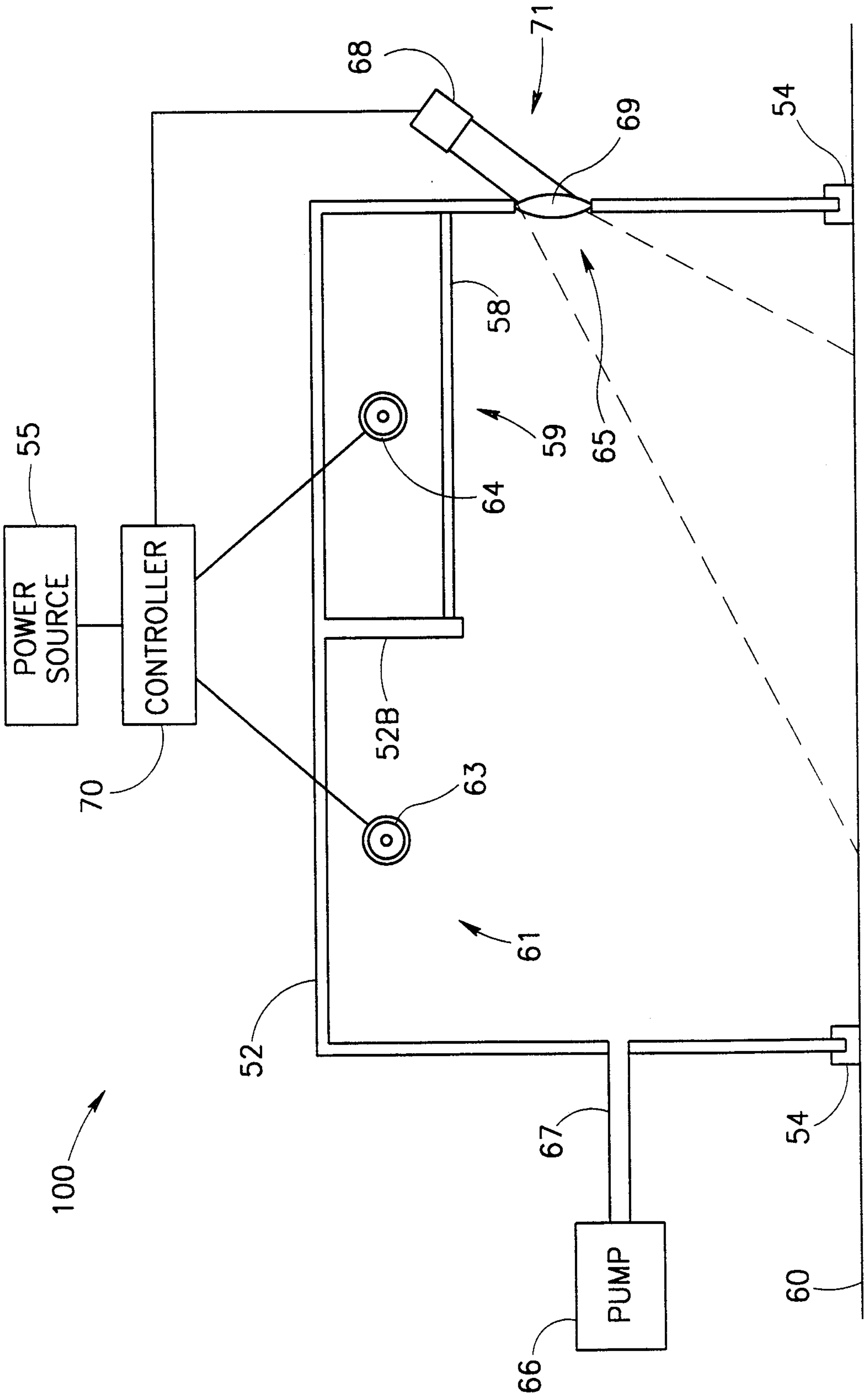
POWER SOURCE
CONTROLLER
PUMP
55
70
68
71
69
54
58
59
65
64
52B
63
61
52
67
54
100
66
60

FIG.9

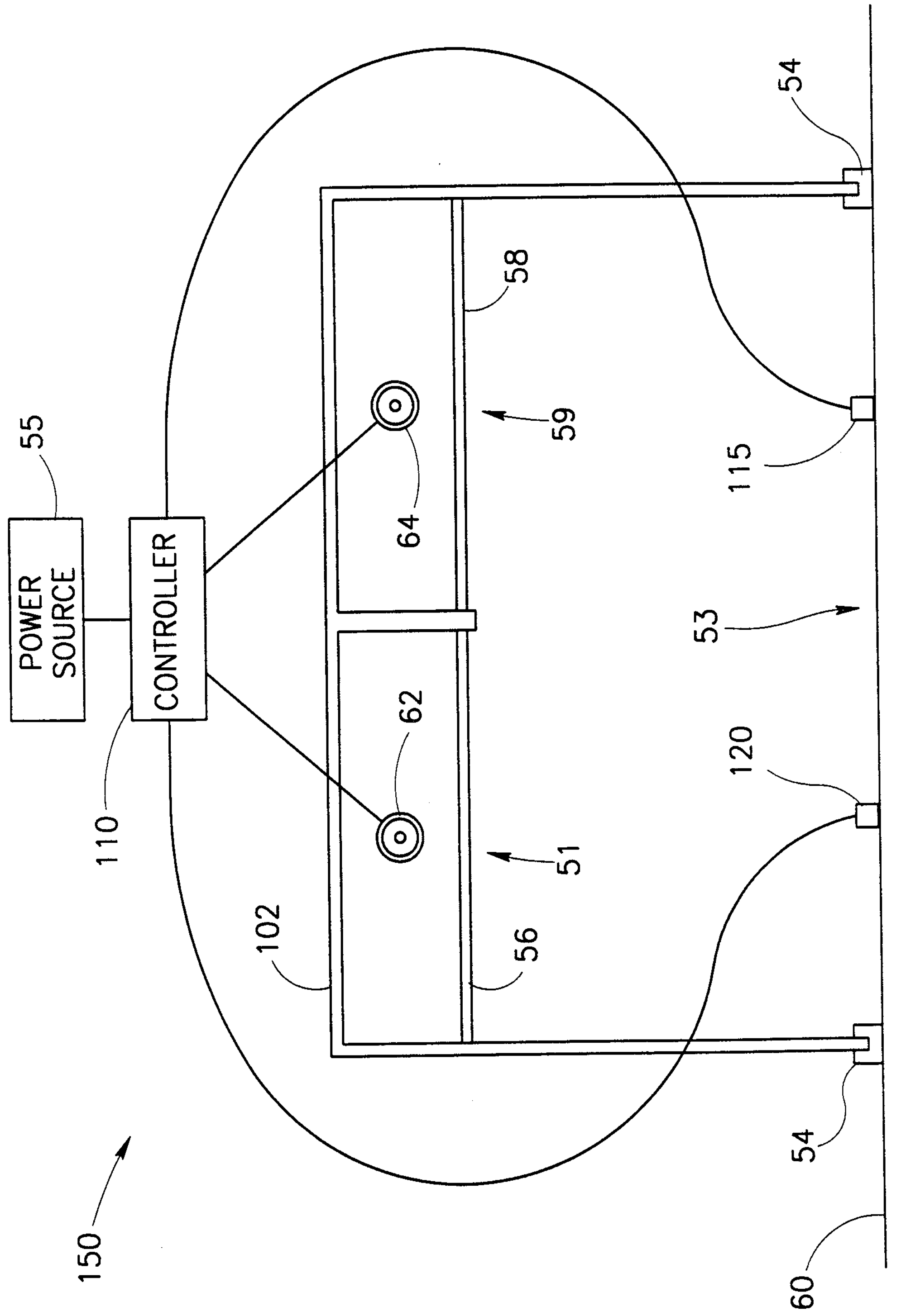
POWER SOURCE
CONTROLLER
55
110
150
102
62
64
51
59
56
58
53
54
54
115
120
60

FIG.10

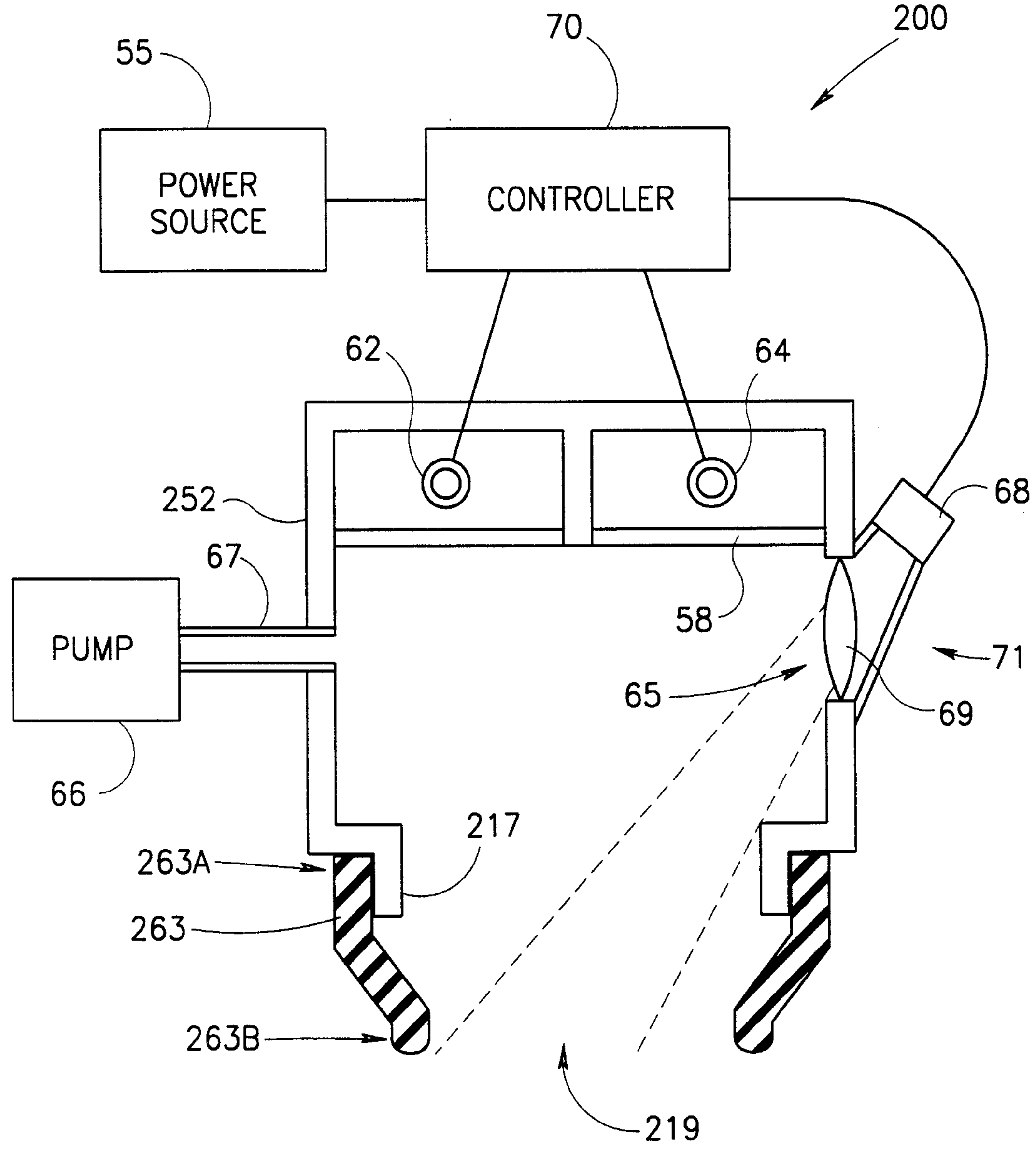
55
70
200
POWER SOURCE
CONTROLLER
62
64
252
68
67
58
PUMP
71
65
69
66
217
263A
263
263B
219

FIG.11

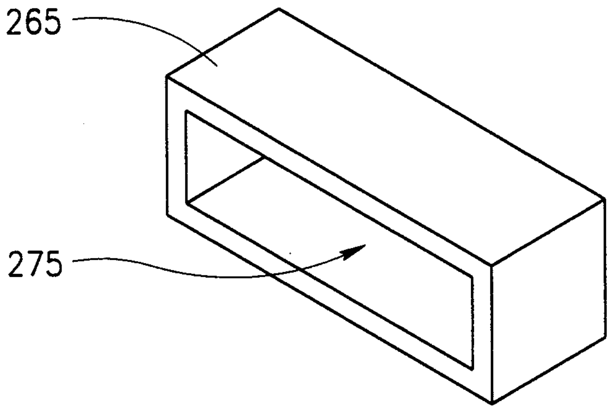

FIG.12

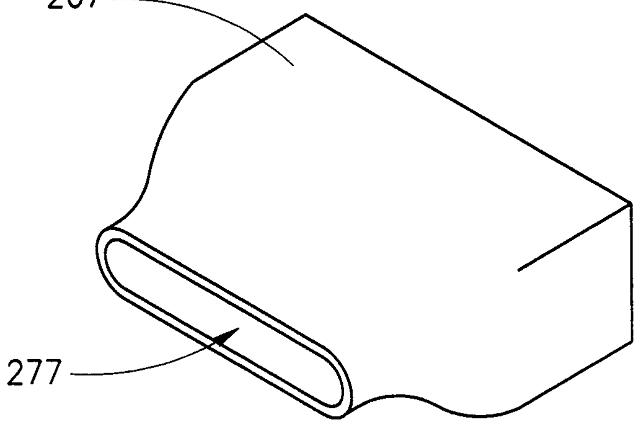

FIG.13

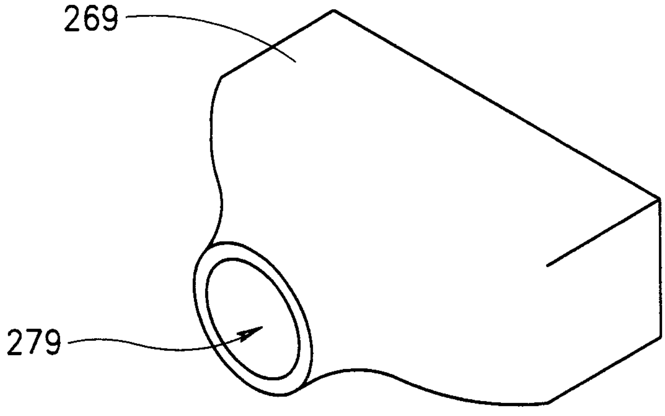

FIG.14

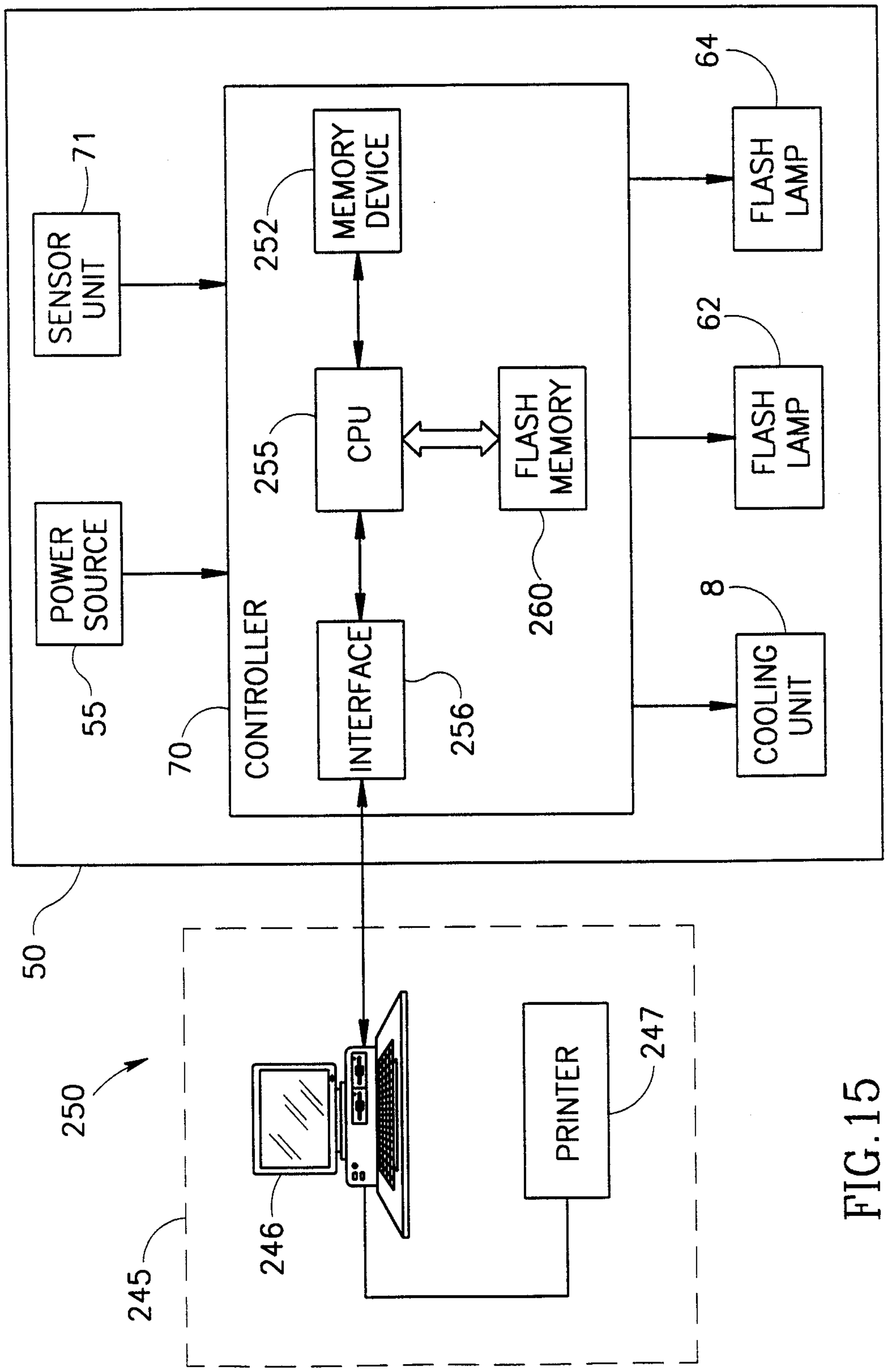
SENSOR UNIT
71
POWER SOURCE
55
CONTROLLER
70
MEMORY DEVICE
252
CPU
255
FLASH MEMORY
260
INTERFACE
256
FLASH LAMP
64
FLASH LAMP
62
COOLING UNIT
8
50
250
245
246
PRINTER
247

FIG.15

INTERNATIONAL SEARCH REPORT

Inte .ional Application No
PCT/IL 99/00210

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61N5/06

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 A61N

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.
A	US 5 720 772 A (ECKHOUSE SHIMON) 24 February 1998 (1998-02-24) column 5, line 9 - column 6, line 67 column 16, line 12 - line 62 ---	1
A	US 5 344 418 A (GHAFFARI SHAHRIAR) 6 September 1994 (1994-09-06) column 4, line 16 - column 5, line 67 column 7, line 39 - line 62 ---	1
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A	US 5 057 104 A (CHESS CYRUS) 15 October 1991 (1991-10-15) column 3, line 65 - column 4, line 66 ---	1
	-/--	

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 August 1999	10/08/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Petter, E

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 99/00210

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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