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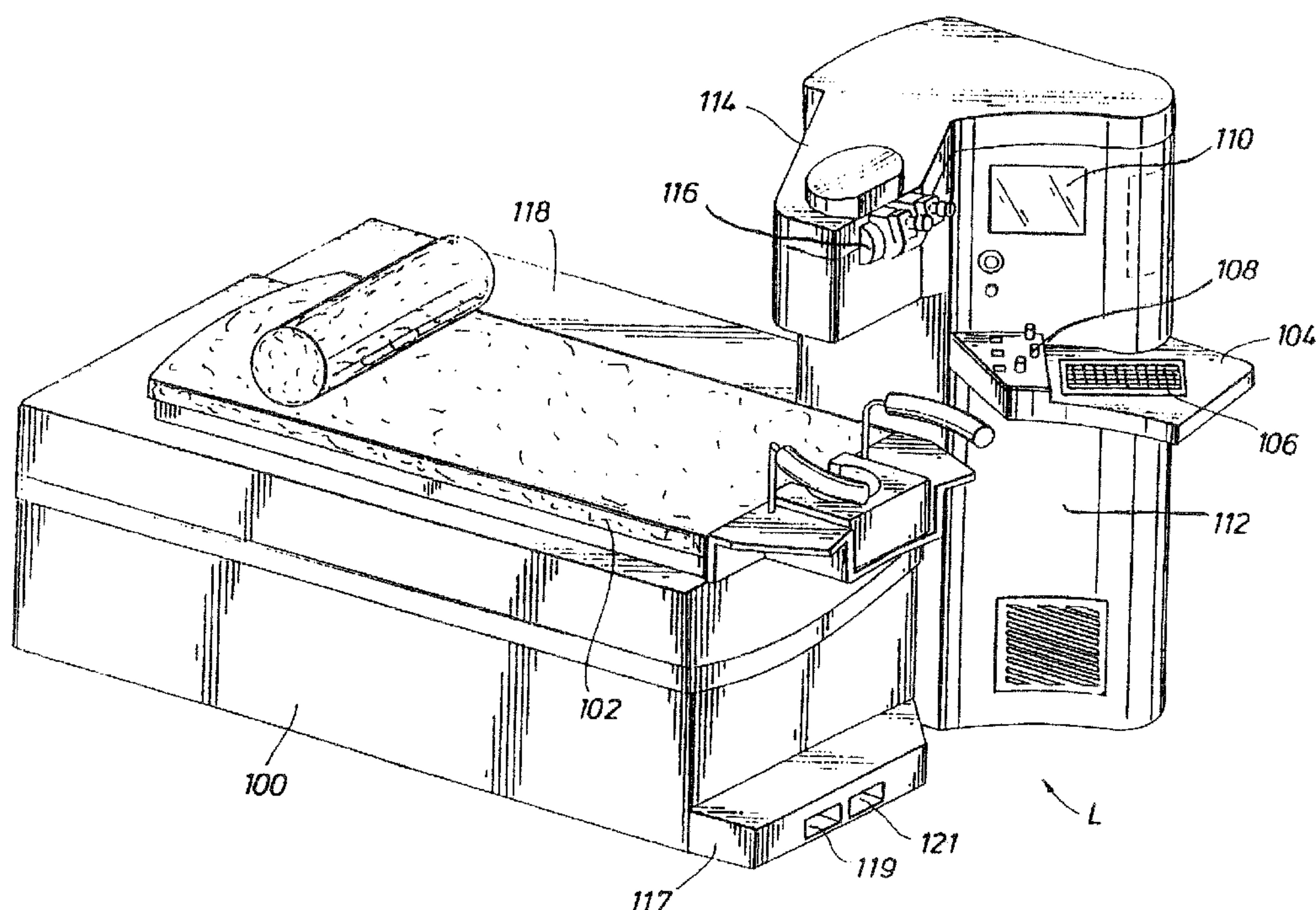
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(54) Titre : SYSTÈME DESTINÉ À UNE CHIRURGIE DE L'OEIL AU LASER EXCIMER

(54) Title: EXCIMER LASER EYE SURGERY SYSTEM



(57) Abrégé/Abstract:

A compact excimer laser system is provided that includes argon fluoride laser gas, electronic, and laser head all compactly arranged such that the patient bed can rotate over all of these components. This allows the patient bed to be rotated for easy egress of the patient without striking the head against an optical extension through which the excimer laser is fired onto the patient's eye. Further, an automated lamellar keratoplasty system is incorporated into the electronics and components of the laser system so that laser in situ keratomileusis can be easily performed.

ABSTRACT OF THE DISCLOSURE

A compact excimer laser system is provided that includes argon fluoride laser gas, electronic, and laser head all compactly arranged such that the patient bed can rotate over all of these components. This allows the patient bed to be rotated for easy egress of the patient without striking the head against an optical extension through which the excimer laser is fired onto the patient's eye. Further, an automated lamellar keratoplasty system is incorporated into the electronics and components of the laser system so that laser *in situ* keratomileusis can be easily performed.

EXCIMER LASER EYE SURGERY SYSTEM

This is a divisional of Canadian Patent Application No. 2,254,714, filed May 26, 1997.

The invention relates to laser systems for eye surgery, and more particularly to a compact excimer laser eye surgery system particularly suited for laser *in situ* keratomileusis.

Since the invention of spectacles, doctors and scientists have striven to improve human vision. From eye glasses, to contact lenses, to radial keratotomy, doctors have sought more convenient and permanent solutions to defective vision.

The development of the excimer laser provided a unique opportunity for vision correction. The excimer laser, especially an argon fluoride excimer laser operating at a 193 nanometers, removes tissue through a non-thermal process of "ablation" in which the molecular bonds of tissue are literally broken. This allows precise amounts of tissue to be removed without heating the surrounding tissue--heating that can burn that tissue leading to scarring. This ablative process using the excimer laser has been employed in a number of ways to literally reprofile the surface of the eye. These techniques are described, for example, in Assignee's United States Patents Nos. 5,683,379 and 6,090,100.

These techniques have been taken a step further through the development of laser *in situ* keratomileusis (LASIK), a technique in which the surface layer of the eye is resected, and the underlying stromal tissue is removed using this laser ablation technique. That surface layer is then replaced, and the epithelium then regrows, holding the surface layer in place. This technique has been patented by Gholam Peyman in U.S. patent no 4,840,175.

Both of these techniques, however, benefit from efficient and compact workstations. These techniques generally should be performed in surgical quality clean rooms. Such clean rooms tend to be expensive, so any reduction in the amount of space taken by an excimer laser surgery system would be beneficial. Further, devices providing an integration of functionality and an increase in efficiency are also greatly desirable.

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Therefore, according to an embodiment of the invention, an excimer laser system is constructed in a highly compact form, in which a patient bed forms an enclosure in which is placed the gas bottle for the excimer laser system, typically holding argon fluoride gas, along with

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electronics for powering and controlling the excimer laser system. Further, the patient bed enclosure can preferably be rolled away to allow easy access to these components for maintenance and service.

The laser head is placed immediately adjacent to the bed, but below the height of the bed. The bed includes a bearing, allowing the bed to rotate over the laser head and away from an excimer laser optical extension through which the laser beam is fired into the patient's eye. This allows the patient to sit up without striking his or her head. Further, the bed can be rotated 90°, allowing non-laser ophthalmic surgery to be performed using the same equipment in the same clean room.

Further according to an embodiment of the invention, an automated lamellar keratoplasty (ALK) system is integrated into the laser system, providing both computer and monitoring and connections for a microkeratome. Two foot switches are provided, one for advancing and retracting the microkeratome, and the other for activating the vacuum to the microkeratome. This integrated system allows an easily used and controlled system for performing laser *in situ* keratomileusis (LASIK).

According to an aspect of the present invention, there is provided a system for laser eye surgery, the system comprising: a laser head for providing a laser beam suitable for removing tissue from an eye; a power supply connected to the laser head for powering the laser head; an aiming system for providing an optical path from said laser head and for aiming the laser beam along the optical path to the eye, said aiming system further comprising: a final beam directing portion extending horizontally over a patient in an operational position, the final beam directing portion directing the laser beam substantially perpendicular to the patient's eye when the patient is in the operational position; a patient bed integrally connected to said laser head, and positioned rotatably below the final beam directing portion, said patient bed rotatable from a first position wherein the patient is in the operational position below said final beam directing portion, to a second position in which the patient is moved away from below said final beam directing portion, whereby the patient can easily sit up without striking his or her head against the final beam directing portion.

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A better understanding of the present invention can be obtained when the following detailed description of the preferred embodiment is considered in conjunction with the following drawings, in which:

Figure 1 is a perspective view of the laser system according to an embodiment of the invention;

Figures 2A-C are top, side, and front views of the laser system according to an embodiment of the invention;

Figures 3A-D are top, front, back and side views of the patient bed enclosure and rotatable patient bed according to an embodiment of the invention;

Figures 4A-C are top, front, and side views of the equipment enclosed by the patient bed enclosure of Figures 3A-D; and

Figure 5 is a front view of the internal components of the system of Figure 1, further illustrating the incorporated automated lamellar keratoplasty (ALK) system for performing LASIK.

Turning to Figure 1, shown is the laser system L according to an embodiment of the invention. This laser system is preferably based on a 193 nm argon-fluoride excimer laser, but other lasers could be used. A patient bed enclosure 100 includes a patient bed 102 disposed on top of

it. A physician workstation platform 104 is situated diagonally away from the patient bed 102, and includes a keyboard 106 and control inputs 108. The keyboard 106 and control inputs 108 provide input to a computer system that in part controls the laser system L. That computer system provides data for a display 110. The control inputs 108, the keyboard 106, and the display 110, all in conjunction with the computer system, serve to control the laser system L, and to fire an excimer laser beam through an optics path that extends perpendicularly through the physician workstation enclosure 112, and then horizontally through an optical extension 114. The source of the laser beam is an excimer laser head found in a laser head enclosure 118. The optical extension 114 directs the excimer laser to the patient's eye as the patient lies on the patient bed 102, and also provides optics 116 for the physician to view the surgery before and while it takes place.

The optical extension 114 also includes an eye tracking system which partially uses the optical path extending through the physician workstation enclosure 112. The eye tracking system preferably employs a high speed video camera and dedicated electronics, and works in conjunction with the computer system to maintain the laser optics aligned with a desired point on the patient's eye.

The patient bed enclosure 100 also includes a foot rest 117 for the physician to use during surgery. This foot rest 117 further includes two foot switches 119 and 121, which control the vacuum and power to a microkeratome in an automated lamellar keratoplasty (ALK) system used in a LASIK procedure. This is further discussed below in conjunction with Figure 5.

Preferably, the eye tracking system also employs Transputer™ boards manufactured by INMOS Limited used in conjunction with a Transputer Frame Grabber™ manufactured by Parsytech, GmbH, installed in the computer system.

Turning to Figures 2A-C, shown are views of the system of Figure 1. A top view in Figure 2A illustrates how the optical extension 114 extends substantially over a head portion 124 of the patient bed 102. The physician then uses the optics 116 to observe the surgery as it takes place.

Also from this position, it is seen that adjacent to the patient bed 102 is the laser head housing 118. This laser head in the laser head housing 118 fires the laser beam, preferably a 193 nanometer excimer laser. This beam is fired parallel to the floor and then

is reflected vertically up through the physician workstation enclosure 112, and then out through the optical extension 114. The laser beam is then reflected down into the patient's eye at a center point 120.

Turning to Figure 2B, another view of the workstation is shown. From this view, a final beam path 122 is shown firing down from the optical extension 114 towards a head portion 124 of the bed 102. It is also seen that if a patient were to sit up, the patient could strike his or her head on the optical extension 114. In Figure 2B, it is seen that the laser head 118 does not extend above the patient bed 102. This feature will be appreciated in conjunction with Figure 3A discussed below.

Turning to Figure 2C, shown is an end view, again showing the beam path 122 at which the excimer laser will fire onto the head portion 124 of the bed 102. Also, it is seen that the height of the workstation platform 104 is set so that the physician is provided easy access to both the keyboard 106 and to the patient's head, which is resting in the head portion 124 of the patient bed 102. Figure 2C also shows a patient bed adjustment platform 125, which is part of the patient bed enclosure 125. This adjustment platform 125 provides motorized control of the patient bed 102 in the x, y, and z axes through the controls 108.

Turning to Figure 3A, shown is the patient bed 102 in its rotated position. The patient bed 102 rotates on a bearing 126, which firmly connects the patient bed 102 to the patient bed enclosure 100. The patient bed 102 position is adjusted by motors and pulleys 140, which provide x, y, and z axes control of the adjustment platform 125. Further, the patient bed 102 rotates over the laser head 118. Preferably, the patient bed rotates sufficient so that the head portion 124 of the patient bed 102 has rotated out from under the optical extension 114. The patient can then sit up without striking his or her head on the optical extension 114. Further, the patient bed 102 can preferably rotate up to 90°, so that a single clean room could be used for performing both laser and non-laser ophthalmic surgery. In this position, not shown, the doctor would operate on the patient's head located within a head portion 124 of the patient bed 102, but rotated 90° away from the physician workstation platform 104. Further, preferably an electric solenoid 127 electrically latches into a latching hole 128 on the patient bed 102, holding the patient bed

102 in place during surgery. By providing the laser head 118 below the surface of the patient bed 102, the patient bed 102 can rotate over it.

Three more views of the patient bed 102 and the patient bed enclosure 100 are shown in Figures 3B, 3C, and 3D. Figure 3B is an end view from the perspective of the head portion 124 end of the patient bed 102, and shows that the patient bed 102 is mounted on rollers 129 and locked into place with stops 1130. In practice, the patient bed enclosure 100 forms a cover that encloses a gas bottle holding argon fluoride gas needed by the laser head, cooling components, and electronics needed by the entire system. This is further discussed below in conjunction with Figures 4A-C.

The patient bed enclosure 100 is rolled over those components in a direction 131 and then locked into place with the stops 130 before the system is operated.

Figure 3C illustrates a left (from a patient's perspective) side view of the patient bed enclosure 100 and the patient bed 102.

Figure 3D illustrates a bottom end view (from the patient's perspective) of the patient bed 102 and the patient bed enclosure 100. As can be seen, an additional recess 132 is formed to accommodate the laser head discussed below in conjunction with Figures 4A-C.

Given Figures 3A-D, it will be appreciated that there is an open space formed underneath the patient bed enclosure 100. This open space is used to enclose the material necessary for the laser system L to operate. By providing the patient bed enclosure 100 as the cover for these components, the patient bed 102 and the patient bed enclosure 100 can be easily rolled away from these components to allow easy access and service. At the same time, using this enclosed space is an advantage in surgical systems because clean room operating space is a scarce resource. Therefore, a smaller and more compact system provides advantages because it reduces then size of the clean room necessary.

Turning to Figures 4A-C, shown are block diagrams illustrating the arrangement of the components underneath the patient bed enclosure 100. Referring to Figure 4A, shown is a gas bottle 200, electronics 202 for both providing power and for providing the computer system for the laser system L, and an internal laser head 204. AC power components are provided in the open space 203 left of the electronics 202. The electronics 202 include the computer system, the bed power supplies, and other system

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electronics, such as transformers and interface circuits. The internal laser head 204 is enclosed by the laser head enclosure 118, and forms a laser beam, preferably a 193 nanometer excimer laser beam that fired a left to right in reference to the diagram of figure 4A. The laser head 204 preferably includes an integral 30K volt power supply. Further included are various cooling components 206.

Referring to the end view of Figure 4B, it is seen that the gas bottle 200 is mounted on rollers 208 for easy replacement of the gas bottle 200 after the patient bed enclosure 100 is rolled out of the way. Further, it is seen that the electronics 202 include a portion that surrounds the gas bottle 200, thereby more efficiently using the space. Again, the laser head 204 is shown, with beam egress points 210 and 212 for providing the excimer laser beam which is then reflected transversely through the optical extension 114, which forms the final beam directing portion. That final beam directing portion then redirects the laser beams into the patient's eye. Further, the final beam direction portion includes optics necessary to adjust the position that the excimer laser beam strikes the patient's eye. Also, an aiming laser is preferably provided in the optical extension 114 colinearly aligned with the excimer laser. This preferably includes two aiming mirrors, one for each axis.

Turning to Figure 4C, a side view from the perspective as Figure 3C is illustrated of the internal components. Again, it is seen how the electronics 202 wrap around the gas bottle 200.

Turning to Figure 5, yet another view is shown. In this case, an ALK, or automated lamellar keratoplasty system 300 is integrated into the laser system L. Automated lamellar keratoplasty is a system used to assist in a LASIK procedure, or a laser *in situ* keratomileusis procedure. This procedure requires a microkeratome, which preferably includes a vacuum port for providing suction for attachment to the eye and a power port for providing a high speed oscillating movement of the blade. Once a flap is taken from the patient's eye as the patient's head rests in the bed 124, the flap is pulled back and tissue underneath is excised, according to the technique described by the above-discussed Gholam Peyman patent.

Such systems, however, require monitoring and control, so preferably the two foot switches 117 and 119 are provided for the ALK system 300. These switches turn the vacuum on and off power the microkeratome. The vacuum and power for the ALK are

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provided integrally through the laser system L through two ports 306 and 308. Preferably, a nurse will be stationed adjacent to the doctor and attach the microkeratome when it is needed. The ports 306 and 308 can of course be located elsewhere on the laser system L, but their integral nature assists in the operation. Further, the ALK system is coupled to the electronics 202 for monitoring. For example, if the vacuum fails, one would immediately wish to cease blade movement, because high speed blade movement is necessary to prevent binding with the lamellar flap as it is taken. Further, the ALK system can be further integrated and controlled through computer access via the computer system in the electronics 202. The computer system is preferably integrated to the electronics 202 and provides control for various systems, including the display 110, the control inputs 108, and the keyboard 106. Further, the computer system preferably controls the eye tracking system, the aiming system, the laser head 204 and the firing of the laser head 204. Further, the computer system preferably includes a remote disk drive slot 312, for example for the insertion of a preprogrammed shot pattern, such as that described in assignee's U.S. Patent No. 656,855.

The computer system can be further integrated with the automated lamellar keratoplasty system 300. The automated lamellar keratoplasty system 300 typically provides a vacuum pressure output signal, microkeratome voltage and current output signals, as well as control inputs. The computer system can both display the microkeratome voltage and current and vacuum pressure, and generate warning messages or disable both the power source within the automated lamellar keratoplasty system and the vacuum source within the automated lamellar keratoplasty system should there be a failure. Further, the computer system can be disposed between the automated lamellar keratoplasty system 300 and the foot switches 119 and 121, so that the computer system itself controls the automated lamellar keratoplasty system 300 responsive to the foot switches 119 and 121.

Further, using the keyboard 106, the user in such a situation could set the power level of the power source in the automated lamellar keratoplasty system 300 and the vacuum pressure of the vacuum source within the automated lamellar keratoplasty system

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300 using feedback on the display 110 on a routine executing in the computer system of the electronics 202.

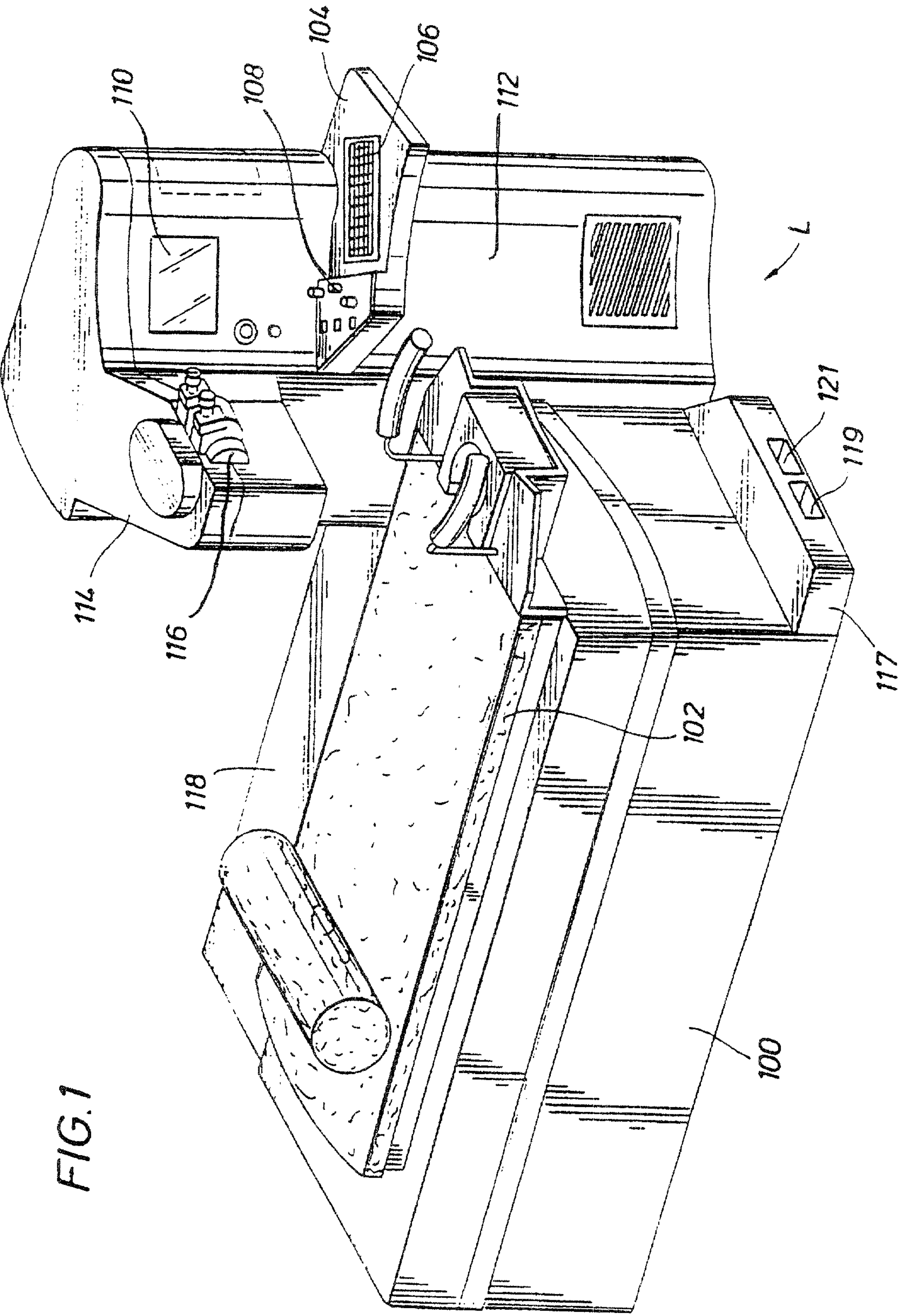
In view of the foregoing discussion and figures, it will be appreciated that the system provides a compact excimer laser surgery system with a rotatable bed for patient convenience and for non-excimer laser operation. Further, an integrated ALK system provides for the convenient performance of laser *in situ* keratomileusis.

Finally, arrangement of components underneath the patient bed enclosure and patient bed, their arrangement next to the laser head, reduces the space taken by the system, thus providing for the more efficient of clean room environments.

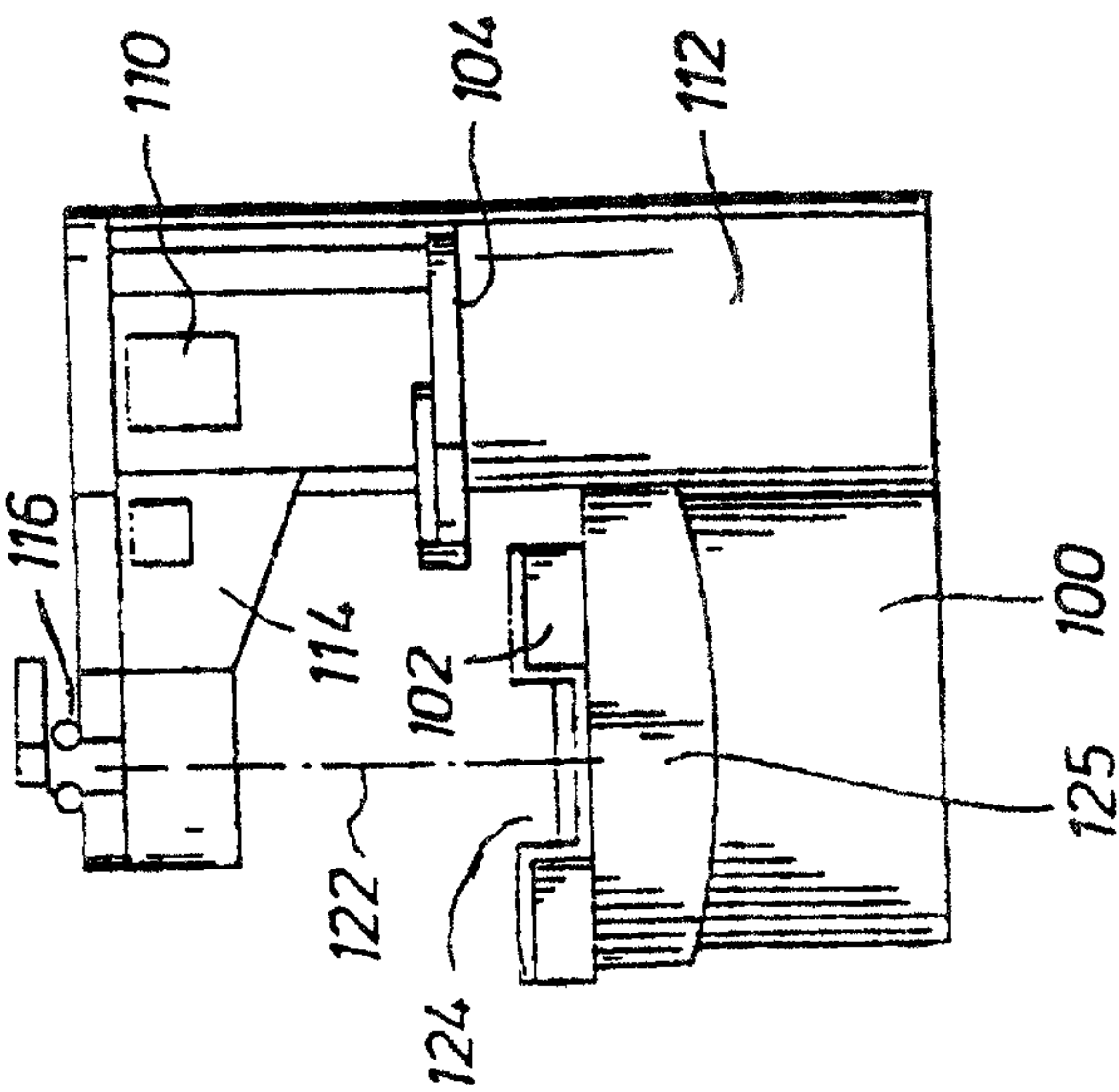
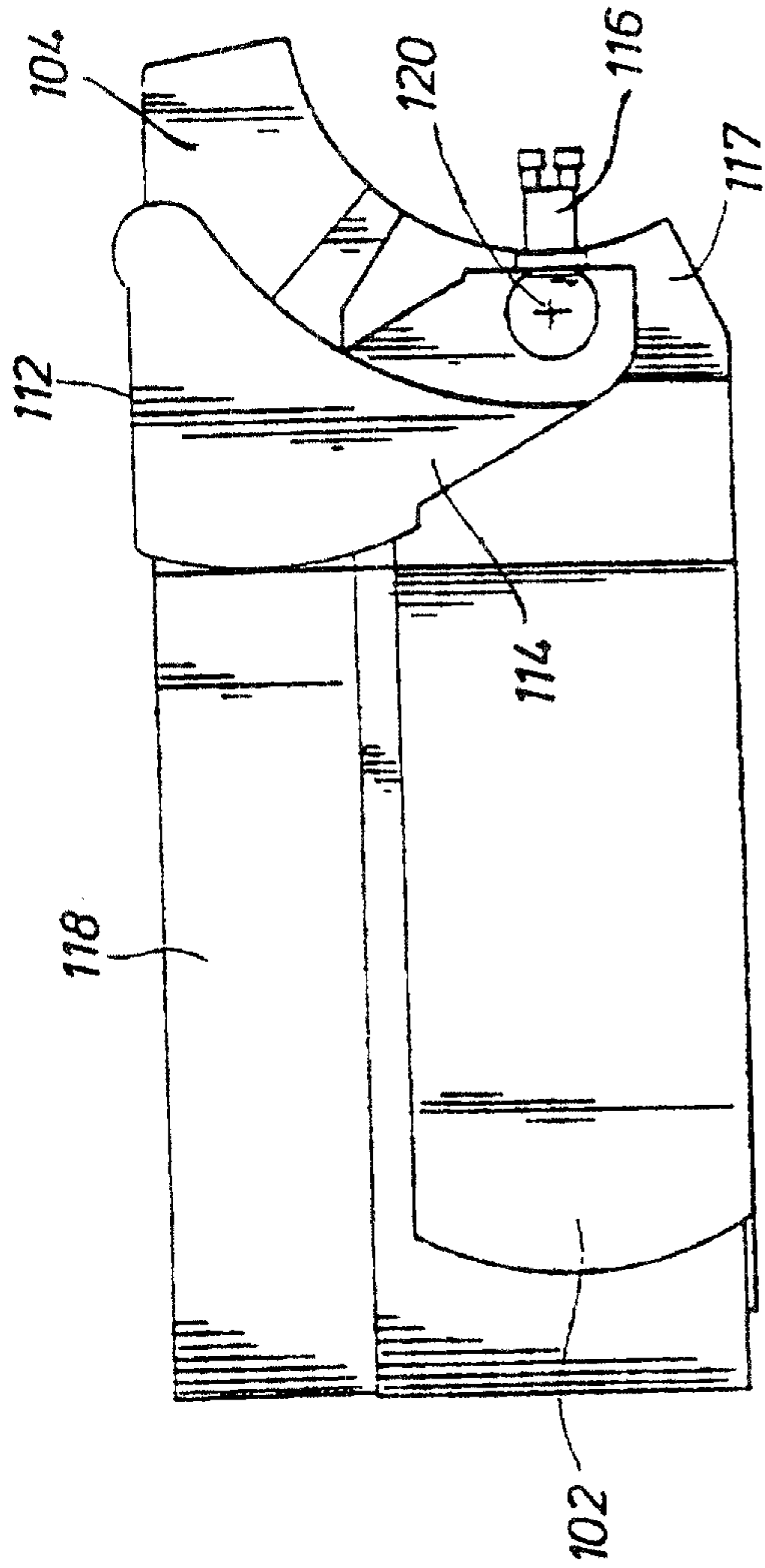
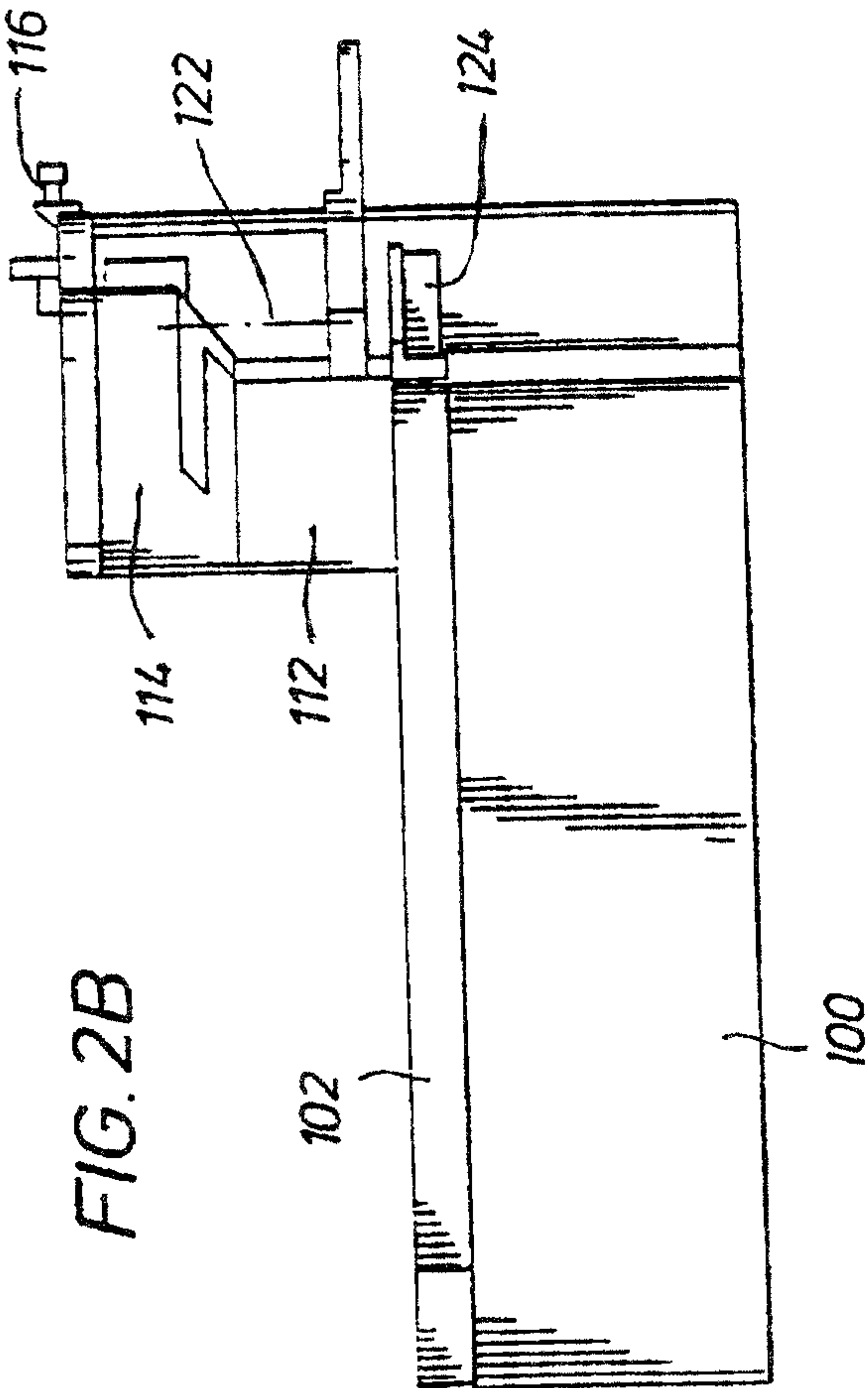
The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, materials, components, circuit elements, wiring connections and contacts, as well as in the details of the illustrated circuitry and construction and method of operation may be made without departing from the spirit of the invention.

CLAIMS:

1. A compact laser surgery system comprising:
a patient bed enclosure with a patient surface and a patient height, said patient bed enclosure surrounding an open space;
a laser gas container disposed in said open space towards a first side of said patient bed;
an electronics package for providing computer control disposed in said open space adjacent to said laser gas container towards a second side of said patient bed;
a laser head located adjacent to said patient at a height less than said patient height, said laser head connected to laser gas container for receiving laser gas and connected to said electronics for receiving power.
2. The system of claim 1, further comprising an aiming system providing an optical path from said laser head, said aiming system disposed perpendicularly upwards from the laser head, transversely across from the laser head in an optical extension above the patient bed, the aiming system to provide the laser beam substantially perpendicular towards the eye of the patient on the patient bed.
3. The system of claim 2, wherein the patient surface rotates across the laser head and away from the optical extension.
4. The system of any one of claims 1 to 3, further including cooling system components disposed in said open space adjacent to said laser gas container towards said second side of said patient bed, but away from said electronics.
5. The system of claim 4, wherein power components are disposed between said cooling system components and said electronics.
6. The system of any one of claims 1 to 5, wherein said patient bed is mounted on rollers with stops, allowing said patient bed to be rolled away to provide access to said gas container and said electronics.



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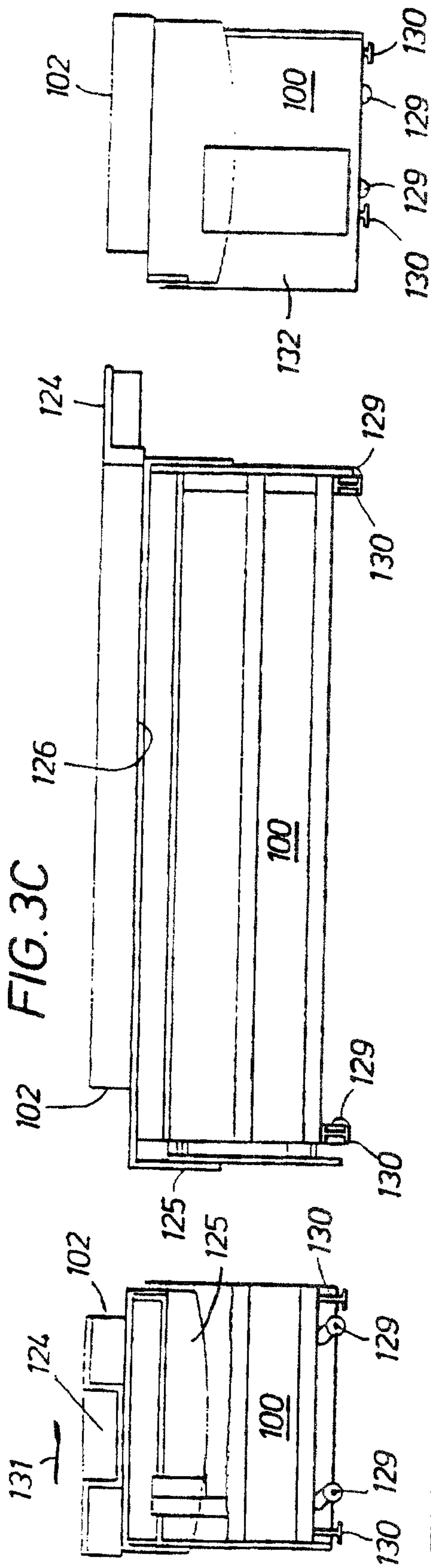


FIG. 3A

FIG. 3B

FIG. 3C

FIG. 3D

FIG. 3E

FIG. 3F

FIG. 3G

FIG. 3H

FIG. 3I

FIG. 3J

FIG. 3K

FIG. 3L

FIG. 3M

FIG. 3N

FIG. 3O

FIG. 3P

FIG. 3Q

FIG. 3R

FIG. 3S

FIG. 3T

FIG. 3U

FIG. 3V

FIG. 3W

FIG. 3X

FIG. 3Y

FIG. 3Z

FIG. 3AA

FIG. 3AB

FIG. 3AC

FIG. 3AD

FIG. 3AE

FIG. 3AF

FIG. 3AG

FIG. 3AH

FIG. 3AI

FIG. 3AJ

FIG. 3AK

FIG. 3AL

FIG. 3AM

FIG. 3AN

FIG. 3AO

FIG. 3AP

FIG. 3AQ

FIG. 3AR

FIG. 3AS

FIG. 3AT

FIG. 3AU

FIG. 3AV

FIG. 3AW

FIG. 3AX

FIG. 3AY

FIG. 3AZ

FIG. 3BA

FIG. 3BB

FIG. 3BC

FIG. 3BD

FIG. 3BE

FIG. 3BF

FIG. 3BG

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FIG. 3BI

FIG. 3BJ

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FIG. 3BV

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FIG. 3BZ

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FIG. 3CB

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FIG. 3CE

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FIG. 3CH

FIG. 3CI

FIG. 3CJ

FIG. 3CK

FIG. 3CL

FIG. 3CM

FIG. 3CN

FIG. 3CO

FIG. 3CP

FIG. 3CQ

FIG. 3CR

FIG. 3CS

FIG. 3CT

FIG. 3CU

FIG. 3CV

FIG. 3CW

FIG. 3CX

FIG. 3CY

FIG. 3CZ

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FIG. 3DB

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FIG. 3DE

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FIG. 3DK

FIG. 3DL

FIG. 3DM

FIG. 3DN

FIG. 3DO

FIG. 3DP

FIG. 3DQ

FIG. 3DR

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FIG. 3DT

FIG. 3DU

FIG. 3DV

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FIG. 3DX

FIG. 3DY

FIG. 3DZ

FIG. 3EA

FIG. 3EB

FIG. 3EC

FIG. 3ED

FIG. 3EE

FIG. 3EF

FIG. 3EG

FIG. 3EH

FIG. 3EI

FIG. 3EJ

FIG. 3EK

FIG. 3EL

FIG. 3EM

FIG. 3EN

FIG. 3EO

FIG. 3EP

FIG. 3EQ

FIG. 3ER

FIG. 3ES

FIG. 3ET

FIG. 3EU

FIG. 3EV

FIG. 3EW

FIG. 3EX

FIG. 3EY

FIG. 3EZ

FIG. 3FA

FIG. 3FB

FIG. 3FC

FIG. 3FD

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FIG. 3GX

FIG. 3GY

FIG. 3GZ

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FIG. 3HR

FIG. 3HS

FIG. 3HT

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FIG. 3HV

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FIG. 3HX

FIG. 3HY

FIG. 3HZ

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FIG. 3IB

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FIG. 3IE

FIG. 3IF

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FIG. 3IH

FIG. 3II

FIG. 3IJ

FIG. 3IK

FIG. 3IL

FIG. 3IM

FIG. 3IN

FIG. 3IO

FIG. 3IP

FIG. 3IQ

FIG. 3IR

FIG. 3IS

FIG. 3IT

FIG. 3IU

FIG. 3IV

FIG. 3IW

FIG. 3IX

FIG. 3IY

FIG. 3IZ

FIG. 3JA

FIG. 3JB

FIG. 3JC

FIG. 3JD

FIG. 3JE

FIG. 3JF

FIG. 3JG

FIG. 3JH

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FIG. 3JJ

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FIG. 3JM

FIG. 3JN

FIG. 3JO

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FIG. 3KA

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FIG. 3KC

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FIG. 3KY

FIG. 3KZ

FIG. 3LA

FIG. 3LB

FIG. 3LC

FIG. 4C

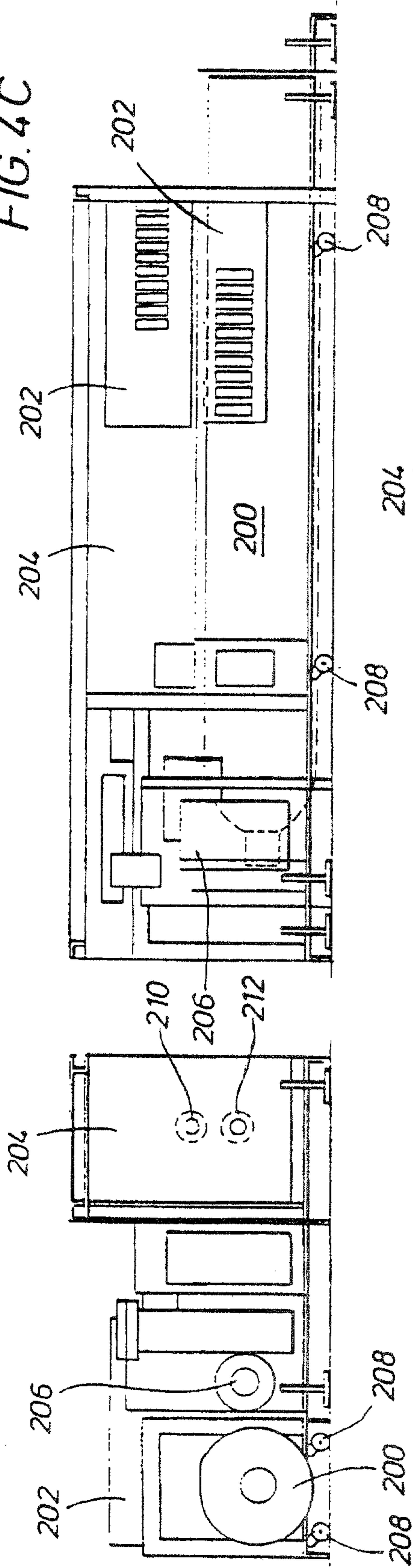


FIG. 4B

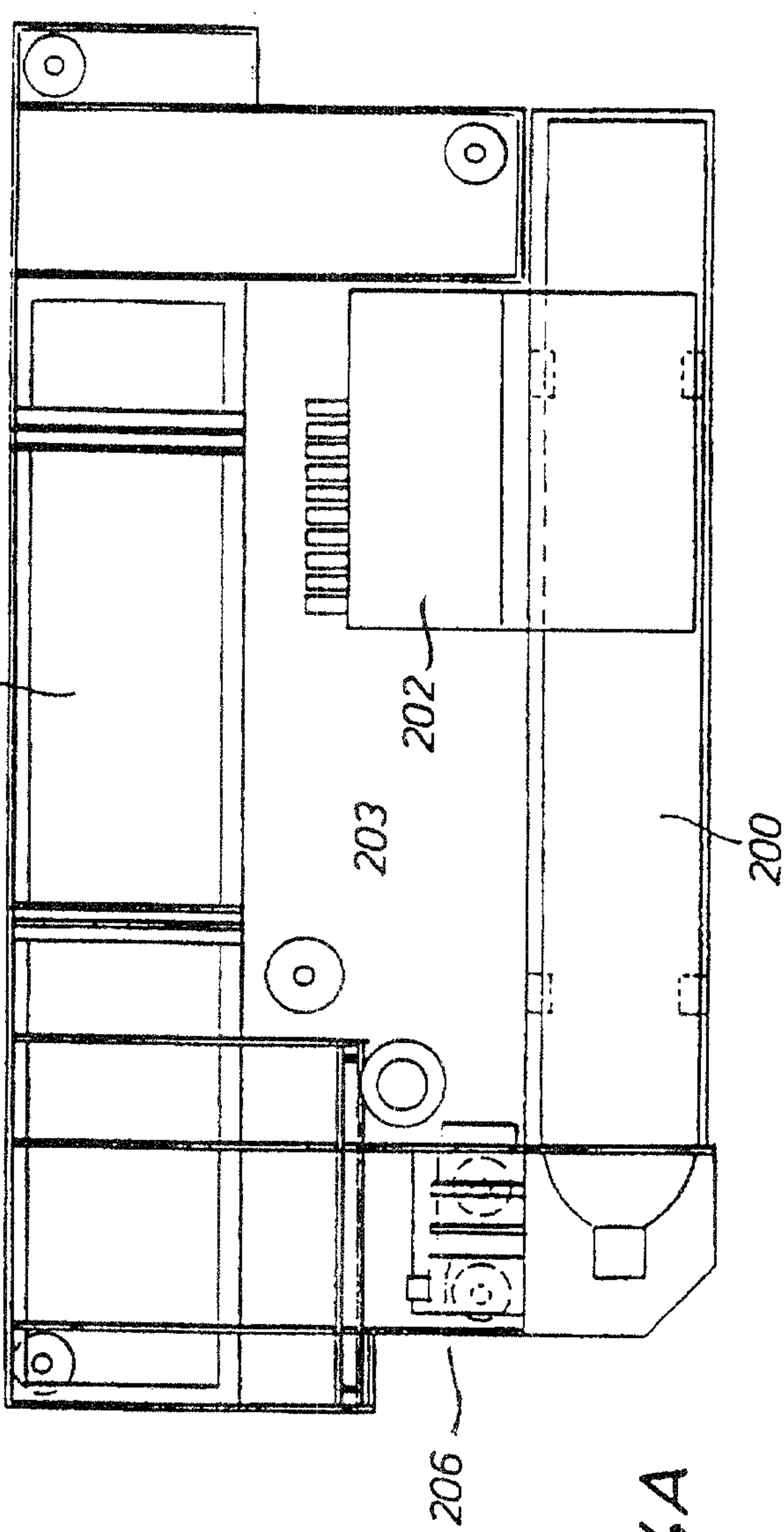


FIG. 4A

FIG. 5

