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(54) **EXCIMER LASER EYE SURGERY SYSTEM**

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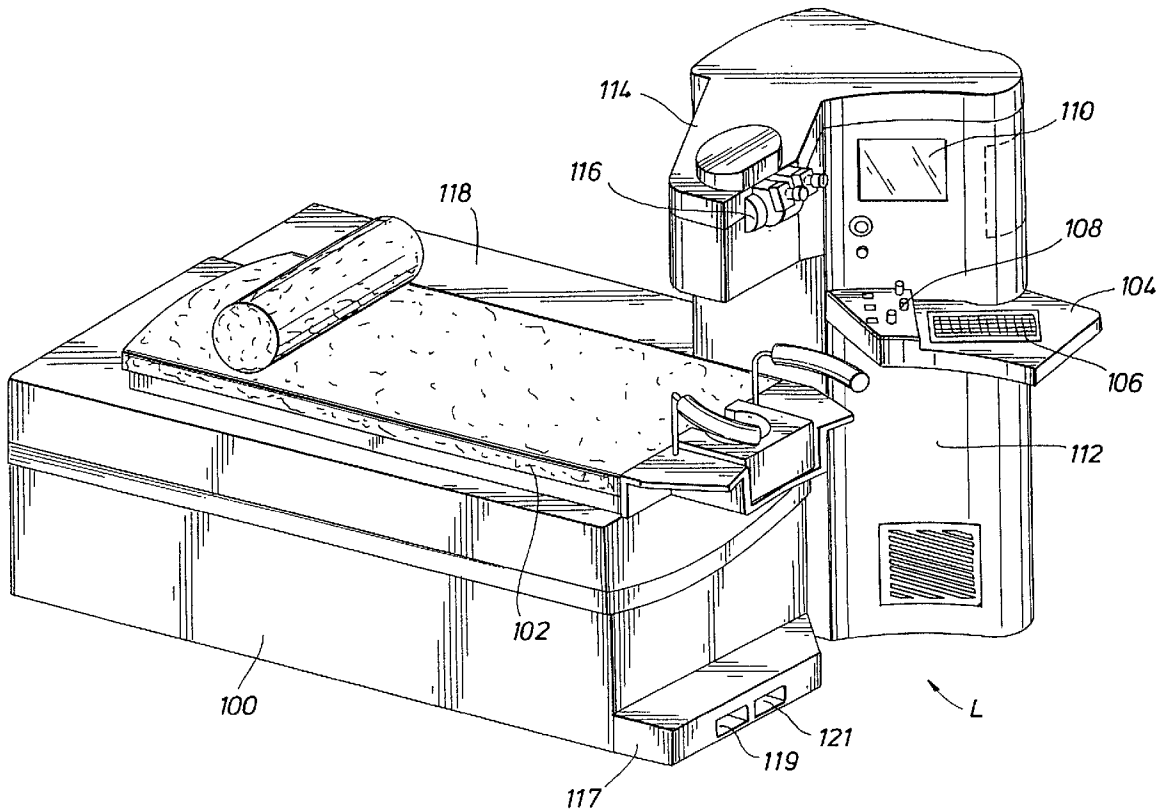
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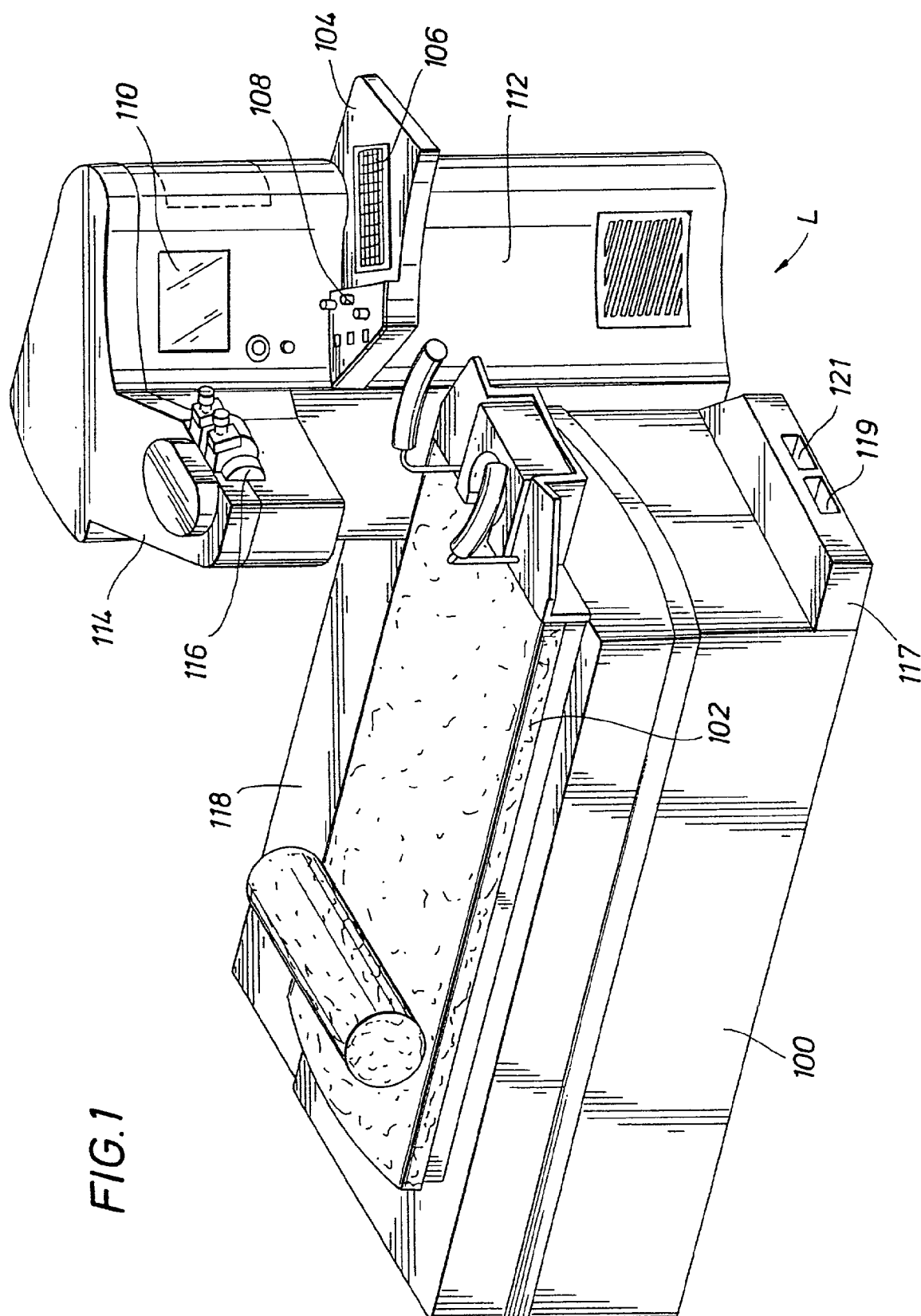
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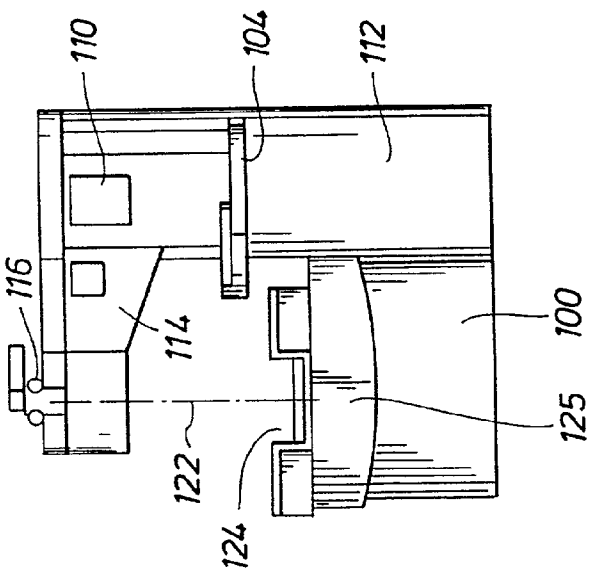
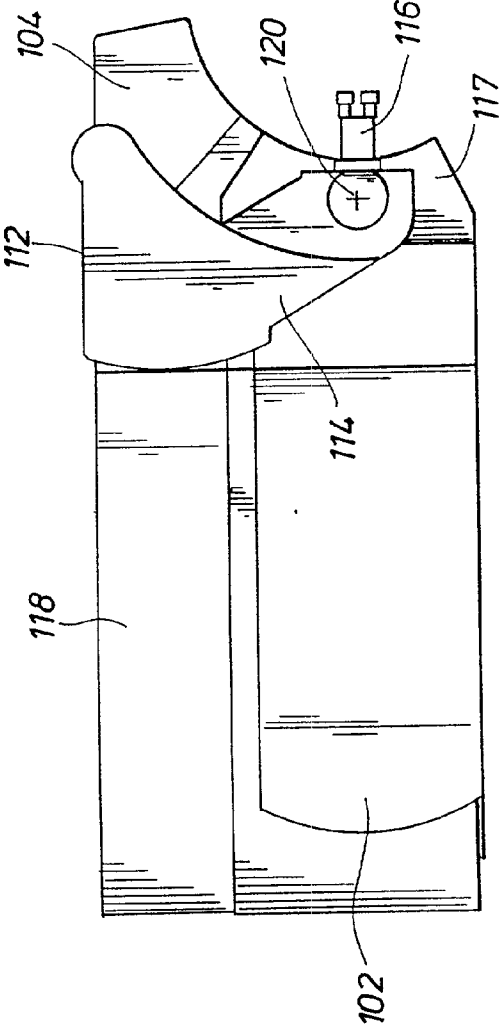
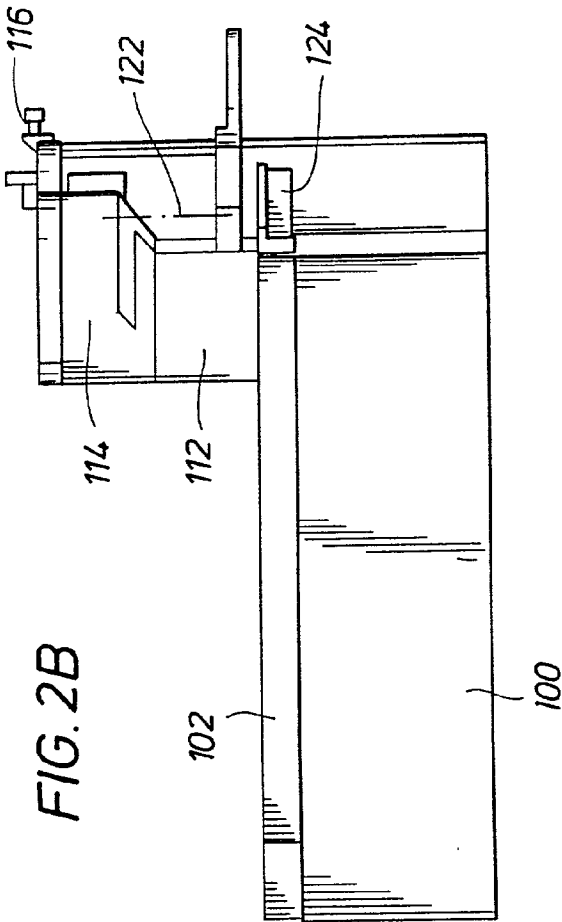
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ABSTRACT

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.







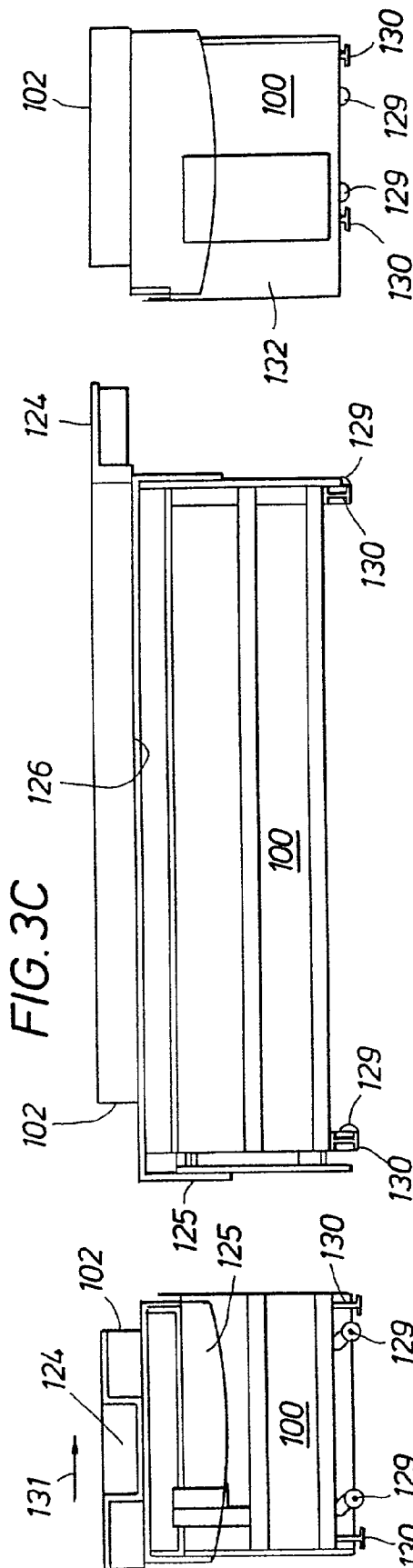


FIG. 3D

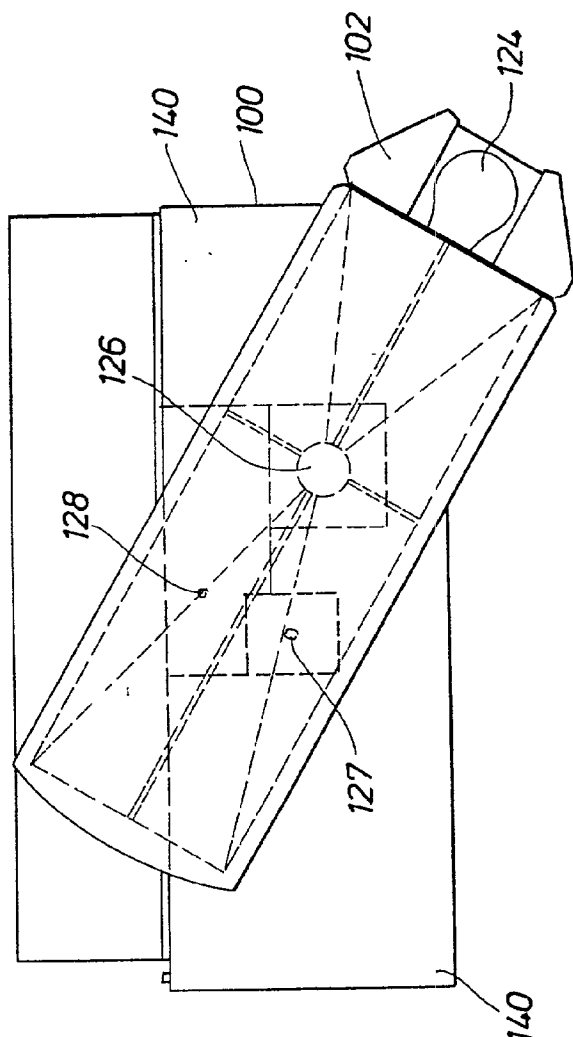


FIG. 3A

FIG. 4C

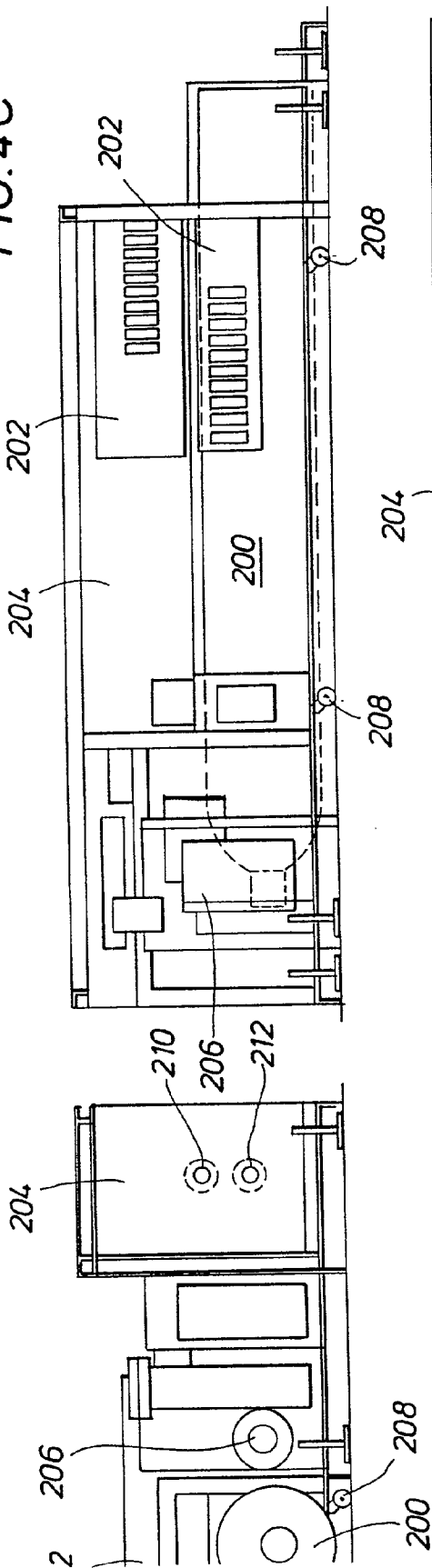


FIG. 4B

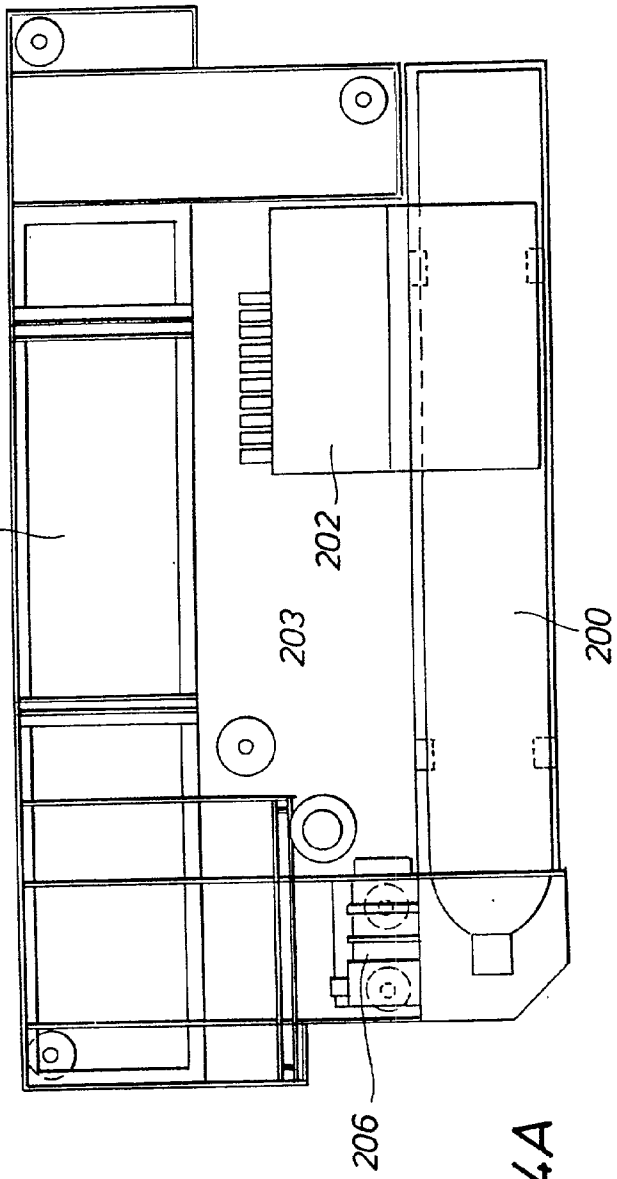


FIG. 4A

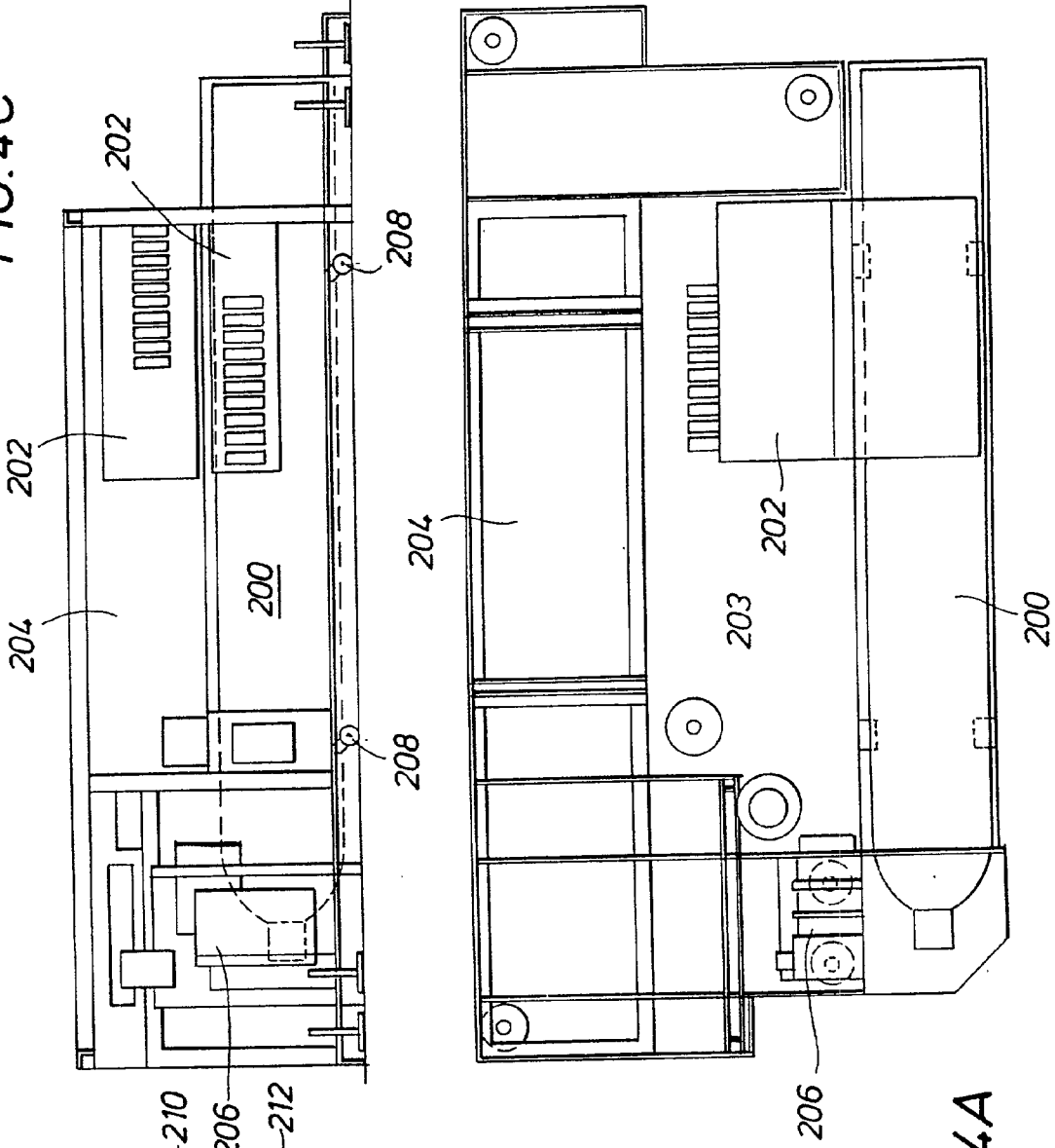
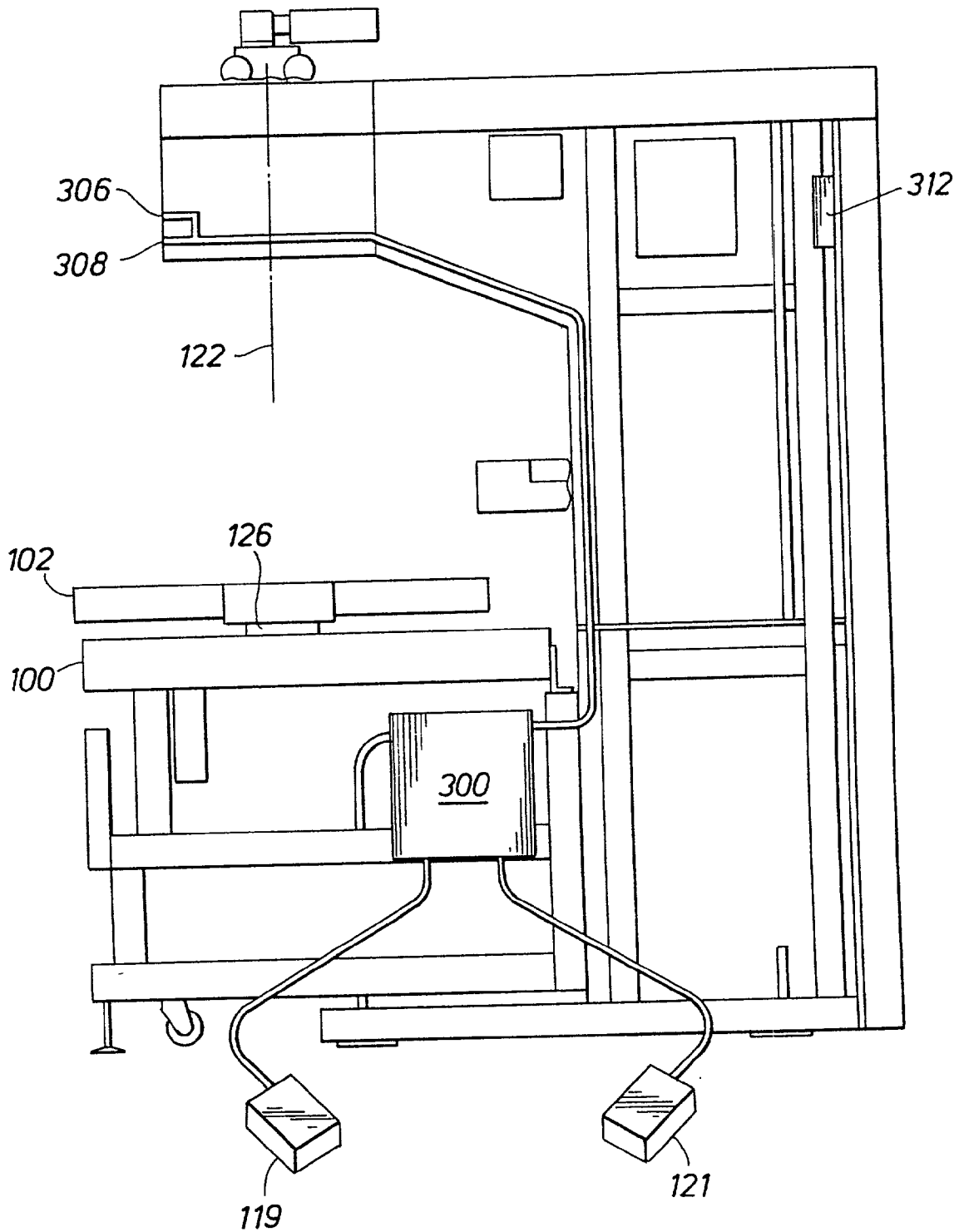


FIG. 5



EXCIMER LASER EYE SURGERY SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] 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.

[0003] 2. Description of the Related Art

[0004] 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.

[0005] 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 bum 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 U.S. patent application Ser. Nos. 08/338,495, filed Nov. 16, 1994, and 08/324,782, filed Oct. 18, 1994, which are hereby incorporated by reference.

[0006] 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. Pat. No 4,840,175, which is hereby incorporated by reference.

[0007] 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.

SUMMARY OF THE INVENTION

[0008] Therefore, according to 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 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.

[0009] 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.

[0010] Further according to 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).

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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:

[0012] FIG. 1 is a perspective view of the laser system according to the invention;

[0013] FIGS. 2A-C are top, side, and front views of the laser system according to the invention;

[0014] FIGS. 3A-D are top, front, back, and side views of the patient bed enclosure and rotatable patient bed according to the invention;

[0015] FIGS. 4A-C are top, front, and side views of the equipment enclosed by the patient bed enclosure of FIGS. 3A-D; and

[0016] FIG. 5 is a front view of the internal components of the system of FIG. 1, further illustrating the incorporated automated lamellar keratoplasty (ALK) system for performing LASIK.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0017] Turning to FIG. 1, shown is the laser system L according to 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.

[0018] 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.

[0019] 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 FIG. 5.

[0020] 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.

[0021] Turning to FIGS. 2A-C, shown are views of the system of FIG. 1. A top view in FIG. 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.

[0022] 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.

[0023] Turning to FIG. 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 FIG. 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 FIG. 3A discussed below.

[0024] Turning to FIG. 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. FIG. 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.

[0025] Turning to FIG. 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.

[0026] Three more views of the patient bed 102 and the patient bed enclosure 100 are shown in FIGS. 3B, 3C, and 3D. FIG. 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 FIGS. 4A-C.

[0027] 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.

[0028] FIG. 3C illustrates a left (from a patient's perspective) side view of the patient bed enclosure 100 and the patient bed 102.

[0029] FIG. 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 FIGS. 4A-C.

[0030] Given FIGS. 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.

[0031] Turning to FIGS. 4A-C, shown are block diagrams illustrating the arrangement of the components underneath the patient bed enclosure 100. Referring to FIG. 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 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 FIG. 4A. The laser head 204 preferably includes an integral 30K volt power supply. Further included are various cooling components 206.

[0032] Referring to the end view of FIG. 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.

[0033] Turning to FIG. 4C, a side view from the perspective as FIG. 3C is illustrated of the internal components. Again, it is seen how the electronics **202** wrap around the gas bottle **200**.

[0034] Turning to FIG. 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 Gholam Peyman in his previously incorporated U.S. patent.

[0035] 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 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 co-pending U.S. patent application Ser. No. _____ entitled "Distributed Laser Surgery System" and filed concurrently herewith.

[0036] The computer system can be further integrated with the automated lamellar keratoplasty system **300**. The auto-

mated 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**.

[0037] 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 **300** using feedback on the display **110** on a routine executing in the computer system of the electronics **202**.

[0038] 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.

[0039] 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.

[0040] 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.

1. 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 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.

2. The system of claim 1, wherein when the patient is in an operational position below said final beam directing portion, the eye of the patient is about one-half meter below said final beam directing portion.

3. The system of claim 1, wherein said bed is rotatable away from below said final beam directing portion by about 30°.

4. The system of claim 1, wherein said bed is rotatable about 90° into a second operational position in which non-laser surgery can be performed.

5. The system of claim 1, wherein the laser head is an excimer laser.

6. The system of claim 5, wherein the excimer laser is an argon fluoride laser providing a laser beam of approximately 193 nanometers.

7. The system of claim 1 further comprising a solenoid between the bed and a base for the bed, said solenoid locking the bed into position when the bed is in the operational position.

8. The system of claim 1, wherein the bed is rotatable on a single bearing connected to the base of the bed.

9. A laser system for performing laser in situ keratomileusis, the laser system comprising:

a laser head providing a laser beam for ablation of stromal tissue;

an aiming system providing an optical path from said laser head for the laser beam and for aiming the laser beam along the optical path to the eye;

a computer system coupled to said aiming system and said laser head, said computer system controlling the firing of said laser head and the aiming system and displaying data on a display, said computer system coupled to said automated lamellar keratoplasty system and displaying vacuum and power data from said automated lamellar keratoplasty system;

an integrated automated lamellar keratoplasty system comprising:

a vacuum source for vacuum port for providing a vacuum to a microkeratome source

a power source for providing power to a port for providing power to the microkeratome.

10. The system of claim 9 further comprising:

a patient bed disposed horizontally, and

wherein said aiming system further comprises:

a final beam directing portion extending horizontally over the patient bed, and

wherein said final beam directing portion includes said vacuum port and said power port for easy access to

a physician performing automated lamellar keratoplasty upon a patient on the patient bed.

11. The system of claim 9 further comprising:

a patient bed, said patient bed including:

a foot rest with two foot switches coupled to the automated lamellar keratoplasty system, said foot switches controlling said vacuum source and said power source.

12. The system of claim 9, wherein said computer system further controls said vacuum source and said power source of said automated lamellar keratoplasty system responsive to said foot switches.

13. The system of claim 9, wherein said computer system further provides input for a physician to set a vacuum level and a power level for said vacuum source and said power source in the automated lamellar keratoplasty system.

14. 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.

15. The system of claim 14 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.

16. The system of claim 14, wherein the patient surface rotates across the laser head and away from the optical extension.

17. The system of claim 14 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.

18. The system of claim 17, wherein power components are disposed between said cooling system components and said electronics.

19. The system of claim 14, wherein said patient bed is mounted on the rollers with stops, allowing said patient bed to be rolled away to provide access to said gas container and said electronics.

* * * * *