4. PRODUCT DESCRIPTION

4.1 INTRODUCTION

JK700 Series lasers essentially comprise three units:

- laser head
- power supply
- operator's control panel

The power supply provides electrical power to the laser head (principally, the flashlamps). The laser head generates light output in response to the power supply input.
The power supply enclosure also houses the cooling system which provides essential cooling for both the laser head and the power supply.
The power supply also houses the microprocessor which serves as the brain of the laser, controlling and monitoring all essential functions.

The control panel is the external means of communication with the microprocessor. It enables the operator's demands to be transmitted to the microprocessor which in turn, ensures that the demands are carried out, and the required output emerges from the laser head.

In addition to executing the operator's demands, the microprocessor has a significant role in monitoring the continued 'health' of the laser system and also, in detecting and if necessary, forbidding illicit operator demands. Moreover, if a system condition should develop then the microprocessor will raise a warning on the control panel. For more harmful conditions, the microprocessor will terminate operation pending rectification of the condition.

In addition to the basic units a fully-equipped JK700 laser would be provided with one or more of the following product options:

- LD resonator options
- fibre-optic beam delivery
- machining head with binocular viewer
- process lens options
- gas nozzle assembly
- safety enclosure
- pointing helium-neon laser
- hand shutter control
- remote control capability

As an alternative to the standard binocular viewer, the laser might be equipped with a trinocular viewer with the following additions:

- CCTV camera
- TV monitor
- electronic graticule

This Section provides information on both basic units and product options.

In addition a safety enclosure can be equipped with

- workhandling tables (linear and rotary)
- CNC (to drive the tables and control the laser)
- fume extraction equipment
- workpiece illumination

These options are available from LUMONICS. However they are not described in this manual.

The equipment described so far, relies on movement of the workpiece to process multiple points on the workpiece. This can present problems when high throughput rates are required and especially, when parts are complex and heavy.

As an alternative solution, multiple sites can often be processed more speedily by rapid deflection of the laser beam using a galvanometer deflection system, also available from LUMONICS with manual/CNC/PLC control options.

Galvanometer deflection is often restricted to multiple sites within a small area of a workpiece which has a simple configuration. However for more complex problems a MULTIFLEX fibre-optic beam delivery system could be the answer. Up to 4 workpiece sites can be processed simultaneously and up to 8 sites can be addressed in rapid succession. Further information can be obtained from LUMONICS offices on both galvanometer and MULTIFLEX beam delivery systems.

In this Section the following items are described:

- the laser head and internal assemblies
- the power supply and cooling unit
- the operator's control panel
- the product options

4.2 LASER HEAD

4.2.1 Introduction

A general view of the laser head is shown in Figure 2.5A, with labels identifying principal external features:

- the laser head lid
- two BET controls (BET = beam expanding telescope or upcollimator)
- the emission indicator
- the machining head with binocular viewer

Figure 4.2A shows a view of the front of the laser head, identifying:

- auxiliary power sockets
- the shutter interlock socket
- the socket for the Hand Shutter Control
- the socket for the control panel

Figure 4.2B shows an internal view of the laser head. Again principal features are labelled

The laser head contains

- the pumping chamber
- the resonator optics
- an energy monitor
- two beam-steering mirrors
- a process shutter with integral beam dump
- a variable magnification beam-expanding telescope (BET)
- a safety shutter

Note that

- the safety shutter is housed in the BET compartment
- the front mirror assembly, both steering mirrors, the energy monitor and the process shutter are all located in the shutter compartment.

Figure 4.2B shows the view with the shutter compartment lid removed. Normally it will be secured in position (6 screws).

The beam path through the laser head and machining head is shown schematically in Figure 4.2C. Note that in practice, the HeNe (helium neon) laser is fitted below the main beam path. Moreover the 'periscope' mirrors which introduced the HeNe beam into the main beam path, are in fact in the vertical plane.

The heart of the laser is the oscillator, comprising the pumping chamber and resonator optics. The oscillator generates a pulsed laser beam in response to current pulses from the power supply.

The energy monitor samples the pulse energy of the beam and provides a value for display on the control panel.

The beam-steering mirrors each turn the laser beam through 90°. The first mirror directs the beam through the process shutter; the second mirror directs the beam through the safety shutter and BET, to the output port on the front of the laser head.

JK700 Series lasers are designed and built to operate in harsh industrial environments. For consistent long-term performance the laser head components must be kept clean and maintained in a stable configuration.

To ensure stability the laser head comprises a rugged single-piece aluminium casting.

To ensure cleanliness of optical components, the laser head is sealed to IP55/NEMA12 standards. The laser head has a close-fitting reinforced plastic lid, secured by four screws and seated on a sealing gasket. In addition all major optical assemblies are mounted in closed compartments and the beam path is totally enclosed by beam-sealing tubes ('beam tubes').

Traditional laser head alignment procedures are eliminated in the JK700 head by the use of

- precision machined reference faces in the laser head for accurate location of all optical assemblies
- precision machined pre-aligned cells for all resonator optics

These unique features enable easy fast interchange between the standard welder resonator and LD resonators. Only one user adjustment is necessary following a resonator change - fine tuning of the rear mirror tilt adjustment to optimise laser output.

Interchange of resonators and their optimisation is described in Section 9 of this Manual.

In the remainder of this sub-section, the optical assemblies in the laser head are described in more detail.

4.2.2 Pumping Chamber

The pumping chamber is an assembly which houses the laser rod and two linear flashlamps, one each side of the rod. The prime purpose of the pumping chamber is to couple light efficiently from the flashlamps into the laser rod.

The pumping chamber comprises a stainless steel box ('block') with a lid which is O-ring sealed to prevent water leaks. Cooling water is pumped through the chamber to dissipate waste heat which is generated during excitation of the laser rod.

The flashlamps comprise thin walled linear quartz tubes, sealed each end with metal electrodes and filled with inert gas - usually krypton. Flexible insulated leads extend from each electrode ('ferrule') and terminate in a plug.

The laser rod is a circular cylinder of crystalline Nd-YAG with a finely ground cylindrical wall and optically polished end faces which are extremely flat and parallel; each face has an anti-reflection (AR) coating. The end faces are critical areas which should only be handled by trained personnel with extreme care.

In order to improve coupling of light from the lamps into the rod, the pumping chamber incorporates two profiled white ceramic plates - one attached to the lid, the other to the block - such that when the pumping chamber is assembled, the two plates mate to form a closed chamber ('close-coupled cavity').

To improve cooling efficiency, the laser rod is housed inside a borosilicate glass (Pyrex) flowtube which also protects the rod from harmful UV wavelengths in the lamp light. Cooling water enters the flowtube from the bottom of the pumping block via the flowtube manifold which supports both the flowtube and the laser rod. After passing over the rod at high velocity, the cooling water vents into the pumping chamber via a second flowtube manifold. It then flows through the chamber in the reverse direction, cooling the lamps before escaping from a second port in the base of the block. A fine-mesh wire gauze is fitted just inside the coolant exit port to trap glass fragments which can be generated when a flashlamp occasionaly breaks.

The laser rod is supported in the flowtube manifolds by O-ring seals which are maintained under compression by two 'rod pusher tubes' which extend from the outer faces of the pumping chamber where they are secured, again with O-ring seals. The pusher tubes therefore provide a water-free passage by which light can pass freely through the laser rod. This method of mounting conveniently exposes the laser rod end faces for inspection and cleaning when the rod pusher tubes are removed.

WARNING

Removal of the rod pusher tubes requires removal of the pumping chamber from the laser head. THESE PROCEDURES SHOULD ONLY BE CARRIED OUT BY AUTHORISED TRAINED PERSONNEL.

Beneath the pumping chamber is a subplate where services from the power supply cabinet - lamp leads and water pipes - terminate. Two cooling water pipes terminate on a manifold block beneath the subplate. Water passes through the manifold via the subplate into the entry port of the pumping chamber block. O-rings seal each interface.

Four lamp power leads terminate below the subplate on insulated lead-throughs which extend up into the pumping chamber via the subplate. An O-ring seal around each lead-through prevents coolant escape at the block-subplate interface. Each lead-through terminates in a socket which mates with the plugs on the flashlamp leads. PTFE (Teflon) pillars in the block and in the lid, locate and maintain the flashlamps assemblies in the correct axial and transverse positions.

The pumping chamber block is secured to the subplate by six recessed M4 screws. The combined block-subplate assembly is secured in the laser head by three recessed M4 screws located in insulated bushes which extend through the block and the subplate. The block is maintained at the correct height in the laser head by mounting it on three reinforced plastic spacers which sit on machined pads in the laser head, locate on the insulated bushes and bear directly on the bottom of the block. The spacers are held captive by O-rings which are trapped between the block and the subplate.

Access to the three fixing screws is gained by removing insulating plugs which have threaded inserts to facilitate removal. The plugs have O-ring seals to prevent the ingress of cooling water.

To ensure correct lateral location of the pumping chamber, two machined reference faces are provided on the vertical wall of the laser head casting, adjacent to the pumping chamber. Precision reinforced plastic spacers are trapped against these reference faces by a sheet of polycarbonate insulation which is mounted between the vertical wall and the pumping chamber. To ensure correct lateral postioning, the pumping chamber should be pressed hard against the exposed faces of the spacers, prior to tightening the three screws which secure the chamber in the laser head.

The pumping chamber lid is secured to the block by eight M4 screws. On top of the lid is a water connector with a small bore pipe which provides a supply of coolant to the process shutter beam dump and the water cooled block for LD optics (See Section 4.2.6 and 4.2.3-B respectively).

Mounted in the laser head beneath the pumping chamber is the flashlamp trigger transformer. Lamp 'simmering' (Section 4.3.2) is initiated by pulsing the trigger transformer. This causes a spark to jump from an electrode on top of the transformer to a machined pad on the bottom of the subplate, thus raising the entire pumping chamber momentarily to about 25kV potential. Accordingly, for electrical safety an interlocked insulated cover is fitted over the chamber.

> **WARNING**
> The pumping chamber is liable to float up to a high voltage at times other than lamp triggering. NEVER OPERATE THE LASER WITH THE PROTECTIVE COVER REMOVED AND THE INTERLOCKS OVERRIDDEN.

To exclude dust and thus keep the laser rod faces clean, the beam path between the pumping chamber and the nearby casting walls is enclosed using short PTFE (Teflon) beam tubes. These tubes are inserted into the rod pusher tubes prior to installing the pumping chamber in the laser head. Subsequently the tubes are withdrawn so as to engage in aluminium inserts in the casting walls. In addition to protecting the laser rod, the beam tubes are necessary to satisfy safety requirements for a gap-free protective housing which prevents human access to laser radiation (Section 8.8).

> **WARNING**
> THE LASER MUST NOT BE OPERATED IF BEAM TUBES ARE ABSENT, DAMAGED OR NOT PROPERLY IN POSITION.

4.2.3 Resonator Optics

A. Standard Resonator

The physical layout of components in the laser head is shown in Figure 4.2B. The equivalent schematic showing the beam path through the component units, appears in Figure 4.2C.

The conventional standard resonator consists of two mirrors positioned on each side of the laser rod. (Figures 4.2D, 4.2E) The rear mirror M1, is a total reflector, housed in an optical assembly provided with two tilt controls (knobs), top and side. The front mirror M2 is a partially reflecting mirror through which the output beam emerges. The front mirror is housed in a precision machined silver-coloured cell.

Both the front and rear mirror cells are firmly secured against precision machined reference faces on the laser head by spring clips. By virtue of the precision machining of the reference faces and the mirror cells, the mirrors are essentially pre-aligned. After the cells have been clipped in position and the lamps are energised, laser output is usually achieved immediately. Optimisation of laser output then requires only mirror adjustments of the rear mirror tilt controls.

The standard resonator gives the highest output power and is invariably used for welding - an application where high mean power is generally more important than small weld size. This resonator is therefore also referred to as the 'welder' or 'welder resonator'.

B. LD Resonator Options

Applications such as cutting and hole drilling require the workpiece material to be heated to a higher temperature than for welding. Such applications benefit from a higher beam intensity at the workpiece. Intensity is a term which indicates the amount of pulse energy per millisecond which is delivered onto each square millimetre (inch) of workpiece within the beam focus. Thus one of the principal methods of increasing intensity is to reduce the diameter of the beam focus ('spot-size'). One method of reducing spot size is to use a short focal length process lens. However a second, more potent method is to reconfigure the laser resonator to achieve lower beam divergence.

Two alternative low divergence configurations - the LD1 and LD2 resonators - are available for both JK701 and JK702 lasers. Lasers provided with the LD option kits are designated by a suffix LD in the model number (e.g. JK701LD).

The three resonator configurations - welder, LD1 and LD2 - are shown schematically in Figures 4.2D and 4.2E respectively for the JK701 and JK702. Equivalent physical layouts are shown in Figures 4.2F and 4.2G respectively.

The LD kit contains components for both LD1 and LD2 resonators as follows

- one lens assembly for each resonator
- a number of metal beam tubes
- a number of PTFE (Teflon) adaptors
- extra spring clips and fixing screws
- an extra output mirror assembly (black)

The resonator component assemblies are colour-coded for easy identification.

A study of the diagrams will show that:

- the LD resonators use a **black** output mirror assembly whereas the standard mirror cell is **silver**
- the standard rear mirror assembly M1 is also used for the LD resonators
- to accommodate changes of position, the fixing clip for M1 must be repositioned for each resonator
- an extra clip is required for the lens assembly of an LD resonator, positioned according to the particular LD configuration.

Components in the rear part of the resonator fit closely together, with PTFE adaptors between them, to form a totally enclosed beam path.

The complete assembly and alignment procedure is described in Section 9. To access the front mirror assembly, the shutter compartment lid must be removed.

NOTE Lens units in LD resonators require cooling. A water-cooled block is provided for this purpose. When a lens unit is in use, the block is fixed on the lens unit. When no lens unit is present the block is 'parked' on a parking bracket.

NOTE LD units are supplied in a storage case and each component assembly is fitted with dust caps to ensure cleanliness of the internal optics.

It is ESSENTIAL always

- to fit the dust caps when units are not in use
- to ensure dust caps are kept clean
- to return units to the storage case when not in use
- to ensure that internal optics in each unit are clean before a unit is put into service

> **WARNING**
> FAILURE TO KEEP RESONATOR OPTICS CLEAN WILL REDUCE COMPONENT LIFE. THE WARRANTY DOES NOT COVER DAMAGE CAUSED BY NEGLIGENCE

Reference to Section 3.4 (Output Specifications) will show that output power for standard resonators is quoted as extending from zero up to a limit value for each laser whereas, for the LD resonators, a single output value is quoted.

The reason for this is that LD resonators are 'tuned resonators' (See Appendix 2A of Section 2) with a fixed input power requirement. The output reaches the specified output value at a specific mean input value (See Figures 4.2D, 4.2E). At greater and lesser mean input powers, the power output diminishes very quickly to a low level. Thus LD resonators must be operated at constant mean input power. LD resonators are not therefore suited to low power operation and intermittent lamp excitation. If necessary intermittent output can be achieved by use of the process shutter.

4.2.4 Beam Steering Mirrors

In order to fit all the components into the compact laser head, the beam path (Figures 4.2B, 4.2C) is folded using two beam-steering mirrors, M3 and M4. M3 is adjacent to the front resonator mirror; M4 is adjacent to the BET.

M3 is a partially reflecting mirror which reflects most of the beam towards M4. The transmitted portion of the output beam is used to measure the energy in the beam. Correspondingly, M4 is a total reflector which directs the beam via the BET and safety shutter.

Both mirrors are mounted in stable pre-aligned mounts which allow easy replacement when required, without the need for further alignment. Each mount is factory set so as to direct the laser beam along the optical axis through the BET, out of the exit port on the laser front plate.

Each mirror has an integral metal backing plate and is held in position against a machined reference face on its mount, by two spring clips. M4 has a solid backing plate; M3 has an aperture in the backing plate to allow passage of the transmitted beam. Each mirror is retained laterally by two protruding pins and vertically, by a plate secured to the top of the mount (2 screws).

4.2.5 Energy Monitor

The energy monitor unit is mounted adjacent to the first steering mirror unit M3 (Figures 4.2B, 4.2C). The measurement is performed by a silicon photodiode which monitors the beam transmitted by M3. Because the photodiode requires relatively little light, the transmitted beam is attenuated by upward reflection off a low reflectivity glass plate. The beam is further attenuated by passage through a ceramic diffuser disc and two filters before it reaches the photodiode.

The photodiode is mounted in a small oven to maintain its temperature (and thus, its calibration) constant. The diode photocurrent is amplified in a circuit located behind the rear plate of the laser head, to give a signal which is proportional to the pulse peak power. This signal is sampled by the microprocessor for every pulse up to 20Hz repetition rate, and at 50mS intervals, for higher pulse rates.

The sensitivity of the monitor circuit is factory calibrated so that the value displayed on the control panel is the pulse energy of the output beam. The microprocessor computes the mean output power, using its knowledge of the pulse-rate. The displayed values are the average of the last two sampled pulses.

The ENERGY key on the control panel is used to display the current values of pulse energy and mean power. Refer to Sections 5.2.7, 5.4 and 5.5.2.

4.2.6 Process Shutter

The process shutter unit is located between steering mirrors M3 and M4. (Figure 4.2B) The purpose of the process shutter is to intercept the laser beam when output is not required and the flashlamps are energised.

In this state, the shutter is 'closed'; correspondingly when output is required, the shutter is 'open'.

The shutter unit comprises a mirror mounted on a fast rotary solenoid, a water cooled 'beam dump' and a number of safety components. The mirror - a total reflector - is mounted on a metal bracket on the solenoid shaft. When power is applied to the solenoid coil, the mirror is rotated out of the beam - the 'open' position. Conversely when the solenoid is de-energised, the mirror is rotated by the solenoid return spring into the path of the laser beam. In this 'closed' position, the beam is reflected down into the beam dump.

The beam dump comprises a water-filled metal cell, with an AR-coated glass entrance window. The laser beam passes through the window into the cell where the energy is absorbed by the metal walls. The absorption process is assisted by a metal pin located in the rear of the dump. The cell is cooled by flowing coolant derived from the water connector on the pumping chamber lid.

To protect against shutter malfunction, the shutter unit contains a number of safety features. Two position sensors are located above the open and closed positions of the shutter mirror. An associated failure detection circuit compares the last shutter demand with the indications provided by the sensors. This eliminates the possibility of the laser operating with the shutter stalled in mid-travel.

Moreover, a thermal fuse is mounted directly above the shutter mirror to ensure early detection, if the shutter mirror should fail. Consequent heating of the mirror mount will open-circuit the fuse. Both the thermal fuse and the position failure detection circuit are linked into the main laser interlock circuit through the failure-detection circuit in the rear compartment of the head. Thus, the laser would be immediately de-energised if a problem were to occur in the process shutter.

Access to the shutter is gained by removing the shutter compartment lid.

Shutter Controls

The shutter controls - OPEN, CLOSE and MULTI SHOT (i.e. single pulse) - are located on the control panel. For more information, refer to Section 5.2.6 (location and operation) and Section 5.4.1 (Multipulse Count).

As an alternative to the control panel, the process shutter can be controlled using an optional Hand Shutter Control (Section 4.5.6) or it can be put under remote control (Section 5.4 and 7).

A CLOSE command originating from either the control panel or the Hand Shutter Control will close the Shutter, provided it has been put under local control via the Remote Control Number.

However OPEN and MULTI SHOT commands can only be received from the selected control mode/station -

- remote control, if the shutter has been put under remote control (Section 5.4).
- Hand Shutter Control if connected; under these circumstances the Hand Control overrides the control panel.

NOTE: Before moving the shutter mirror in response to a command, the microprocessor ensures that a laser pulse will not coincide with movement of the shutter mirror. If necessary the time interval between laser pulses will be extended to 25mS, the time required for a shutter operation.

SAFETY WARNING

A MULTI SHOT command will only result in the issue of 1 pulse if the Multipulse Count has been set to 1. Otherwise a number of pulses will be issued equal to the value set for the Multipulse Count.

4.2.7 Beam Expanding Telescope (BET, Upcollimator)

The beam expanding telescope is housed in a closed compartment - a box with a lid - located adjacent to the second steering mirror M4 on the output beam path.

As the name implies, the purpose of the BET is to increase the diameter of the beam, because this has the effect of reducing beam divergence and therefore, spot-size at the workpiece.

NOTE: Beam diameter x beam divergence = a constant (at fixed output power).

A second function of the BET is to compensate for differences in the focal length of the process lens for visible light and light at the laser wavelength. A minor correction to the setting of the BET will ensure that the laser beam focus can be made coincident with the visual focus seen through the viewing optics.

The BET is shown schematically in Figure 4.2H, with the BET lid removed. The BET incorporates three lenses. The laser beam passes in turn, through:

- a negative input lens which diverges the beam
- a positive lens (the Ratio lens) which converges the beam
- another negative lens (the Focus lens) which can be used to recollimate (make parallel) the output beam.

The input lens is fixed in the input wall of the BET compartment. Correspondingly the Ratio and the Focus lenses are secured in mounts which can slide along parallel bars. Lead screws with nuts connected to the sliding mounts, provide the means to move the Ratio and Focus lenses. Moreover these lens motions can be controlled using knobs on top of the laser head (Figure 2.5A). These controls are connected to the respective BET lead screws by a combination of linkages and gearwheels.

The control knobs are appropriately labelled RATIO and FOCUS.

Information detailing how to set the FOCUS and RATIO controls is given in Section 6.7. The primary adjustment is the RATIO control. The FOCUS control is set to recollimate the beam following change of FOCUS setting. Thus the settings of each control are related.

Control settings also have to be set according to the laser mean output power. Section 6.7 includes comprehensive graphs (Figures 6.7A, 6.7B) showing how to set the controls according to output power and desired beam size.

NOTE: There is a possibility of focussing the laser beam onto the optical components in the viewing optics, with consequent risk of component damage if the BET lenses are not set properly and especially, if the BET controls are adjusted in turn, with the process shutter open and laser operating.

WARNING

NEVER CHANGE THE BET CONTROL SETTINGS WITH THE SHUTTER OPEN AND NEVER LOOK INTO THE EYEPIECES OF THE VIEWING OPTICS UNDER THESE CIRCUMSTANCES.
ALWAYS CLOSE THE (PROCESS) SHUTTER BEFORE ADJUSTING BET CONTROLS.
ALWAYS SET THE BET CONTROLS AS INDICATED IN FIGURES 6.7A, 6.7B.

Also housed in the BET compartment is the safety shutter.

Beam Sealing

On JK700 Series lasers the protective housing comprises the various beam tubes between optical units and the housings of the units.

To complete the protective housing, a final beam tube is fitted between the BET housing and the inside face of the laser head front plate. The beam tube is sealed by O-rings onto spigots on the BET and the front plate. The procedure for removing the beam tube is described in Section 8.6.11 (Alignment HeNe Periscope Assembly).

To prevent the ingress of contamination into the laser head via the final beam tube, an anti-reflection-coated window (the BET Sealing Window) is mounted on the inside face of the exit plate of the BET housing. To remove the window for maintenance, refer to Section 8.6.2H (BET Sealing Window).

4.2.8 Safety Shutter

The safety shutter assembly is mounted on the underside of the BET compartment lid. It satisfies the requirements of the safety authorities for a 'beam attenuator' - a means of physically blocking laser output.

The shutter comprises a robust metal blade, rigidly mounted on the shaft of a 45° rotary solenoid. When power is applied to the solenoid coil, the blade is rotated out of the laser beam path (shutter 'open'). However when the solenoid is de-energised the blade is rotated fully into the beam path by the solenoid return spring, thus stopping the laser beam (shutter 'closed').

Normally, when the safety shutter is closed, the laser beam does not reach the safety shutter because control circuitry ensures closure of the process shutter whenever the safety shutter is closed. However if, as a result of malfunction of the process shutter, the laser beam did reach the safety shutter then, the beam would be reflected off the shutter blade onto a ceramic beam stop and a thermal fuse, thus causing the thermal fuse to fail. Since the thermal fuse is linked into the main laser interlock chain, this would terminate laser operation. Closure of the safety shutter is confirmed by a position sensor.

Closure of the safety shutter is initiated by open-circuiting the Shutter Interlock terminals, located on

socket SK A301 (terminals A, B) at the bottom front of the laser head (Figure 4.2A); OR
terminal block TB 801 (terminals 9, 10) in the Termination Chamber in the power supply enclosure (Figure 4.3E)

The Shutter Interlock facility will normally be used for safety situations where personnel must not be exposed to laser radiation yet it would be inconvenient to terminate laser operation.

Typically the Shutter Interlock will be used

with an interlock switch on the work area access door, when the laser is used without a Class 1(I) safety enclosure
to interlock the access doors on a Class 1(I) safety enclosure.

4.2.9 Laser Head Electronics

Located behind the main panel on the back of the laser head are the following electronic circuits:

- flashlamp (low voltage) trigger circuitry
- process shutter drive circuitry
- process shutter failure detection circuitry
- safety shutter drive and position detection circuitry
- energy monitor pre-amplifier
- interlock circuitry

Flashlamp power leads from the power supply via the conduit (umbilical) also terminate at this location.

In fact this compartment contains no user controls and access is not required for routine maintenance.

For electrical safety the rear panel is interlocked by two series connected microswitches; removal of the panel disables the power supply.

In addition to these facilities, located beneath pumping chamber assembly is a trigger transformer which generates high voltage spikes ($\gg$20kV) necessary to trigger the flashlamps (See Section 4.3).

4.3 POWER SUPPLY

4.3.1 Introduction

Largest of the three units which comprise the laser, is the power supply enclosure, a rugged environmentally sealed unit (Figure 4.3A) mounted on heavy duty castors.

The power supply enclosure houses

- the laser power supply
- the cooling system
- the microprocessor system

The power supply provides the services required for operation of the laser. High power electronic circuits control electrical energy to the flashlamps.

The cooling system disposes of waste heat from the laser head and the power supply enclosure. The cooling system comprises two units:

- the Air Cooler Module which cools the power supply enclosure.
- The Water Cooler Module which cools components in the laser head

Manual and remote operation of the complete system is accomplished by the microprocessor system which controls and monitors the power electronics, cooling system and laser head functions.

EXTERNAL FEATURES

Notable features on the exterior of the power supply enclosure (Figure 4.3A) are

- two access doors - 1 and 2
- the mains power Disconnect switch
- the access panel for the Termination Chamber
- the data plate

Access Doors

Access into the power supply enclosure proper for maintenance and service is gained via the two access doors. They are mechanically interlocked with the power Disconnect switch and cannot normally be opened when the switch is ON. Conversely when the doors are open, the Disconnect switch cannot normally be turned ON. However a special interlock override facility is provided for service use only, which enables power to be switched on with the access doors open.

Each door has a lock located in the door handle under a slide-up cover. To unlock a door, the key is turned approximately 30 degrees in either direction; this unlocks the handle which automatically springs up ready for use. The handle is then turned 130 degrees clockwise to open the door. The left hand door (Door 2) cannot be opened unless Door 1 is open.

For added security the doors can also be padlocked. A pocket inside Door 2 contains the system circuit and wiring diagrams.

Disconnect Switch

The Disconnect switch is ON (I) when the handle is in the upper position; then the handle appears red. Correspondingly, in the OFF (O) position, the handle appears black. The Disconnect switch can be padlocked in the OFF position - an essential safety precaution when working on potentially live ('hot') components.

System Data Plate

The system data plate is fixed to the bottom corner of the Termination Chamber access panel. A typical data plate is shown in Figure 4.3B. A duplicate data plate is fitted inside Door 1.

NOTE Some of the data, particularly the Serial No., will be required when ordering spare parts or requesting service assistance.

INTERNAL FEATURES

Modules

The power supply is completely modular in construction. Figure 4.3C shows a block diagram of the power supply showing the principal modules and interconnections. Figure 4.3D shows a view inside the front of the power supply cabinet indicating module locations.

The incoming 3-phase electrical supply (Figure 4.3C) passes via the Disconnect switch to the Power Distribution Module which contains the system fuses and auxiliary power supplies. Power for the two flashlamps passes through identical but independent sets of power modules, each set comprising

- a transformer module
- a switching module
- an output module

The cooling system modules are located in the bottom of the power supply enclosure - the Air Cooler Module in Bay 2, the Water Cooler Module in Bay 1. The cooler modules are isolated from the electronics modules by a baffle. Cooling air from the ACM is carried by ducts behind the electronic modules. After passing through the modules, the circulating air returns to the ACM via the baffle.

Termination Chamber

Removal of the right side panel of the power supply enclosure (6 screws) gives access to the Termination Chamber, where incoming services (power, water) arrive and outgoing connections to the laser head, control panel and ancillary equipment depart. Access to the Termination Chamber is normally required only for installation. For further information on installation and commissioning, contact your nearest LUMONICS office or agent (Section 8.13), or refer to the appropriate Installation Manual.

Figure 4.3E shows a view inside the power supply Termination Chamber. Physical features include:

- the Disconnect switch
- the Interface Termination Panel
- the Lamp Cable Termination Panel
- the Conduit Gland Plate
- the Coolant Connections Compartment

All external connections terminate in the Termination Chamber. Electrical connections have to pass through the Conduit Gland Plate; this is one of the sealed panels of the power supply enclosure.

The incoming mains power lead passes through the Conduit Gland Plate and terminates on the Disconnect switch.

The laser head is connected to the power supply by a flexible conduit, containing the power and control leads, and a hose assembly - one supply, two return hoses - which carry primary cooling water. The hoses terminate via a sealed bulkhead in the Coolant Connection Compartment in the bottom of the Termination Chamber. The external cooling water supply is also connected to the Air Cooler Module and Water Cooler Module, in the Coolant Connection Compartment.

Cables from the laser head conduit terminate in the sealed area on

- the Lamp Cable Termination Panel
- the Interface Termination Panel
- earth terminals

The operator's control panel is fitted with a 2.5m (8ft) long flexible conduit and plug.

It can be connected either

a) to a socket (SK A302) on the bottom front of the laser head (Figure 4.2A); or
b) to a socket on the Interface Termination Panel (SK 806)

In case (a), the control panel is connected to SK 806 via a lead which runs through the laser head conduit.

In case (b), the control panel plug is connected into a socket on the Conduit Gland Plate and a lead attached to the socket, is plugged into SK806.

In addition to the control panel, other external connections for interlocking and optional Remote Control terminate on the Interface Termination Panel. This is the interface with the microprocessor control module which in turn, controls all the modules in the power supply cabinet except the Air Cooler Module.

Any unused holes in the Conduit Gland Plate must be fitted with plastic caps (supplied), to complete the sealing of the power supply.

4.3.2 Power Electronics

The power electronics comprises the Power Distribution Module and two identical sets of power modules, each supplying power to one flashlamp.

Each set comprises

- a Transformer Module
- a Switching Module
- an Output Module

The Power Distribution Module provides for various internal auxiliary power supplies, and mains power for accessory sockets on the front of the laser head (Figure 4.2A) and also in the Termination Chamber. It also houses control gear for the circulating pump in the Water Cooler Module.

There are separate versions of the Power Distribution Module for 50Hz and 60Hz supply frequencies. The 60Hz version has an additional transformer and extra fuses to accommodate the extended range of supply voltages found in 60Hz territories. Otherwise the two versions are similar.

Figure 4.3F is a block diagram showing one set of power modules. The Transformer Module comprises a 3-phase power transformer and rectifier producing a nominal 420 volt d.c. supply (the 'd.c. link'). Resistors between the transformer and the rectifier limit the inrush current into the reservoir capacitors when the power contactor is closed.

At the end of the start-up sequence these resistors are shorted out by the bypass contactor.

A high voltage power transistor connects the reservoir capacitors to the flashlamp. The transistor is repeatedly switched on and off many times at high frequency during each laser pulse by its control circuit so as to maintain the average flashlamp current at the desired value. The mean current is continuously variable up to 300 amps. An output filter circuit between the transistor and the flashlamp minimises variations in current caused by the switching action.

Normally flashlamps have high impedance and a 420V supply will be inadequate to switch the lamps to a low impedance state. This is achieved by applying a high voltage 'trigger pulse' to 'trigger' the lamps; this breaks down the gas in the flashlamp, causing a spark to jump between the lamp electrodes. The trigger pulse thus lowers the lamp impedance to a point where the d.c. link voltage is adequate to pass significant current. To eliminate the need to trigger the lamps before every pulse, they are maintained in a permanent low impedance state after initial triggering, by passing low level ('simmer') current continuously through each lamp. The simmer current is supplied by a separate simmer supply in the Output Module.

4.3.3 Control Electronics

The control electronics comprise the Microprocessor Control Module and Interface Termination Panel (Figure 4.3H). The Microprocessor Control Module receives commands from the operator's control panel and optionally, a remote CNC system or computer, and controls the power electronics modules, Water Cooler Module and laser head. Safety critical circuits are functionally independent of the microprocessor but are monitored along with all other major system functions, enabling abnormalities and faults to be detected and diagnosed.

A block diagram of the control electronics is shown in Figure 4.3G. The Microprocessor Control Module comprises a motherboard, through which all external connections are made and which interconnects a number of printed circuit boards via the microprocessor I/O bus.

Microprocessor Board

The microprocessor board contains

- the microprocessor chip
- an EPROM chip storing the control programme
- a RAM chip storing operating parameters and other variables

When the system is switched off, the contents of the RAM are preserved by a special battery system that has a 10 year life. Also on this board is a Watchdog circuit which monitors operation of the microprocessor system and disables the laser system in the event of a fault.

Laser Interface Board

The laser interface board principally comprises monitoring, control, pulse generation and laser protection functions. Under microprocessor control the pulse generation circuit allows control of the flashlamp current (Height), duration (Width) and frequency (Rate). The pulse Height can even be changed during a pulse, giving the JK700 its unique pulse shaping capability. The laser protection circuit monitors critical voltage, current and power levels in the power electronics and flashlamp circuits, to provide a very high degree of protection against misuse, faults and flashlamp failures.

Remote Control Interface Board

The optional Remote Control Interface board is required to control the laser from a CNC system or external control device.

Interface Termination Panel

All signal and interface connections external to the power supply are made via the Interface Termination Panel located in the Termination Chamber (Figure 4.3E). The Interface Termination Panel is shown in Figure 4.3H.

Principal features include

- a group of five BNC type sockets
- a group of seven D-type sockets
- a group of single phase mains supply sockets SK 807
- a QM connector SK 808
- a screw terminal block TB 801

Further details are as follows:

BNC-type sockets

SK 8201	Shape I/P (Not normally used)
SK 8202	Sync O/P (Output)
SK 8203	Trig I/P
SK 8204	Laser O/P
SK 8205	Current O/P

These sockets provide for the connection of instruments - for example, an oscilloscope, or a frequency counter - to monitor and test the system.

Use of an oscilloscope to monitor the laser pulse, is described in Appendix 5A.

D-type sockets

PL 800	Remote Meter
SK 801	Shutter Control
SK 802	Laser Head
SK 803	RS232 Interface
PL 804	CNC Parameter
PL 805	CNC Function
SK 806	Control Panel

These connectors are used for signals to the operators control panel and laser head, remote control interfaces, remote shutter control and energy monitor meter (PL 800).

SK 807

These accessory supply sockets are for powering equipment such as a workpiece illuminator used in conjunction with the laser system. On standard 50Hz supply systems, the accessory supply is 240 volts a.c. and there are 3 standard European CEE 17 sockets. On standard 60Hz supply systems, the accessory supply is 120 volts a.c. and there are 2 standard North American NEMA 5-12 grounding sockets. The accessory supply sockets are duplicated on the laser head. In all cases the total accessory supply rating is 240VA.

SK 808

This QM Connector supplies switched mains power to the laser head for the Optional HeNe laser. The supply is switched via the OPTICS and SET keys on the control panel (Section 5.2.7)

This connector also supplies power to the accessory power sockets on the front of the laser head.

TB 801

Terminals

1 - 2	Interlock 1)	Remote Interlock Connectors;
3 - 4	Interlock 2)	Laser disabled when open circuit
5 - 6	Gate -	switching modules disabled when open circuit
7 - 8	Not allocated	
9 - 10	Shutter Interlock	
11 - 12	Interlock Relay	
13 - 14	) Additional	
15 - 16	) Emission Indicator	
17 - 18	) outputs	

For further details on interfacing to the JK701 and JK702, contact your LUMONICS office or agent.

4.3.4 Cooling System

The cooling system comprises the Air Cooler Module, which controls the cooling air within the power supply enclosure, and the Water Cooler Module, which controls the cooling water to the Laser Head. Both transfer waste heat to the external cooling water supply. A schematic diagram of the cooling system is shown in Figure 4.31.

Air Cooler Module

The Air Cooler Module comprises a powerful tangential fan, a thermostatic water valve and an air-to-water heat exchanger. The fan operates continuously, circulating cooling air to the power modules via ducts. The air returns to the fan via the heat exchanger which transfers the waste heat to the cooling water. The water flow rate is automatically regulated by the thermostatic valve, to maintain the return air at constant temperature.

Water Cooler Module

The Water Cooler Module primarily cools the flashlamps and laser rod in the pumping chamber. It also cools the process shutter beam dump and water block for LD resonator lens units.

The Water Cooler Module mainly comprises:

- a circulating pump
- a rechargeable de-ioniser unit
- a filter unit with replaceable filter
- a water-to-water heat exchanger
- a thermostatic water valve
- a reservoir tank

The pump circulates deionised water from the reservoir tank to the laser head via the connecting hose. The majority of the flow returns to the reservoir tank via an electronic flow sensor and the heat exchanger. A small proportion returns via a separate loop which is derived from the top of the pumping chamber. This arrangement also automatically ensures that air is cleared from the pumping chamber after, for example, changing flashlamps.

The heat exchanger transfers waste heat to the external cooling water supply. The flow of external cooling water is automatically controlled by the thermostatic valve. In addition to the flow sensor, the laser coolant circuit also incorporates an electronic temperature sensor, an overtemperature switch and a coolant level float switch.

Refer to Section 8.3 for further details and for maintenance procedures. Note that the reservoir tank is provided with a sight tube (Figure 8.3A) to enable a quick check of the coolant level. The Water Cooler Module is accessed by the right hand door of the power supply enclosure.

4.4 CONTROL PANEL

The operator's control panel is shown in Figure 4.4A. It comprises a sealed membrane panel with 23 integral keyswitches, grouped according to function, an 80 character alphanumeric liquid crystal display with backlight, light emitting diode (LED) indicator lamps, a 5 position key control and an EMERGENCY OFF push button.

The key control has 2 OFF positions and 3 ON positions corresponding to the 3 colour coded keys supplied. Refer to Section 5 for more details.

The control panel is supplied in a moulded enclosure for mounting on a desk or bench. By reversing the rear cover, the panel can be mounted on a vertical surface such as a machine enclosure. Alternatively, the panel may be removed from the moulded enclosure and built into a machine control station, pendant or pedestal.

The control panel is connected to either the power supply or laser head by a flexible conduit, which is fitted with detachable connectors at both ends and is available in various lengths up to 30 metres (100 ft).

4.5 ADDITIONAL OPTIONS

4.5.1 Pointing helium-neon (HeNe) laser

A pointing HeNe is available, comprising:

- a 2mW helium-neon laser, mounted in an alignment assembly
- HeNe power supply with integral fixing plate
- beam-insertion periscope assembly

The HeNe assembly is secured on pads in the bottom of the laser head, directly below the long beam tube which extends from the BET compartment to the laser head front plate (Figure 4.5A).

The HeNe power supply fits in a recessed cavity in the casting wall adjacent to the gas laser, and is secured in place by its fixing plate. Mains power for the gas laser is available nearby on a socket on a flying lead. The HeNe can be switched on/off using the OPTICS and SET keys on the control panel.

The HeNe beam passes under the BET compartment in the opposite direction to the Nd-YAG beam; it is directed up into the main laser beam path by the periscope, an optical assembly located between the BET compartment and the shutter compartment.

The HeNe beam is adjusted to be concentric with the pulsed laser beam, using four adjusting screws on the HeNe alignment assembly (Figure 4.5B). At each end of the laser tube there are two adjusting screws which enable horizontal and vertical movement of the laser head.

Because the HeNe beam is injected into the Nd-YAG beam path downstream from the process shutter, the HeNe beam is available at the output when the process shutter is closed. However the periscope is upstream of the safety shutter so that when the Shutter Interlock is open-circuit (e.g. safety enclosure doors open) then, the HeNe beam will be blocked.

Note that the HeNe beam is available whenever the control panel is powered up and the keyswitch enabled.

4.5.2 Machining Head

The machining head assembly is mounted on the front of the laser head via an interface block - the 'machining head boss'.

A standard machining head comprises

- the machining head
- a binocular viewer
- a process lens assembly

A schematic of a standard viewer is shown in Figure 2.5B.

In the upper part of the machining head block is located a gimbal mount which carries a 45° beam steering mirror (the 'machining mirror'). In the lower part of the block, there is the 'lens tube' which houses the process (focus) lens. The machining mirror deflects the laser beam vertically down towards the process lens which then converges the beam to a focus, with a 'spot-size' (focus diameter) normally less than 1mm (0.040 inches). The lens tube is held in twin pre-loaded linear bearings which permit precise linear motion within the block. The position of the lens tube can be adjusted by a micrometer Fine-Focus control.

Clamped beneath the process lens is the 'protection slide' - a sacrificial glass slide which stops debris (hot sparks and fume) generated by the machining process from contaminating the lens. The slide is made of special iron-free water white glass. If normal glass is used it is likely to crack or melt because of impurities which absorb the laser beam.

The machining mirror is a total reflector at the laser wavelength but it has quite high transmission at visible wavelengths, sufficient to permit viewing of the workpiece using an infinity-corrected binocular viewer. Infinity correction allows the workpiece to be located consistently at the same distance from the process lens, irrespective of the axial position of the lens.

The 'infinity correction' lens is located in a cell in the bottom end of the viewer head. (See Figure 2.5B). Also mounted in this cell is a green safety filter which absorbs any laser radiation which passes through the machining mirror.

A target graticule is fitted in one of the binocular eyepiece tubes, to enable the laser focus to be targeted on specific workpiece locations. The binocular eyepieces have individual focus adjustment to accommodate variations in operators' eyesight.

A range of process lenses is available with focal lengths ranging from 50 to 300mm (2 to 12 inches); 80mm (3.2 inches) is probably the most commonly used, followed by 120mm (4.8 inches). More information on choosing the process lens is given in Section 6.8, particularly Section 6.8.5.

For information on the alignment of the machining head and viewing optics, refer to Section 9.4.

4.5.3 Closed circuit TV viewing (CCTV)

As an alternative to direct viewing, the workpiece can be viewed using a CCTV option comprising usually

- a 'trinocular' viewing head
- an image relay unit
- a CCTV camera and TV monitor
- an electronic graticule generator

A schematic diagram of a CCTV system is shown in Figure 4.5C.

The trinocular head is similar to the binocular head but it has an extension tube on which to mount the TV camera. The trinocular head allows the option of CCTV viewing or direct viewing, with quick changeover, simply by rotating the eyepiece assembly through 45° about the main view axis.

When set for direct viewing, the correction lens and the process lens together form an image of the workpiece at the focal plane of the eyepieces, where the graticule is located.

When set for CCTV viewing the workpiece image is now formed inside the top of the trinocular head extension tube. The optical arrangement is shown in Figure 4.5D. In order to make the image accessible, it is transferred outside the extension tube by a pair of 1:1 image relay lenses, mounted in a cell in the Image Relay Unit. The cell is secured in position axially by a screw which passes through an axial slot in the wall of the lens unit.

The CCTV camera has a threaded nosepiece and mounts on a threaded spigot on top of the Image Relay Unit. The camera is locked in position using a large lockring. This arrangement allows a small variation in the axial location of the TV camera.

By appropriate adjustment of the position of the image relay lens cell, the relayed workpiece image is formed on the photosensitive surface of the TV camera tube, and thus, onto the TV monitor.

There is an option to fit an optical graticule at the image plane inside the trinocular extension tube. Usually however the system is fitted with an electronic graticule. In this case the TV camera signal is fed to the TV monitor via the electronic graticule generator, which superimposes the graticule on the monitor screen. The graticule enables the laser beam focus to be targeted on specific workpiece locations. To facilitate alignment of the graticule to the laser beam, the graticule can be shifted vertically and horizontally on the TV monitor using controls on the graticule generator.

CCTV viewing can be provided as the sole option, without direct viewing. In this case there is no viewing head. Instead the CCTV camera is mounted on the machining head via an interface unit which houses a telephoto lens assembly (TLA). Together with the process lens, the TLA forms an image of the workpiece directly on the TV camera photosurface. In this case only the electronic graticule option is available.

The TLA lenses are mounted in a cell which is secured in position by a screw, via a slot in the wall of the interface unit. The image of the workpiece is focussed on the TV camera by adjustment of the axial position of the TLA cell.

CCTV will typically be selected in the following situations:

- where there is an overriding concern about eye safety
- to avoid eye strain where prolonged viewing is required
- when the machining head is inaccessible
- when the machining head is in continual motion
- where the laser is located in an area which presents a safety hazard

For more information on setting up and aligning CCTV systems, refer to Section 9.5.

4.5.4 Gas nozzle assembly

In cutting and drilling applications, substantial benefits can be derived by using a coaxial gas jet (usually oxygen, sometimes compressed air) in conjunction with a focussed laser beam. The principal effects of the gas jet are

- to promote an exothermic reaction
- to blow molten material out of the hole or slot, thus
- reducing the recast layer thickness

A gas nozzle assembly is available which fits directly into the lens tube of the machining head, replacing the usual process lens cell and protection slide. A sectional schematic of the nozzle assembly is shown in Figure 4.5E.

The process lens, a positive lens of 80mm (3.2 inches) focal length located in the upper portion of the assembly, acts as the entrance window for what is basically a pressurised gas cell. The nozzle assembly is essentially of conical shape. Pressurised gas is introduced into the nozzle immediately below the process lens and escapes through a 1mm (0.040 inch) diameter nozzle tip at the bottom of the assembly.

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To prevent contamination reaching the process lens, a circular protection slide is located midway down the nozzle assembly. The protection slide is made of water-white iron-free glass to avoid cracking/melting by the laser beam. The slide is located on a specially-profiled seating which allows the gas to pass through to the nozzle.

The lower portion of the nozzle assembly is secured to the upper portion, by three screws via oversize clearance holes which permit a limited range of lateral adjustment, sufficient for the nozzle tip to be set concentric with the focussed beam.

The nozzle itself can be of either PTFE (Teflon) or copper and screws into the bottom of the nozzle assembly.

4.5.5 Safety Enclosure

The standard Safety Enclosure is a profiled rectangular metal cabinet with two shaped sliding doors which form the top and front of the cabinet. In its usual format, the Safety Enclosure is mounted on the table of a drill stand and the laser is mounted on a platform on top of the vertical pillar of the stand. In order to direct the beam safely from the laser into the Enclosure, it is essential for a machining head to be fitted to the laser. The lens tube on the machining head passes through a circular aperture formed by semi-circular cutouts in the mating edges of the Enclosure doors.

To enable processing operations to be observed, a viewing window is fitted in each door.

The Safety Enclosure converts a JK700 Series laser to a Class 1(I) product, by virtue of:

- overlapping joints between the doors, and between the doors and adjacent panels
- light baffle plates attached to the machining head lens tube
- safety filter in the viewing windows
- high integrity safety interlock switches fitted to each sliding door
- a grommeted interface plate in the back of the Enclosure which allows auxiliary services (power, gas) to enter the Enclosure without escape of light

4.5.6 Hand Shutter Control

As an alternative to the control panel, a Hand Shutter Control (Figure 4.5F) is available with a coiled 4.5m (15ft) long lead which plugs into a socket on the bottom front of the laser head (Figure 4.2A).

The hand control has

- a white MULTI SHOT button
- a green shutter OPEN button
- a red shutter CLOSE button
- an amber emission indicator lamp

NOTE The emission indicator is required by the safety authorities to indicate that the laser is in a state where laser output is possible. In accordance with CDRH requirements the emission indicator lights up 10 seconds before laser operation is possible.

In order to enable the shutter control to be parked in a convenient location, a barbed pad has been applied to the back of the shutter control box. A mating barbed self-adhesive pad is also provided for the user to apply at the chosen parking site. Then, to park the shutter control, press it onto the parking pad; and to release, pull the control off the parking pad.