JK LASERS

A LUMONICS GROUP COMPANY

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OPERATOR'S MANUAL

HOLOGRAPHIC LASER SYSTEM

Serial No: 7219

Customer: FERMILAB 3/26/85

Operating Voltage/Frequency: 208/60

JK Lasers Limited

TABLE OF CONTENTS

1. INTRODUCTION

The holographic oscillator (HLS1) manufactured by J K Lasers Ltd. is the basis of a family of lasers, formed by the addition of one or two amplifiers to produce output energies up to 10 J, and the necessary reference beam delay line, beamsplitter, etc. to produce a complete, self-contained holocamera.

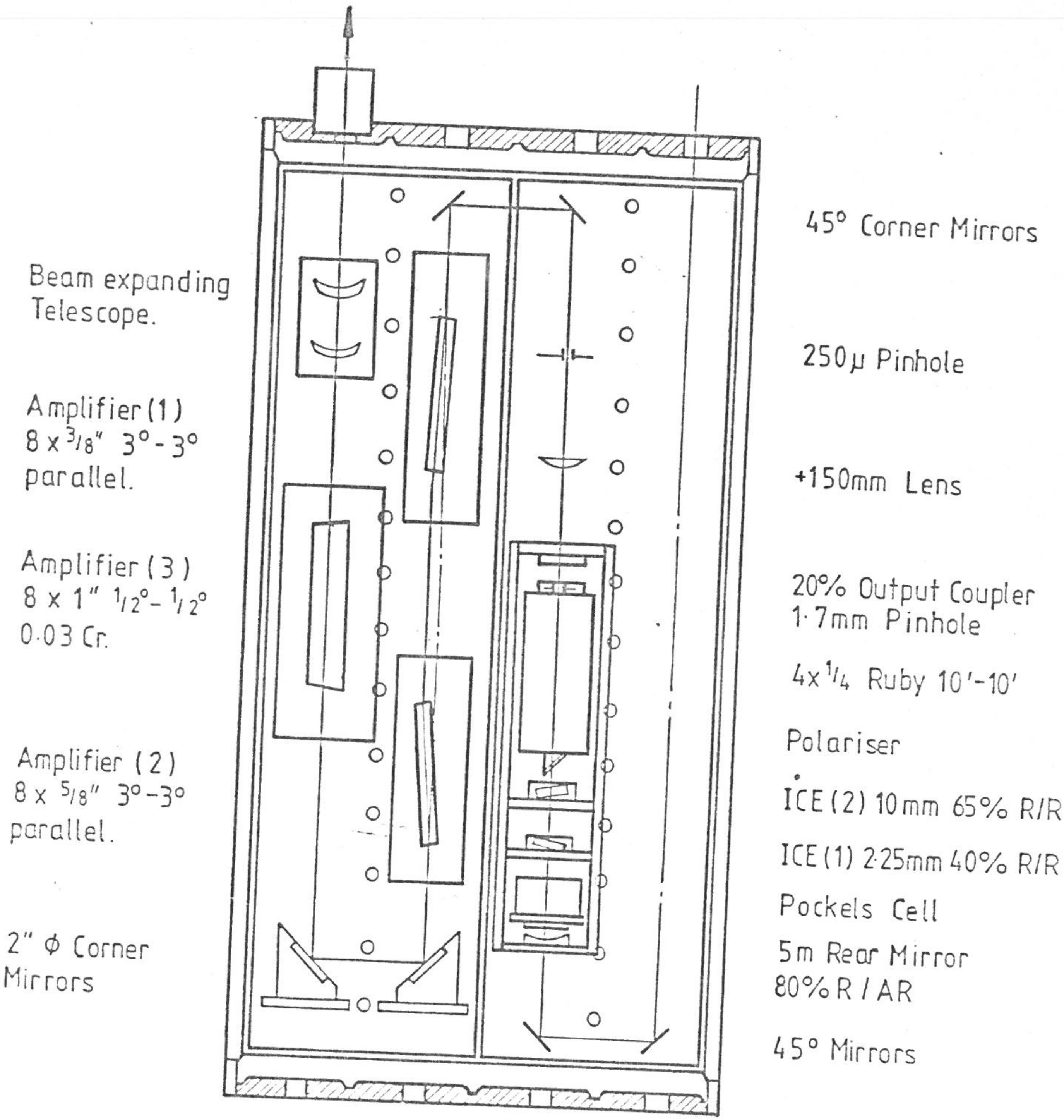
The following sections constitute a user's handbook for the whole family of lasers and not every section, therefore, may be appropriate for your particular holographic system, but each section has been made self-contained so that you can just ignore those that do not apply.

Section 3 is a brief description of this type of laser, and the component layout for your particular system is given in Figure 1. Section 4 then details the operating procedure for the various parts of the system, to enable you to achieve the optimum performance simply and quickly.

The laser will be set up and aligned for you by a J K Lasers engineer (or an appointed agent) at the time of installation and therefore full alignment procedure is not given in this handbook. However, the last section does deal with the basic routine maintenance that will occasionally be needed - namely, on the flashtube replacement and on the cooler.

Finally, appendices are included listing the system specifications, the factory settings which gave the specified performance and also special features of this system.

COMPONENT LAYOUT



2. SAFETY PRECAUTIONS

This equipment can be extremely dangerous.

2.1. High Voltages

The power supply output is potentially LETHAL and operation with any covers removed should only be carried out by competent technical personnel. Never rely on the automatic discharging system. Always follow the instructions for manual discharge of the capacitors given on the warning labels attached to the laser head and to the inside of the psu cabinets and switch off the mains supply before working on the equipment. If the system has more than one capacitor shorting probe, make sure they are all firmly in their sockets before proceeding.

2.2. Laser Radiation

The laser output is of high intensity and would cause IRREPARABLE DAMAGE TO THE EYES if viewed directly; EYE DAMAGE could also result from diffuse reflections from any surface in the path of the beam. When laser radiation at invisible wavelengths is generated, even more care needs to be taken. SAFETY GOGGLES SHOULD BE WORN AT ALL TIMES by personnel within sight of laser radiation. Ensure that the goggles are suitable for the wavelength(s) being emitted and that they fit snugly.

Extreme care should be taken to ensure a clear path between the laser and the intended target, and safe containment of the beam should it not be absorbed by the target.

An energy dump placed close behind the target is recommended.

Guard against CARELESSNESS, UNTIDINESS AND IMPATIENCE.

Ensure adequate precautions are taken to prevent unauthorised personnel from entering the equipment area when the laser is operating. This can be achieved by interlocking the work area entry door into the laser power supply interlock circuit and/or providing warning notices.

Ensure that the laser controls are always set within the operating specifications for the equipment, and that the laser head cover is always fitted during routine operation. Whilst the cover has to be removed for some adjustments, the laser has been designed so that the need for such removal is ..nimised and the practice of not replacing the cover is very bad since not only does it increase the danger from stray radiation, but it allows ingress of room dust and dirt to the various optical surfaces.

For further guidance on the safe use of laser equipment, the following is a list of suggested reading material.

1) RADIATION SAFETY OF LASER PRODUCTS AND SYSTEMS. (A GUIDE FOR PROTECTION OF PERSONNEL AGAINST HAZARDS FROM LASER RADIATION.)

   Part 1 - General

   Part 3 - Guidance for users

   BS4803; 1982 British Standards Institution (and subsequent draft revision)

2) LASER SAFETY HANDBOOK

   A Mallow & L Chabot

   Van Nostrand Reinhold Co (PUB) 1978

3) SAFETY IN UNIVERSITIES: NOTES ON GUIDANCE PART 2:1 LASERS (Association of Commonwealth Universities for the Committee of Vice-Chancellors & Principals, 29 Tavistock Square, London WC1.)

4) In the U.S.A. additional information can be obtained from:-

   BUREAU OF RADIOLOGICAL HEALTH (B.R.H.)

   Regulations for the Adminstration and Enforcement of the Radiation Control for Health and Safety Act of 1968 Chapter 21 CFR sub-chapter J.

   available from:-

   U.S. Dept. of Health, Education and Welfare

   Public Health Service,

   Food and Drug Administration Section.

2.3. Solvents

The following solvents recommended for use when maintaining the equipment can be injurious to health unless adequate precautions are taken.

TRICHLOROETHANE : Degreasing solvent for optics. Irritating, harmful vapour. Avoid breathing vapour and contact with skin, eyes and clothing.

PROPAN - 2-OL (ISOPROPANOL, IPA) : Degreasing solvent for optics. Highly flammable. Avoid breathing vapour and contact with eyes.

WARNING : DO NOT SMOKE FOR AT LEAST 30 MINUTES AFTER USING TRICHLOROETHANE. THIS SOLVENT IS TOXIC AND MUST BE USED IN THE OPEN AIR OR A WELL VENTILATED PLACE (e.g. CHEMICAL FUME CUPBOARD).

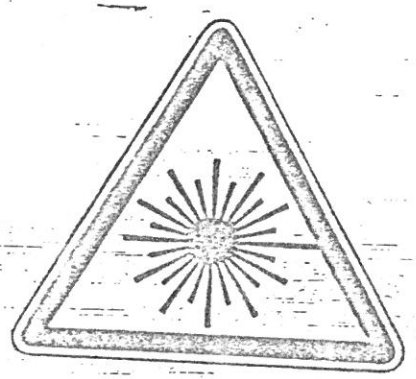
2.4. Safety Labelling

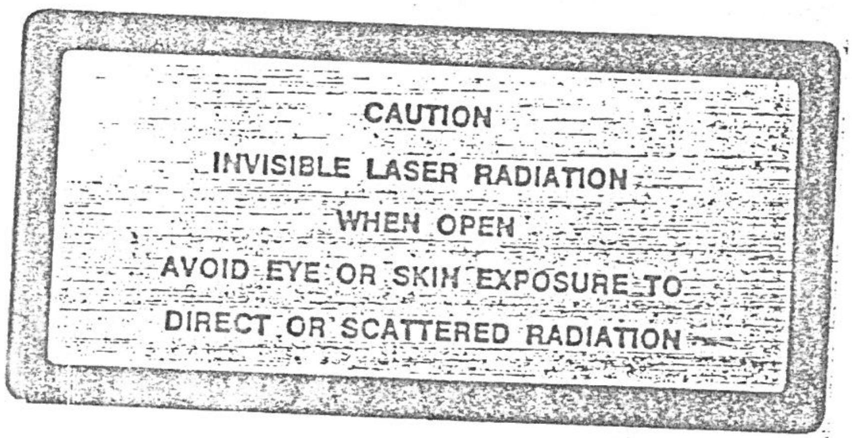
All J K Lasers products are categorised 'Class 4' and safety standards require the prominent display of warning labels as illustrated below.

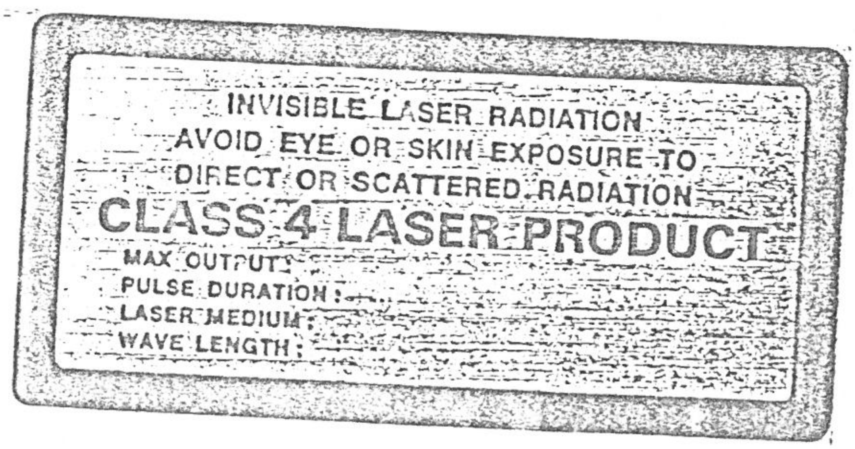
Laser Head Warning Labels

On the outside of the laser head cover.

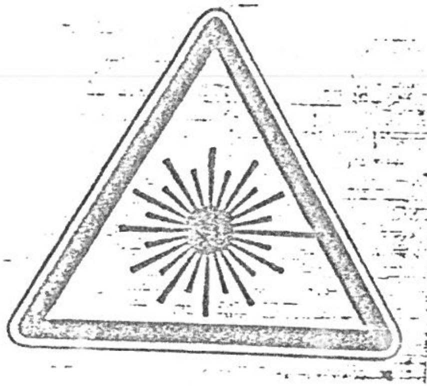
(a) When only invisible radiation is emitted (i.e. outside the range 400-750 nm).

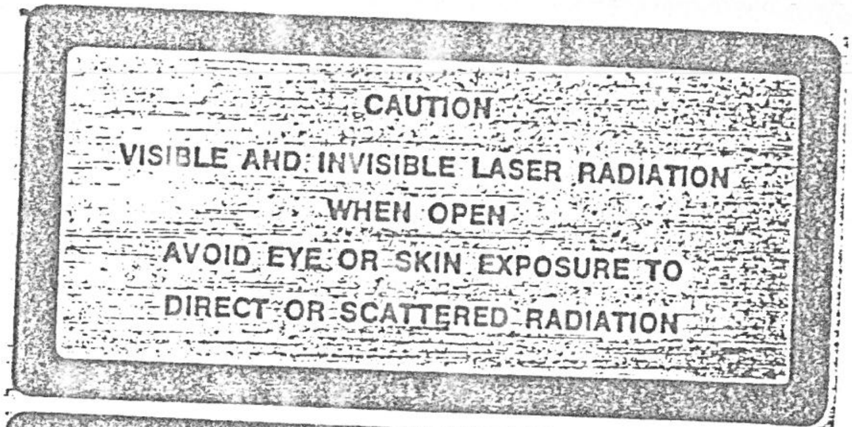


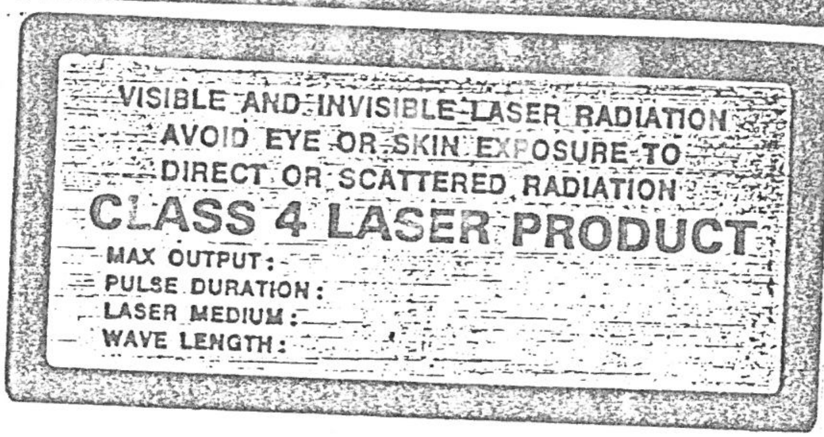




(b) When both visible and invisible radiation may be emitted:



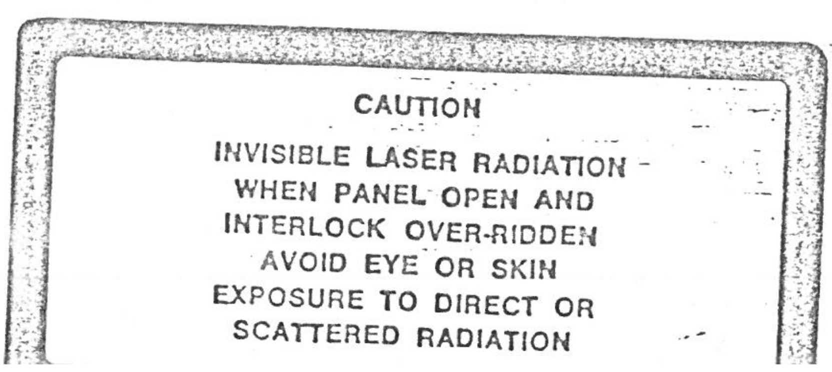




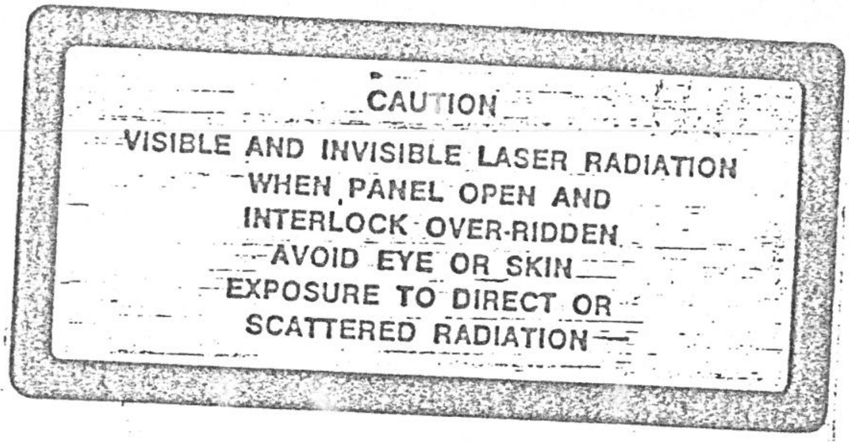
Adjacent to each aperture through which laser radiation may be emitted:

On the inside of removable covers and on the laser rail, in positions visible when the cover is open.

(a) When only invisible radiation is emitted (i.e. outside the range 400-750 nm).



(b) When both visible and invisible radiation may be emitted:



On the outside of the laser head cover, with the following information stated in the area below the line (U.S. market only).

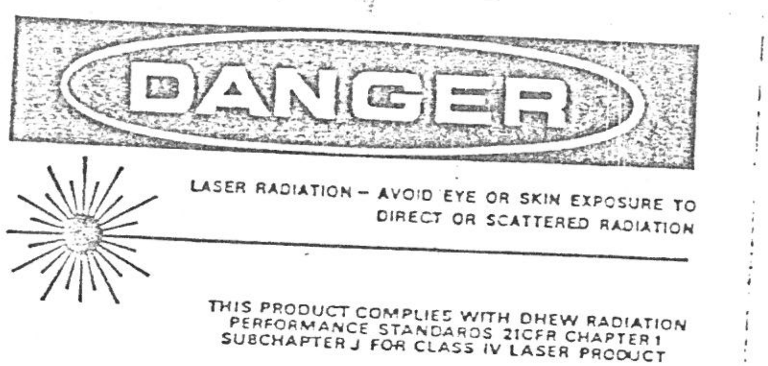
i) max. output of laser (joules)

ii) pulse duration

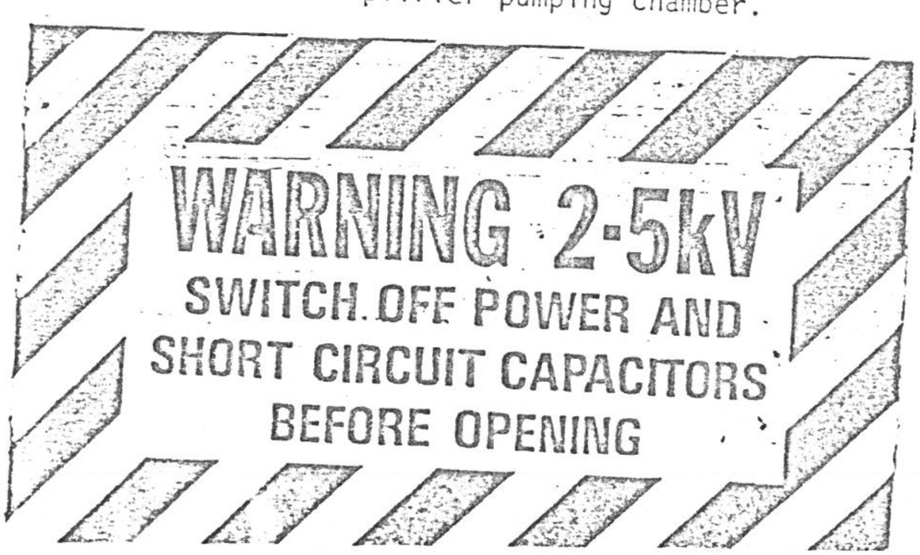
iii) emitted wavelength

iv) laser medium.

Also, a label stating date of manufacture in format "MANUFACTURED (MONTH)(YEAR)".



On the cover of each amplifier pumping chamber.



On the covers of the oscillator pumping chamber, the Q-switch module, the single pulse selector module and its driver unit.

DANGER

HIGH VOLTAGE

W. H. BRADY CO. STOCK NO. 45125

3. GENERAL DESCRIPTION OF THE LASER

3.1. OPTICAL HEAD

A holographic oscillator is a special type of laser in which the necessary coherence length is obtained by the use of bandwidth limiting etalons in the resonator and its satisfactory performance depends very largely on the care with which the oscillator components are set up by the J K Lasers test engineer. The layout of the optical components comprising this laser is given in Figure 1.

A selected quality ruby laser rod is used, 4" long and ¼" diameter. This is held in a close coupled type pumping chamber featuring a glazed ceramic reflector to provide diffuse coupling of the pump light into the laser rod. A flow of distilled water at an accurately controlled temperature provides optimum water cooling for the laser rod and the flashlamps.

The basic optical resonator is provided by a plane 20% reflecting, wedged output mirror and a 5m curvature concave, fully reflecting rear mirror. Operation in single transverse mode is assured by the inclusion of a small aperture, mounted in the end plate of the pumping chamber. A mechanical safety shutter is incorporated in the laser front plate.

The oscillator is pumped by a Xenon-filled flashtube driven by a high stability power supply. Q-switching is achieved by a Pockels cell and a polariser and the drive circuit is designed so that either one or two Q-switched pulses are emitted, as required (in this latter case, the pulse separation is adjustable between wide limits - see Appendix A - to allow use of the laser in a wide range of engineering applications). The Pockels cell features a KD*P crystal set in a sealed cell containing index matching fluid and anti-reflection coated windows to give a very low insertion loss. The Pockels cell windows are set at 5' to the crystal faces to minimise unwanted etalon effects within the cavity. The polariser consists of two plates mounted at the Brewster angle: no alignment is required, and the polariser is secured in the pumping chamber rear end plate.

A Q-switched laser will normally operate in several longitudinal modes at the same time. The number of modes depends on the natural fluorescent linewidth of the laser, the number of transverse modes operating and the degree of excitation of the laser rod prior to Q-switching. In order to reduce the number of modes operating and hence increase the coherence length of the holographic oscillator, additional wavelength selecting elements in the form of etalons are introduced into the laser resonator. The etalons are used in transmission and can therefore be coated with high reflectivity dielectric coatings to increase their finesse and reduce further the bandwidth of the laser. The etalons are thermally linked to the rod by the laser coolant, ensuring that any drift in rod temperature is compensated for by the etalons.

In order to prevent additional etalon effects within the resonator the output mirror and rod ends are wedged. The mirrors and etalons are mounted on an invar bar structure for high stability of the optical alignment. The beam from the oscillator is passed through a spatial filter to remove any unwanted perturbations from the beam profile, and to match the beam size to the amplifiers if fitted.

Amplifier stages are based on an 8" x $\frac{3}{8}$" Ruby rod which on its own will produce an output of 1 J. Used with a 4 x $\frac{1}{4}$" preamplifier an output of 3 J is available. With a second amplifier using an 8" x $\frac{5}{8}$" Ruby rod the 1 J output is increased to 10 J. To prevent self lasing within the amplifier the ends of the rods are cut at 3^{o} and anti-reflection coated, and to compensate for the beam offset caused by the rod wedge angles, the pumping chambers are skewed with respect to the optical axis. The amplifier rods are mounted in pumping chambers of similar construction to the oscillator one, but each 8" rod is pumped by four lamps, to ensure maximum uniformity of the output beam profile.

All systems incorporate a photodiode energy monitor which is used to monitor the laser output and may also be used to balance the beams of an external holographic system. Output signals are provided for oscilloscope display.

The holocamera is based on the standard 1 J or 3 J holographic laser, but is built onto a 1m x 0.5m base and incorporates all additional optics and plate holder to enable holograms to be taken wherever required. The system has external controls to vary the reference beam path length and beam ratio without removing the cover. The system is designed to be portable and optically stable so that it can be taken to any factory or industrial location to study problems on the spot instead of having to simulate them in the laboratory.

3.2. POWER SUPPLY UNITS

The power supplies needed for driving the flashlamps in the laser head are contained in one or two 4 ft. cabinets, depending on the system complexity. The power supply control unit, which incorporates the Pockels cell drive electronics and energy monitor interface unit, is situated either on top of the power supply cabinet in its own housing or built into the power supply cabinet.

The flashlamps are driven by conventional capacitor discharge supplies. The capacitors are charged from the constant current charging unit and the discharge is initiated by the series injection of a high voltage impulse from the trigger transformer. The timing and control circuits are built onto printed circuit cards situated in the control unit.

An overvoltage protection trip circuit board is situated on the power chassis of each charger and is powered directly from the incoming a.c. supply. Should the capacitor voltage exceed a set reference voltage the interlock circuit is broken and the capacitors are discharged. Once the trip level has been exceeded the circuit can only be reset by isolating the equipment from the mains.

On the 3J system the oscillator and preamplifier operate together from the oscillator charger. The total energy of the system is set with the amplifier capacitor voltage control. On the 10 J system, the amplifier charger operates both amplifiers at the set voltage.

All lasers are supplied with a closed circuit cooler system which works via a heat exchanger to the external mains supply. A heater is incorporated in the cooler unit to maintain the coolant temperature when the laser is not operating and the ambient temperature is below the recommended operating temperature for the coolant. Where mains water supplies of a suitable temperature are unavailable a refrigerator unit may be supplied.

3.3. THE CONTROL UNIT

The control unit has four sections labelled Power, Pockels cell, Oscillator and Amplifier, and all connections are via connectors on the rear of the chassis. The unit can be operated from the remote control box supplied. The controls are as follows:-

Enable Keyswitch. This forms a link in the interlock circuit and prevents unauthorised use of the laser.

On. Once power has been applied depression of this button will cause the capacitors to be charged and the laser to operate in the set mode.

Off. Depression of this button will stop the operating cycle of the laser and will dump the energy stored in the discharge capacitor bank. The laser is ready for re-use without further operation of the enable keyswitch.

Interlock. This neon lights when the power circuit breaker is closed. If any interlock switch remains open when the laser is operated the capacitor banks are dumped and this lamp remains lit.

The interlock circuit comprises microswitches on the power supply cabinet doors and on the end plates of the laser pumping chambers, a pressure switch in the laser coolant circuit, a key-controlled switch, an external access point at the rear of the power supply cabinet and a plug on the laser head cover.

Other conditions which will cause the interlock warning to light are actuation of the overvoltage trip and of the main thermal overload trip.

INT/EXT. This switch determines the triggering source for firing the flashtubes. In the 'INT' position triggering occurs at a steady repetition rate preset at the factory. In the 'EXT' position the laser may be fired by feeding a signal into the TRIG socket on the rear of the control unit or from the remote firing button on the box.

Single/Auto. The position of this switch determines whether the discharge capacitor bank will automatically recharge after firing. In the Single Shot position it will be necessary to depress the ON button each time it is required to charge the discharge capacitor bank. This is recommended as the SAFE way of operating the laser when only occasional single pulses are required.

Operation in the AUTO position is necessary for repetitive operation, either from the internal or an external pulse generator.

Oscillator/Amplifier Main Circuit Breakers. This switch is used to apply main power to the system. It does not initiate charging of the discharge capacitor bank. In addition, it protects the circuit under fault conditions.

Capacitor Voltage. This control sets the voltage to which the discharge capacitor bank will be charged. It should be set prior to charging to obtain reproducible results. It is important to note that once charged the discharge capacitor bank voltage cannot be reduced by reducing the potentiometer setting; this action will affect the voltage level only on subsequent shots. However, the discharge capacitor bank voltage level will always respond immediately to any increase in potentiometer settings.

Ready. This indicator is lit when the capacitor banks are charged and the laser is ready to fire.

Delay. This control sets the delay between firing the oscillator flashlamps and the amplifier flashlamps.

POCKELS CELL CONTROLS

Meter. The meter displays the voltage applied to the Pockels cell.

Bias. This Potentiometer sets the voltage applied to the Pockels cell.

Balance. This potentiometer controls the size of the signal sent to the Pockels cell to reduce the first pulse energy and hence balance the pulses.

Delay 1. This control sets the delay between firing the laser flashtubes and triggering the oscillator Q-switch.

Delay 2. This delay sets the pulse separation between the two laser pulses.

REMOTE CONTROL BOX

Laser Off. Switches off the laser and dumps the capacitors.

Laser On. Depression of this button will cause the capacitors to be charged and the laser to operate in the set mode.

Fire. With the INT/EXT switch in the EXT position, depression of this button will fire the laser.

Ready. This indicator is lit when the capacitor banks are charged and the laser is ready to fire.

4. OPERATING PROCEDURES

4.1. HOLOGRAPHIC OSCILLATOR

Step-by-step instructions for switching on and operating a holographic oscillator to its specified performance are listed below. (Refer to 4.3. for double pulsing details.)

1. Ensure that the tap water supply to the cooler is turned on or that the chiller unit (if used) is switched on.
2. Turn the "ENABLE" keyswitch clockwise to the horizontal position and lift the oscillator power breaker. The "INTERLOCK" lamp should be lit.
3. Switch on the cooler, wait a few minutes for the coolant to reach correct operating temperature.
4. Ensure that the INT/EXT and SINGLE/AUTO switches are set to give the mode operation required.
5. Check that the following controls are set as per data in Appendix B - System Control Settings.

   CAPACITOR VOLTAGE
   DELAY 1
   DELAY 2
   BALANCE

6. Switch on the Pockels cell.
7. Press the "ON" button. The capacitors will now charge and the laser operate in the set mode.
8. Press the "OFF" button to stop the laser operating and dump the energy stored in the capacitors.

4.2. AMPLIFIERS

In this section the controls available for the range of holographic amplifiers is briefly described and then the operating procedures are listed.

HLS2. The amplifier is controlled from the amplifier section of the control unit.

HLS3. The preamplifier is controlled by the oscillator control section of the control unit. The main amplifier is controlled by the amplifier section.

HLS4. Both amplifiers are controlled by the amplifier control section of the control unit. The operating procedure is as follows.

1. Switch on the holographic oscillator as outlined in Section 4.1., but do not press the "ON" button.
2. Set the amplifier delay as indicated in Appendix B.
3. Lift the mains power circuit breaker on the amplifier section of the control unit.
4. Set the "CAPACITOR VOLTAGE" control to give the required laser output. (Do not exceed the factory setting of this control as detailed in Appendix B.) When using lower drive levels than indicated, a different amplifier delay may be necessary to maintain equal double pulses.
5. Press the "ON" button. The capacitors will now charge and the laser operate in the set mode.

4.3. DOUBLE PULSE OPERATION

Switch on as detailed in Sections 4.1. and 4.2. and monitor the laser output on an oscilloscope by means of the integrating photodiode energy monitor supplied with the system. Adjust the "BALANCE" and "DELAY 1" controls until a signal similar to that shown in Figure 4 is obtained.

In general for pulse separations longer than 300 μS the "BALANCE" control is set at maximum and the two pulses are equalised by adjusting "DELAY 1".

For short pulse separations, "DELAY 1" is set to the optimum value and the two pulses are equalised by using the "BALANCE" control.

For short separations, where there is insufficient time for re-pumping the laser rod between pulses, and for long separations, where the laser is operating in the 'wings' of the flashlamp pulse, it may be found necessary to increase the input energy to the laser. Care must be taken to ensure that this level is reduced, however, before returning to a more efficient mode of operation. It is important to note that, once the flashlamp capacitor bank is fully charged, resetting the input voltage to a lower value before the lamps fire will have no effect. Therefore, it is important to switch the laser off and reset the input voltage before changing other operating conditions.

4.4. 1 HZ OPERATION

When operating at repetition rates faster than 6 pulses per minute, the equilibrium temperature of the rod is higher than the normal value. This requires a different setting of the micrometers of the intra-cavity etalons. Full details of the settings are given in Appendix B. After adjustment of the etalons, the resonator may require re-optimisation to restore the output energy or improve beam quality. The following alignment procedure should be carried out.

1. Switch off the laser and dump the capacitor.
2. Remove the aperture assembly from the oscillator pumping chamber end plate by loosening the grub screw situated under the cover fixing screw.
3. Operate the laser at the required repetition rate and capacitor voltage but with the Pockels cell switched off.
4. Monitor the oscillator output using the integrating photodiode supplied with the system and display the output on an oscilloscope.
5. Adjust the rear mirror only to obtain maximum output consistent with a smooth oscilloscope trace.
6. Check with burn patterns at the output of the oscillator that the output beam profile is symmetrical. NOTE: a small side beam may be seen at this point. (This is generated by the intracavity etalon and is quite normal.)
7. Switch off the laser and replace the aperture assembly.
8. Adjust the X-Y position of the aperture only to obtain maximum output consistent with a smooth oscilloscope trace.
9. Check with burn patterns that the output beam profile is truly circular and even. Some ring structure is normal in the beam profile at this stage.
10. Switch on the Pockels cell and check for satisfactory Q-switched performance.
11. Carefully remove any burn paper debris.

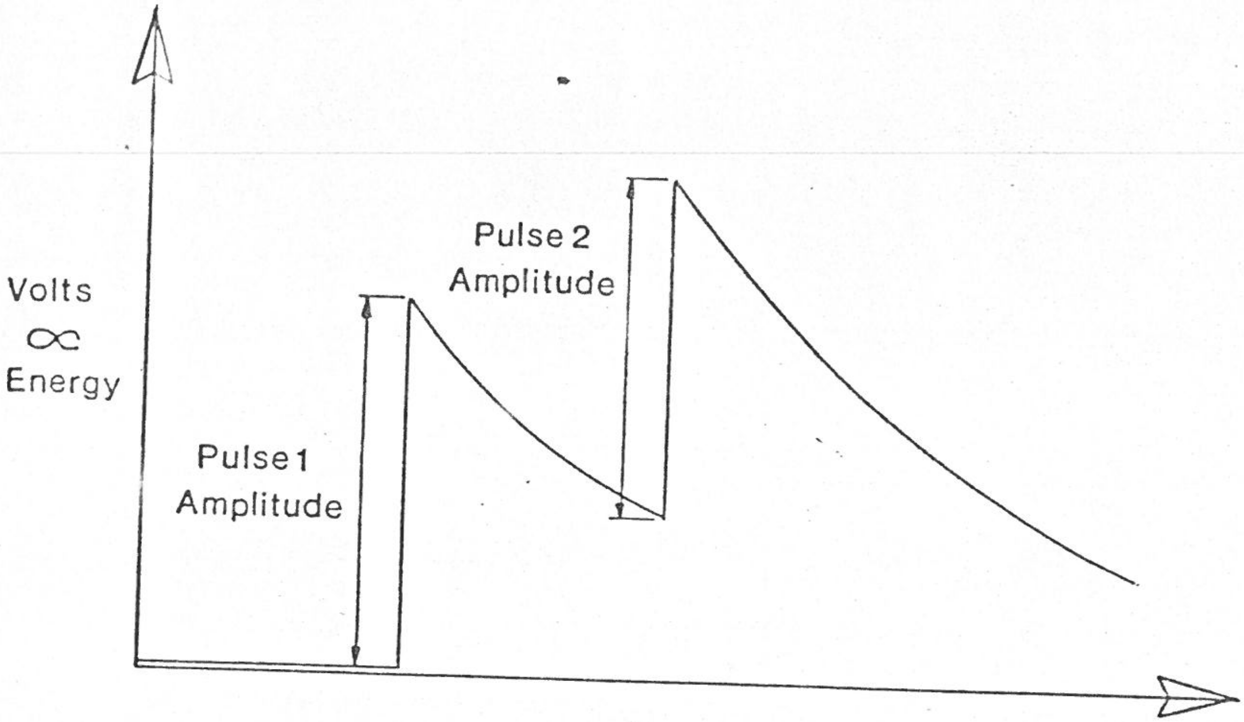


Fig. 4 · C.R.O. DISPLAY OF DOUBLE PULSE LASER OUTPUT

5. MAINTENANCE

5.1. LAMP CHANGING

Changing of flashlamps will be necessary when they have aged to the extent that the required laser energy cannot be achieved with the available input energy, or if they become dirty on the outside due to contamination of the coolant, resulting in the loss of laser output. In this second case they can be cleaned, as detailed later, and re-used. Occasionally, a flashlamp may fail explosively and shatter inside the pumping chamber. In such cases, ensure that all fragments have been removed from the pumping chamber, to guard against any possibility of blockage.

The presence of other optical modules close to the pumping chambers means that these latter have to be removed bodily before the lamps are changed, but the mounting of the pumping chamber assemblies has been designed to make this operation very simple and to ensure that the chamber - and hence the ruby rod - fits back accurately so that the beam path is not disturbed.

Flashlamp Removal

1. Ensure that the cooler is switched off and that the power supply is disconnected from the mains electricity supply.
2. Ensure that the lamps are safe to work on. The safety probe(s) - to be found behind the cabinet doors - must be fitted into the discharge socket(s) according to the instruction label.
3. Remove the laser cover and then the two screws which secure the pumping chamber cover and remove this cover.
4. Slacken off the bleed screw on the end block. At this point a hissing sound will be heard as air enters the coolant circuit causing the level of the coolant to fall below the baseplate.
5. Carefully slide the lamp clips off the flashlamp ferrules.
6. Carefully slide the PTFE gaitering tubes (if fitted) away from the pumping chamber end blocks.
7. Remove the four screws which secure the baseplate to the mounting plate.
8. Carefully lift away the complete pumping chamber assembly.
9. Remove the two retaining screws and the clamp plate from the '0' ring seal at each end of the lamp.
10. Gently move the lamp to and fro to unseat the '0' rings. When the '0' rings are free on the lamp, carefully withdraw it out of the pumping chamber.

Flashlamp Replacement

1. Ensure that the flashlamps are clean; any traces of adhering '0' ring should be carefully removed, taking care not to scratch the envelope.
2. Slide the lamps into position in the pumping chamber, ensuring the polarity is correct (+ lead to red terminal). Unless the original '0' rings are perfect, use new ones, rolling them into position from each end.
3. Replace the pumping chamber by a reversal of the procedure for removing it, using new '0' rings unless the old ones are perfect. (Take particular care when replacing the gaitering tubes and when sliding the clips back onto the lamp ferrules.)
4. Switch on the coolant pump and look carefully for any leaks.

NOTE: Flashlamps in quad. pumping chambers are held in place by castellated clamping nuts. These are removed and replaced using the special tool supplied in the laser tool kit.

Flashlamp Cleaning

Discolouration of the flashtubes can either be external or internal. First clean the lamp envelope in isopropyl alcohol. If discolouration persists, and is definitely on the outer surface, clean again with dilute nitric acid, keeping it away from the electrodes. If colouration is internal and extends far beyond the electrodes, the flashtubes probably need replacing. Generally, removal of external discolouration from the flashtubes should be accompanied by flushing of the cooling system and refilling with fresh coolant.

5.2. COOLER MAINTENANCE

The materials and components of the cooling system have been carefully chosen to minimise the possibility of contamination of the de-ionised water, and the primary maintenance task is thus just to check the level of the water. This can be done with the cooler in situ by unscrewing the large cap on the top of the stainless steel reservoir: the level, when the tubing and pumping chambers are full of water, should be just above the top of the heat exchanger coil. Do not overfill, or the water may spill over the top when the laser head is drained to change a lamp.

Depending on the frequency and conditions of operation, it may be necessary occasionally to change the coolant and possibly clean the system. If a marked drop in output occurs, check the flashtubes first. If these are contaminated on the inside through electrode sputter, but are clean externally, then it is probably not a coolant problem, and lamp replacement is indicated if the desired laser output cannot be achieved with the available input pumping energy. The transparency of the coolant should be checked, however, and, if in doubt, replaced first. If examination of the external surface of the lamps or the interior of the reservoir shows contamination, then the coolant will certainly have to be changed.

Changing the Coolant

1. Drain the laser head by removing the bleed screws in the pumping chamber(s).
2. Remove the screws holding the cooler chassis to the cabinet.
3. Unplug the electrical connector.
4. Undo the quick-release coolant connectors, and slide the cooler unit out clear of the cabinet.
5. Remove the lid of the reservoir and empty out the coolant.
6. Thoroughly clean every surface inside the reservoir, paying special attention to the corners and the coil: a paper towel is ideal for the purpose.
7. Replace the bleed screw in the pumping chamber.
8. Refill the reservoir with clean water, temporarily replace the lid, fit the cooler in the cabinet and remake the electrical and coolant connections.
9. Switch the coolant pump on and flush for a few minutes.
10. Repeat Steps 1, 3, 4 and 5.
11. Replace the bleed screws and refill the reservoir with de-ionised water.
12. Refit the cooler in the cabinet.

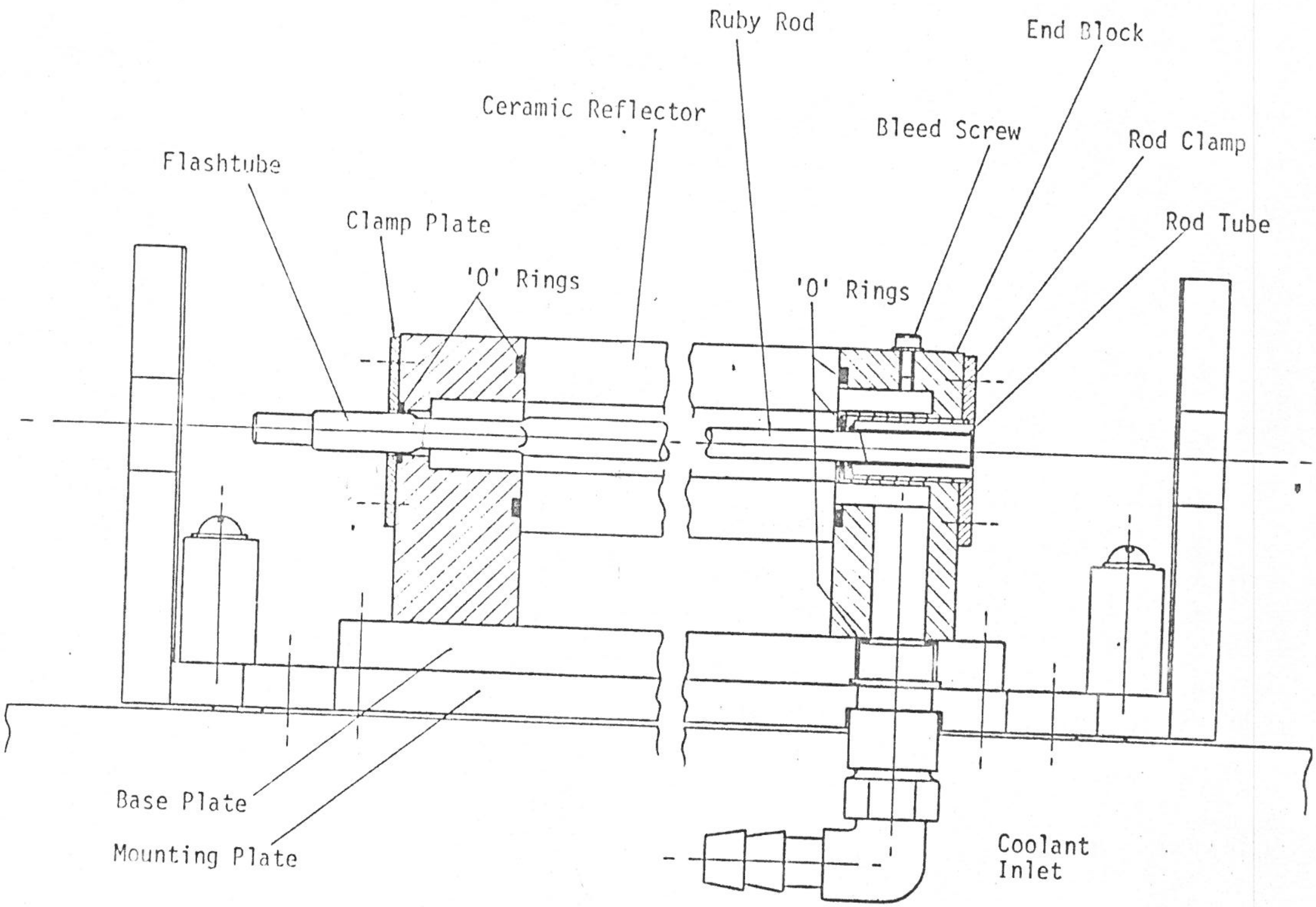


FIG. 5: CROSS-SECTIONS OF LASER HEAD ASSEMBLY SHOWING FLASHTUBE (LEFT) AND ROD (RIGHT)

APPENDIX B - System Control Settings

(for laser serial no 7219

In this appendix the final system control settings from factory testing are recorded. They provide a useful reference for both initial user operation of the system and subsequent changes to operating conditions as the components age or are replaced due to damage.

Pockels Cell Bias	3.0 KV	
Energy Monitor Calibration		
Coolant	Distilled Water	
Coolant Temperature	20 C	
Micrometer Settings	top	side
Pockels Cell		
Etalon 1		
Etalon 2		
Spatial Filter Lens		
Spatial Filter Pinhole		

APPENDIX A - SYSTEM PERFORMANCE

(For Laser Serial No:7219)

In this Appendix the Basic specifications are given for this particular system. The system control settings to achieve this performance are given in Appendix B.

WAVELENGTH	694 nanometres
OUTPUT ENERGY	25 Joules
MAX. REP. RATE	4ppm
COHERENCE LENGTH	Greater than 1m
PULSE DURATION	30 nS nominal
POLARISATION	Vertical

WARNING

This system is not protected against back reflections. Do not focus the beam except in a vacuum of at least 0.1 Torr.

JK LASERS

A LUMONICS GROUP COMPANY

MAINTENANCE MANUAL

HOLOGRAPHIC LASER SYSTEM

Serial No: ____________________

Customer: ____________________

Operating Voltage/Frequency: ____________________

JK Lasers Limitec
Cosford Lan
Swift Valley, Rugb
Warwickshire CV21 1ON

HOLOGRAPHIC LASERS

TABLE OF CONTENTS

PREFACE

The purpose of this maintenance manual is to detail all the procedures that may need to be carried out to keep an HLS laser in good working order - thus it gives the information to enable a technically-minded owner to carry out repairs, adjustments, etc., without having to call in a JK Lasers service engineer.

The manual is intended to be read in conjunction with the operator's handbook supplied with every HLS laser. Accordingly, the section numbering starts at 6, to follow on from the operator's manual sections, and frequent cross references are made.

A large part of this manual is concerned with the alignment procedures which will have to be made if the laser is dismantled for cleaning or replacement of any of the optics. A helium-neon alignmment laser is absolutely essential for this, and the text assumes that one fixed in the JK Lasers adjusting mount is available. It must be stressed that the HLS lasers are quite complex and successful operation is critically dependent on very precise alignment and adjustment.

6. LASER RODS: REMOVAL, CLEANING & REPLACEMENT

The oscillator rod is fitted with stainless steel end tubes, whereas the (pre)amplifier rods are not. Further, the oscillator and preamplifier rods are ¼" diameter and use the same design of pumping chamber with (series connected) twin lamps for pumping, whereas the main amplifier rods have four lamp pumping. Because of this, the methods of removal, cleaning and replacement are different for oscillator, preamplifier and main amplifier rods, and are detailed in separate subsections below.

In each case, the pumping chamber has to be moved bodily from the laser head and this should be done using the following procedure:

1. Ensure that the cooler is switched off and that the power supply is disconnected from the mains electricity supply.

2. Ensure that the lamps are safe to work on. The safety probe(s) - to be found behind the cabinet doors - must be fitted into the discharge socket(s) according to the instruction label.

3. Remove the laser cover and then the two screws which secure the pumping chamber cover and remove this cover.

4. Slacken off the bleed screw on the end block. At this point a hissing sound will be heard as air enters the coolant circuit causing the level of the coolant to fall below the baseplate.

5. Carefully slide the lamp clips off the flashlamp ferrules.

6. Carefully slide the PTFE gaitering tubes (if fitted) away from the pumping chamber end blocks.

7. Remove the four screws which secure the baseplate to the mounting plate.

8. Carefully lift away the complete pumping chamber assembly.

9. Remove the two retaining screws and the clamp plate from the '0' ring seal at each end of the lamp (oscillator and preamplifier) or use the special key in the toolkit to remove the '0' ring clamp nuts (amplifiers).

10. Gently move the lamp to and fro to unseat the '0' rings. When the '0' rings are free on the lamp, carefully withdraw it out of the pumping chamber.

11. Place the pumping chamber on a suitable table surface and arrange a HeNe laser so that its beam passes along the axis of the rod.

6.1. Removal of the Oscillator Rod

1. Note the deflection imposed on the gas laser beam after passing down the rod axis. Note also the positions of the back reflections from the two surfaces of the rod. This will greatly facilitate reinstallation of the rod.

2. Slacken the M3 screws securing the rod clamps and withdraw both clamps.

3. Very carefully push and pull the exposed thin wall end tubes with a gentle screwing motion to unseat the '0' rings and then withdraw the laser rod from one end of the pumping chamber.

4. Check the ends of the rod for damage or contamination. Carefully wrap the rod in tissue and put it in a safe place until required.

6.2. Oscillator Rod Cleaning

1. If the rod faces are dirty and the contamination cannot be blown off with a stream of clean, dry air, the protective end tubes will have to be removed. NEVER poke tissues, etc down the tube in an attempt to clean the rod; the only way to satisfactorily clean the whole face of the rod is to remove the tube.

2. The tubes are glued in place. The ends of the rod should be completely immersed in nitromethane for about an hour, by which time the tubes should slide off easily.

3. Gently, but thoroughly, clean the exposed rod end and the cylindrical surface with nitromethane, followed by trichloroethane and then isopropanol. The anti-reflection coatings should be treated most carefully, since they are easily scratched and damaged.

6.3. Fitting End Tubes on the Oscillator Rod

It is important that the laser rod end tubes are fitted the correct distance apart. The '0' ring seal at each end is made on the actual rod just clear of the tubes. Thus, there is no requirement for the glued joint to be waterproof, the purpose of the rods is simply to facilitate handling and to protect the rod faces. If the tubes have too little separation, the '0' rings will seat on them rather than on the rod and coolant may leak onto the rod faces. If the tubes are too far apart, their security on the rod will be adversely affected.

1. Make a pencil mark at the exact centre of the cylindrical surface of the rod.

2. Squeeze a drop of cyanoacrylate adhesive, such as Loctite 496, onto a microscope slide.

3. Preferably using a purpose-made jig (a length of aluminium angle supported between vee-blocks will serve), lay the rod down with the protective tubes pushed over each end. The tubes should fit snugly, otherwise adhesive may creep along the gap and reach the end face of the ruby.

4. Adjust the tubes until they are 98 to 98.5 mm apart and exactly centred on the rod.

5. Pick up a small quantity of adhesive with the tip of a scalpel blade.

6. Taking care not to disturb the position of the tubes, lightly run the tip of the scalpel blade in the angle between the rod tube and the rod until there is a continuous light fillet of adhesive.

7. Ensure the tubes are not tilted with respect to the rod and leave for a few minutes for the adhesive to enter the joint by capillary action and set.

8. Apply a second run of adhesive over the first once it has set, and then leave the rod on the jig for 2 hours for the adhesive to fully harden.

9. Gently remove surplus adhesive with the scalpel blade to leave a fine chamfer on the surface.

10. Check that both surfaces of the rod are perfectly clean. The anti-reflection coatings should look blue when viewed in reflected light. Any hint of yellow indicates that a haze of adhesive has spread onto the surface and the tubes will have to be removed and fitted again after cleaning the haze off the end of the rod.

6.4. Replacement of Oscillator Rod

1. Check that both ends of the rod are perfectly clean and that there is no water lying in the bore of the pumping chamber end blocks.

2. Fit an '0' ring in position on the rod close to one end tube. Use new '0' rings unless the original ones are perfect.

3. Insert the other end into the end block of the pumping chamber, taking care to keep clear of any coolant in the pumping chamber.

4. Feed the rod assembly right through the pumping chamber and roll an '0' ring onto the other end tube. Push the '0' ring into position on the rod by means of the rod clamp. If the tubes are the correct distance apart, you should be aware of the '0' ring sliding off the rod tube onto the rod itself as the clamp

is pushed home. Now remove the clamp and the rod should have a small amount of longitudinal play - a considerably greater pressure should be required to push the '0' ring up the chamfer onto the rod tube.

5. The rotational position of the rod can now be set. Align the gas laser beam to the axis of the rod. Rotate the rod until the deflection imposed on the gas laser beam after passing down the rod axis is again in the same direction (upwards) as it was before removal of the rod and that the two back reflections from the ends of the rod are disposed vertically above and below the gas laser aperture.

6. Without disturbing the rod orientation, refit the rod clamps and loosely fit the M3 screws.

7. Place a gelatine polariser each side of the pumping chamber and arrange for the gas laser beam to pass through onto a viewing screen. Ensure the polarisers are crossed and then finely rotate the laser rod to give the best extinction of the gas laser beam.

8. Carefully tighten the rod clamp screws.

9. Refit the flashlamps and refit the pumping chamber, as detailed in Section 5.1.

CAUTION: Do not forget to vent the air from the pumping chamber whenever the coolant has been drained from the laser head. This is done by slackening the bleed screw, with the pump running, until water starts to ooze out.

6.5. Removal of the Pre-Amplifier Laser Rod (HLS3)

1. Slacken the two M3 screws securing the input end rod clamp and withdraw the clamp.

2. Carefully clean the thin walled stainless steel loading tube supplied in the toolkit with isopropanol both inside and outside. The loading tube is fragile and should be treated with care: if it is deformed in any way it will be rendered useless.

3. Very carefully slide the loading tube over the exposed end of the ruby rod. It is important at this stage not to touch the end of the rod with the loading tube as damage to the anti-reflection coatings may result. Gently push the loading tube under the '0' ring seals with a screwing motion and then into the pumping chamber as far as it will go.

4. Remove the screws from the rod clamp at the other end and withdraw the clamp.

5. Push the loading tube right through the pumping chamber until it is possible to remove the rod from the end of the loading tube.

6. Check the ends of the rod for damage or contamination. Carefully wrap the rod in tissue and put it in a safe place until required.

6.6. Replacement of Preamplifier Rod (HLS3)

1. Gently, but thoroughly clean the rod ends and cylindrical surface with trichloroethane followed by isopropanol. The anti-reflection coatings should be treated carefully, since they are easily scratched and damaged. Check that there is no water lying in the bore of the pumping chamber end blocks. Ensure that the loading tube is perfectly clean and dry.

2. Fit an '0' ring over one end of the rod. This is best done using the loading tube to avoid contamination of the rod end. Use new '0' rings unless the old ones are perfect. Roll the '0' ring along the rod until there is about 2 mm gap between it and the end of the rod.

3. Insert the rod into the loading tube until the '0' ring is resting against the end of the loading tube.

4. Insert the loading tube and rod into the output end of the pumping chamber and push it right through until the end of the rod is almost flush with the end block.

5. The rotational position of the rod can now be set. Align the 'C' axis of the rod by rotating the loading tube until the cylindrical surface of the rod showing the darkest colouration is horizontal.

6. Fit an '0' ring over the other end of the loading tube and push it into position with the rod clamp. Loosely fit the M3 clamp screws.

7. Place a gelatine polariser each side of the pumping chamber and arrange for the gas laser beam to pass through onto a viewing screen. Ensure the polarisers are crossed and then finely rotate the laser rod to give the best extinction of the gas laser beam.

8. Without disturbing the rod orientation, place the second rod clamp over the exposed end of the rod against the '0' ring. Simultaneously push the rod clamp and draw the loading tube through the pumping chamber until the clamp is in position against the end block. Fit and carefully tighten the M3 screws.

9. Slowly withdraw the loading tube completely and secure the remaining clamp screws.

10. Check that both '0' rings are securely seated on the laser rod and that the rod ends are still clean.

11. Refit the flashlamps, and refit the pumping chamber, as detailed in Section 5.1.

<u>CAUTION:</u> Do not forget to vent the air from the pumping chamber whenever the coolant has been drained from the laser head. This is done by slackening the bleed screw, with the pump running, until water starts to ooze out.

6.7. Removal of Amplifier Rod

1. Note the deflection imposed on the gas laser beam after passing down the rod axis. Note also the positions of the back reflections from the two surfaces of the rod. This will greatly facilitate reinstallation of the rod.

2. Slacken the four M3 screws round the periphery of the input end rod clamp a little at a time until the clamp is loose. Withdraw the clamp.

3. Carefully clean the thin walled stainless steel loading tube supplied in the toolkit with isopropanol both inside and outside. The loading tube is fragile and should be treated with care: if it is deformed in any way it will be rendered useless.

4. Very carefully slide the loading tube over the exposed end of the ruby rod. It is important at this stage not to touch the end of the rod with the loading tube, as damage to the anti-reflection coatings may result. Gently push the loading tube under the '0' ring seals with a screwing motion and then into the pumping chamber as far as it will go.

5. Remove the screws from the rod clamp at the other end and withdraw the clamp.

6. Push the loading tube right through the pumping chamber until it is possible to remove the rod from the end of the loading tube.

7. Check the ends of the rod for damage or contamination. Carefully wrap the rod in tissue and put it in a safe place until required.

6.8. Replacement of Amplifier Rods

1. Gently, but thoroughly, clean the rod ends and cylindrical surface with trichloroethane, followed by isopropanol. The anti-reflection coatings should be treated most carefully since they are easily scratched and damaged. Check that there is no water lying in the bore of the pumping chamber end blocks. Ensure that the loading tube is perfectly clean and dry.

2. Fit an '0' ring over one end of the rod. This is best done using the loading tube to avoid contamination of the rod end. Use new '0' rings unless the old ones are perfect. Roll the '0' ring along the rod until there is about 2 mm gap between it and the end of the rod.

3. Insert the rod into the loading tube until the '0' ring is resting against the end of the loading tube.

4. Insert the loading tube and rod into the output end of the pumping chamber and push it right through until the output end of the rod is almost flush with the end block.

5. The rotational position of the rod can now be set. Align the gas laser beam to the axis of the rod. Rotate the rod until the deflection imposed on the gas laser beam after passing down the rod axis is in the same direction as it was before removing the rod.

6. Refit the flashlamps, as detailed in Section 5.1. Do not fit the clamp plates.

7. Slacken the flashlamp clamping rings in both clamp plates by about one turn. Fit an 'O' ring over the other end of the loading tube and push it into position with the rod clamp. Loosely fit the M3 clamp screws.

8. Place a gelatine polariser each side of the pumping chamber and arrange for the gas laser beam to pass through onto a viewing screen. Ensure the polarisers are crossed and then finely rotate the laser rod to give the best extinction of the gas laser beam.

9. Without disturbing the rod orientation, place the second rod clamp over the exposed end of the rod against the 'O' ring. Simultaneously push the rod clamp and draw the loading tube through the pumping chamber until the clamp is in position against the end block. Fit and carefully tighten the M3 screws.

10. Slowly withdraw the loading tube completely and secure the remaining clamp screws. Tighten the clamp rings securing the flashlamps.

11. Check that both 'O' rings are securely seated on the laser rod and that the rod ends are still clean.

12. Refit the pumping chamber to the laser rail as detailed in Section 5.1.

CAUTION: Do not forget to vent the air from the pumping chamber whenever the coolant has been drained from the laser head. This is done by slackening the bleed screw, with the pump running, until water starts to ooze out.

7. OSCILLATOR ALIGNMENT

The purpose of this chapter is to detail every step in the full alignment and optimisation of the holographic laser oscillator. Some steps will not be necessary for a minor or partial realignment and these should be disregarded: it is stressed that complete system realignment is certainly not considered routine and should only be necessary after major component replacement.

If major adjustments have to be made and difficulties are encountered, do not hesitate to contact JK Lasers for advice.

7.1. Minor Reoptimisation

Reoptimisation on a routine basis is not recommended and should only be carried out when a fall off in output energy or beam quality occurs or it becomes difficult to obtain stable double pulse performance. Follow the procedure outlined in Section 4.4. under 1 Hz operation.

CONTOURING: The oscillator is normally completely free from contouring (which is caused by incorrect etalon tuning). Should contours be observed on holograms taken with the laser, first check the temperature of the coolant before attempting to retune the etalons. Check also for pre-lasing as this can cause the oscillator to contour - see Section 9. If all seems well, then the etalons can be optimised as follows:

1. Arrange to monitor the oscillator output by placing the energy monitor after the oscillator. (Note that the beam must not be allowed to reach the spatial filter pinhole, since the energy monitor skews the beam somewhat and it will thus not pass centrally through the pinhole, with consequent risk of damage.)

2. Switch off the Pockels cell and display the normal mode output on the oscilloscope.

3. Adjust the top micrometer only of the thin (rear) intracavity etalon to obtain the maximum energy as indicated by the height of the oscilloscope trace.

7.2. Complete Alignment Procedure

The procedure detailed in this section (and in Sections 8, 10 and 11) is essentially the same as that used in the initial factory build of the laser and therefore assumes that no optics are mounted. Do not allow the oscillator beam to reach the spatial filter or amplifiers until proper alignment into these is carried out.

1. Mount a HeNe gas laser to the port in the laser end plate such that the gas laser beam enters the oscillator through the rear mirror.

2. Fit the output mirror and rear mirror, in their holders, to the angular adjusting mounts at front and rear end of the invar stabilised resonator structure. The mirrors should be fitted with their wedge-planes oriented to compensate for the rod wedge - ie with the thinnest edge of each mirror at the top. This orientation can be found by noting the skew of the HeNe beam as it traverses the mirror.

3. Using the alignment card supplied with the laser, adjust the gas laser beam to be exactly on the optical axis at two points equal distances either side of the laser rod, but between the laser mirrors.

4. Slacken the NOMAR screws which lock the output mirror adjustment and adjust the output mirror until the brightest spot it reflects is concentric with the gas laser aperture: this is best done by placing the alignment card just in front of the rear mirror, and arranging it so that the HeNe beam passes through the hole, since reflections from the rear mirror complicate things on the HeNe aperture disc. Retighten the locking screws.

5. Adjust the rear mirror in a similar fashion until the spot it reflects is also concentric with the gas laser aperture, placing the alignment card just before the output mirror to check for concentricity. Ignore the faint return from the second surface of the mirror.

6. The oscillator should now be operated at the specified repetition rate with up to 1 Joule output. Adjust the rear mirror only to obtain maximum output and a smooth oscilloscope trace. Check with burn patterns that the output beam profile is even and symmetrical.

7. Switch off the laser and fit the polariser in the pumping chamber end plate, correctly orientated for vertical polarisation. The polariser is held in position by a NOMAR screw situated beneath the pumping chamber cover fixing bolt, and the plates should be hanging below the Brewster angled support.

8. Fit the Pockels cell in its holder next to the rear mirror and align it , as detailed in Section 9.1. The Pockels cell windows are set at 5 minutes to the crystal faces and therefore will impose a small deviation on the laser beam.

9. Insert the mode selecting aperture assembly. Operate the laser (still fixed-Q) and adjust the x-y position of the aperture to give maximum energy output consistent with a smooth oscilloscope trace. All adjustments from now on will be with the aperture in place.

10. Set the Pockels cell delays to zero and note the bias voltage extremes at which breakthrough occurs, increasing the pump level if necessary to give a resonable 'window' width. Set the bias to the mid-point between these extremes. Increase the pump level to obtain breakthrough again and adjust the Pockels cell tilt to minimise this. Note the readings for future reference.

11. The etalons must now be fitted. If either of them is new, it must be angle tuned according to the detailed procedure given in the next section, and this requires the use of additional optical components, care and patience. However, if the original etalons are used again, tuning should not be necessary: the critical adjustment is the offset of the etalons (by the top micrometer for the thin - rear - etalon and the side micrometer for the thick - front - one) from the settings which put them normal to the beam. Adjustment of the etalons to be normal to the beam is given in Steps 7, 8 and 11 of Section 8, and the correct offsets can be found from the original sets of micrometer readings given in Appendix B of the Operator's Manual, supplied with the laser.

8. ETALON TUNING

The purpose of the etalons is to increase the coherence length of the laser by restricting the bandwidth in which lasing occurs, and for satisfactory operation of the oscillator there must be coincidence between a transmission peak of each etalon and the peak in the fluorescence curve for the ruby - see Figure 8.1.

The thin etalon (2.25 mm, 40%R) is first fitted and angle-tuned, and then the thick one (10 mm, 65%R). This latter is more critical to adjust, since its thickness and high reflectivity mean that beam 'walk-off' can be a problem if the tuning tilt is too great (resulting in a poor beam shape and a degraded finesse value), whereas if the tilt is too small fringing is obtained on the oscillator output beam because of interference effects.

To tune the etalons it is necessary to examine the spectrum of the laser output using a Fabry-Perot analysing etalon of suitable spectral range. A 1 mm, 65%R etalon is used, in conjunction with a concave lens of focal length -20 mm to diverge the beam. The detailed procedure is:

1. Set up the negative lens outside the laser cavity to provide a beam of divergent light and to avoid damage to the analysing etalon.

2. Set up the analysing etalon beyond the lens in a plane where the diverging beam is 10 to 20 mm in diameter.

3. Set up a suitable screen a metre or so beyond the etalon.

4. Operate the laser at 40 mJ and with the Pockels cell switched off (since the wavelength varies too much from shot to shot when the oscillator is Q-switched). Note that, for the 1 Hz version of the HLS1, the etalon tuning varies with the repetition rate, and the complete tuning process should be carried out both at 1 Hz and at 10 ppm.

5. With the room darkened, examine the ring structure projected onto the screen when the laser is fired. A series of concentric circles will be seen, well spaced at the centre, but closer together further out and of gradually decreasing intensity. Adjust the x-y position of the lens to centre the beam on the ring structure.

6. Adjust the screen until the first or second ring from the centre is approximately 200 mm diameter. Clearly mark the position of this ring on the screen, taking the mean position of the ring over several shots.

7. Place the thin etalon, in its temperature stabilised holder, in the angular adjusting mount next to the Pockels cell. Align its surfaces with the resonator mirrors by means of the HeNe, having re-aligned this so that its beam travels through the aperture and normal to the output mirror reflecting surface.

8. Place a card between the intracavity etalon and the Pockels cell and operate the laser. Finely adjust the tilt of the etalon to give maximum laser output, and record the micrometer settings. Decrease the reading of the top micrometer only by 0.3 mm.

9. Remove the card and operate the laser in the Q-switched mode. Inspect the rings produced by the analysing etalon and continue to decrease the reading on the top micrometer of the intracavity etalon until the ring structure is the same as before, as indicated by the marks on the screen.

10. Switch off the Pockels cell and fine tune the etalon, using the top micrometer, for maximum fixed-Q output.

11. Place the thick intracavity etalon, in its temperature stabilised holder, in the angular adjusting mount next to the polariser. Align its surfaces with the resonator mirrors by means of the gas laser. Place a card between the two intracavity etalons and operate the laser. Finely adjust the tilt of the thick intracavity etalon to give maximum laser output, and record the micrometer settings. Decrease the reading of the side micrometer only by 0.3 mm.

12. Remove the card and operate the laser in the Q-switched mode. Inspect the rings produced by the analysing etalon and continue to decrease the reading on the side micrometer of the thick intracavity etalon until the ring structure is the same as before, as indicated by the marks on the screen.

13. If the micrometer reading offset from the normal exceeds approx. 0.6 mm, return the thick etalon to the 0.3 mm off-set position and retune the thin etalon by further reducing the top micrometer reading, until the ring pattern again resembles that originally obtained. The net result of this procedure is to bring the peaks of the two etalons into coincidence but slightly away from the broad maximum of the ruby fluoresence curve.

14. Switch off the Pockels cell and fine tune the thin etalon on the top micrometer only to obtain maximum fixed-Q output. Switch on the Pockels cell and check the ring pattern is still as before. Record all etalon micrometer readings.

15. Optimise the rear mirror tilt for best beam shape and output energy, and repeat the output v input measurements up to 35 mJ, both fixed-Q and Q-switched.

9. THE POCKELS CELL Q-SWITCH

The purpose of the Pockels cell Q-switch is to produce laser pulses of short duration, typically 20 to 30 nanoseconds in the case of the ruby holographic oscillator, by storing energy in the laser rod during the first part of the flashtube pulse and then releasing it in a single giant pulse. To do this a high voltage bias is applied axially across the DKDP crystal within the Pockels cell which, in conjunction with the polariser, inhibits lasing by acting as an electro optic shutter. Removal of this bias voltage after a period set to maximise the stored energy allows formation of the Q-switched laser pulse.

Two consecutive laser pulses are obtainable from the standard holographic oscillator,but by the use of a special driver, up to four pulses may be generated.

The Pockels cell is a sealed unit with anti-reflection coated windows at each end. The space between the windows and the crystal is filled with FC104 index-matching fluid to minimise transmission losses through the cell. The windows are set at about 5 minutes of arc to the crystal faces and to each other to minimise unwanted etalon effects within the oscillator cavity, and this means that the rear mirror must be re-optimised when the cell is fitted. For correct operation, the crystal must be set so that its optic axis is aligned to the beam: it is not good enough to align only the crystal faces. In addition, the other axes of the crystal must be set parallel and perpendicular to the laser polarisation plane.

Maladjustment of the Pockels cell parameters can cause prelasing - a condition which must be avoided, as it can result in high local beam intensities which rapidly degrade the crystal faces and can cause damage to other oscillator components. Also, prelasing may cause contours to be produced on the holograms.

9.1. Pockels Cell Alignment

The Pockels cell is set up for best performance at the factory and only if the original alignment has been lost, or a new cell is being fitted, should the procedure outlined below be necessary.

1. Fit the Pockels cell so that the indented mark on the black rim lies exactly above the optical axis of the laser oscillator.

2. Remove the aperture assembly and both intracavity etalons.

3. Set up and align a HeNe gas laser, as detailed in Section 7.2, paragraphs 1 and 3.

4. Place one of the gelatine polarisers (supplied in the toolkit) against the Pockels cell on the pumping chamber side. Place the other gelatine polariser between the Pockels cell and the rear mirror with its pass plane orthogonal to the first one. Place a diffuser (eg a lens tissue) between the Pockels cell and the rear mirror and place a white card after the Pockels cell, against the pumping chamber.

5. Observe the HeNe beam projected onto the card. It will be seen to form a pattern: a central dark cross, or near cross, surrounded by concentric rings. It may be necessary to move the diffuser or screen back and forth to obtain the clearest image. Alignment of the optic axis of the Pockels cell consists of adjusting its tilt until the bright central HeNe spot falls on the point of symmetry of the pattern - Figure 9.1.

(Steps 6 - 8 only need to be carried out if the correct rotational setting of the Pockels cell is in doubt.)

6. Rotate one of the gelatine polarisers through 90 degrees, so that the pass planes of both polarisers are the same. The central pattern on the card will now consist of four dark areas disposed about the centre on axes passing through the centre at 45 degrees to the vertical - Figure 9.2.

7. Set the bias control to minimum and the balance control to maximum. Connect the Pockels cell and switch on. Gradually raise the bias voltage observing the pattern projected onto the card. Rotate the Pockels cell until raising the bias voltage causes two of the dark areas in the projected pattern to move towards each other along the 45 degree axis until they merge to form a diamond shape at the centre - Figure 9.3.

8. The Pockels cell is now correctly set for rotational position and Steps 4 and 5 should be repeated, with the bias switched off.

9.2. Pockels Cell Maintenance

Over a period of time, the fluid level in the cell may fall. The cell should always contain enough fluid to completely cover the crystal, and 'topping up' is carried out as follows:

1. Note the correct rotational position of the Pockels cell and remove it from its mount.

2. Undo the two screws securing the filler plug and remove this.

3. Fill a syringe with FC104 (both are supplied in the toolkit) and carefully insert this into the cell. Do not overfill - leave a small air space for expansion.

4. Refit the filler plug and secure.

5. Inspect the surfaces of the crystal for laser damage and the anti-reflection coatings of the windows for dirt and damage and then replace the cell. If this is done carefully, no adjustment or re-alignment should be necessary.

10. SPATIAL FILTER ALIGNMENT (NOT HLS2)

All systems are fitted with a spatial filter after the oscillator to remove unwanted perturbations from the beam profile and to produce a gaussian distribution without the need for an extended beam path between the oscillator and amplifier. The focal length of the input lens is chosen to allow the natural beam divergence produced by the spatial filter to fill the following amplifier(s) without the need for subsequent beam expanding optics. For alignment of the spatial filter on the HLS2, refer to Section 11.

1. Inspect the pinhole for cleanliness and circularity, preferably using a microscope.

2. Fix a piece of burn paper about one metre from the laser and make a burn with 30-40 mJ Q-switched operation. Adjust the rear screws on the gas laser to centre its beam on the burn spot, the front screws to centre the beam on the laser aperture, and repeating these adjustments as necessary.

3. Mount the pinhole in its holder to the second fixed plate following the oscillator.

4. Mount the lens in its centering mount to the first fixed plate after the oscillator. Adjust the x-y position of the lens until the gas laser beam is focussed centrally through the diamond pinhole.

5. Adjust the x-y position of the lens to obtain maximum FQ mode output through the spatial filter, as indicated by an energy monitor. Note: up to 20% loss of energy through the spatial filter is not uncommon.

6. Check the output beam quality with burn pattern. Make fine adjustments to the x-y position of the lens to obtain an even and truly circular beam profile.

7. Switch on the Pockels cell and check the output energy and beam profile for Q-switched operation at about 35 mJ at the oscillator output mirror. Because of slight differences in beam geometry for Q-switched instead of fixed-Q operation, it may be necessary to make final slight adjustments to the spatial filter lens, but note that a Q-switched pulse must never be fired at the pinhole until careful adjustments under fixed-Q conditions have been made, for if more than 50% of the Q-switched beam is intercepted, damage to the diamond can result.

8. Record the spatial filter lens centering mount micrometer settings.

11. AMPLIFIER ALIGNMENT

All holographic lasers fitted with amplifiers have two turning mirrors and it is essential that these are clean and damage-free, since even a small imperfection can degrade the quality of the beam into the amplifiers. If there is any doubt about their condition, they should be inspected before starting the amplifier alignment procedure.

To gain access to a turning mirror, undo the four screws at the corners of the top plate, which allows this, complete with the mirror assembly, to be withdrawn from the protective housing. The actual mirror is glued to its immediate mounting bracket and this complete subassembly should be replaced, as necessary.

11.1. HLS2 Amplifier Alignment

1. Fit the two 45 degree incidence beam steering mirrors in their mounts at the rear end of the laser rail.

2. Mount a HeNe gas laser to the port in the endplate behind the second turning mirror.

3. Using the alignment card, adjust the front alignment screws of the gas laser until the beam is on the 50/60 axis near to the second 45^{o} mirror.

4. Adjust the rear alignment screws to centre the gas laser beam in the output end of the amplifier rod. The beam should be 8 mm to the outside of the 50/60 axis.

5. Repeat Steps 3 and 4 until no further improvement is seen.

6. Fire the oscillator and take burn patterns just beyond the second 45 degree mirror. Adjust the first mirror until the burns are exactly coincident with the gas laser beam.

7. Make burn patterns at the input to the amplifier pumping chamber, and adjust the second turning mirror until the burns are coincident with the gas laser.

8. Repeat Steps 6 and 7, until no further improvement is seen.

9. Inspect the spatial filter pinhole for cleanliness and circularity, preferably using a microscope, place it in its mount and adjust its x-y position to centre it on the gas laser beam.

10. Place the spatial filter lens in its holder between the second turning mirror and the pinhole. Adjust the x-y position of the lens until the gas laser beam is again centered on the pinhole.

11. Switch off the Pockels cell and monitor the laser fixed-Q output after the spatial filter. Adjust the spatial filter lens to obtain maximum output.

12. Switch on the Pockels cell and remove the monitor. Make fine adjustments to the x-y position of the spatial filter lens to give completely round and even burn patterns at the input to the amplifier pumping chamber for a Q-switched pulse of about 35 mJ at the oscillator output mirror, but observe the warnings under Instruction 7 of Section 10.

13. The oscillator-amplifier combination may now be fired. Starting with the oscillator operating at 30-35 mJ single pulse, and a low amplifier voltage, progressively increase the amplifier gain. It may be necessary to adjust the spatial filter to centre the beam in the amplifier rod and obtain the most symmetrical and even burn pattern: this should be done with great care. Note that, to a first approximation, the filter will remain correctly set for optimum transmission if the micrometers centering the lens and the pinhole are each adjusted by the same amount.

14. Record the micrometer settings for the centering mounts of both the pinhole and the lens.

11.2. HLS3 Amplifier Alignment

1. Fit the two 45 degree incidence beam steering mirrors in their mounts at the rear end of the laser rail.

2. Mount a HeNe gas laser to the port in the end plate behind the second turning mirror.

3. Using the alignment card, adjust the front alignment screws of the gas laser until the beam is on the 50/60 axis near to the second 45 degree mirror.

4. Adjust the rear alignment screws to centre the gas laser beam in the output end of the main amplifier rod. The beam should be 8 mm to the outside of the 50/60 axis.

5. Repeat Steps 3 and 4 until no further improvement is seen.

6. Fire the oscillator and take burn patterns just beyond the second 45 degree mirror. Adjust the first mirror until the burns are exactly coincident with the gas laser beam.

7. Make burn patterns at the input to the main amplifier pumping chamber. Adjust the second turning mirror until the burns are coincident with the gas laser.

8. Repeat Steps 6 and 7 until no further improvement is seen.

9. The complete laser may now be fired, starting with the oscillator operating at 30-35 mJ single pulse, and a low amplifier voltage.

10. Progressively increase the amplifier gain, adjusting the turning mirrors to centre the beam in both the pre-amplifier and amplifier rods and obtain the most symmetrical and even burn pattern.

12. HOLOCAMERA ALIGNMENT

The HLS2 and 3 lasers may be supplied in a modified format as complete holocameras, and whilst the basic lasers are unchanged technically, the new layout and the additional components mean that a new setting up procedure is needed.

1. The oscillator has a standard layout but the beam emerges in the opposite direction along the rail. It may be aligned by the internal HeNe, using mirrors e and f to steer the HeNe beam, or by an external HeNe, as preferred: refer to the layout in the Operator's Manual.

2. Follow the procedure for testing an HLS2 or 3, as appropriate, centering the beam on the spatial filter pinhole, using turning mirror b, and on the optical axis just after mirror b, using mirror a. Note that the mount for mirror b has a tube fitted, to hold the photodiode assembly.

3. Fit the prisms. Note that the fixed prism mounting plate is wedged 3^{0}, and the front edge of this is set perpendicular to the 50/60 axis whilst the prism hypotenuse face is parallel with the rear edge, ie at 87^{0} to the beam.

4. Fit and align turning mirrors e and g such that the HeNe beam is on the 50/60 axis just beyond mirror c and centred on a burn pattern 1-2 metres from the laser output.

5. Fit the beamsplitter into its mount with the uncoated surface facing the amplifier. Rotate the beamsplitter to centre the beam vertically on the filters and clamp the mount in position to centre the beam horizontally on the filters and perpendicular to the rail axis. Note that the broad side of the wedge should be towards the centre of the holocamera base.

6. Fit the reference beam 45^{0} dielectric mirror such that the gas laser beam is positioned centrally on it and is collinear with the rail axis and centred horizontally in the first moving prism. Adjust the first prism such that the return beam is parallel to the incident beam. Ensure that the position of the beam on the fixed prism is constant as the moving prisms are translated along the rail.

7. Adjust the fixed prism to centre the beam vertically at the reference beam exit port and adjust the second moving prism, such that the beam leaving it is parallel to the beam incident on it.

8. To centre the beam horizontally in the reference beam output port, translate the reference beam turning mirror in a direction perpendicular to the rail axis. Note that this is difficult to do without affecting the tilt of the mirror, which must be checked and reset as necessary.

9. Make fine adjustments to all elements to ensure that the HeNe beam is optimally centred in the reference beam output port throughout the entire travel of the moving prisms. Fire the ruby laser and make any further fine adjustments as required.

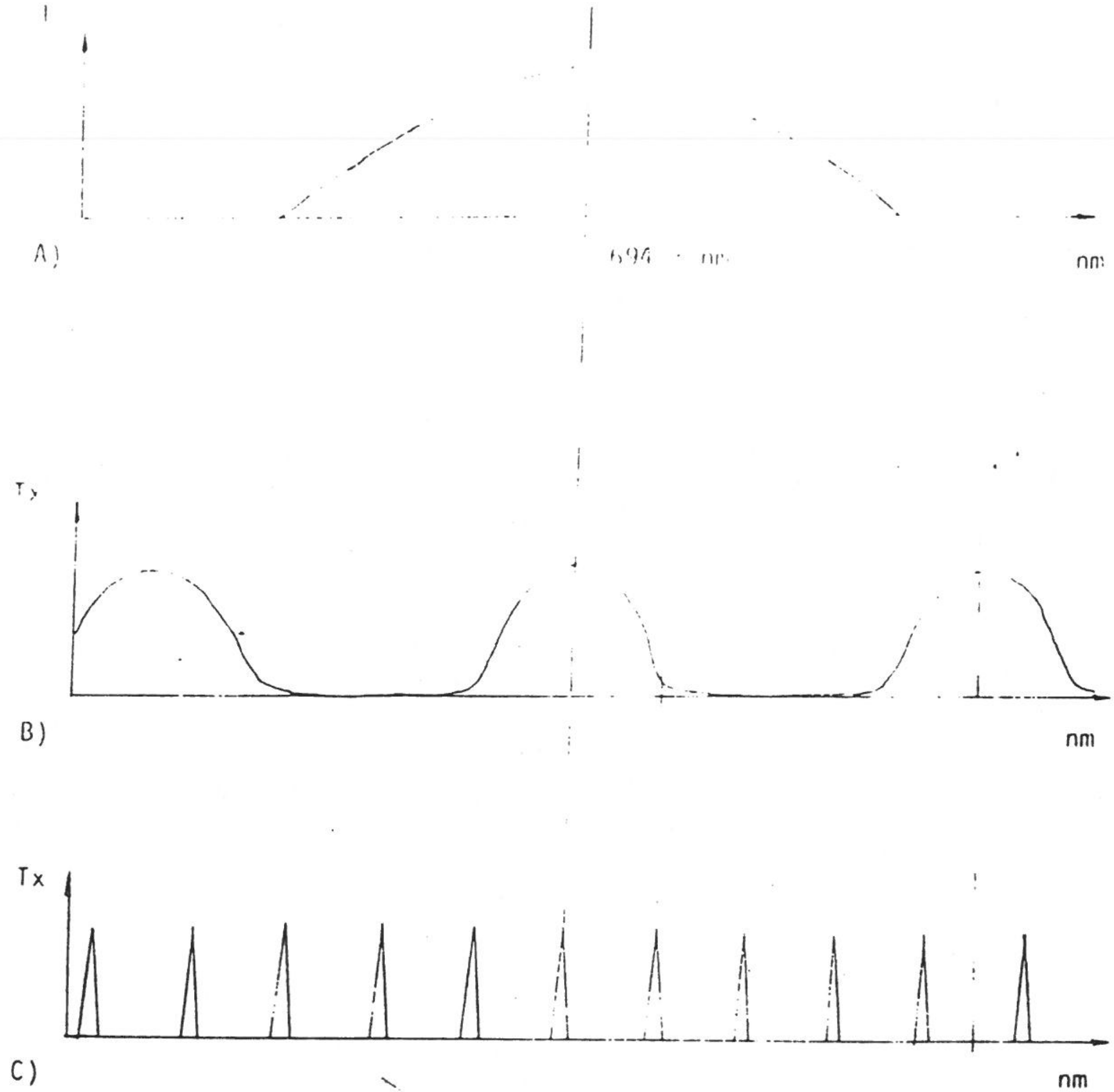
10. Fit the energy monitor diode and adjust its position so that the beam from the AR (back) surface of the beamsplitter falls centrally on the 19 mm ceramic diffuser.

11. Fit the main beam expanding lens in its holder such that the plano face of the lens is towards the laser. Adjust the x-y position of the lens to be central on the HeNe beam. Fire the ruby laser and make any further small adjustments to centre the beam in the lens.

    (NB: This lens is not intended to steer the beam: the centering mount is to centre the lens on the beam.)

12. Fit the plate holder and reference beam outrigger mirror assembly. Adjust the reference beam steering mirror in this assembly to centre the reference beam on the plateholder.

13. The alignment is now complete, and test holograms should be taken at representative pulse separations, to check for satisfactory coherence length and freedom from contouring. The reference beam intensity at the plateholder should be 2-4 times that of the main beam reflection intensity from the chosen object, and this ratio is checked by using the energy monitor photodiode. Firstly, the reference beam is blocked off by closing the tube cover plate and the photodiode is held in front of the plateholder. Then the reference beam outrigger mirror is uncovered again, the photodiode is pointed towards it and the intensity adjusted by selection of the appropriate filters.



A) Spectral output of ruby laser without mode selection.

B) Transmission characteristic of 2.25 mm etalon.

C) Transmission characteristic of 10 mm etalon

FIGURE 8.1: ETALON TUNING

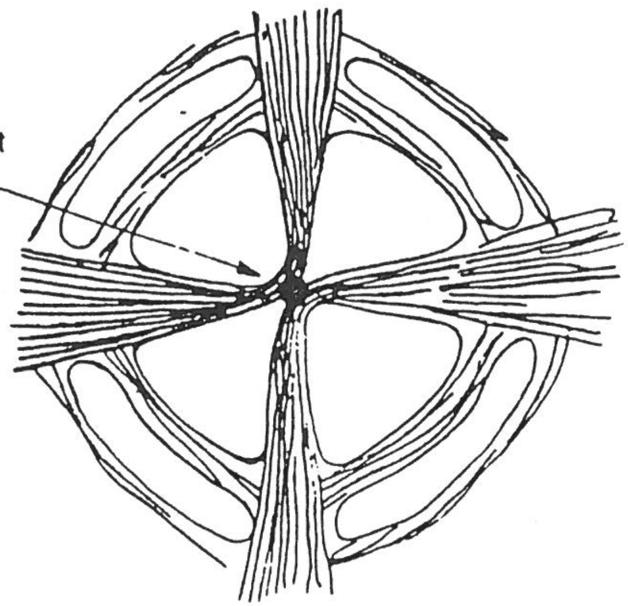


Fig. 9.1 PATTERN OBTAINED WITH CORRECTLY ALIGNED POCKELS CELL

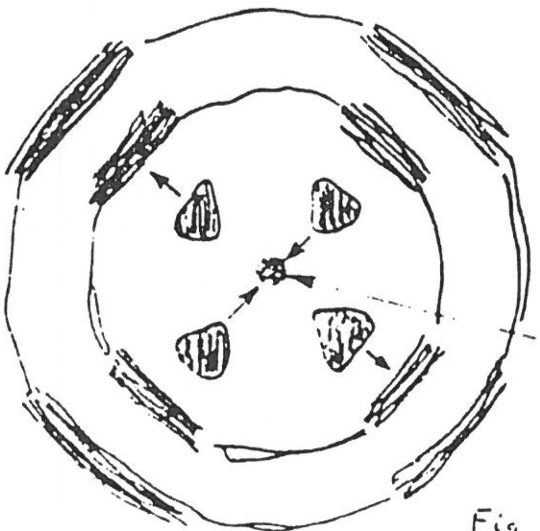


Fig 9.2

Fig 9.3

PATTERNS OBTAINED WITH CORRECTLY ROTATED POCKELS CELL

40. THE COOLING SYSTEM

40.1 INTRODUCTION

All laser cooling systems are indirect. They consist of a closed circuit incorporating the laser head pumping chamber(s) round which the primary cooling fluid is circulated, the heat from this circuit being transferred either to mains or refrigerated water or to air.

The cooling unit is self-contained and is connected to the laser head by polyurethane hoses. Electrical connections are made by plug and socket and (except on high power systems) self-sealing couplings are fitted in both the feed and return lines so that the unit can easily be removed. The coolant connections are separated by drawing back the sleeve surrounding one half of the coupling until they spring apart.

A pressure or flow switch in the primary circuit form a link in the power supply interlock system so that the laser cannot be operated with insufficient coolant flow.

Two washers are supplied for the reservoir filling cap. One is a sealing washer which should always be fitted when the unit is being moved. The other provides venting for the reservoir and must be fitted in place of the sealing washer when the laser is to be operated. (Except for 6/12kW cooler).

40.2 GENERAL COOLING REQUIREMENTS AND PRECAUTIONS

The laser primary coolant must be at a temperature above the prevailing dewpoint to avoid the risk of condensation on the laser rod faces. This is not generally a problem, but should be considered when operating in humid or cold ambient conditions, or when the laser system has been moved from a cold to a warm area. Other requirements depend on the type of heat exchanger (see subsequent sections) and on the laser rod material.

Ruby

Ruby is quite sensitive to variations in temperature, its lasing efficiency rising with a reduction in temperature. So, with regard to the precautions outlined above, the coolant temperature is generally controlled at approximately 20^{o}C. The cooling medium used is distilled water.

Neodymium

Both glass and YAG rods are insensitive to temperature variations, but avoidance of low temperatures is again necessary. The upper limit in the case of air cooled high power YAG systems is generally set by a temperature sensor mounted on the end block of the pumping chamber which trips at about 35^{o}. In contrast with ruby, the UV end of the spectrum plays little useful part in pumping neodymium. For this reason, the cooling fluid used with glass and YAG systems is generally an 8% solution by weight of sodium nitrite in distilled water, as this absorbs much of the UV pump light and thus reduces the heating of the rod.

The exceptions to this rule are:

1) where neodymium and ruby rods are used interchangeably in the same system.
2) 6/12 kW coolers, as used with high power welding systems.

In these cases, plain distilled water must be used.

40.3 THE LIQUID TO WATER HEAT EXCHANGER

40.3.1 Mains Water Cooling

The cooling system is shown schematically in fig. 40A.

The primary circuit comprises the pumping chamber(s), the coolant reservoir, circulating pump and pressure sensing switch. The laser coolant temperature is controlled by passing cold water through a stainless steel cooling coil immersed in the reservoir. The flow rate of the mains water is controlled by a thermostatic valve actuated by a sensor which monitors laser coolant temperature. The equilibrium temperature of the laser coolant is set by means of the thermostat control protruding from the fascia of the cooling unit*. The higher the setting on the scale, the higher the set temperature. Coolant temperature is displayed by the gauge on the opposite side of the panel. The control is set at the factory and normally only requires adjustment if the mains water is too warm to accept heat from the laser coolant at the set temperature causing the valve to remain permanently fully open.

Ideally the set temperature should also be below ambient temperature. If this is not the case, the thermostatic valve will remain closed until the temperature has been raised by external means to the point at which the valve starts to control. Normally a temperature which satisfies

* Inside the cooler cabinet in the case of 6/12kW systems.

these requirements will be found within the range 17-24°C.

40.3.2 Liquid to Water Heat Exchanger

The 6/12kW Cooler

The cooling system is shown schematically in figure 40B . The primary circuit comprises the pumping chamber, the coolant reservoir, heat exchanger unit, deioniser and filter set, flow switch and circulating (turbine) pump. The laser coolant is continuously drawn from the tank by the pump, passed through the deioniser-filter set to the pumping chamber, and back, through the stainless steel heat exchanger and flow switch, to the UPVC tank. The coolant used is distilled water.

The laser coolant temperature is controlled by passing mains water, via a thermostatic valve actuated by a sensor mounted in the coolant, through the heat exchanger. The equilibrium temperature of the laser coolant is set by means of the thermostatic control mounted inside the cabinet. The higher the scale setting the higher the set temperature. Coolant temperature is displayed by the front panel mounted guage. The control is set in the factory and adjustment is only usually necessary if the mains water temperature is above the valve set temperature causing the valve to remain permanently open. Ideally the set temperature should be below ambient temperature. If this is not the case, the thermostatic valve will remain closed until the temperature has been raised by external means to the point at which the valve starts to control. Normally a temperature which satisfies these requirements will be found within the range 17-24°C.

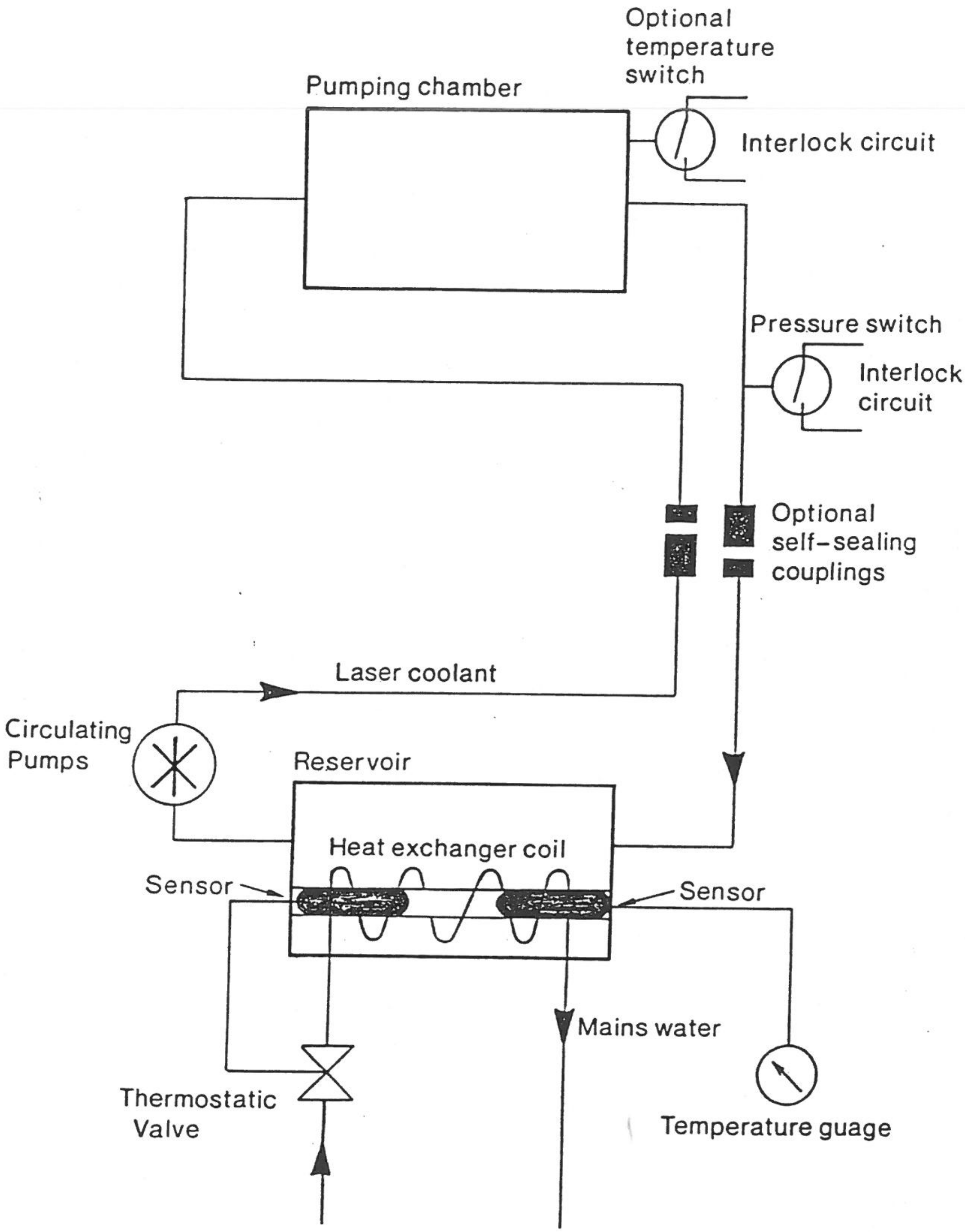
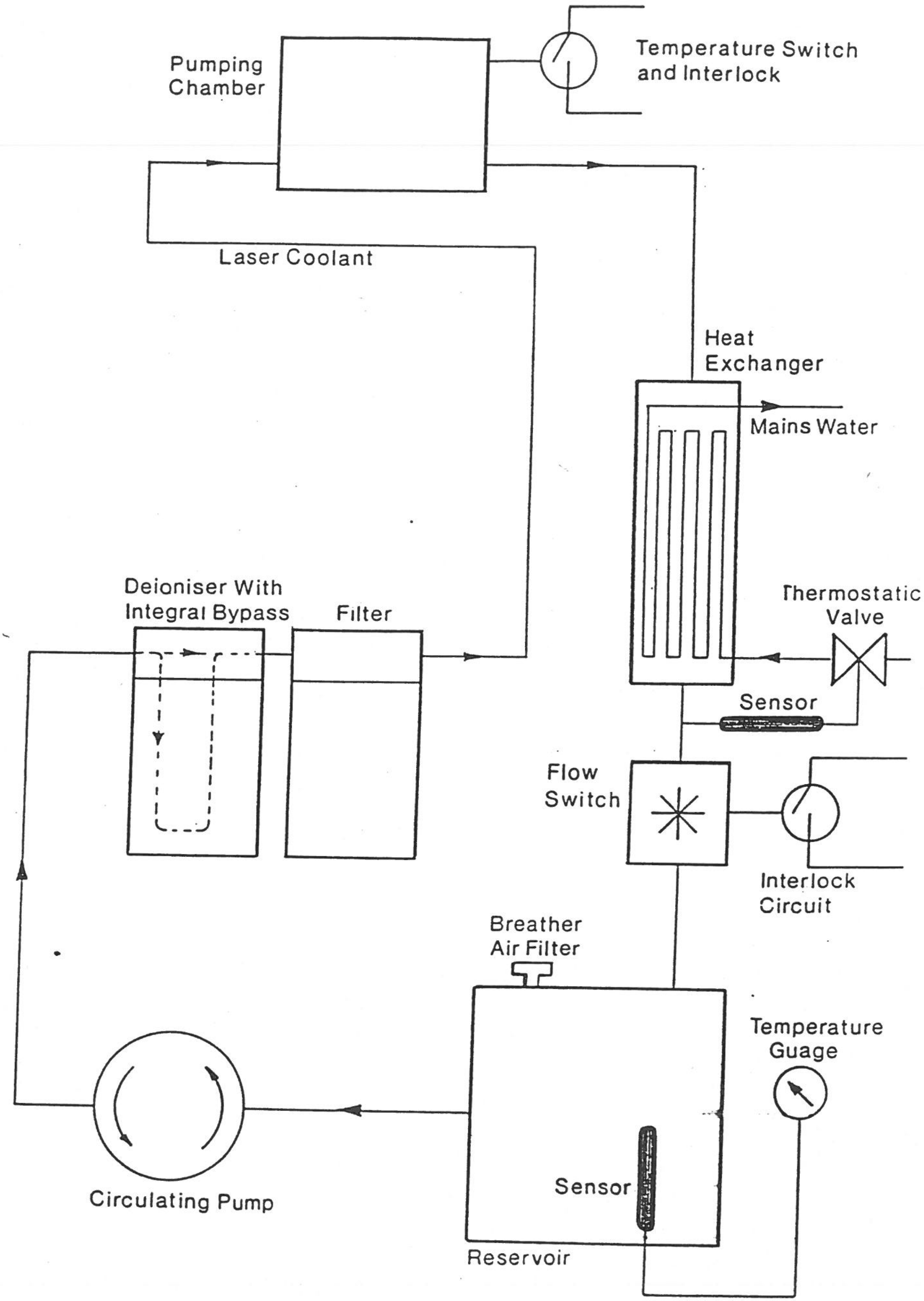


Fig. 40A LIQUID TO MAINS WATER COOLING SYSTEM


Pumping Chamber
Temperature Switch and Interlock
Laser Coolant
Heat Exchanger
Mains Water
Thermostatic Valve
Sensor
Deioniser With Integral Bypass
Filter
Flow Switch
Interlock Circuit
Breather Air Filter
Temperature Guage
Sensor
Circulating Pump
Reservoir

40.5 MAINTENANCE (NOT 6/12KW UNIT)

The cooling liquid for a laser system should remain optically clear at the pump band wavelengths at all times. To this end the materials and components of the cooling system have been carefully chosen to minimise the possibility of contamination.

However, depending on the frequency and conditions of operation, it may be necessary occasionally to change the cooling liquid and possibly clean the system. If a marked drop in output occurs, check the flashtubes first. If these are contaminated on the inside through electrode sputter, but are clean externally, then it is probably not a coolant problem, and lamp replacement is indicated if the desired laser output cannot be achieved with the available input pumping energy. The transparency of the coolant should be checked however and, if in doubt replaced first.

Note that the sodium nitrite solution usually used in neodymium systems is a pale yellow colour when fresh. The colour of the solution will deepen with the passage of time, but this is normal and tolerable as long as laser output does not suffer unduly.

If examination of the external surface of the lamps or the interior of the reservoir shows contamination, then the coolant will have to be changed.

40.5.1 Changing the Coolant

1) Drain pumping chamber(s) (section 4.1,4.2.1/4.3.1). Do not dismantle.

2) Disconnect laser coolant hoses and electrical supply from the cooling unit. Remove the four retaining screws at either side of the fascia panel and withdraw from its housing.

3) Remove the lid of the reservoir and empty out the coolant.

4) Thoroughly clean every surface inside the reservoir paying special attention to the corners and the coil fitted in liquid to water systems. Paper towel is ideal for the purpose.

5) Replace and secure flashtubes (section 4.2.3/4.3.3; 4.2.2/ 4.3.2).

6) Refill reservoir with clean water, temporarily replace lid, fit cooler in its housing and remake electrical and coolant connections.

7) Switch the coolant pump on and flush for a few minutes.

8) Repeat steps 1-3, 5.

9) Repeat step 6, but this time using clean water to which a small quantity (about 5ml) of Decon 90/Contrad has been added (suppliers of Decon 90/Contrad are listed at the end of this chapter). If this is not available, use

the same quantity of 'Domestos' or similar non-abrasive sodium hypochlorite-based batericide. Allow this to circulate for an hour or so if possible making sure it comes in contact with all internal surfaces of the reservoir.

10) Repeat steps 1-5.

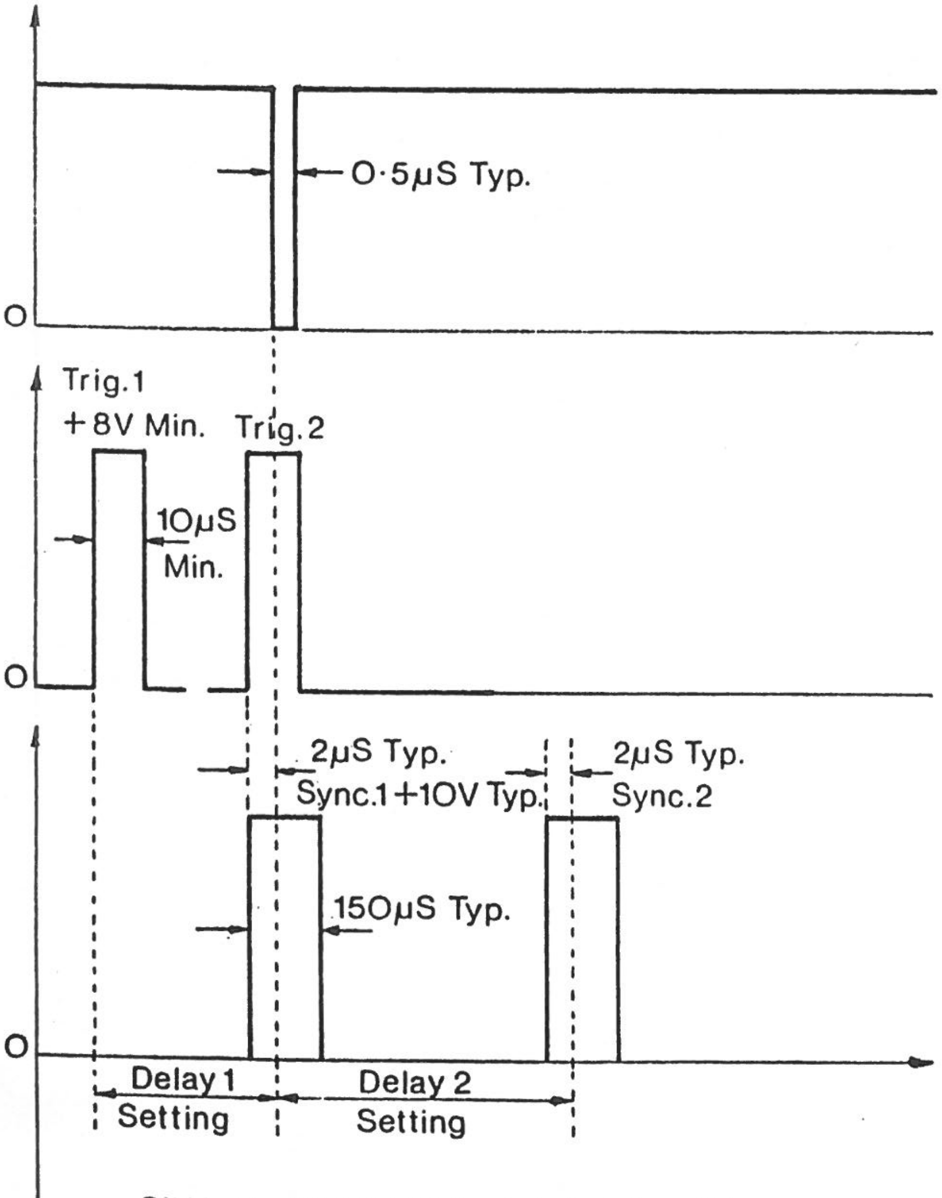
11) Repeat step 6, but this time using distilled water. Allow this to circulate for a few minutes.

12) Repeat steps 1-3, replace and secure flashtubes and connections (4.2.2/4.3.2).

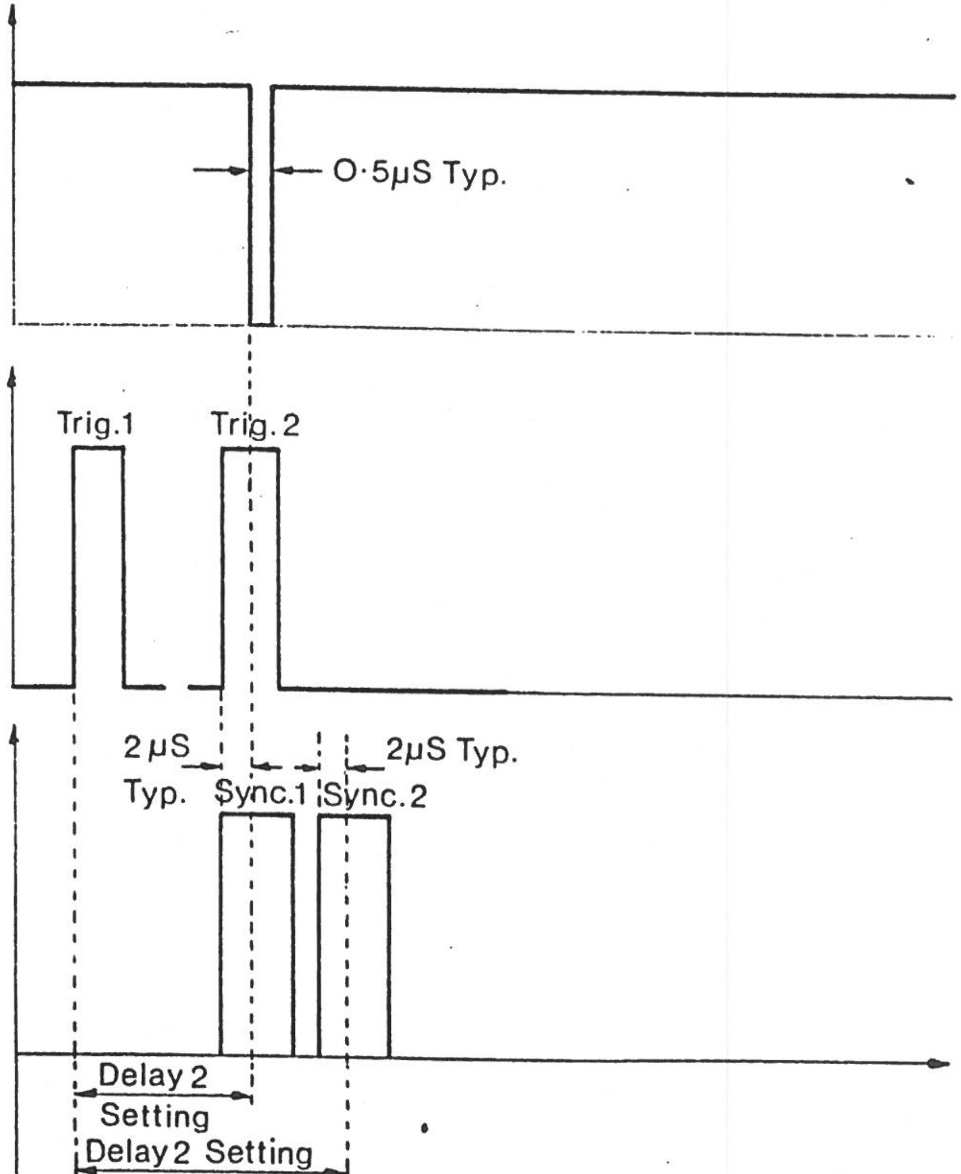
13) Refill with the correct coolant. Make sure that there is sufficient air space above the coolant in the reservoir to accomodate the coolant filling the rest of the system, so that it does not overflow when the pumping chamber are drained. 7 litres of coolant are required for the standard liquid to water system and 5 litres for the liquid to air unit. Fit reservoir lid and secure.

14) Refit cooler in its housing and remote electrical and coolant connections.

15) Switch on and check for leaks. The system is now ready for operation. Depending on the initial degree of contamination, the laser may perform with considerably greater efficiency; bear this in mind when setting the power supply controls.



SINGLE PULSE WITH SERIES DELAY



SINGLE PULSE WITH PARALLEL DELAY

Fig. 6B. POCKELS CELL DRIVER CHARACTERISTICS – contd.

N.B. Idealised pulse forms not to scale

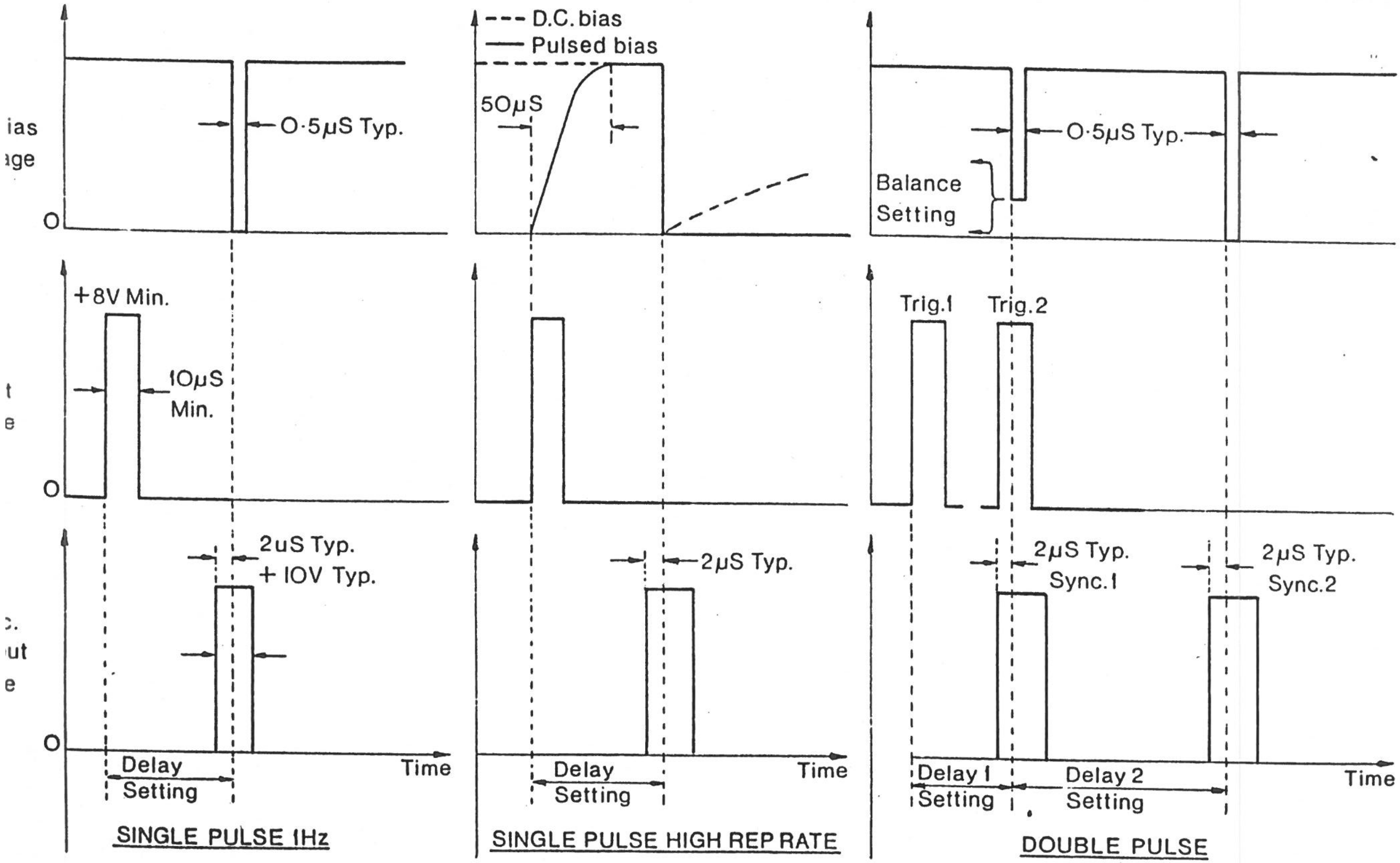


Fig. 6A. POCKELS CELL DRIVER CHARACTERISTICS

N.B. Idealised pulse forms: not to scale

APPENDIX B - System Control Settings

(For Laser Serial No: 9253)

In this appendix the final system control settings from factory testing are recorded. They provide a useful reference for both initial user operation of the system and subsequent changes to operating conditions as the components age or are replaced due to damage.

Pockels Cell Bias ....3.0........ kV

Energy Monitor Calibration

Oscillator ....100........ mJ/Volt

Filter ....5..........

Shoulder to Block ....0.......... mm

Amplifier ....200........ mJ/Volt

Filter(s) ....6..........

Shoulder to Block ....1.......... mm

Coolant Distilled Water

Coolant Temperature 20°C

Micrometer Settings (mm):	Top	Side
Thin Etalon (rear), when normal to beam	6405	6070
Thick Etalon (front), when normal to beam	5375	5600
Thin Etalon - Final Settings	5100	6070
Thick Etalon - Final Settings	5375	5150
Thin Etalon - HLS1, 1 Hz, Final Settings	-	-
Thick Etalon - HLS1, 1 Hz, Final Settings	-	-
Pockels Cell Settings	4450	8030
Spatial Filter Lens Settings	2230	0450
Spatial Filter Aperture Settings	2970	2120