

LF100 LASER AUTOFOCUS OPERATING MANUAL



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1. Important Safety Information

- Do not expose the product to water or moisture.
 - Do not expose the product to extreme hot or cold temperatures.
 - Do not expose the product to open flames.
 - Do not touch the glass plate fitted between the circular dovetail and the top plate. Any dust, dirt, fingerprints will cause degradation of image quality
 - Do not poke inside the open aperture in the base plate of the unit. There are delicate optical components which are easily damaged if touched.
 - **WARNING.** This unit emits visible laser light from the aperture in the base plate of the unit. The total continuous power does not exceed 1mW thus it falls into a **CLASS 2 Laser Product**. As such the user should not stare directly into the laser beam although the normal eye reflex response will offer protection. The laser power is less than most commercially available laser pointers sold in novelty shops.
 - **DANGER.** Under no circumstances unscrew the lid off the unit. The unit contains a **CLASS 3A visible laser diode** with a maximum continuous power of 5mW. This laser power is only accessible with the unit dismantled and should only be performed by Authorized Service Centers. Disassembly of the unit will void the warranty. This product does not contain consumer serviceable components.
 - Use only the proper type of power supply cord set (provided with the system) for this unit. Failure to do so could instantly destroy the electronics and laser diode. The unit requires **+12VDC at 3 amperes**.
 - Always switch off the unit using the on/off rocker switch **SW1** or unplug the power supply unit (**CON3**) when plugging/unplugging the stepper motor (**CON4**) or DIGIPOT (**CON2**). It is safe to plug/unplug the RS232 connector (**CON1**) with the unit powered.
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2. Product Description

The Prior Scientific Laser Auto Focus Module model LF100 is a very advanced and integrated unit which combines a low power visible laser diode, associated optical components and detectors, electronics with on-board micro controller and power output stage to micro step a focus stepper motor. It is a simple procedure to add the unit into the optical path of many of the popular laboratory microscopes using infinity corrected optics. Attach the Prior focus motor to the fine focus knob of the microscope and connect the motor to the Laser Focus module. The laser beam passes through the microscope objective on to the sample. The detection circuitry in the Module monitors the spot position on the sample and continuously servos the focus motor to maintain a stable focus position, thus assuring that optimum visual focus is maintained. The Laser Auto Focus Module is available in two models. The LF100L (Line) model is better suited for samples with detailed features such as, patterned wafers or metallurgical samples. The LF100S (Spot) model is ideal for highly polished specimens with less detailed features such as bare wafers.

Optimizing the LF100 to maintain a stable visual focus requires connecting the RS232 serial port of the module to a PC and running Hyperterminal software.

Once the system has been configured then the LF100K keypad allows fully stand alone operation. The Micro Controller built into LF100 allows the unit to act as an intelligent motorized focus controller in addition to its primary task of automatic focus control. The SERVO action can be disabled and manual focus achieved using the integral rotary digipot. Remote focus control can be implemented by connecting the RS232 communication port of the unit to a host PC. Focus positioning can be achieved in incremental steps of 0.1 microns (depending on fine focus mechanism of the microscope).

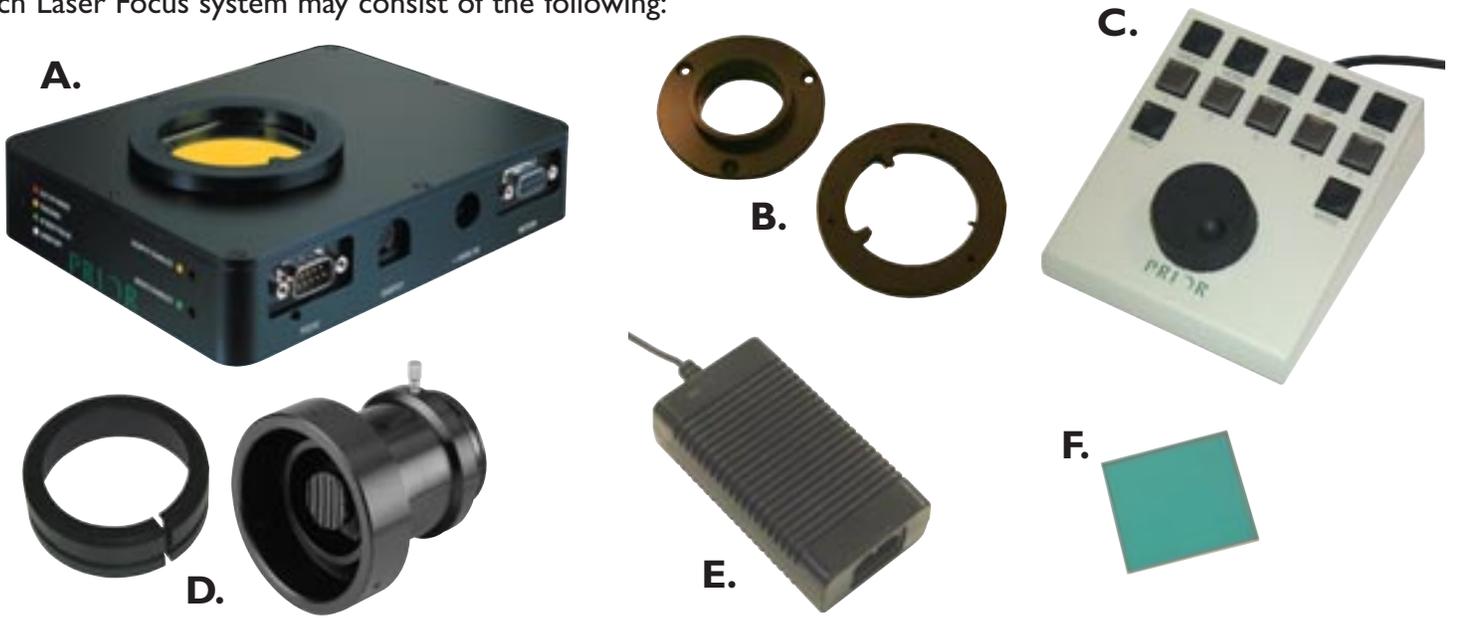
The 2 essential requirements required for correct operation of LF100 are as follows:

- Microscope must have infinity corrected optics (Infinity corrected objectives used in conjunction with tube lens.
- It must be possible to insert LF100 in the collimated region of the microscope optics. This is the region between the objectives and the tube lens.



3. Unpacking the System

Each Laser Focus system may consist of the following:



Component	Component Description
A	Model LF100 Laser Focus Module (Line or Spot)
B	Appropriate set (top/bottom) of dovetail flanges for a particular make/model of microscope. (See Below)
C	Model LF100K Control Pad (optional)
D	Model HI22 Focus Drive with correct clamping ring (see below)
E	Model WI726 desktop universal Power Supply Unit +12 VDC at 35V A.
F	W2753 Short Pass Filter

DOVETAIL FLANGES:

These come as a pair and will be factory fitted to the top/bottom halves of the LF100 unit to fit the correct microscope manufacturer/model number. Flanges will be mounted onto microscope. The part numbers are as follows:

Flange Part Number	To Fit Microscope
LF310	Leica DMLM
LF320	Nikon I50
LF330	Olympus BH
LF335	Olympus BX
LF340	Zeiss
LF350	Mitutoyo FSI 10
Other models available. Check with Prior Dealer	



Flanges for other microscopes are available. Please contact Prior Scientific Instruments for details.

FOCUS CLAMPING RING:

These fit within the H122 Focus adapter and are made to clamp over the coarse focus knob of the particular microscope. The part numbers are as follows:

Focus Sleeve Part Number	To Fit Coarse Focus Knob of Microscope
H122LB	Leica DMLM
H556	Nikon I50
H551	Olympus BH
H807	Olympus BX
Check With Prior For Zeiss Model Number	Zeiss
H557	Mitutoyo FS110

Focus Sleeve



Note: Make sure that all of the components that should be included with your LF100 System have been supplied. If parts are missing please contact your local Prior Dealer.

Take great care when unpacking the LF100 Unit. In particular, do not touch the glass plate in the lid of the unit or poke any object up the aperture in the base. This could cause catastrophic failure of the unit or significant loss of performance.

SHORT PASS FILTER:

The Short Pass Filter mounts in the top cover of the laser focus module. The filter blocks the 670 nm laser light from reaching the eyepieces. It may be necessary to remove the filter during the set up procedure.



4. Installation

MECHANICAL INSTALLATION OF LF100

- Installing the LF100 Unit onto the microscope is quite simple. Some microscope have a detachable incident illuminator placed between the nosepiece and the binocular head, Other manufacturers have the incident illuminator integral with the nosepiece (i.e. they cannot be separated.)
- In the case of the detachable incident illuminator design remove the binocular/illuminator from the nosepiece using the Allen (hex) key provided by the microscope manufacturer. Fit the Laser Focus between the binocular/illuminator and the nosepiece using the same Allen (hex) key. Before tightening up the LF100 onto the nosepiece ensure that the front of the unit faces the front of the microscope. Ensure that the dovetail fittings are secure. If the dovetail fittings do not fit then check the part numbers for the dovetail fittings (Chapter 3). When the illuminator is not detachable the LF100 unit has to be placed between the binocular head and the illuminator/nosepiece. In this instance remove the binocular head and insert LF100 between binocular head and illuminator/nosepiece. Using a 1.5mm Allen (hex) key tighten flanges.
- It is preferable to place the LF100 unit between the illuminator and the nosepiece due to the fact that the laser light does not then pass through the illuminator beam splitter with a resultant attenuation in the detected signal. The LF100 unit must be placed between parallel beams of light, ideally between the objectives and tube light. Typically therefore LF100 will receive stronger reflected light in this configuration (for a given surface reflectivity).



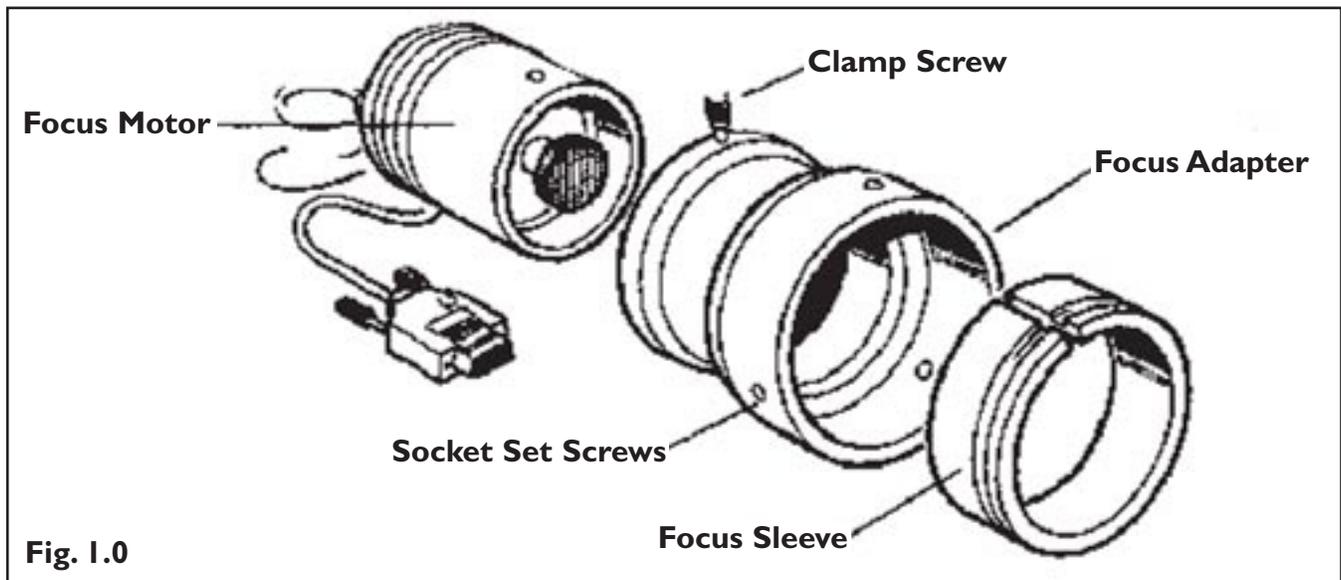
MECHANICAL INSTALLATION OF H122 FOCUS MOTOR

Loosen the clamp screw on the focus motor assembly and remove the focus motor from the focus adapter. (See fig.1.0)

- Loosen the 3 socket set screws around the periphery of the focus adapter using a 2mm Allen wrench until the focus sleeve is able to fit inside the adapter. Note that it is important to insert the sleeve in the correct orientation with the lip furthest inside the adapter (the chamfered edge of the sleeve will be inserted first). Note the orientation of the sleeve as it has a recess around its outer surface, which will hold the sleeve in when the set screws are tightened. This recess must line up with the tips of the socket set screws. (See fig.1.0).
 - With the sleeve in place, tighten the 3 socket set screws in sequence until they all just touch the sleeve, ensuring that the split in the sleeve does not line up with any of the set screw positions. **DO NOT TIGHTEN UP ANY OF THE SET SCREWS AT THIS STAGE.**
 - Push the adapter onto the preferred coarse knob of the microscope as far as it will go. The preferred side is normally the left side of the microscope (as viewed by the operator) since H122 will then not interfere with the drop down controls of the stage which are often down the right side of the microscope. The inside fitting diameter of the sleeve is designed to be slightly larger than the coarse knob, provided the set screws have not been tightened and are compressing the sleeve.
 - While holding the adapter in place, tighten the set screws in sequence only enough to secure the unit onto the coarse focus knob. The focus knob will have to be rotated to gain access to all of the screws.
-

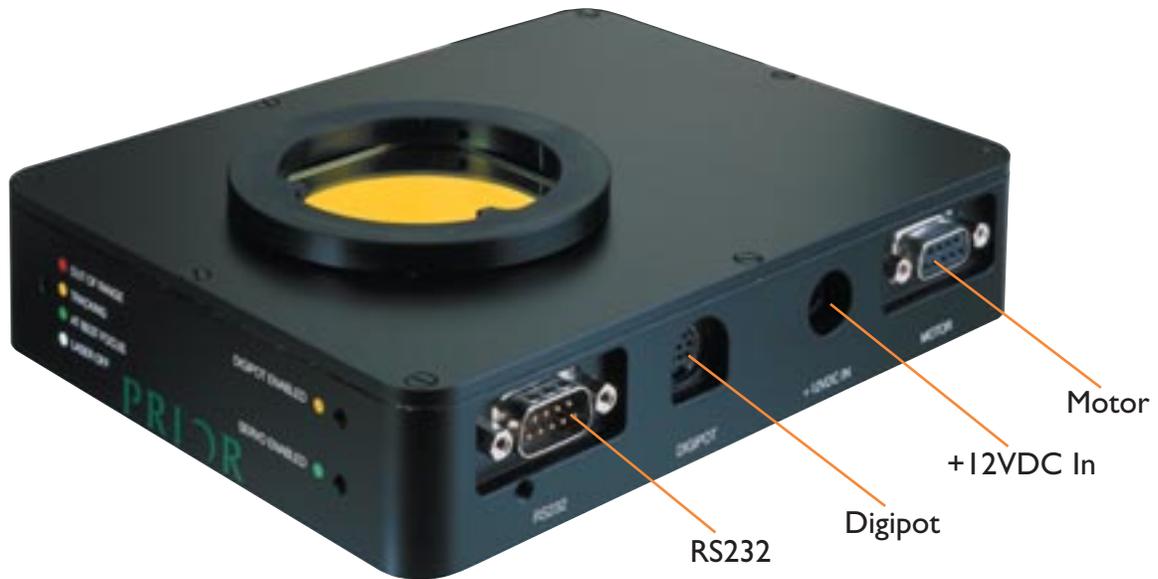
MECHANICAL INSTALLATION OF H122 FOCUS MOTOR (CONT'D)

- Check that the unit has been tightened sufficiently by taking hold of it and turning it. If the adapter is correctly fitted it will stay attached to the coarse knob.



- Slide the focus motor into the adapter as far as it will go and while applying gentle pressure to the motor tighten the clamp screw. This will hold the motor in place. The rubber drive bush on the end of the motor spindle should now be pressing against the end surface of the fine focus control knob. This can be confirmed by manually rotating the exposed fine focus knob on the opposite side of the microscope and feeling for the resistance caused by the detent positions of the stepper motor as it rotates. Rotating the motor in this manner will not cause any damage to the focus motor.
-

ELECTRICAL INSTALLATION OF LF100:



1. Ensure that the W1726 Power Supply Unit is not yet plugged into the wall power outlet and that the rocker switch on LF100 is off.
 2. Plug the 9 way D-Type plug of the H122 focus motor into the socket of LF100 marked MOTOR.
 3. Plug the 8 way MiniDin plug of LF100K Control pad (optional accessory) into the socket marked Digipot
 4. Plug a lead from RS232 port of a PC into socket marked RS232. The other end of this cable (standard with Kit H276) should be plugged into an RS232 Com port of a PC (running Windows 95/98/2000).
 5. Plug the 2.5mm connector of the +12V Power Supply Unit into the socket marked +12V DC IN
 6. Plug the main power cord of the Power Supply Unit into the wall power outlet.
 7. Switch unit on using the rocker switch.
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5. Getting Started

Remove one of the objectives or go to an empty nosepiece position.

Manually move the stage a reasonable distance (5-10mm) from the objective using the coarse focus. (It is safe to manually rotate the HI22 focus drive housing.)

Switch on the unit using the rocker switch. **Be prepared to switch back off immediately in the unlikely event that the focus motor immediately begins moving the focus rapidly towards the objective.**

The unit should not cause the focus motor to rotate. The LED marked Digipot enabled should be on. This confirms power is now applied to the unit.



Rotate the digipot. The focus motor should mimic the rotation (i.e. speed and direction) of the digipot. If this is not the case, then undo the focus motor from the focus adapter to see whether the motor itself rotates. If the motor is not responding to the digipot then see Chapter 9 (Troubleshooting).

Confirm that UP/DOWN buttons work. When pushing the UP button the sample should move closer to the objective, if not, please do one of the following:

1. Move focus motor to opposite side of microscope.
2. The LF100 can be configured to reverse its direction electronically. This can be done by sending the ZD,1 or ZD,-1 command along the RS232. This new configuration is permanently saved (even after a power cycle) See instructions to use Windows Hyperterminal utility to enable RS232 commands to be sent to unit.

The unit's default setting for direction of rotation for the HI22 focus drive fitted to the left side of microscope (as viewed by the user from the front) is for the UP button to rotate the fine focus clockwise (as viewing the fine focus knob on the right of the microscope).

Place a white card on the stage under the objective (e.g. a business card). Switch the LF100 on. Observe the red light falling on the card. Switch on the incident illuminator of the microscope and adjust the intensity such that it shows the aperture of the objective but not too bright to wash out the red laser light. Correct alignment of the laser beam should show the red light in the center of the illuminated circle. The line should be at 45 degrees. The elliptical laser beam should have one end of the ellipse at or very close to the optical axis of the objective (centre of the aperture). Use ADJ1 and/or ADJ2 to achieve correct alignment.

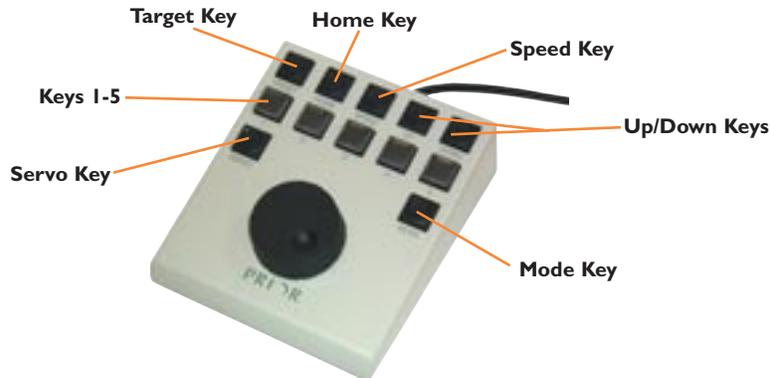
Turn off the LF100 using the rocker switch in order to power off the laser beam.

The unit is now ready to operate. Some optimization of its settings will be necessary to suit users requirements.

6. LF100K Keypad and Digipot

USING THE KEYPAD (LF100K)

Check that the LF100K Keypad is plugged into the Digipot input of the Laser Focus Module LF100. Turn on the LF100 and place a typical sample on stage. The Keyboard allows for standalone operation of the system. The basic functions it offers are as follows:



- Rotary digipot offers remote motorized operation of the fine focus of the microscope when SERVO key is not active
- Allows optimum servo response for any magnification using Objective Select keys labeled 1 to 5.
- Allows set up capability such as TOP and BOTTOM software limits HOME and TARGET positions.
- Allows for rapid UP and DOWN movements.

Assuming that the LF100 has been installed as per Chapter 4 then follow the following procedure: (Procedures 1-4 are optional)

1. Write the objective magnification on the buttons marked 1-5 by removing the clear plastic button tops. The buttons have clear plastic snap in tops with white inserts. It is suggest that the lowest magnification is the lowest number button eg. x5, x10, x20, x50, x100 are buttons 1, 2, 3, 4 and 5.
2. Start by rotating the nosepiece until the lowest power objective is in place. Press the key corresponding to this magnification. This now will associate all subsequent settings to this objective.
3. Use the Rotary digipot move the stage to achieve best focus. Continue to move the stage up through the focus to the minimum safe gap between sample and objective. Press MODE then UP buttons (MODE+UP) This records the highest position the motor will move the stage.
4. Use the rotary digipot to move the stage down through best focus. Continue to move the stage down until the largest gap required between objective and sample is achieved.. Press MODE+DOWN to record the lowest position the motor will move the stage.
5. Use the rotary digipot to move the stage back up to best focus. Use MODE+SPEED to set the Absolute Z position of the Module to zero. This is not absolutely essential but may prove useful if Absolute Position is read in future by a host p.c. (see chapter 7 - RS232 Commands).
6. Without moving stage press TARGET. This establishes this as the target best focus the module will servo to. It is not the target Z position since this will change with stage movement for a sample with differing height or with tilt.

USING THE KEYPAD (LF100K) (CONT'D)

7. The initial set up for objective 1 is now complete. Further configuration (electrical servo gain “KP” and damping “KD”) will need to be done connecting the module to a PC using the RS232 port (see chapter 7).
8. Use the rotary digipot to move the focus slightly away from best focus. Press the SERVO key. The Servo enabled LED on the front of LF100 should light red. The focus motor should rotate to bring the image back to best focus and then stop. *(Be prepared to turn SERVO off by pressing the SERVO button again, should the motor not stop at best focus. If this should happen see Chapter 9 Troubleshooting).*

FIRST TIME SET UP FOR EACH OBJECTIVE

1. Put on lowest power objective. Rotate nosepiece to objective being configured.
2. Press the corresponding # (1-5) on keypad for the objective chosen.
3. Focus on sample.
4. Push TARGET button
5. Move focus slightly away with digipot.
6. Press SERVO button.
7. Observe system reaction:
 - If the focus reacts slowly, the control variables KP and KD need to be increased
 - If focus oscillates, KP and KD need to be decreased(KP and KD are read via the RS232 link to a PC running Hyperterminal. Type KP and press ENTER to read KP value. Type KP, 200 and press ENTER, changes KP to 200.) KD is changed in a similar manner.

TYPICAL KP AND KD VALUES FOR VARIOUS OBJECTIVES		
Objective	KP	KD
5X	1000	40
10X	500	40
20X	100	30
50X	20	6
80X	15	4
100X	7	2

DIGIPOT KEY FUNCTIONS:

The table below describes the function of each key.

Note that MODE+KEY works as follows:

- A. Press MODE key. LED will flash indicating its active.
- B. Release MODE key then press appropriate key.
- C. This completes the action. Note that the MODE key then becomes inactive (indicated by its led going out)

The exception to this operation of MODE/UP and MODE/DOWN which increases/decreases buzzer volume respectively. Here MODE key is kept pressed while repetitively pressing UP/DOWN key MODE key is cancelled afterwards by pressing it again.

I to 5	Selects the optimum parameters for the particular objective. The following parameters are associated with each objective and are normally pre set using the RS232 communication with p.c. and/or using keystrokes with the MODE key (see below). The pre set parameters for each objective are TARGET, KP, KD, MIN, DEAD (see RS232 Commands).
SERVO	Switches on and off the SERVO or Auto Focus function. LED is lit when SERVO is active. Switching SERVO off enables the Digipot. The LF100 will also then function as an intelligent motorized focus drive controlled using commands sent along the RS232 connection (if fitted to a PC.) SERVO/DIGIPOT mode of LF200 is also indicated by the LED's on the front of LF100.
UP	With unit in DIGIPOT mode holding UP button will cause focus to move up continuously at a speed set by the SPEED button.
DOWN	With unit in DIGIPOT mode holding DOWN button will cause focus to move down continuously at a speed set by the SPEED button.
SPEED	With unit in DIGIPOT MODE each successive momentary depression of this button will cycle the speed at which the focus moves using UP/DOWN buttons or Digipot through 100%/25%/50%. The preferred setting is stored even through a power cycle. This button will change the speed setting whether motor is moving (using UP/DOWN/DIGIPOT) or stationary. The unit must however be in DIGIPOT MODE.
HOME	Moves stage to a preset HOME position.
TARGET	Using the digipot to establish best visual focus and then pressing this key will set the present position focus as the focus which will be maintained during SERVO action for the current objective.
MODE + HOME	This establishes the current position to be the HOME position. Future use of HOME key on its own will move the focus to this position.
MODE+UP	This establishes the current position to be the TOP software limit. The controller will not allow the focus to move any higher (using Digipot, RS232 move or SERVO motion)
MODE+DOWN	This establishes the current position to be the BOTTOM software limit. The controller will not allow the focus to move any lower (using Digipot, RS232 move or SERVO motion)
MODE+SPEED	Sets the current position to Absolute Zero. This will often be the parfocal distance of the set of objectives. In most instances this position is not useful except when using unit as an intelligent motorized focus drive.
MODE+3	Clears Top and Bottom Software limits.
MODE/UP	Keeping MODE key pressed while repetitively pressing UP key increases volume of buzzer. Note that a maximum volume will be reached such that further presses of the UP key has no effect.
MODE/DOWN	Keeping MODE key pressed while repetitively pressing DOWN key increases volume of buzzer. Note that minimum volume is the buzzer switched off.

7. RS232 Commands

LF100 Module can accept commands from a host computer (running Application Software or Terminal Emulation Program) using the RS232 serial port. The port defaults to a baud rate of 9600.

All commands are terminated with a Carriage Return code <CR>.

Commands are separated from arguments by one or more of the following delimiters.

COMMA
SPACE
TAB
EQUALS
SEMICOLON
COLON

Thus to move the focus UP by 100 steps the user could enter any of the following:

U,100<CR>
U 100<CR>
U:100<CR>
U;100<CR>
U 100<CR>

Proof of successful acceptance of any command sent to LF100 is the response 'R'<CR> (in the case of a command which instructs a motor move) or 0<CR> when the command requires no motor movements (e.g. a configuration set up). The response is immediate i.e. it does not wait. The response to any command is shown in the Command Table below.

Commands can be stacked (queued) although they are not necessarily acted upon immediately. e.g. sending a move command U,1000 immediately followed by PZ,0 will zero the Z position after the Up move has finished.

COMMANDS SPECIFIC TO LF100 OPERATING AS AUTO FOCUS UNIT:

COMMAND	ARGUMENTS	RESPONSE (ALL END WITH <CR>)	DESCRIPTION
OBJ	n	0	Sets the correct configuration parameters appropriate to the current objective. These parameters such as TARGET, KP can be subsequently changed and will be associated with this objective. n is objective number 1 to 5.
TARGET	none	0	Used directly after OBJ command above. Operator establishes best focus using the digipot. This command sets this as the focus to be maintained for objective n. This command will set ERROR to zero (see Test Routines)

COMMANDS SPECIFIC TO LF100 OPERATING AS AUTO FOCUS UNIT: (CONT'D)

COMMAND	ARGUMENTS	RESPONSE (ALL END WITH <CR>)	DESCRIPTION
KP	p		Sets Proportional Gain Constant for objective n. Decrease value for better stability but slower response. Typical values will be 20 to 2000.
KD			Sets Derivative Gain Constant for objective n. Increase this value for more stability. Typical values will be 20 to 200
SERVO	n	0	n=1 Enables servo. Best focus set using TARGET command (see above) will be maintained. n=0 disables servo. Digipot control is enabled.
DEAD	m	0	Sets servo deadband as +/-m for objective n. Default is 250. The value m can normally be larger for the low power objectives due to the greater depth of field. Note that this is a dead band value for the ERROR signal (see Test Routines) not Z position.
READ	none	p,q	p is sensor position of spot on sensor (Arbitrary units) q is focus motor position (units of 0.01 microns).
LASER	n	0	n=1 turns laser on. n=0 turns laser off.
MIN	t		t is 1 to 10000 This sets the minimum light intensity for normal servo action. A light level less than t causes the motor to stop. t is the same units as sensor sum in TEST 4. A light intensity 2t is needed to enable SERVO again.
ZD	n	0	n=1 or -1. Used to change the sign convention for Z position. Use P to read Z position. Correct convention is movement of stage and objective closer to each other is positive movement of Z. If the opposite is observed change the argument n Note that incorrect setting will result in SERVO behaving with positive feedback not negative feedback causing the focus to run away from TARGET.
ZD	none	n	Returns n.
VERSION	none		Returns version number of software.
DATE	none		Returns date of compilation of software
SLMT	t	0	Sets current position to be top software limit (t=top)
SLMT	b	0	Sets current position to be bottom software limit (b=bottom).
SLMT	n	0	Disables (top and bottom) software limits (n=none). The values for Top and Bottom software limits are not lost.

COMMANDS SPECIFIC TO LF100 OPERATING AS AUTO FOCUS UNIT:

COMMAND	ARGUMENTS	RESPONSE (ALL END WITH <CR>)	DESCRIPTION
SLMT	u	0	Enables top (upper) software limit.
SLMT	d	0	Enables bottom (down) software limit.

COMMANDS SPECIFIC TO LF100 OPERATING AS MOTORIZED FOCUS CONTROLLER:

Note SERVO must be disabled for LF100 to operate as an intelligent motor controller responding to commands sent along the RS232 port.

COMMAND	ARGUMENTS	RESPONSE (ALL END WITH <CR>)	DESCRIPTION
COMP	none	0	This returns the compatibility mode of the controller. This is included purely to comply with other Prior Scientific controllers. This unit will only operate in this mode.
SERVO	n	0	n=1 Enables servo. Unit automatically maintains focus using laser detection. n=0 disables servo. Digipot control is enabled. Unit now operates as an intelligent motorized focus controller using digipot of RS232 commands.
Z	none	0	Zeros z position
PZ	none	z	Returns Z position in units of 0.01 microns (see UPR)
PZ	z	0	Sets Z position to z.
<cr>			Returns Z position
SMZ	m	0	Sets maximum motor speed of a software move as a percentage 1 to 100
SAZ	a	0	Sets acceleration/deceleration of motor speed of a software move as a percentage 1 to 100
ZD	n	0	n=1 or -1. Used to change the sign convention for Z position. Use P to read Z position. Correct convention is movement of stage and objective closer to each other is positive movement of Z. If the opposite is observed change the argument n
C	n	0	Sets the step size for U and D commands.
U	u	R	Moves Up by a distance u. If u is omitted then the move size is as set by C
D	d	R	Moves Down by a distance d. If d is omitted then the move size is as set by C
V	z	R	Go to absolute position z.
M	none		Sends motor to zero position (same as V,0)

COMMANDS SPECIFIC TO LF100 OPERATING AS AS MOTORIZED FOCUS CONTROLLER:

COMMAND	ARGUMENTS	RESPONSE (ALL END WITH <CR>)	DESCRIPTION
\$	none	n	Checks motor status :- n=0 motor stationary n=4 motor moving. (n=4 allows compatibility with other Prior Scientific which have X and Y axes)
UPR	n	0	Sets microns per revolution of the motor. Allowed values for n are 100,200,250 and 400. It is assumed the motor has a full step angle of 1.8 degrees. Incorrect setting will result in software moves not being correctly set at 0.01 microns units.
VZ	v	0	Sets motor to velocity to v microns per second. Range is 0.00 to 500.00

If a command is not valid a response of “E,n” is returned. The n specifies an error type as listed below. The error codes are the same as for Prior Scientific’s other motor controllers (ProScan and OptiScan).

ERROR CODE	ERROR DESCRIPTION
2	Not Idle
3	
4	String Parse
5	Command Not Found
7	
8	Value Out of Range
10	ARG1 Out Of Range
11	ARG2 Out Of Range
12	ARG3 Out Of Range
13	ARG4 Out Of Range
14	ARG5 Out Of Range
15	ARG6 Out Of Range
16	
18	
19	
21	

8. Principles of Operation

The LF100 relies on the knife edge principle.

Half the aperture of the collimated light is blocked. The diagram below shows how this spoils the symmetry of the optical system about the optical axis. The collimation of the laser beam is adjusted to be the same as the objective lenses so that the best visual focus and the laser focus coincide. Moving the focus either side of focus not only defocuses the laser spot but moves laterally on the sample surface.

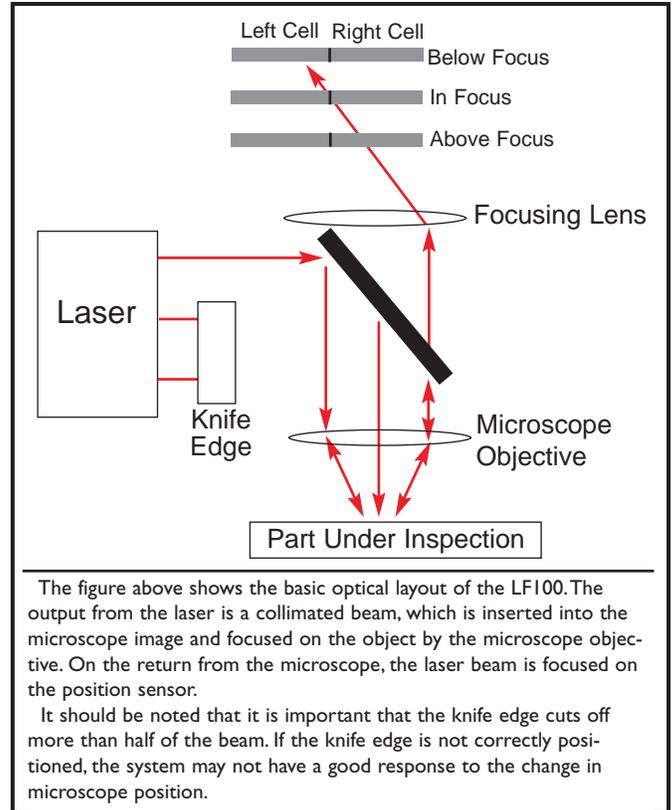
The reflected light retraces the path of the incident beam, 50% reflecting off a beam splitter through a focussing lens onto a position sensor. The image falling on the position sensor is effectively the same as seen by the camera viewing the sample.

The microprocessor observes the laser on the position sensor and actuates the focus motor in order to maintain a stable focus position i.e., keep the laser at the same location on the position sensor.

Background light/current leakage which would result in voltage offsets are measured on power up prior to the laser being switched on. **As a result it is important to ensure that all covers of unit are in place before power up.**

LF100 has 5 test routines to examine these numbers:

TEST	0	Stops all test reports.
TEST	1	Returns sensor POSITION and sensor ERROR every second. Error is zero when at TARGET position for this objective.
TEST	2	X SPOT POSITION Y SPOT POSITION SUM every second. Range of spot position is +/-50000 (nominal zero when spot at center)
TEST	3	Returns X DIFFERENCE, Y DIFFERENCE and SUM (light intensity) every second (Maximum value for SUM is 30000) This is raw sensor data where:- X DIFFERENCE = difference in current between left and right electrodes. Y DIFFERENCE = difference in current between top and bottom electrodes. SUM = sum of left and right currents or sum of top and bottom currents (these will be the same) and is proportional to light intensity. Maximum value for SUM is 30000
TEST	4	Returns sensor ERROR x difference and SUM every second.
TEST	5	X ERROR Y ERROR SUM (Use TARGET to zero both axes)



9. Troubleshooting

PROBLEM:

LF100 is totally inactive when switched on using the rocker switch. The green LED of the W1726 power supply is not lit.

SUGGESTIONS:

Check that the mains socket used by the PSU is live (plug in another electrical appliance). Check the fuse in the mains plug (if present), or alternatively replace mains cable with another which is known to work with another appliance. Pull out the 2.5mm socket from (LF100) to see if unit is shorting out the output of the PSU. If the led on the PSU remains off then it is likely that PSU is faulty and needs replacement.

WARNING:

Replace +12V 35W PSU with genuine Prior replacement (Prior part number W1726) otherwise permanent damage can be done to LF100

PROBLEM:

The unit is totally inactive when switched on using the rocker switch. The green led of PSU is on.

SUGGESTIONS:

The DIGIPOT led should be on when power is applied to the unit. If no led is lit then the unit has no power. Although the green led of PSU is on it may be that the PSU is still faulty. Switch PSU off by removing the mains. Reapply mains power to PSU. If fault persists then return complete system back to Prior.

PROBLEM:

LF100 is DIGIPOT Enabled but the focus will only move in one direction irrespective of direction of rotation of the Digipot.

SUGGESTIONS:

There is a hardware limit switch failure or the system has reached the software limits.

PROBLEM:

The focus motor turns but the microscope fine focus knob does not.

SUGGESTIONS:

The focus drive may not be properly positioned against the fine focus knob.

Loosen the knurled screw that holds the focus motor and press it gently against the fine focus knob. While pressing re-tighten the knurled screw. Note: If the fine focus knob on the microscope is difficult to turn or the movement rough, then the focus drive may not function until the microscope is properly adjusted.

10. System Specifications

PART NUMBER	DESCRIPTION	DIMENSIONS (LxWxD)	WEIGHT
LF100	Laser Focus Unit	130mm x 168mm x 35mm	.5 lbs., (.23kg)
LF100K	Keypad for stand-alone operation of LF100	127mm x 152mm x 64mm	2 lbs., (.91kg)

POWER

Universal integral power supply

Input: 90 - 265V 110 - 240V, 50/60Hz 60W

Output: 12VDC 35VA

Specifications subject to change without notice.

11. Glossary of Terms

Aperture - The area which is available for the passage of light

Autofocus - The ability of a Z focus system to automatically find the correct focus

Coarse Focus Knob - The large knob on the side of a microscope that moves the stage up and down relatively large distances with relatively small motion.

Compatibility Mode - The serial communication status which allows the HI29 Controller to be backwards compatible with the HI27 and HI28 controllers. See the "COMP" command. LFI00 only operates in COMP,0 mode.

Controller - The device which provides positional control to the stage, focus drive, filter wheel, or shutter.

Digipot - A circular device/encoder, typically mounted on a joystick used to manually rotate the fine focus knob. The digipot rotates the focus knob at an angle relative to the angular movement of the rotation of the digipot.

Encoder - A feedback device which provides positional information for either an XY stage or the focus drive assembly. Encoders can either be rotary or linear.

Fine Focus Knob - The small knob on the side of the microscope that moves the stage up and down relatively small amounts with relatively large movements. Typically 100 microns per revolution of the fine focus knob.

Flash Memory Capability - The ability of the Prior controller to download new software without requiring an EPROM change. This ability is analogous to that of a solid state hard drive.

Focus Drive - A motor and adapter assembly that typically mounts to the coarse focus knob of a microscope and drives the fine focus knob.

Hyperterminal - A terminal emulation program provided with Windows 95,98 NT. Instructions for setting up Hyperterminal to communicate with the Prior controller are located in the appendices.

Incident Illumination - Light which falls on the object from any direction

Inverted Microscope - A microscope that views the object from below. The objectives are underneath the stage.

Legacy Commands - The set of RS232 commands that are common between the HI27, HI28 and HI29 Prior Motor Controllers. See also compatibility commands.

Open Loop System - A control system that has no means of comparing the output with the input for control purposes. Open loop stage systems rely on the controller to send the proper amount of pulses to the motor to achieve the required movement.

Plug & Play Facility - The ability of the Prior Scientific controller to recognize which components/accessories are connected and to auto-configure itself to work when powered up.

GLOSSARY OF TERMS (CONT'D)

RS-232 - A communication standard which specifies electrical, mechanical and functional characteristics for serial binary communication circuits in a point to point link. Commands from a computer's COM port travel to the controller via RS-232.

Serial Control - A type of information transfer where the bits are handled sequentially

Servo Motor - A motor that rotates due to the interaction of the stator field and armature field. Servo motors require feedback loops, i.e... encoders or

Stepper Motor - A motor which when current is applied generates a holding torque. The motor is rotated by switching the coils on and off. The step motors in Prior stages and focus motors generally have 200 steps per revolution, which is then microstepped to 50,000 microsteps per revolution.

TTL - Transistor-Transistor Logic. An integrated circuit with its inputs and outputs directly tied to transistors. Inputs and outputs are low voltage (<1 VDC) and high voltage (>3 VDC).

Transmitted Illumination - Light which passes through the object

Upright Microscope - A microscope that views the object from above

XYZ - The term used to describe the axes of a microscope that move left/right(X), front/back(Y) and up/down(Z)

12. Replacement Parts

ACCESSORIES	PART NUMBER
Focus Drive and Adapter	H122
Focus Drive and Adapter for Zeiss	H122AXIO
RS232 cable for PC (9 or 25 pin)	H276K
RS232 cable for MacIntosh	H277
Solid Couple Adapter for Focus Drive on Olympus/Nikon	H122KON
Solid Couple Adapter for Focus Drive on Leica	H122KLC
Dovetail flange for Leica DMLM	LF310
Dovetail flange for Nikon I50	LF320
Dovetail flange for Olympus BH	LF330
Dovetail flange for Olympus BX	LF335
Dovetail flange for Zeiss	LF340
Dovetail flange for Mitutoyo FSI 10	LF350
Other flanges are available. Check with Prior Dealer for more information	

13. Returns and Repairs

Should you experience problems with your LF100 System and want to send it back for service, warranty, or otherwise, a Return Material Authorization (RMA) number must be obtained from the appropriate Prior Scientific office before returning any equipment. For North and South America contact prior Scientific, Inc. and for the rest of the world call Prior Scientific Instruments Limited on the telephone shown below.

**PRIOR SCIENTIFIC INC.,
80 RESERVOIR PARK DRIVE,
ROCKLAND, MA 02370-1062
TELEPHONE 781-878-8442
FAX 781-878-8736
INFO@PRIOR.COM**

**PRIOR SCIENTIFIC INSTRUMENTS LTD,
UNIT 4, WILBRAHAM ROAD, FULBOURN,
CAMBRIDGE CB1 5ET
TELEPHONE 01223 881711
FAX 01223 881710
UKSALES@PRIOR.COM**

14. Appendices

Appendix A

12.1 Non Standard Focus Drive Installations

Notice

This installation should only be attempted by a qualified technician. It involves some minor disassembly of critical mechanical components. If you are not familiar with this type of mechanical assembly do not attempt this installation, consult your local microscope representative.

Introduction

The focus drive is compatible with all of the Zeiss Axio type microscopes listed below. However, it is not compatible with the Zeiss Axioskop 2 and Axioplan 2. The focus drive must be attached to the fine focus ball reduction mechanism as follows:

Axioplan..... Left Side	Axiotron 10..... Right side	Axiolab..... Right side
Axioskop..... Left Side	Axiovert 35..... Right side	Standard..... Right side
Axiovert 25..... Left Side	Axiovert 100..... Right side	Axiovert 135 Right side

Components

The focus drive assembly is comprised of the following:

- Drive motor, motor bracket and switch assembly
- Mounting block
- Anti backlash gear and locknut
- Cover and lead

Also included are screws and hexagon keys needed to install the focus drive unit.

Tools Required

14mm AF spanner or socket, 1pt Philips screw driver, 1.27mm hexagon key (supplied) 2.5mm hexagon key (supplied) 3.0mm hexagon key (supplied).

APPENDIX A (CONT'D)

Prepare the focus drive

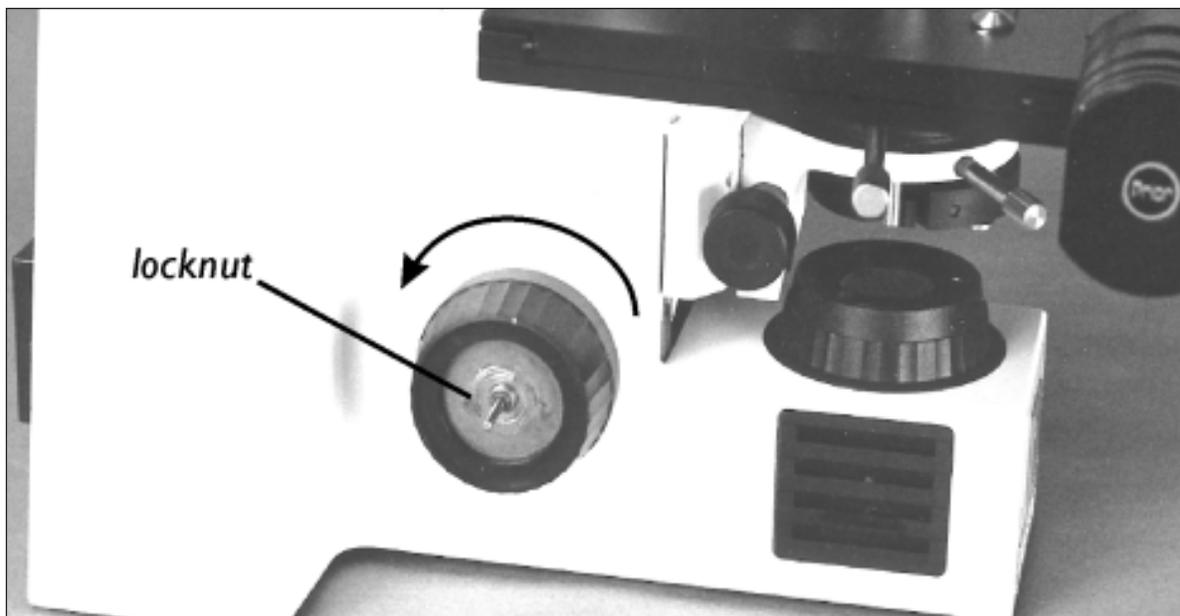
- Remove the cover.
- Remove bag containing anti-backlash gear, locknut and hexagon keys.
- Using 3.0 hexagon key remove the two 4mm cap head screws that hold the mounting block to the motor\bracket assembly.

INSTALLATION OF THE FOCUS DRIVE



1. Determine which side the focus drive must go (see introduction).

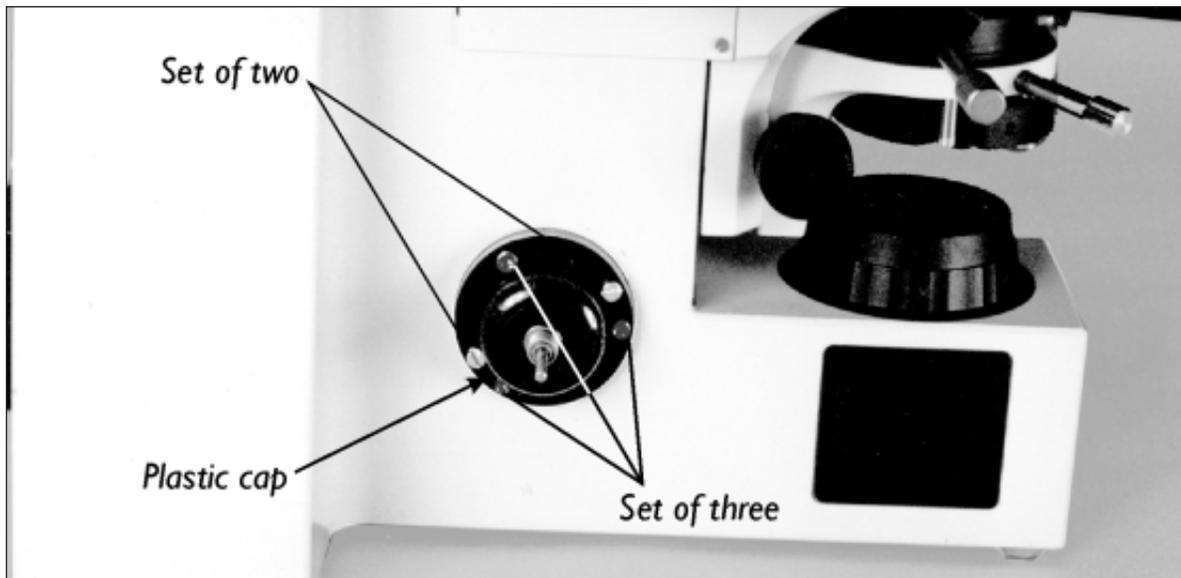
Remove the fine focus knob by using the 1.27mm hexagon key to unscrew the set screw. The knob can then be pulled off.



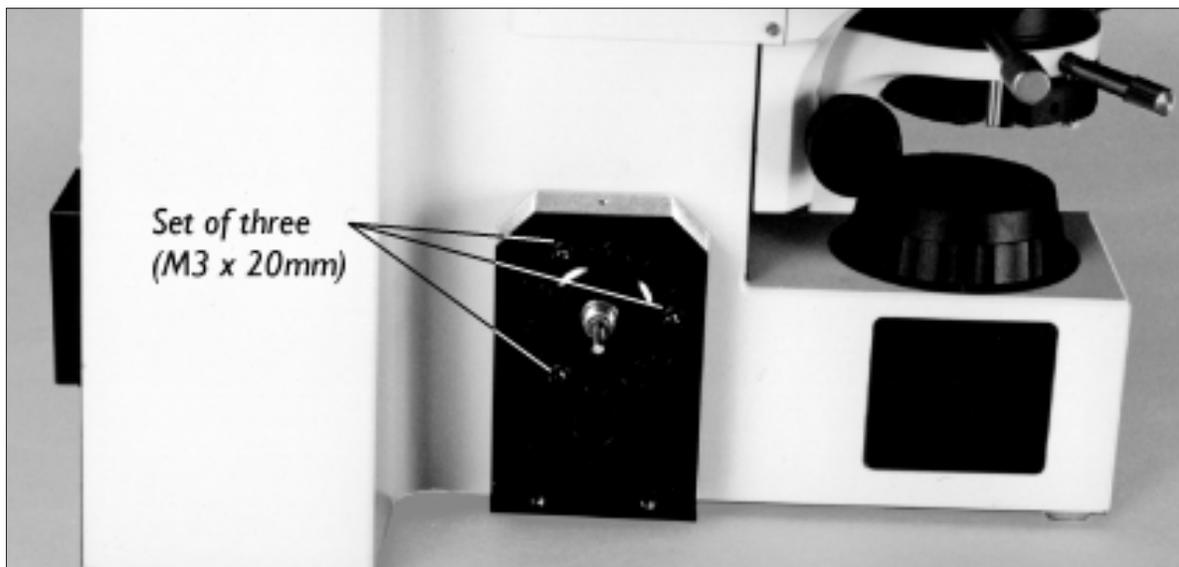
2. Using the 14mm spanner or socket to remove the lock nut. The coarse knob can now be removed by turning anti-clockwise and unscrewing from the coarse focus shaft.
-

APPENDIX A (CONT'D)

3. A black plastic cover should now be visible. If this is not the case, check the introduction to ensure you removed the knobs from the correct side. It is very important that you replace both coarse and fine knobs before removing the knobs on the opposite side.

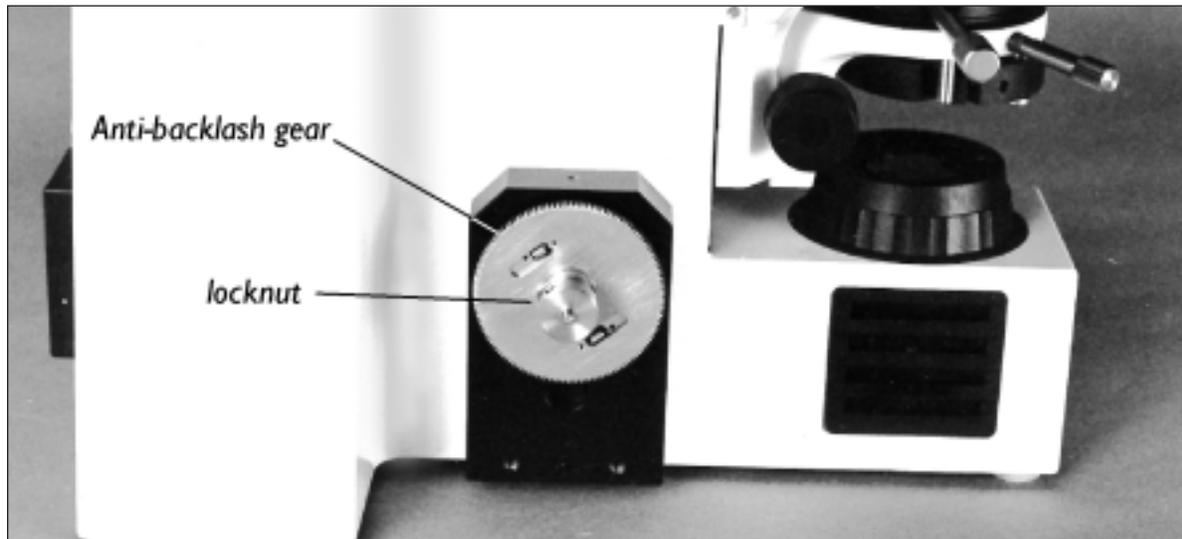


The plastic cap is held on with five screws, one set of two screws and one set of three. If the set of two screws are missing then install the two M3 x 6mm cap head screws supplied. Remove the set of 3 screws using the 2.5mm hexagon key.



4. Place the mounting block over the plastic cap and hold in place using the 3 M3 x 20mm cap head screws supplied.
-

APPENDIX A (CONT'D)

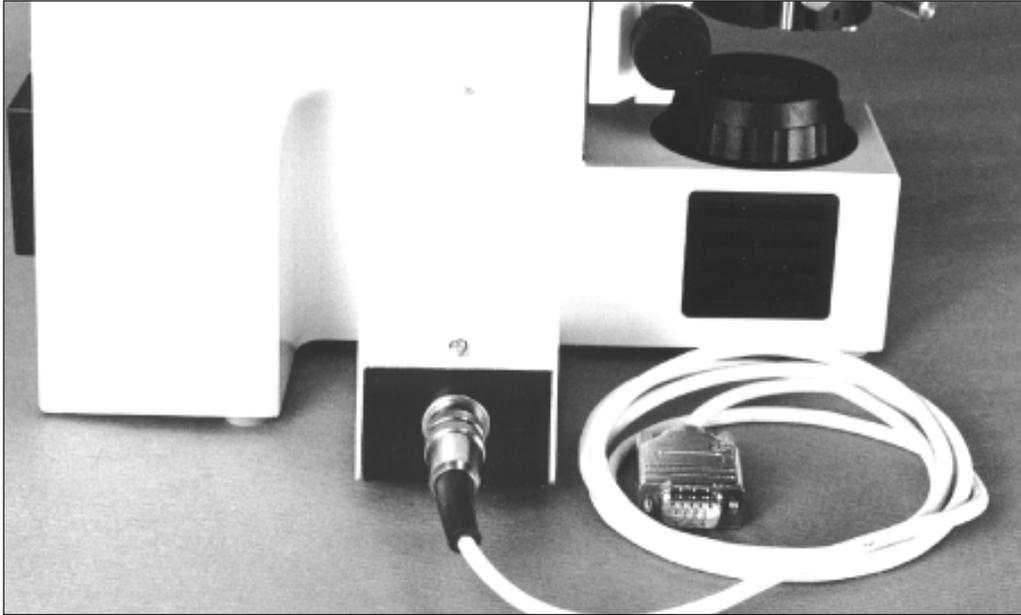


5. Screw the anti-backlash gear onto the coarse drive shaft, making sure the gear's boss is facing outwards. Screw the locknut into the boss and tighten.



6. Attach the motor, bracket and switch assembly to the mounting block using the two M4 cap head screws. The anti-backlash gear has two gears, one fixed, the other spring loaded and free to rotate. Rotate this gear approximately 6 teeth before aligning with the motor gear.
-

APPENDIX A (CONT'D)



7. Replace the cover and attach the lead.

8. If the focus drive unit appears to drive in the wrong direction, i.e. you ask the controller to move up and the stage moves down, then the switch is set to the wrong position. Disconnect the power supply to the focus drive, remove the cover, move the switch and then replace the cover.

The unit will now move in the correct direction.

FOCUS DRIVE INSTALLATION FOR THE LEICA DMLB AND DMLM RANGE

H122LB motorized focus kit parts list

Fitting the H122LB to the Leica DMLB involves removing the right hand fine focus knob. Note that this has



- A. H249 Microstep Focus Motor
- B. H1073 Adapter ring (for Leica DMLB)
- C. H1166 Drive coupling (For Leica DMLB)
- D. H569 Focus motor sleeve
- E. S690 Thumb locking screw
- F. W1401 2mm hexagonal wrench
- G. W347 1.5mm hexagonal wrench

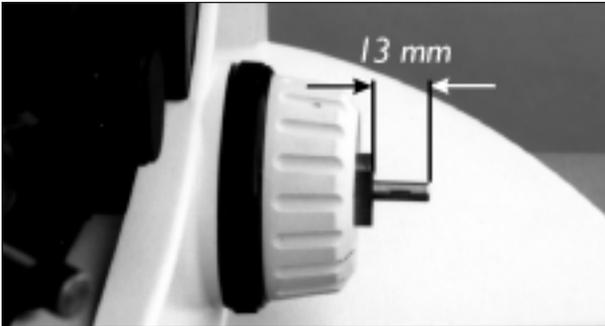
two sensitivity settings depending on whether the fine focus mechanism is pushed to the right (4 microns) or pushed to the left (1 micron). This option is indicated by the label on the front surface of the left hand stabilizer.

APPENDIX A (CONT'D)

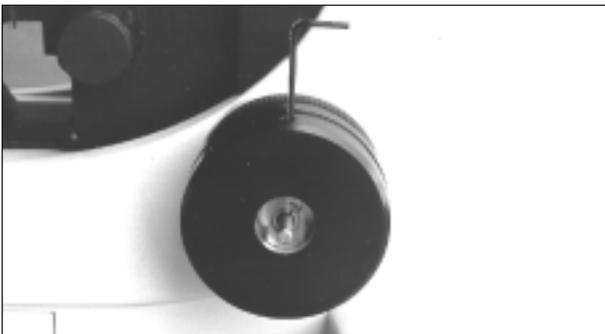
The fine focus must be set at the 1 micron position.



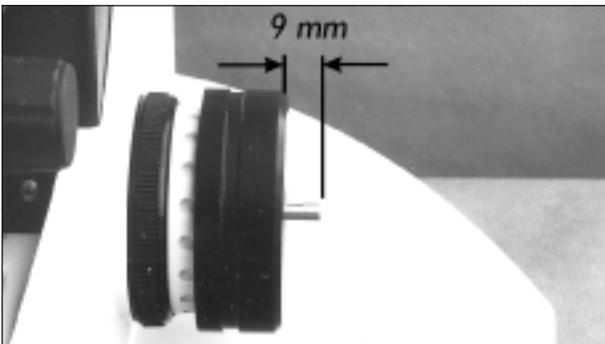
1. Push the fine focus fully to the left. Note the amount of the vernier scale showing on the left hand knob (figure 1). Fitting the HI22LB is done with the fine focus in this 1 micron position.



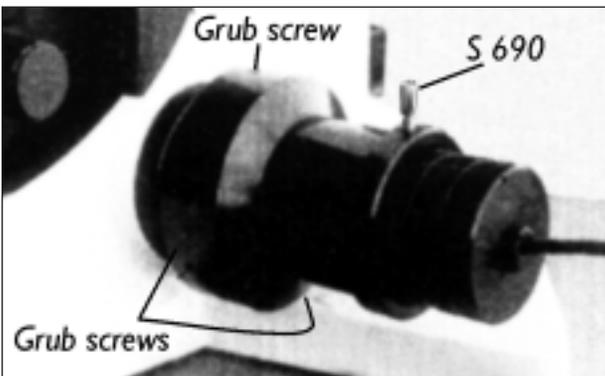
2. Remove the right hand focus knob using the 1.5 mm hexagonal wrench key inserted down the small hole in the right hand fine focus. Hold the left hand fine focus knob when pulling off the right hand fine focus knob ensuring that there is no lateral movement of the shaft. There should be approximately 13mm shaft length protruding from the brass boss (figure 2). Ensure that the small spring washer is still on the shaft.



3. Fit the large adapter ring over the brass boss. Note that the orientation of the adapter ring should be such that the grub screw in the adapter ring screws down onto the centre of the radius (curved part of the brass boss) - (figure 3)



4. Push this fully towards the body of the microscope leaving approximately 9mm of shaft protruding from the adapter ring whilst tightening up the adapter ring using the 2mm hexagonal wrench key (figure 4).



5. Fit the drive coupling on the fine focus shaft using the 1.5mm hexagonal wrench key. Orient the shaft so that the grub screw will locate on the flat of the shaft. Push the drive coupling gently towards the adapter ring whilst tightening the grub screw. Check that the fine focus rotates freely and is still set at 1 micron.

APPENDIX A (CONT'D)

6. Fit H569 motor sleeve on the adapter ring. Tighten up 3 grub screws in sequence using the 2mm Hexagonal wrench key (figure 5). It may be necessary to rotate the motor sleeve to gain access to each grub screw. The motor sleeve and adapter ring are now attached to the coarse focus.

7. Slide the H249 Microstep Focus motor assembly into the motor sleeve and tighten the S690 thumb screw whilst gently pushing the focus motor assembly towards the microscope such that there is a good contact between the rubber surfaces of the drive of the motor and the drive coupling (figure 5). The fitting is now complete. The motor is now able to drive the fine focus mechanism of the microscope.

APPENDIX B

How to Run HyperTerminal

Instructions for using Windows HyperTerminal Emulation Program (Windows 95) for communication to a Prior Controller.

1. Click Start, then Programs, then Accessories, then HyperTerminal.
2. Double-click the "Hypertrm" icon.
3. Enter file name e.g. prior, select an icon and press OK
4. Select File, then Properties, then Phone Number
5. Select COM1 or COM2 as appropriate for the "Connect using..." option.
6. Press Configure...button
7. Enter the following parameters in the Port Settings box;

Bits per second	9600
Data bits	8
Parity	None
Stop bits	1
Flow Control	None

8. Press OK button.
9. Select Settings tab.
10. Press ASCII Setup...
11. Select "Echo typed characters locally" and "Append line feeds to incoming line ends"
12. Press OK.
13. Press OK.

Instructions for using Windows HyperTerminal Emulation Program (Windows NT) for communication to Prior Controller.

- 1) Click Start, then Programs, then Accessories, then HyperTerminal.
- 2) Select the "HyperTerminal" icon.
- 3) In the "Connection description" dialog box enter file name e.g. prior, select an icon and press OK.
- 4) In the "Connect to" dialog box enter Phone Number (if required) and Select COM1 or COM2 as appropriate and press OK.
- 5) Enter the following parameters in the Port Settings box ;

Bits per second	9600
Data bits	8
Parity	None
Stop bits	1
Flow Control	None

- 6) Press OK button.
- 7) Select File, Properties and Settings tab.
- 8) Press ASCII Setup...
- 9) Select "Echo typed characters locally" and "Append line feeds to incoming line ends" (you should find that "Wrap lines that exceed terminal width" has already been selected).
- 10) Press OK
- 11) Press OK.

APPENDIX C

Optical Alignment

WARNING

Any procedures below will require possible exposure to laser light and should therefore only be carried out by an experienced engineer.

Removal of the laser barrier filter (see below) does not offer a laser exposure hazard in itself since the power of laser light entering the binocular head is still less than 200 NanoWatts. However it is strongly recommended to view the image using a camera instead of direct viewing when the barrier filter is removed.

Tools Required:

Long reach 1.5mm Allen key. Prior part number W2815

The internal optical components of LF100 have been aligned and set at the factory. Small variations of the positioning and alignment of the optics of the microscope may require a small 'tweak' of the angle of the downward facing dichroic mirror inside LF100 in order to achieve optimum performance..

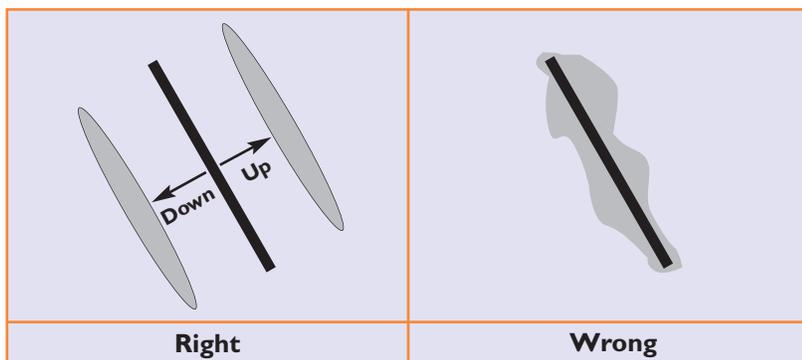
If problems arise with reliable performance the optical alignment can be checked as follows:

1. The laser spot hitting the surface of the sample will need to be viewed. To achieve this the laser barrier filter will need to be removed. This is held in place in a recess between the top lid and the flange fitted to the top lid. Remove the top lid by removing the 8 screws (36), removing the flange by undoing the 3 screws, removing the barrier filter and reversing the process without the barrier filter. Only the 4 screws (36) need be fitted for the moment since the barrier filter will need refitting.

BEWARE. The barrier filter sits loosely between the top lid and flange. Do not drop it.

2. Reassemble complete system. Place a front surface mirror (use Prior mirror W2836) on the stage, select x20 objective and focus on surface of mirror. There is now sufficient laser light to see it on the camera. The best focus of the laser spot should coincide closely to the best focus of the surface of the mirror. Use the digipot of LF100K to move either side of best focus.

3. Optimum optical alignment is achieved when the laser spot behaves as shown below either side of focus. If movement of laser spot moves diagonally then use 1.5mm Allen Key (Prior 2815) inserted in aperture ADJ1 (left side of LF100) to achieve correct top/bottom movement of spot.



Make sure that small changes to the focus position moves the whole line up or down. If the line only expands, then the location of the line must be changed with ADJ1 and ADJ2.

APPENDIX C (CONT'D)

4. Adjustment of Allen key in ADJ2 (right side of LF100) will move the spot backwards/forwards and also affect the amount of movement of the spot when focus moved either side of best focus. This adjustment is achieved through experience. It is steering the beam away from the optical centre. The further away from the optical centre the laser is moved then its movement with focus is magnified but the light will then begin to fail to pass through the aperture of the objective. Bear in mind that the image of the laser spot on the surface of the sample falls on a light detector which gives an output signal proportional to position of the 'centre of gravity' of the laser beam. Look at the movement of laser spot while changing focus for each power of objective. It will be noticed that the sensitivity is far higher for the high power objectives. Ensure that the laser light is not vignetted when using the highest power objective.

5. With laser spot behavior being as shown above when focus moved either side of best focus then this is considered good alignment.

APPENDIX D

Communication Protocol between LF100K keypad and LF100 Laser Focus Unit

The table below lists the TTL signal pattern sent to the LF100 from the LF100K keypad when a key or key sequence is pressed. The communication is single direction only, from keypad to Focus unit using 4 wires. A key press generates a pattern for a short period of time, as given below which is read and acted upon by the Focus Unit.

KEY/KEY SEQUENCE	MSB.....LSB	ACTION
0	0000	MODE
1	0001	OBJ 1
2	0010	OBJ 2
3	0011	OBJ 3
4	0100	OBJ 4
5	0101	OBJ 5
6	0110	HOME
7	0111	TARGET
8	1000	SERVO ON
9	1001	SERVO OFF
10	1010	MODE CLEAR (second press of mode key)
11	1011	
12	1100	SPEED
13	1101	DOWN
14	1110	UP
15	1111	No keys pressed
MODE+HOME	0000+0110	SET HOME
MODE+UP	0000+1110	SET TOP LIMIT
MODE+DOWN	0000+1101	SET BOTTOM LIMIT
MODE+SPEED	0000+1100	Set absolute Position to Zero
MODE+OBJ1	0000+1010	LASER ON
MODE+OBJ2	0000+1011	LASER OFF
MODE+OBJ2	0000+0011	CLEARs SOFTWARE LIMITS

DATA BIT	WIRE COLOR (8 WAY MINIDIN)	DESIGNATION IN LASER HEAD
D00	Green	SW1 UP
D01	Red	SW2 DOWN
D02	Black	JX
D03	Purple	JY

Specification subject to change without notification

15. LF100 Alignment Procedure

Tools Required:

570-LF303 Alignment Kit

Consists of:

570-W2844	Storage Box
570-LF550	Detector Alignment Jig
570-LF551	Axial Alignment Jig with Center Pin
570-LF552	Laser Cap with Pin Hole
570-W2815	1.5mm Allen Key
570-W2836	50mm Diameter Mirror
570-W2839	2mm Allen Key

Other tools required for alignment:

- 3/16 inch hex socket wrench
- small flat head screwdriver
- 2.5mm Allen key

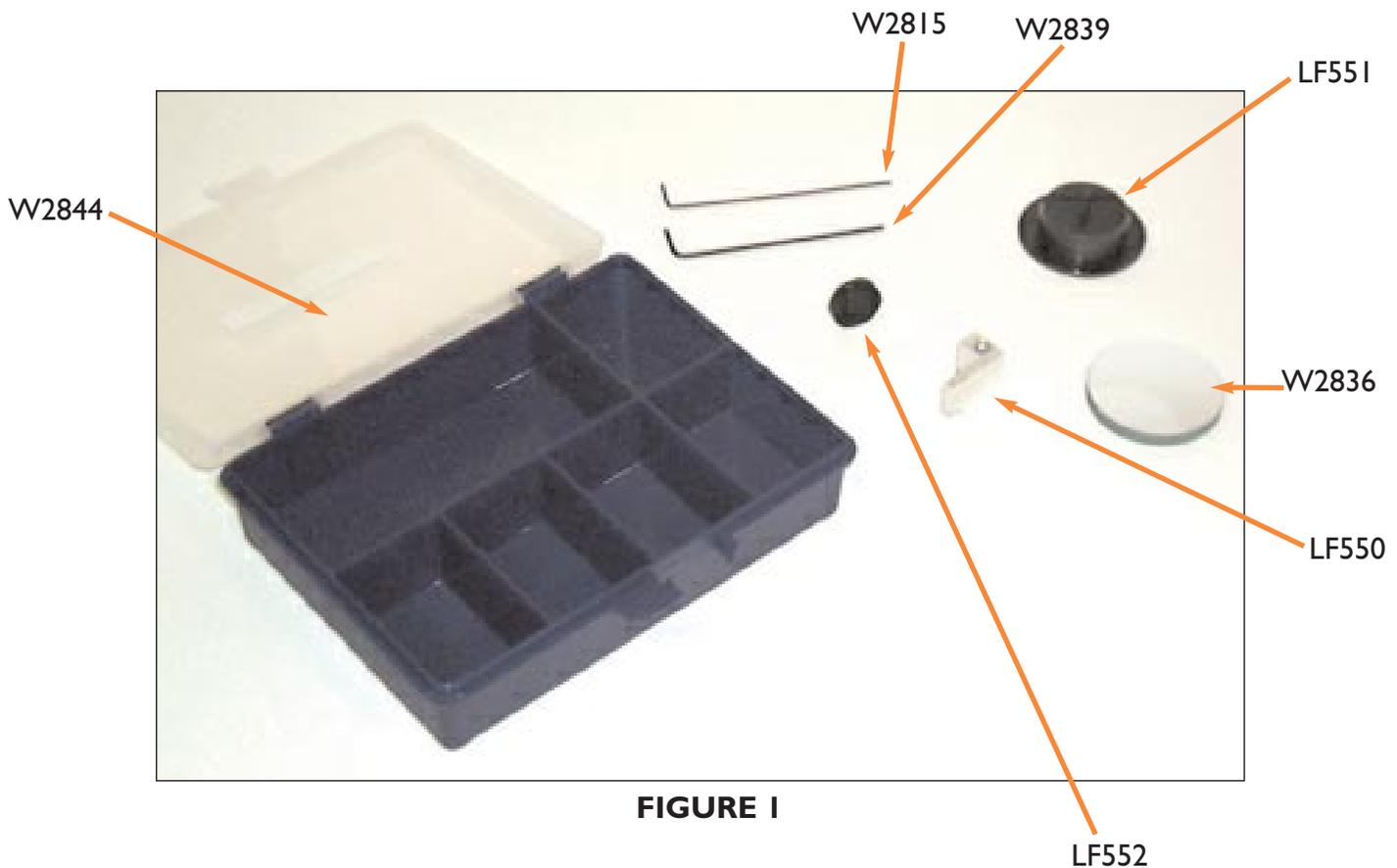


FIGURE I

LF100 ALIGNMENT PROCEDURE (CONT'D)

1. Remove cover of LF100. Remove the 3/16 inch nuts on the 9 way D connectors along with the two flat head screws on the back of the LF100 as shown in Figure 2.

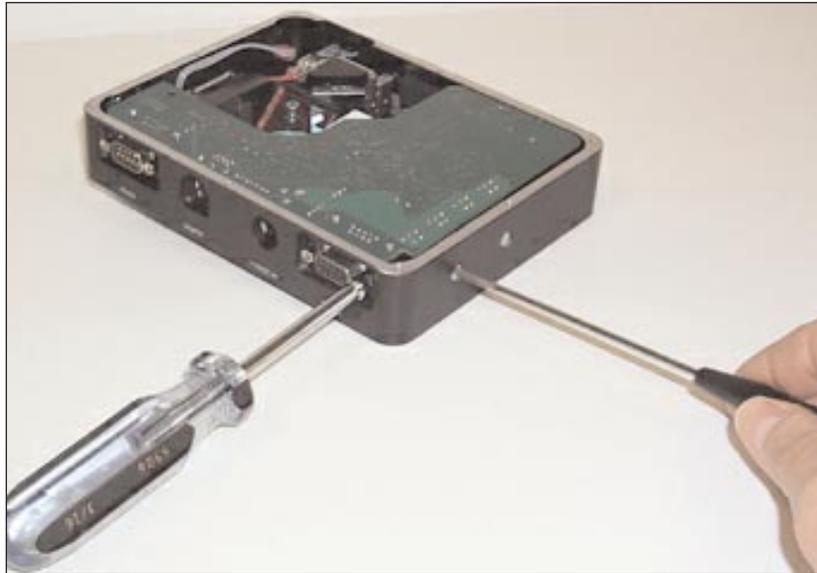


FIGURE 2

2. Carefully remove the PC board and then remove the knife edge lens assembly from the front of the laser with the 1.5mm Allen key as shown in Figure 3 and replace it with the LF552 Pin Hole Cap and tighten.

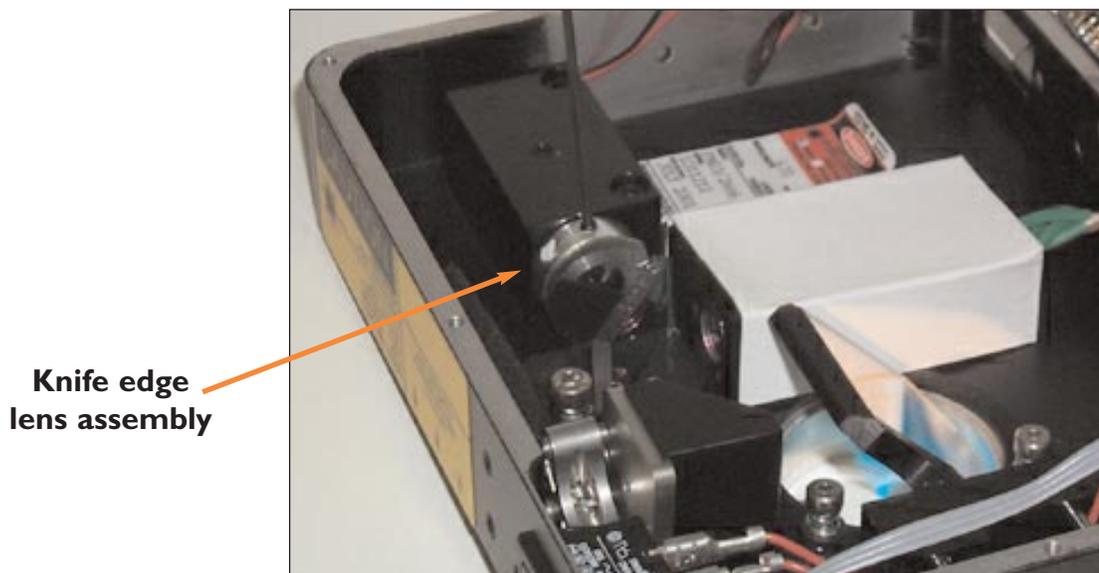


FIGURE 3

LF100 ALIGNMENT PROCEDURE (CONT'D)

3. Place the LF551 Axial Alignment Jig with center pin into the mounting flange on the underside of the LF100. The pin should protrude up into the LF100 and come near, but not touch the dichroic. Remove top and bottom right grub screws from the housing as shown in Figure 4. These are just plugs.



FIGURE 4

4. Use the top and bottom right adjustment screws to adjust the mirror until the laser spot falls in the center of the jig pin (Figure 5). Do not look through the dichroic to find the spot on the pin as the image may be distorted.



FIGURE 5

Use these holes
to adjust mirror

LF100 ALIGNMENT PROCEDURE (CONT'D)

5. Remove the plug grub screws from the right front and left front of the LF100 as shown in Figure 6.

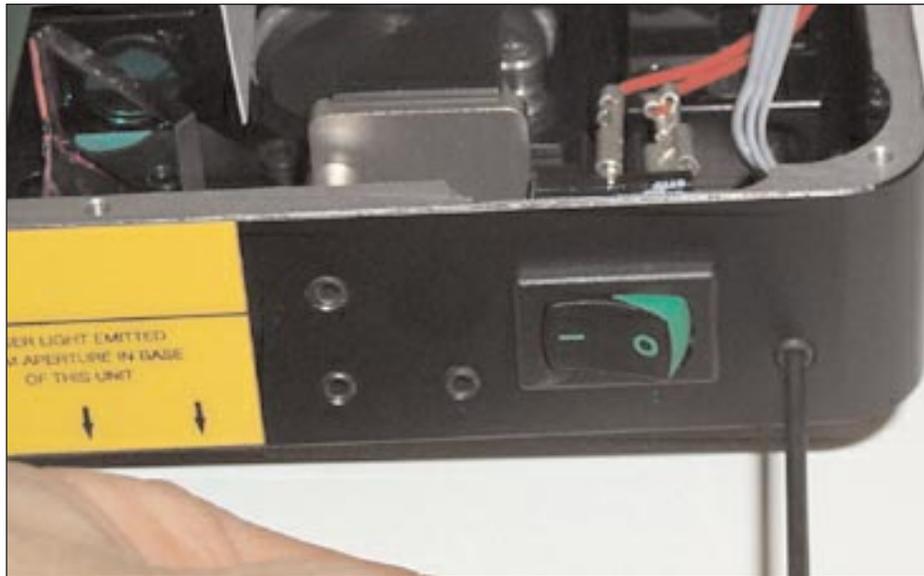


FIGURE 6

6. Remove the LF55I Axial Alignment Jig with center pin and place the W2836 Mirror against the mounting flange on the underside of the LF100 as shown in Figure 7. Note that the reflective side of the mirror should be against the flange and the glass side should face down.



FIGURE 7

LF100 ALIGNMENT PROCEDURE (CONT'D)

7. Adjust the dichroic by inserting the 1.5mm Allen key into the holes on either side of the front of the LF100 (Figures 8 and 9). Adjust the dichroic until the spot that is reflected from the mirror falls back onto the center of the laser pinhole jig. The right side adjustment moves the spot horizontally and the left side adjustment moves the spot vertically.



FIGURE 8



FIGURE 9

8. Carefully lift the PC board from the LF100. Remove the stray light blocking cover that is attached to the focus lens and the detector. Remove the hex screw holding the sensor mount with the 2.5mm Allen key as shown in Figure 10.

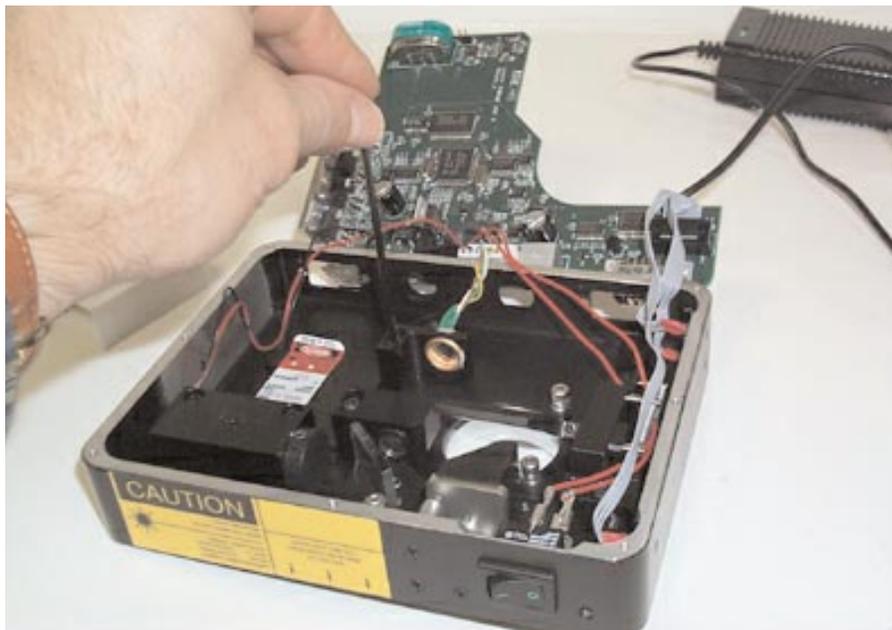


FIGURE 10

LF100 ALIGNMENT PROCEDURE (CONT'D)

9. Put the 570-LF550 Detector Alignment Jig in its place and tighten the screw (Figure 11).



FIGURE 11

10. Remove the imaging lens/interference filter block and replace the detector and its mount with LF550 detector alignment jig. This has a pin hole where the center of the detector would normally be. With the mirror still held flat against the underside of the flange adjust the 50/50 beamsplitter till the laser beam passes through the pinhole. Height adjustment is achieved using the tilting grub screw in the base beamsplitter holder (the grub screw which is NOT in the V groove of the beamsplitter assembly).

Horizontal adjustment is achieved by loosening off the whole beamsplitter sub assembly and using the small amount of rotation offered by the clearance holes. Replace the imaging lens block and detector. Place both assemblies in the mid positions of the slots.

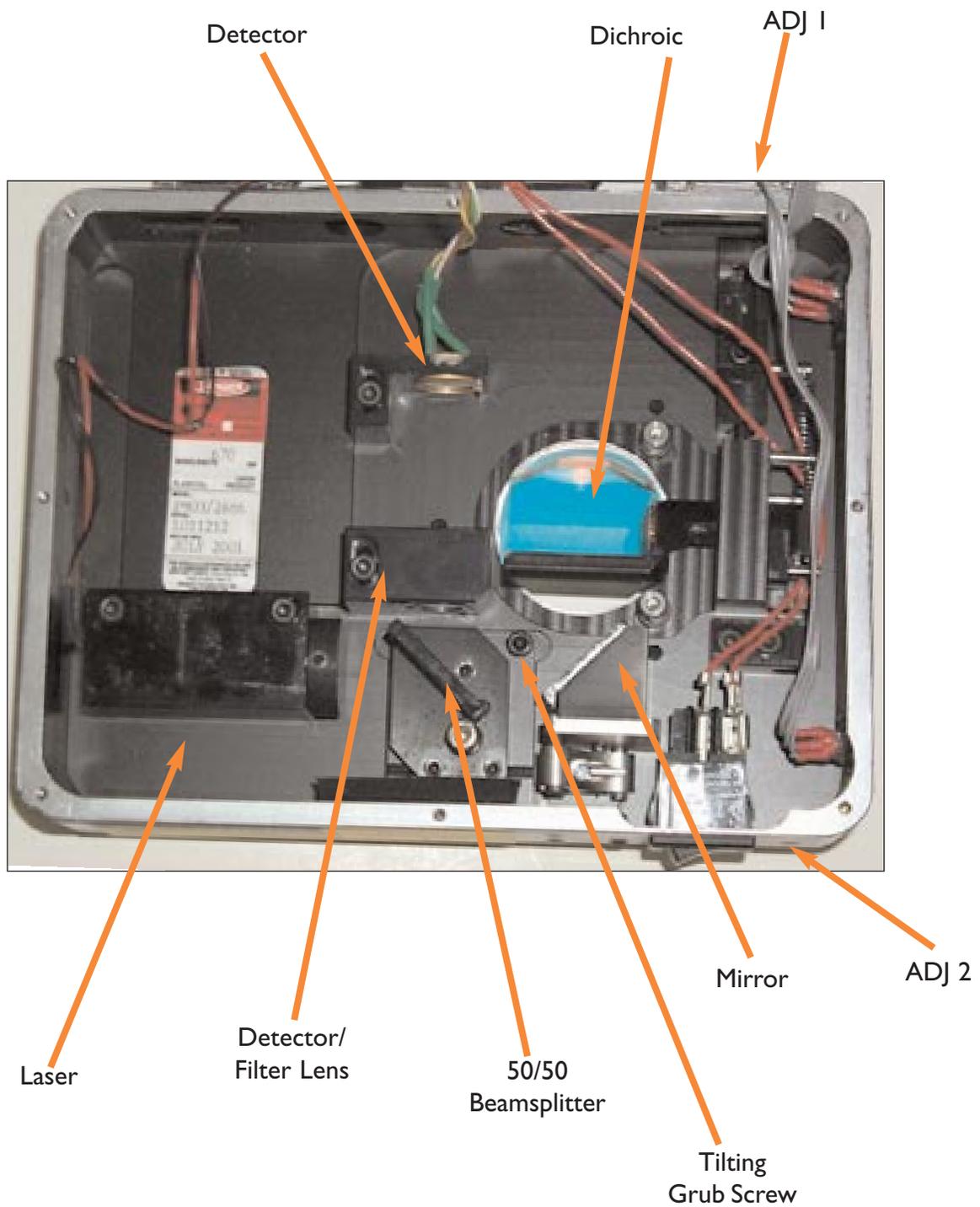


FIGURE 12

11. The LF100 laser focus unit is now aligned. Now do the following:

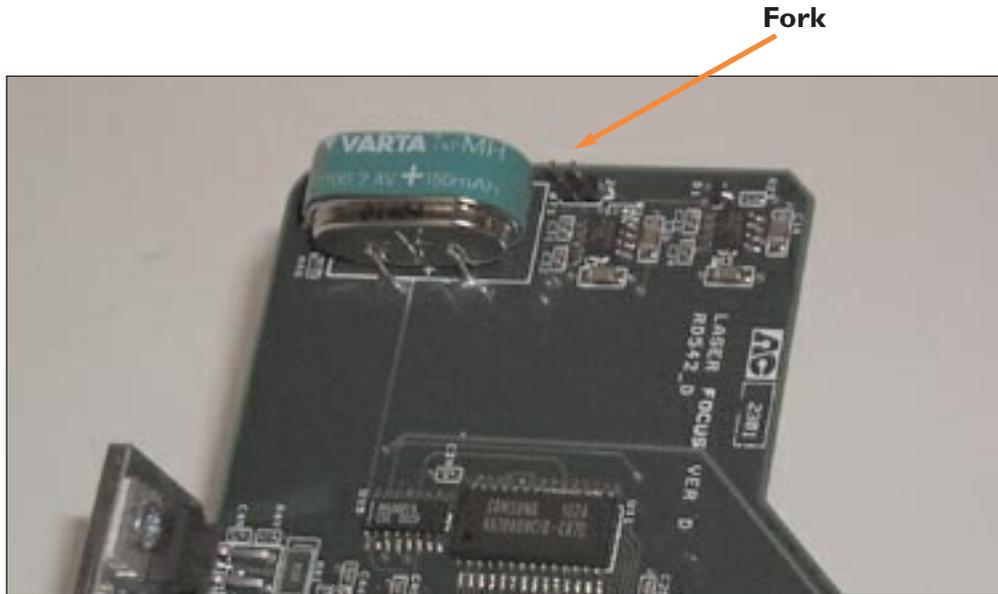
- Remove the LF550 detector alignment jig and mount the detector back in making sure that the detector is locked in the midway point of the slot.
 - Replace the stray light blocking cover.
 - Remove the LF552 Pinhole cap and put the original knife edge lens back on being careful that the laser light is blocked in the lower left half running at 45 degrees.
 - Replace the PC board and put the 9 way D screws back in along with the two slotted countersunk screws on the back.
-

LF100 ALIGNMENT PROCEDURE (CONT'D)



16. Downloading New Software

Remove cover of LF100. Remove the 3/16 inch nuts on the 9 way D connectors along with the two flat head screws on the back of the LF100. Carefully lift the PC board and find the two-pronged fork on the underside of the board. Place the jumper onto the fork shorting the two prongs.



Place the PC board back into the housing, power up, and download using the Flash program. When the program is completed, turn the LF100 off and remove the jumper.

17. Wiring Diagrams

RS232 and Pulse/Direction Output

PIN	FUNCTION
2	Tx
3	Rx
5	Signal Ground
7	Pulse
8	Direction
9	OV Reference

Focus Motor

PIN	FUNCTION
1	A +
2	B +
6	A -
7	B -
3	Limit +
8	Limit -
4	OV Common

Limit switches are normally closed. If not using limit switches, pins 3,4 and 8 should be shorted together.
