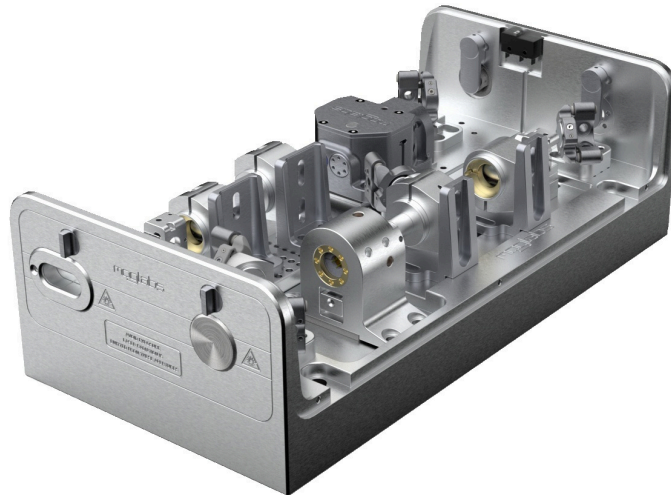




Injection-locked amplified laser system

Model ILA



Revision 1.09

Limitation of Liability

MOG Laboratories Pty Ltd (MOGLabs) does not assume any liability arising out of the use of the information contained within this manual. This document may contain or reference information and products protected by copyrights or patents and does not convey any license under the patent rights of MOGLabs, nor the rights of others. MOGLabs will not be liable for any defect in hardware or software or loss or inadequacy of data of any kind, or for any direct, indirect, incidental, or consequential damages in connections with or arising out of the performance or use of any of its products. The foregoing limitation of liability shall be equally applicable to any service provided by MOGLabs.

Copyright

Copyright © MOG Laboratories Pty Ltd (MOGLabs) 2017 – 2025. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying or otherwise, without the prior written permission of MOGLabs.

Contact

For further information, please contact:

MOG Laboratories P/L
49 University St
Carlton VIC 3053
AUSTRALIA
+61 3 9939 0677
info@moglabs.com
www.moglabs.com

Santec LIS Corporation
5823 Ohkusa-Nenjozaka, Komaki
Aichi 485-0802
JAPAN
+81 568 79 3535
www.santec.com

Preface

The MOGLabs ILA injection-locked laser system provides up to 1 W of tunable highly coherent optical radiation for optical lattice clocks, atomic cooling, Bose-Einstein condensation, ion trapping, and other spectroscopic applications. It reproduces the optical spectrum of the seed laser, maintaining the linewidth while increasing the output power by up to 100 times (+20 dB). It can be configured with cateye ($\lambda > 500$ nm) or Littrow ($\lambda < 500$ nm) seed laser. Fibre coupling is available for the amplified and seed laser beams. The MOGLabs DLC and ILD drivers are ideally suited for operating the seed and amplifier components.

The MOGLabs injection-locked systems are incredibly stable due to implementation of a proprietary method for auto-tracking the injection lock to ensure the amplifier remains locked to the seed.

Please let us know if you have any suggestions for improvement of our products or of this document, so that we can make life in the lab better for all.

MOGLabs, Melbourne, Australia
www.moglabs.com

Safety Precautions

Your safety and the safety of your colleagues depends on careful attention to proper operation of this product. Please read the following safety information before attempting to operate. Also please note several specific and unusual cautionary notes before using the MOGLabs ILA, in addition to the safety precautions that are standard for any electronic equipment.

CAUTION
USE OF CONTROLS OR ADJUSTMENTS OR
PERFORMANCE OF PROCEDURES OTHER THAN
THOSE SPECIFIED HEREIN MAY
RESULT IN HAZARDOUS RADIATION EXPOSURE

Laser output from the ILA can be dangerous. Please ensure that appropriate hazard minimisations have been implemented for your environment, such as laser safety goggles, beam blocks, and door interlocks. MOGLabs takes no responsibility for safe configuration and use of the laser. Please:

- Avoid direct exposure to the output beams, both from the injection seed input aperture and the amplified output aperture.
- Avoid looking directly into either beam.
- Note the safety labels (examples shown in figure below) and heed their warnings.
- The ILA must be operated by a controller with keyswitch interlock. The ILA must not be powered unless the key is inserted and switched on. It should not be possible to remove the key before turning off the power to the ILA.

- When the seed laser and amplifier are switched on, there should be a delay of at least two seconds before the emission of laser radiation, mandated by European laser safety regulations (IEC 60825-1).

WARNING Laser output from the ILA can be dangerous. Please ensure that you implement the appropriate hazard minimisations for your environment, such as laser safety goggles, beam blocks, and door interlocks. MOGLabs takes no responsibility for safe configuration and use of the laser.

WARNING If using water cooling, the water must be distilled (not de-ionised). The cooling channel is part of the 6061 aluminium chassis which will react with many cooling additives.

WARNING The laser chassis should be in good electrical contact to an optical table or other surface, which in turn should be connected to the same mains power supply electrical ground as the controller.

NOTE The MOGLabs ILA is designed for use in scientific research laboratories. It should not be used for consumer or medical applications.

Protection Features

The MOGLabs ILA includes a number of features to protect the user and the device. They should be used with a power supply that provides additional safety features such as key lock operation, current limit, temperature limit, cable continuity and short-circuit detection, soft-start and turn-on delay.

Softstart A 2s time delay followed by a linear 0.67 A/s ramp of the diode current.

Current limit Sets a maximum possible diode injection current, for all operating modes. Note that modulation applied through the rf connector on the laser headboard is not monitored.

Cable continuity If the laser is disconnected, the system will switch to standby and disable all laser and piezo power supplies. If the laser diode, TEC

or temperature sensor fail and become open-circuit, the laser will be disabled accordingly.

Short circuit If the laser diode, TEC or temperature sensor fail and become short-circuit, or if the TEC polarity is reversed, they will be disabled accordingly.

Protection relay When the power is off, or the temperature controller is off, the amplifier diode is shorted via a normally-closed relay.

LEDs Separate LED indicators illuminate when the seed laser and amplifier diode current supplies are enabled.

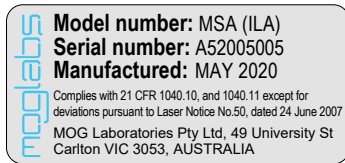
Mains filter Protection against mains transients.

Key-operated The laser cannot be powered unless the key-operated STANDBY switch is in the RUN position, to protect against unauthorised or accidental use.

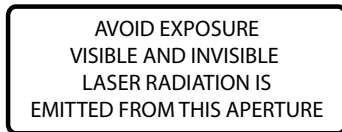
Interlocks Both the power supply unit and the laser head board have interlocks, to allow disabling of the laser via a remote switch, or a switch on the laser cover.

Label identification

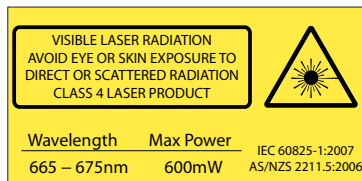
The International Electrotechnical Commission laser safety standard IEC 60825-1:2007 mandates warning labels that provide information on the wavelength and power of emitted laser radiation, and which show the aperture where laser radiation is emitted. Figures 1 and 2 show examples of these labels and their location on the ILA.



US FDA compliance



Aperture label engraving



Warning and advisory label
Class 4

Figure 1: Warning advisory and US FDA compliance labels.

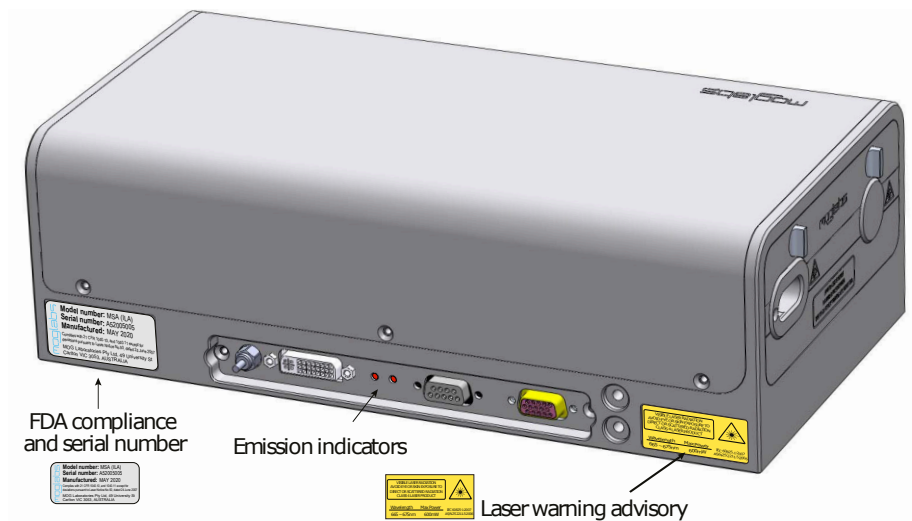


Figure 2: Schematic showing location of warning labels compliant with International Electrotechnical Commission standard IEC 60825-1:2007, and US FDA compliance label. Emission indicator for seed laser (left) and amplifier (right). Aperture label engraved on front and rear apertures; warning advisory label on right hand side, compliance label left hand side near exit aperture.

Contents

Preface	i
Safety Precautions	iii
1 Introduction	1
2 First light	3
2.1 Basic setup	3
2.2 First light	4
3 ILA full realignment	9
3.1 Seed laser	9
3.2 Measure PI curve	16
3.3 Injection lock monitor	17
3.4 Injection optimisation	18
3.5 Amplifier diode replacement	19
4 ILD controller and MOGILD	23
4.1 MOGILD computer control software	23
4.2 Locking an amplifier with MOGILD	27
5 Fibre coupling	31
5.1 Fibre alignment	32
5.2 Fibre coupler collimation	34
5.3 Polarisation control	36
5.4 Common fibre coupling issues	36
A Specifications	37
B Troubleshooting	39
C Electrical connections	45

C.1	ILA amplifier headboard	45
C.2	Connector pinouts	47
D	Chassis dimensions	49
E	Log messages	51

1. Introduction

The MOGLabs ILA is a master oscillator with power amplifier (MOPA); that is, a laser (seed) injected into an amplifier diode, see figure 1.1. Faraday isolators protect the seed and amplifier diodes from optical feedback. Fibre coupling options are available for both seed and amplified outputs.

In normal operation, the seed laser produces a collimated beam with up to 100 mW power, depending upon wavelength. Beam shaping optics can be installed to correct for astigmatism and beam ellipticity. The seed beam propagates through the seed isolator, and is then split by a polarising beam splitter (PBS). The reflected beam is coupled via mirrors M1 and M2 through the rejection port of the amplifier isolator, into the amplifier diode. A fraction of the seed laser output is available as a secondary (optionally

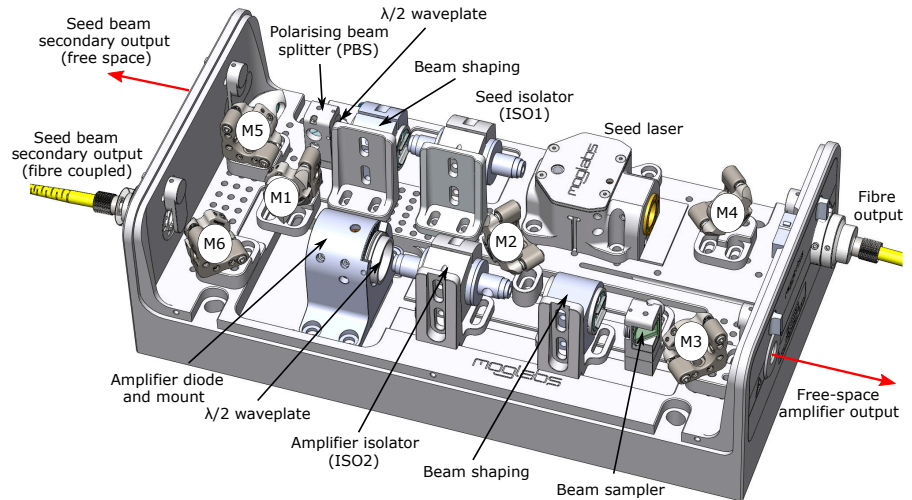


Figure 1.1: Schematic diagram of key components for a fully optioned ILA, including seed laser, amplifier diode, Faraday isolators, beam-shaping optics and mirrors M1 to M6. The seed laser has a primary output to the amplified diode and a secondary output that can be free space, fibre coupled or both.

fibre coupled) output beam, useful for locking or monitoring. The ratio of power between direct output and injection into the amplifier can be varied by adjustment of the waveplate installed before the PBS.

The amplifier diode is easily user-replaceable. A flexure adjustment mount controls the transverse position of the collimation lens, providing precise alignment with high mechanical stability. The amplifier diode can be translated along the optical axis relative to the collimation lens for fine collimation adjustment.

Beam shaping optics can be installed to correct for astigmatism and/or to circularise the amplifier beam profile. The output beam passes through a high-power Faraday isolator.

A beam sampler provides monitoring and feedback control of the amplifier diode current. The amplifier output exits through the free-space output port, or it can be reflected by mirrors M3, M4 to a fibre coupler. See chapter 5 for details on fibre coupling.

The MOGLabs ILA stability is achieved through good coupling of the seed and amplifier diode modes, and intelligent auto-tracking and rellocking software control of the amplifier diode current with the MOGLabs ILD.

Optimum spatial mode matching between seed and amplifier is achieved with M^2 beam propagation measurement, for example with the MOGLabs M2M, which allows real-time simultaneous measurement of both amplifier and seed. Note that even if the coupling is sub-optimal, the ILA can remain resilient to environmental perturbations with automatic tracking of the amplifier diode current as provided by the MOGLabs ILD.

2. First light

2.1 Basic setup

1. The ILA should be firmly mounted to an optical table or other stable surface. Mounting holes can be accessed by removing the cover, then M6 (or 1/4-20) socket head cap screws can fix the device to the optical table. The hole spacing allows direct mounting to metric and imperial tables.
2. The ILA chassis should be in good electrical contact to the optical table or other surface, which in turn should be connected to the mains power supply electrical ground.
3. If necessary, connect water cooling using the quick-fit connections provided (for 4 mm OD tubing by default and 6 mm OD upon request). For most applications, water cooling is not required, but may be helpful if operating at unusually high or low temperatures, or in laboratories with poor temperature regulation.
4. The exit apertures should be blocked with a suitable power meter or beam dump.
5. Connect to MOGLabs DLC and ILD controllers, for example, using the supplied head cables.
6. On the ILD and DLC controllers, turn the rear power switch on, and turn the key on the front panel from STANDBY to RUN. Ensure the seed (DLC) temperature is approaching the temperature setpoint as specified in the supplied seed laser test report. Press the TEC button on the ILD to engage the amplifier temperature controller, and monitor the temperature on the ILD display to ensure it stabilises to the setpoint as specified in the supplied ILA laser test report. The typical and maximum current settings for the seed and amplifier diodes can also be found in your ILA test report. Detailed instructions for the controllers are provided in their associated manuals: ILD

chapter 2 *Menus, TEC menu* and DLC chapter 2 *Connections and controls, Front panel display/monitor*.

7. Check seed operation and alignment to the amplifier, as described below and in the following chapters.

2.2 First light

The seed and amplifier have been aligned in the factory and only very minor adjustments should be required. However, before operating the laser system at full power, verify that the seed is operating correctly and the alignment was not perturbed during transport. Before reading through this section, please familiarise yourself with the key components of an ILA, shown in figure 1.1.

1. Refer to the supplied seed laser test report to ensure familiarity with the maximum diode current limits. Adjust the seed current such that a few mW of output power should be emitted. Do not exceed the *Current limit without feedback* value in the seed laser test report. Instructions on seed laser operation are provided separately in the MOGLabs LDL or CEL laser manual.
2. Verify that the seed laser is performing as expected according to the seed laser test report. That is, compare the power – current response of your seed laser to the seed laser test report, and verify that the seed laser is operating single mode at the desired wavelength when running at the typical operating current listed in the ILA test report.
3. Measure the seed power before and after the seed isolator (ISO1) and compare the isolator transmission efficiency to the seed test report. Verify that the seed beam is reasonably centred on the injection (side) port of the amplifier isolator (ISO2).
4. On the ILD, enable the diode current output then adjust the current until a few mW of power is available from the amplifier diode after ISO2. Do not exceed the maximum unseeded current for the device (if

relevant, this is specified in the ILA test report). Ensure the amplifier output beam is well-centred through ISO2 and reasonably centred on the exit aperture at the end of the chassis (i.e. not clipping). If the amplifier is fibre coupled, the beam should instead be well-centred on the fibre coupler.

If the beam is not centred on ISO2 but is comfortably clearing the exit aperture, translate ISO2 so the amplifier beam is centred on both the input and output of ISO2. If the beam is clipping the exit aperture, the $x - y$ lens translation flexure mount of the amplifier diode may need adjustment to centre the beam on the exit aperture. In either case please contact MOGLabs before proceeding, as full seed realignment will then be required (chapter 3).

5. Ensure that the amplifier and seed beams overlap by placing a viewing card between the amplifier mount and ISO2. Both beams should have similar spatial profiles and the same polarisation. Polarisation can be checked using a linear sheet polariser, for example using a linear polarising filter from a photographic store.
6. Position the viewing card between the PBS and M1 to verify that the beam propagating through the injection port of ISO2 from the amplifier diode is well overlapped with the seed beam. Only a small portion of the amplifier beam should propagate through the rejection port back towards the seed laser, typically less than 1%.

If there is any concern that the system alignment has been disturbed in shipping, please contact MOGLabs before proceeding to full seed alignment described in chapter 3.

7. If the alignment is good, monitor and record the amplifier output power for the remaining steps.
8. Increase the seed power to 5 mW, measured between the amplifier diode mount and ISO2. With the amplifier diode set to the lowest current listed in the the *Amplifier injection* section of the ILA test report, adjust mirrors M1, M2 to optimise the amplifier output power. Only very small adjustments should be needed to obtain amplifier

output powers comparable to the ILA test report values, to within about 10 to 20%.

9. Increase the seed current to the typical operating current listed in the ILA test report. Verify that the injected power at this current agrees with the typical *Seed power injected into amplifier* value listed in the ILA test report (measured between the amplifier diode mount and ISO2). Verify that the seed is operating at the desired wavelength; otherwise refer to the seed laser manual for how to adjust the seed wavelength.
10. Ensure the ILD is connected to local ethernet (or to a computer via USB). Run MOGILD and connect to your ILD.
11. Using MOGILD, set the amplifier current to the typical value listed in the ILA test report.
12. In MOGILD, the top graph shows the injection locking signal, which should have a similar trace structure to that shown in the test report. Make sure you are seeing a ramp and that the ramp value matches that in your test report. If the trace is very different, try small adjustments of the seed current to find a good mode.
13. If a step (drop) discontinuity feature is not observed, first try increasing the amplifier current by 5 mA (no more than 30 mA change) then reducing the amplifier current towards the desired amplifier current setpoint in small increments of 0.1 mA. Otherwise, refer to the troubleshooting section in appendix B or contact MOGLabs if no step feature is observed.
14. Once the scan has a step-like feature, adjust mirror M2 a *very* small amount, in order to maximise the height of the step discontinuity (refer section 4.2).
15. Record a power vs. current (PI) curve for the amplifier diode as a future reference. See section 3.2.
16. Once the amplifier is well seeded as described above, lock the amplifier current mode to the seed by activating LOCK in the MOGILD

window. This procedure is described in chapter 4. If the amplifier does not lock, refer to the troubleshooting section, Appendix B.

3. ILA full realignment

The ILA seed and amplifier have been aligned in the factory and only very minor adjustments should be required for optimisation. Refer to the ILA *Getting started guide* first, and then proceed to section 2.2 for guidance instructions on initial operation.

The rest of this chapter is an advanced guide. Please contact MOGLabs support before embarking on the following complete realignment procedure. These instructions apply only if there has been major disruption to the alignment, for example during transport or when changing the amplifier diode.

3.1 Seed laser

Proper seed laser operation is required prior to correct amplifier operation. Refer to the ILA *Getting started guide* first and seek further instructions for seed laser operation separately in the MOGLabs CEL cateye or LDL Littrow laser user manual as necessary.

The seed beam profile should be similar to the amplifier diode profile, and typically a well-collimated 1×3 mm ($1/e^2$ full width) beam with at least 10 mW power. A cylindrical telescope may be installed in the seed beam path (see Fig. 3.1). The seed laser polarisation must match the amplifier; a $\lambda/2$ waveplate is installed between the amplifier diode and amplifier isolator (ISO2) if needed (see the ILA test report). The seed laser should be stable, i.e. not near a mode-hop, for all adjustments in this chapter.

3.1.1 Seed collimation

To evaluate the seed laser collimation:

1. Place a beam block between mirrors M1 and M2 then adjust the seed laser to the typical operating current specified in the seed laser test

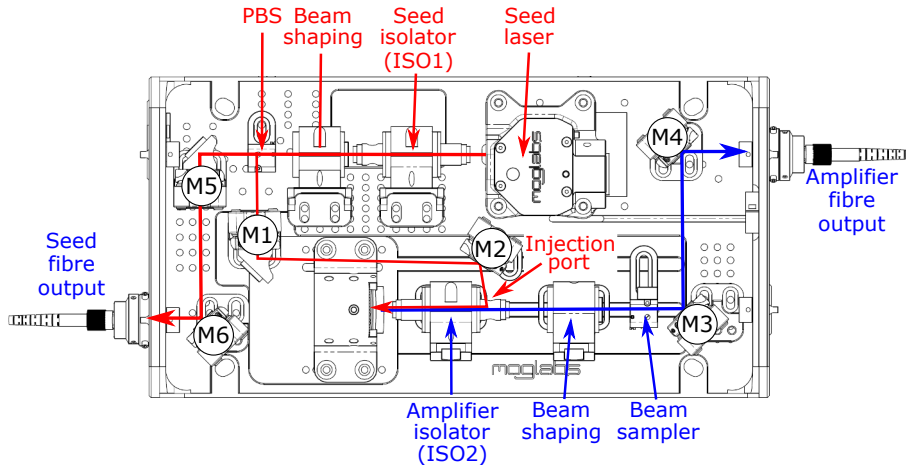


Figure 3.1: Configuration of an ILA showing all major components: the seed laser and amplifier diode, two isolators, beam shaping optics, mirrors, the PBS (with waveplate mounted on incident face) used for picking off the seed beam for injecting the amplifier diode.

report.

2. Check that transmission through the seed isolator ISO1 is optimised by ensuring the beam is centred on both the input and output of the isolator without clipping.

Seed collimation with no cylindrical telescope installed

- (a) Check the beam collimation by using the seed laser secondary free space output, or remove the mirror M5 if a seed pickoff is not available or cannot be inserted into the seed laser beam path. The seed laser beam should be well collimated, or come to a beam waist at a distance of at least 4 m from the seed laser. If no cylindrical telescope is installed for the seed beam, it is normal for there to be one well-collimated axis and the other axis will have a beam waist far from the laser.
- (b) If collimation adjustment is clearly necessary and the seed laser

is a CEL, insert a lens tube spanner into the end of the CEL. It may be necessary to *carefully* remove the isolator ISO1 – it has a very strong magnetic field, so take extra care. For LDL seed lasers, collimation adjustment is possible but not advised given the strong dependence of the seed laser performance on the diode collimation lens; contact MOGLabs if you believe correction of an LDL is needed.

- (c) Optimise the collimation by ensuring the slowly diverging axis has a beam waist beyond 4m or more, or use a shear plate interferometer, or a beam profiler such as the MOGLabs M2M beam profiler.
- (d) Reinstall the isolator if it was removed. Check that transmission through ISO1 is optimised by ensuring the beam is centred on both the input and output of the isolator with no clipping.

Seed collimation with cylindrical telescope installed

- (a) Evaluate the beam collimation by using the seed laser secondary free space output, or remove the first mirror M5 if a seed pickoff is not available or cannot be inserted into the seed laser beam path. Ensure that the laser beam is well collimated on the axis which the cylindrical telescope is *not* acting on.
- (b) If collimation adjustment is clearly necessary and the seed laser is a CEL, insert a lens tube spanner into the end of the CEL. It may be necessary to *carefully* remove the isolator ISO1 – it has a very strong magnetic field, so take extra care. Adjust the final collimation lens until the axis the cylindrical telescope is *not* acting upon is well collimated. For LDL seed lasers, collimation adjustment is possible but not advised given the strong dependence of the seed laser performance on the diode collimation lens; contact MOGLabs if you believe correction of an LDL is needed.
- (c) Ensure the beam is centred on the cylindrical telescope at both ends. If not, the cylindrical telescope may need to be adjusted such that the beam is centred on both ends.

- (d) The resulting seed laser beam should be well collimated, fairly symmetric, and have a weakly converging beam waist at a distance greater than 4 m from the seed laser. Use a beam profiling device such as a MOGLabs M2M beam profiler to evaluate the astigmatism. Astigmatism can also be checked by focusing the beam with a lens onto a suitable camera; for example with an $f = 100$ mm lens the difference in horizontal and vertical beam waist positions should be less than 10 mm along the optical axis. If the output beam shows appreciable astigmatism, please contact MOGLabs for advice.

3.1.2 Seed alignment

Keep a record of the power measurements throughout the following steps.

1. Adjust the seed laser current for an output power of about 10 mW before ISO1.
2. Check that transmission through ISO1 is optimised by ensuring the beam is centred on both the input and output of the isolator with no clipping. Optimise the transmitted power using a power meter and adjusting the isolator position, and rotation through horizontal and vertical planes.
3. A polarising beam splitter (PBS) and $\lambda/2$ waveplate are installed after ISO1 to allow adjustment of the injected power into the amplifier. Verify that the seed beam is approximately centred on the PBS and adjust the PBS position if necessary (within central 50% of clear aperture and not clipping the edges). The seed beam reflected off the PBS should be incident close to the centre of both M1 and M2.
4. If the amplifier is fibre coupled, remove mirror M3 to allow the output beam to be directly observed.
5. Turn on the amplifier diode and adjust the amplifier diode current until the output power is a few mW. Check that this current is similar to the current indicated in the ILA test report.

- The amplifier beam will likely have an elliptical beam profile. If necessary, rotate the amplifier diode to best match the orientation of the elliptical beam profile to the seed laser beam. To do this, release the amplifier set screws (see Fig. 3.2) and insert a screwdriver into the notch in the back of the diode tube to rotate the diode. Once aligned, ensure the set screws are firmly re-engaged.

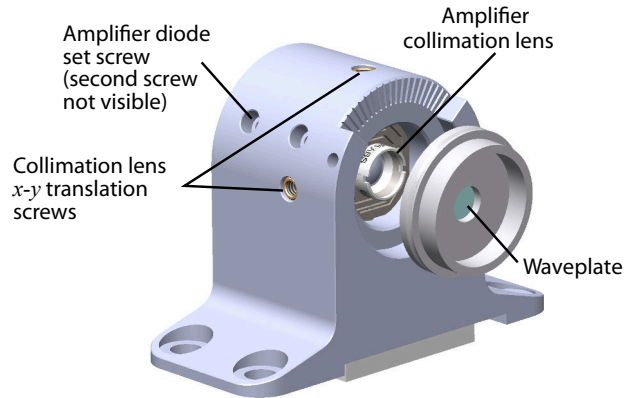


Figure 3.2: Amplifier mounting assembly, showing aspheric collimation lens, location of flexure screws for collimation lens $x - y$ translation, set screws for locking the amplifier diode in place (second screw not visible here), and waveplate for optimising the amplifier polarisation.

- The beams in and out of the amplifier diode are focused with a lens in a flexure $x - y$ translation mount. If the amplifier beam is not well collimated, or is not weakly focusing at a distance of at least 4 m from the output, adjust the lens focus. For fine adjustments, the brass ring on the rear (diode side) of the mount can be adjusted using the Y-shaped adjustment tool supplied by MOGLabs.
- Using the flexure alignment screws, *very* gently adjust the $x - y$ position of the collimation lens so that the beam is parallel to and aligned with the ILA optical plane. The $x - y$ flexure mount has a small range and should not require any force to impart a translation. The amplifier beam should be approximately centred on the free space output aperture when correctly aligned.

9. Install ISO2 and optimise transmission of the beam. First rotate the isolator about the optical axis until the injection port is aligned perfectly to the horizontal plane. A weak rejected beam from the amplifier diode will exit the isolator injection port hitting the centre of mirror M2. Ensure the amplifier beam is centred at both the input and output of the isolator. The waveplate in front of the amplifier diode should then be rotated to maximise transmission through the isolator.
10. Using mirrors M1 and M2 between the seed laser and amplifier, align the seed laser beam with the amplifier beam. Both beams should be collinear and collimated. For rough alignment, the following procedure should be followed:
 - (a) Place a viewing card between the amplifier diode mount and ISO2, and overlap the seed laser with the amplifier beam using mirror M1.
 - (b) Move the viewing card to between ISO1 and the PBS, then adjust mirror M2 so that the (weak, diffuse) amplifier beam exiting the rejection port of ISO2 overlaps with the seed beam passing through ISO1.
 - (c) Iterate steps a) and b) until there is no longer a difference in position at either card location. At some point the amplifier output will flash brightly as the output power dramatically increases, typically by 5 to 10 mW. Note that some amplifier diodes only show a very small flash of a few mW; refer to the ILA test report for what to expect.
11. Once initial injection has been achieved and a flash observed, the alignment can then be further optimised by using a walking procedure as follows:
 - (a) For the horizontal axis first, find the maximum output power by adjusting mirror M2. Record the output power value.

- (b) Adjust the horizontal deflection of mirror M1 clockwise such that the output power drops by no more than 25%. Take note of roughly how much rotation was required.
 - (c) Adjust the horizontal deflection of mirror M2 and maximise output power. Compare the new maximum to that at step (a).
 - (d) If the new power is greater, repeat steps (b) and (c). If the new power is lower, adjust the horizontal deflection of mirror M2 anti-clockwise to return it to its original angle as noted at step (b), then optimise the horizontal deflection of mirror M1 to return to the output power noted in step (a). If the first horizontal clockwise adjustment of both mirrors at steps (a) and (b) resulted in a decrease in output power, repeat steps (b) and (c) using an anti-clockwise adjustment instead.
 - (e) With horizontal alignment optimised, repeat steps (b) through (d) for the vertical alignment.
 - (f) Iterate the horizontal and vertical alignment procedure until the output power no longer increases. Reduce the output power by smaller increments than 25% as the alignment improves, e.g. 10% then 5%.
 - (g) Record the maximum amplifier output power, the seed power and seed current. Temporarily block the seed beam and record the unseeded amplifier output power.
12. The amplifier collimation may require a small adjustment to mode match the amplifier to the seed. Translate the amplifier diode a very small amount by using the Y-shaped adjustment tool provided to rotate the brass ring on the diode side of the amplifier diode mount, then re-optimize the power by adjusting only mirror M2. If the power increases, continue to translate the diode in the same direction. If the power decreases, translate the diode in the opposite direction. Note there may be a small amount of hysteresis in the translation.
 13. After the amplifier collimation adjustment, repeat the walking procedure from step 11 with mirrors M1 and M2 to ensure optimal injection.

14. With the injection alignment optimised, the amplifier polarisation should next be optimally matched to the seed laser. Rotate the $\lambda/2$ waveplate installed in front of the amplifier diode collimation lens to maximise the transmission of the amplifier beam through ISO2. Once optimised, lock the waveplate in place using the set screws.
15. Optimise the amplifier injection to correct for any deviations introduced by the waveplate, by again walking the seed beam with mirrors M1 and M2 and adjusting focus. Very little adjustment should be needed.
16. Compare the 5 mW seeded and unseeded amplifier diode power to the MOGLabs ILA test report. If there is a significant difference (more than about 10%), contact MOGLabs support.
17. Increase the seed laser current to the typical operating current listed in the ILA test report.
18. Place a power meter between the amplifier diode mount and ISO2, and adjust the waveplate in front of the seed PBS such that injected power into the amplifier diode matches the value listed in the ILA test report.

3.2 Measure PI curve

Verify the amplifier diode current response by measuring the output power (P) against input current (I) and comparing to the PI curve measured at MOGLabs:

1. Block the seed laser beam.
2. Measure the amplifier PI curve by recording power immediately after ISO2 as a function of amplifier diode current (see figure 3.3). Do not exceed the maximum bare diode current specified in the ILA test report. Make sure that the output power is comparable to the factory test results (within 10%), otherwise contact MOGLabs for advice.

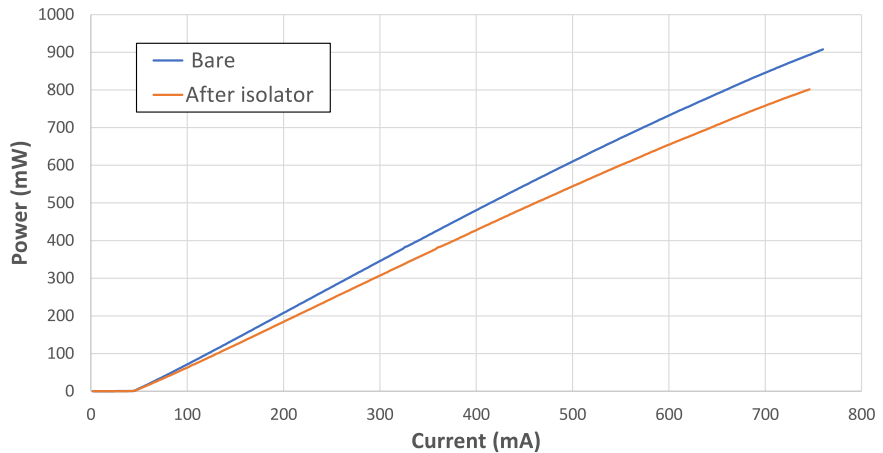


Figure 3.3: Amplifier output power-current characteristic curves, measured before and after the isolator.

3.3 Injection lock monitor

The beam sampler, shown in figure 3.4, allows continual monitoring of the amplified laser output.

1. If necessary, adjust the position of the beam sampler such that the amplifier beam is centred on the window. For horizontal translation, release the channel screw on the slotted base, slide mechanics orthogonal to the chassis channel, then retighten the channel screw. No vertical adjustment is possible. The beam sampler should be angled such that the mechanics face is square to the amplifier beam with the slotted base orthogonal to the chassis channel.
2. Remove the photodiode by releasing the set screw. The beam reflected from the beam sampler through the now-vacant photodiode aperture should propagate parallel to the optical table. If adjustment is required, revisit the previous step.
3. Increase the amplifier diode current to the maximum bare current specified in the ILA test report.

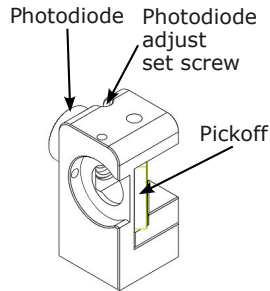


Figure 3.4: Beam sampler. The photodiode has a linear polariser installed on the front window to allow attenuation by rotating the photodiode about the optical axis. The photodiode amplifier also has an adjustable gain trimpot at the PCB connection board (not pictured).

4. Ensure the ILD is connected to local ethernet (or to a computer via USB). Run MOGILD and connect to your ILD.
5. Turn the amplifier ramp off from within the MOGILD software program.
6. Reinstall the photodiode while monitoring the MOGILD top graph *Signal* in the ILA software (it should be a mostly flat line). Rotate the photodiode in its mount until the signal has an amplitude of about 0.3, then firmly engage the photodiode set screw to secure the photodiode.

3.4 Injection optimisation

1. Turn the seed laser on, set to the typical operating parameters listed in the ILA test report, and verify that it is operating at the desired wavelength. Ensure the seed laser is not scanning, and if required, lock it to an external reference.
2. Connect the ILD to the MOGILD software, and set the amplifier current to the typical value listed in the ILA test report.
3. The MOGILD top graph should show an increasing signal, with a step-like (drop) discontinuity at some point in the ramp (highlighted

green in figure 3.5). Adjust the amplifier current such that this discontinuity is approximately centred in the scan. It is best to start at a higher current and reduce the current to the target value to minimise hysteresis effects.

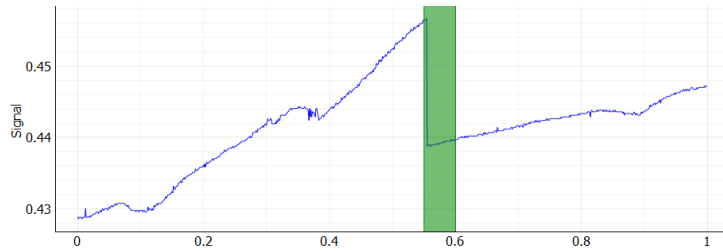


Figure 3.5: The injection locking signal during an amplifier diode current ramp. The step discontinuity evident in the green region indicates good injection by the seed laser.

4. Make very small horizontal and vertical adjustments to M2 to maximise the height of this step, noting that the step will typically move to the right (higher current) as injection improves, and to the left (lower current) as it degrades. Note also that the vertical axis may autoscale. Refer to figure 4.8 in chapter 4 for an example of how the step feature changes with injection angle.

When initially retesting the ability of the ILA to lock to the seed, it can be helpful to verify single mode operation of the seed with an independent measurement such as a scanning Fabry-Perot interferometer or atomic resonance.

3.5 Amplifier diode replacement

If the replacement amplifier diode is supplied by MOGLabs, it will be supplied installed in a new amplifier diode tube for easier exchange, typically with connectorised wires ready to be attached to the laser headboard. In that case:

1. Ensure all head cables are disconnected from the laser, then disconnect the laser diode connectors from the headboard, underneath the chassis in the PCB compartment.
2. Remove the brass ring at the rear of the amplifier diode mount using the supplied Y-shaped wrench. Remove the nylon washer from between the brass ring and the diode tube.
3. Loosen the two amplifier diode set screws (see figure 3.2) and carefully remove the amplifier diode tube from the amplifier mounting assembly. If the tube seems stuck, an M2.5 screw can be screwed into the tapped hole at the rear of the tube to act as a pull knob.
4. Run the new laser diode wire connectors through the nylon washer first, then through brass retaining ring (notches facing away from the diode).
5. Insert the new amplifier diode tube into the amplifier mount assembly, then the nylon washer. Reinstall the brass ring into the amplifier mount assembly to firmly hold the diode tube in place.
6. Thread the diode wire connectors through to the PCB compartment from the top of the chassis and ensure the connectors are fully inserted into their sockets.
7. Reconnect the head cables, turn the amplifier current out to 0 and power on the amplifier diode. Verify the voltage across the diode is as expected to indicate a correctly connected diode before proceeding.
8. Set the amplifier current to a low current, above the lasing threshold. Observe the amplifier diode output on a viewing card, then rotate the diode tube using a screwdriver inserted into the rear the notches, rotating until the elliptical axis is aligned as previously. Tighten both amplifier diode set screws.
9. Follow the instructions in section 3.1.2 (skipping to the relevant step) and note that the waveplate installed in front of the amplifier diode

may also need some adjustment to optimise the injection lock (see figure 3.2).

4. ILD controller and MOGILD

4.1 MOGILD computer control software

The output from the amplifier is typically a combination of the desired seed (amplified), and some free-running amplifier diode output at a different wavelength. The amplifier is injection-locked when the output is entirely amplified seed, with no output at the free-running amplifier wavelength. Achieving and maintaining lock requires precise adjustment of the amplifier diode cavity. The MOGILD software controls the MOGLabs ILD and automatically adjusts the amplifier diode cavity to maintain a lock to the seed. Figure 4.1 shows the MOGILD interface window.

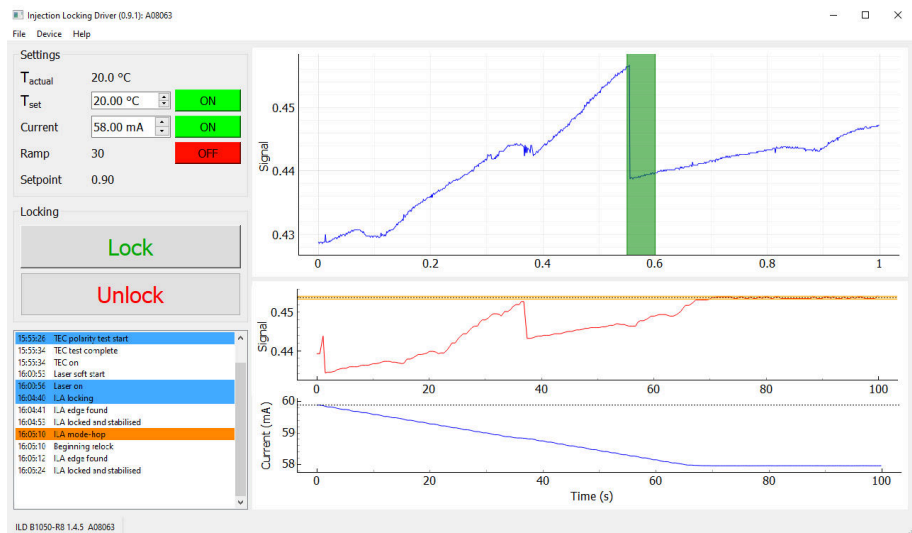


Figure 4.1: The MOGILD window displays the amplifier diode settings (top left) and a log of ILD events (bottom left). The graphs show the injection locking signal (top) during an amplifier diode current ramp, and the time dependence once locked of the injection locking signal (middle) and amplifier current (bottom).

4.1.1 Amplifier settings

Settings for injection locking the ILD are found in the top left corner of the MOGILD window.

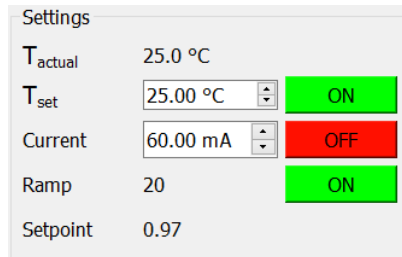


Figure 4.2: Amplifier diode settings in MOGILD.

Temperature

Temperature readout (live), temperature setpoint (adjustable) and temperature control on/off button. Refer to the ILD manual for further information.

Current

Diode current setpoint and current on/off button. The amplifier diode current output has a soft start. The STANDBY/RUN key switch must first be in the RUN position and the temperature controller must be on and operating for the current to enable and the setpoint to be adjustable. Note that when the amplifier is locked to the seed, the amplifier diode current will adjust to maintain lock, hence MOGILD will dynamically change this value. Refer to the ILD manual for further information.

Ramp

Current ramp amplitude. Set at the factory.

Setpoint

Amplifier lock setpoint. Adjusts the threshold the ILD uses to lock the amplifier diode to the seed. Generally larger values ensure more reliable single mode operation of the amplifier diode. Set at the factory; seek guidance from MOGLabs before making any changes to the setpoint.

Locking

'Lock' engages injection lock and auto-tracking, allowing the ILD to adjust the amplifier cavity until the injection signal reaches the

desired setpoint. 'Locking' indicates searching for a lock solution. 'Locked' indicates a stable injection lock with the amplifier locked to the seed. 'Unlock' disengages the injection lock.

4.1.2 Events log

15:55:26	TEC polarity test start
15:55:34	TEC test complete
15:55:34	TEC on
15:55:39	Laser soft start
15:55:42	Laser on
16:00:36	Laser off
16:00:53	Laser soft start
16:00:56	Laser on
16:04:40	ILA locking
16:04:41	ILA edge found
16:04:53	ILA locked and stabilised
16:06:10	ILA mode-hop
16:06:10	Beginning reload
16:06:12	ILA edge found
16:06:24	ILA locked and stabilised
16:06:39	ILA unlocked

Figure 4.3: The events log records ILD events relating to monitoring the laser and injection lock status.

The events log records a list of ILD events that have occurred in relation to monitoring of the laser and injection lock status. Event types are described in Appendix E.

4.1.3 MOGILD graphs

Three graphs are shown on the right hand side of the MOGILD window: the injection locking signal (except when locked), the signal variation with time during locking, and the amplifier diode current variation with time during locking.

Signal

Injection locking signal during an amplifier diode current ramp. The vertical axis shows the injection locking signal during a 110 ms amplifier current ramp. The signal is used to verify that the amplifier can be locked to the seed, in which case there will be a large step (drop) discontinuity evident in the ramp. If a step discontinuity is

not evident, the amplifier is either not well seeded, or the seed laser is not single mode. Examples of such cases are given in the ILA test report.

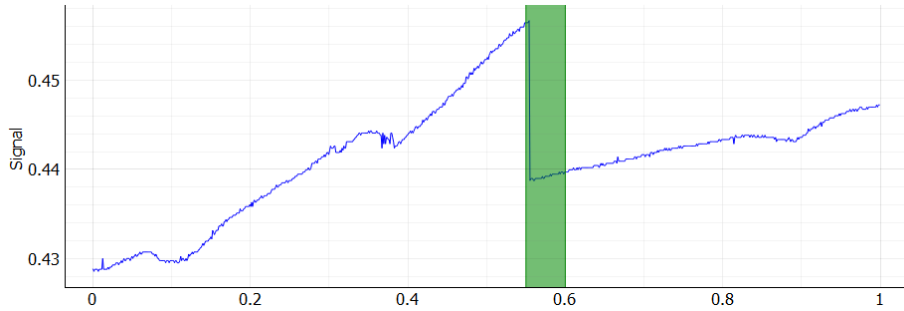


Figure 4.4: The injection locking signal during an amplifier diode current ramp. The step discontinuity evident in the green region indicates good injection by the seed laser.

Injection locking signal time series Injection locking signal time series. Once the injection lock is engaged, a dashed line indicates the setpoint target, and the shaded horizontal band indicates the range of acceptable fluctuations about the setpoint. Once the ILD has reached the setpoint, the amplifier is locked to the seed diode, and the lock status indicator reads 'Locked'.

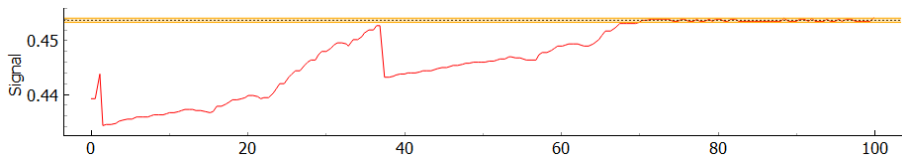


Figure 4.5: Injection locking signal time series with setpoint target (broken line). The shaded band indicates the acceptable range about the setpoint.

Current time series

Amplifier diode current time series. Once the injection lock is engaged, the current time series graph shows the amplifier diode current. Typically the time series will have a reduction of the current as the lock approaches the target setpoint, followed by a long stabilised

tail. Large excursions in the current indicate large external perturbations to the injection of the diode, such as changes to injected power or frequency, or large changes in the external temperature.

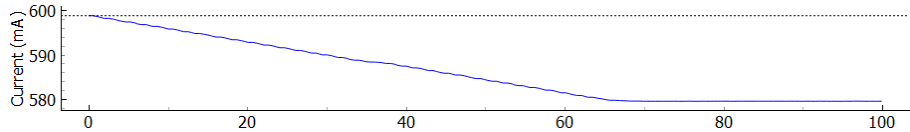


Figure 4.6: Amplifier diode current time series during the amplifier lock.

4.2 Locking an amplifier with MOGILD

Auto-track locking will be successful when a distinct falling edge can be observed in the injection locking signal as the amplifier diode current is ramped, as in figure 4.7. It is important to maximise the size of this signal

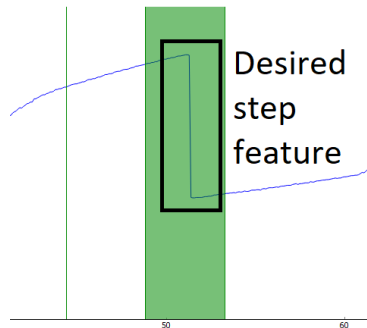


Figure 4.7: Step-like discontinuity in the injection locking signal of the ramp scan required for MOGILD injection locking.

before attempting to lock the amplifier to the seed. Use small adjustments of mirror M2 while observing the signal in the ramp scan of MOGILD.

Figure 4.8 shows the injection locking signal when the amplifier diode is not well-injected (red), when the injection angle is improved (blue) and when the best injection has been achieved (green). As the injection is improved, the locking feature becomes wider and taller.

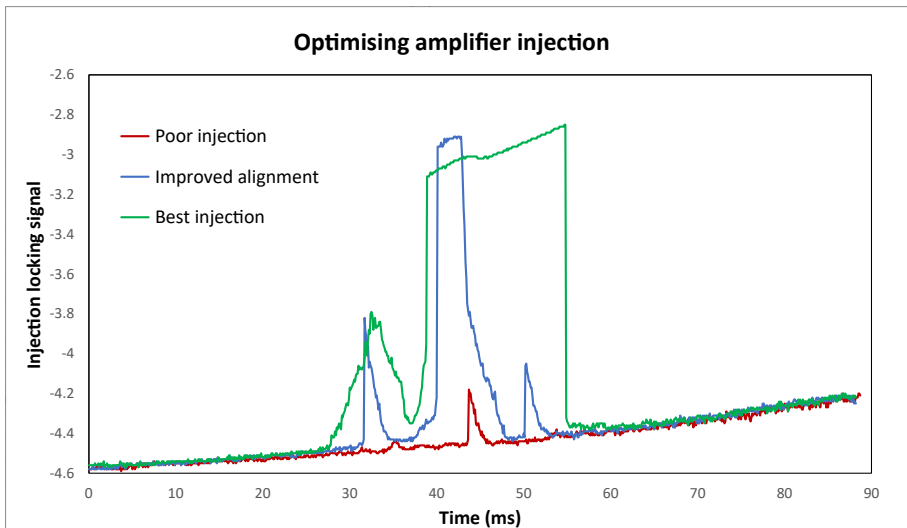


Figure 4.8: Injection locking signals for three different injection angles of the seed beam: poor (red), improved (blue) and fully optimised (green).

The locking feature also depends on the amplifier diode current and temperature, not just the injection angle. Optimisation should be performed at the desired operating temperature and current, unless the desired operating current is above the maximum unseeded diode current (if relevant, this is specified in the ILA test report), in which case optimise at the maximum unseeded amplifier diode current.

After optimising the amplitude of the step discontinuity, the amplifier can be locked to the seed as described below.

1. Switch on the seed laser to the typical operating conditions found in the ILA test report, and ensure it is operating at the desired wavelength. If the seed laser is to be locked to an external reference such as an optical cavity or via saturated absorption spectroscopy, ensure stable lock is achieved before proceeding.
2. Ensure the ILD is connected to local ethernet (or to a computer via USB) and the ILA is connected to the ILD as described in the ILD

user manual. Start MOGILD and connect to the ILD.

3. Switch the key on the front of the ILD from STANDBY to RUN, press the TEC button, and watch the diode temperature on the display to ensure it stabilises to the temperature setpoint. The typical temperature and current settings for the amplifier diode can be found in the ILA test report.
4. Set the amplifier diode current to the ILA test report and engage the current by checking the *ON* button next to the current set point.
5. An injection locking signal trace similar to figure 4.1 will appear in the top window of MOGILD. Adjust the amplifier diode current a small amount to bring the step discontinuity closer to the right side of the dark green region in the graph.
6. Press the LOCK button on the left hand side of MOGILD to engage the injection lock.
The ILD will adjust the amplifier cavity to centre the step discontinuity and then will stop ramping the amplifier diode current.
7. The signal and current time series graphs will begin to update as the ILD adjusts the amplifier diode cavity to lock the amplifier diode to the seed laser.
8. Once the injection locking signal enters the horizontal shaded region of the injection locking signal time series graph, the amplifier diode is locked to the seed laser, and the ILD then adjusts the amplifier diode cavity to maintain the injection lock. At this point, the lock status will display 'locked' and the amplifier is successfully injection locked to the seed.

5. Fibre coupling

A cylindrical telescope can be installed in the amplifier beam path to correct any amplifier diode astigmatism. The beam shaping telescope can improve the spatial mode matching to the seed laser and/or to match the spatial mode for fibre coupled output of the amplifier beam.

For an amplifier diode the typical fibre coupling efficiency is generally 60% to 70% of the power incident on the fibre, despite Fresnel losses at each fibre facet (typically 4% each).¹

Some instruments and tools helpful for quickly achieving optimum coupling efficiency:

1. Suitable single mode fibre patchcord.
2. Fibre laser pen or fibre visual fault locator (see Fig. 5.1).



Figure 5.1: A fibre laser pen or visual fault locator injects visible laser light into a fibre, allowing basic alignment and mode matching.

3. OD3 neutral density filter.
4. Power meter and sensor head.

Note that silicon photodiode power sensors easily saturate below their 'maximum' power when the full sensor is not illuminated, giving false readings. Integrating sphere sensors are recommended to avoid saturation.

¹Note that if the seed laser has a fibre coupled output option, the fibre coupling procedure described in this chapter can be used with mirror M3 and M4 replaced with M5 and M6 in the following text.

5.1 Fibre alignment

The amplifier diode should have good free space output properties as described in the previous chapters; in particular, the output should be relatively well collimated both horizontally and vertically without any clipping, *at the desired operating current and power*. The optimum fibre alignment and focus are power-dependent, and must be adjusted if the operating laser power is changed.

1. Remove any fibre patchcord from the fibre coupler.
2. Operate with the seed turned off (or blocked) and amplifier producing approximately 10 mW of power at the input to the fibre coupler.
3. Walk the M3, M4 mirror pair to pass the beam through the fibre coupler. The beam should be approximately normal to the end of the ILA chassis and centered on the fibre coupler aperture.
4. Reconnect the fibre patchcord, connect the visual fault locator to the fibre output end and switch the visual fault locator on.
5. The visual fault locator will emit a counter-propagating beam along the fibre which can be used to spatially match the amplifier diode beam with the fibre mode. Insert a mirror between the amplifier isolator (ISO2) and M3 to reflect the visual fault locator beam to approximately 4 m away. If the beam does not appear as a small spot at this distance, refer to section 5.2 for fibre coupler focus adjustment.
6. Remove the mirror you have just inserted and ensure that the amplifier beam and the visual fault locator beam are well overlapped by walking the M3, M4 mirror pair. Use M3 to overlap the amplifier beam with the fault locator beam immediately in front of the fibre coupler. Use M4 to then overlap the fault locator beam with the amplifier beam between the beam sampler and ISO2. Iterate these two mirror adjustments until no improvement in overlap can be made.
7. Remove the visual fault locator from the output of the fibre, and attach a power sensor to allow monitoring of the fibre coupling efficiency.

8. Walk the M3, M4 mirror pair to optimise output power using the following technique (the same as optimising the seed to amplifier coupling from section 3.1.2)
 - (a) For the horizontal deflection, find the maximum output power by adjusting mirror M4. Record the output power value.
 - (b) Adjust the horizontal deflection of mirror M3 clockwise such that the output power drops by no more than 25%. Take note of roughly how much rotation was required.
 - (c) Adjust the horizontal deflection of mirror M4 and maximise for output power. Compare the new maximum power obtained to the output power measured at step (a).
 - (d) If the new power is greater, repeat steps (b) and (c). If the new power is lower, adjust the horizontal deflection of mirror M4 anti-clockwise to return it to its original angle as noted at step (b), then optimise the horizontal deflection of mirror M3 to return to the output power noted in step (a). If the first horizontal clockwise adjustment of both mirrors at steps (a) and (b) resulted in a decrease in output power, repeat steps (b) and (c) using an anti-clockwise adjustment instead.
 - (e) With horizontal alignment optimized, repeat steps (b) through (d) for the vertical alignment.
 - (f) Iterate the horizontal and vertical alignment procedure until the output power no longer increases. It is best to reduce the output power by smaller increments than 25% as the alignment improves, e.g. 5% to 10%.
 - (g) At low amplifier current you should expect to be able to achieve 50% fibre coupling efficiency. The efficiency at higher current will be improved in the next steps.
 - (h) If you cannot achieve 50% fibre coupling efficiency by walking the M3, M4 mirror pair, first block the amplifier beam from entering the fibre coupler using a suitable beam block and closing the ILA chassis shutter. Remove the fibre patch cord from the fibre coupler then check the the input and output ends of

the fibre patchcord are clean and undamaged by using a fibre microscope inspector. If both ends present cleanly, the fibre coupler collimation may need adjustment. Refer to section 5.2 for how to make this adjustment.

9. Once optimised at low power with at least 50% efficiency, close the ILA output shutter to block the fibre coupler, insert a neutral density filter (NDF) after ISO2 to attenuate the power. Increase the amplifier current to the desired operating value. Adjust the choice of NDF so that you have approximately 10 mW of power at the input to the fibre coupler. Open the ILA output shutter.
10. Reoptimise the coupling efficiency by walking the M3, M4 mirror pair a very small amount. If the fibre coupling efficiency has now decreased compared to step 8f above, the fibre collimator focus will likely need to be adjusted to account for thermal lensing effects. Refer to section 5.2 for how to make this adjustment before proceeding.
11. Remove the NDF and check the coupling efficiency. A small amount of walking the mirror pair will be needed due to small deflections introduced by the NDF. Be careful not to walk the beam too far (aim for less than 10% decreases), as walking the high power beam across the fibre end-face will damage the fibre.

5.2 Fibre coupler collimation

It will not normally be necessary to adjust the focus of the fibre coupler. The fibre coupler was optimised by MOGLabs for best efficiency when the amplifier is well-seeded at typical operating current and power for the fibre core specified in the ILA test report. If the same fibre core type is not used, or the amplifier is not well-seeded, or the amplifier current/power is low, then the fibre coupling efficiency will be lower than expected. The procedure below should only be used if it clear that there is a problem with the fibre collimator focus. Discuss with MOGLabs if unsure.

To coarsely collimate the fibre coupler:

1. Connect the fibre patchcord to the ILA fibre output connector.
2. Connect the visual fault locator tool to the fibre patchcord output end and turn on.
3. A red tracer beam from the ILA fibre coupler should be emitted back towards the amplifier diode.
4. Insert a mirror between ISO2 and M3 to reflect the visual fault locator beam to approximately 4 m away.
5. Insert the focus adjustment tool provided in your MOGLabs toolkit into the fibre coupler (see Fig. 5.2). Adjust the lens collimation so that the tracer beam is well-collimated over at least 4 m distance.

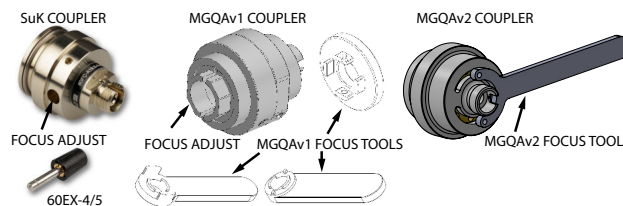


Figure 5.2: Fibre couplers showing access to fibre collimation lens adjustment. There is a slot in the SuK coupler mount for the eccentric focus tool 60EX-4/5 off-centre pin to mate with. The MGQAv1 coupler will come with one of three MGQAv1 focus tools indicated to adjust the internal nut acting on the collimation lens. The MGQAv2 coupler will come with the C-shaped pin-spanner focus tool indicated.

6. Remove the mirror you have inserted between ISO2 and M3, and walk the M3, M4 mirror pair (see section 5.1) so that the tracer beam is well overlapped with the amplifier beam.

Once the fibre coupler is roughly collimated, the fibre coupling efficiency should then be further optimised for best performance.

1. Walk the M3, M4 mirror pair to optimise fibre coupling efficiency (see step 8). Note the efficiency achieved.

2. Adjust the collimation lens focus clockwise by a very small amount (a few degrees at most) using the adjustment tool provided.
3. Reoptimise the fibre coupling efficiency by walking the M3, M4 mirror pair again.
4. Iterate the above two steps, with clockwise or anti-clockwise rotations of the focus as required, until the maximum coupling efficiency is achieved.

5.3 Polarisation control

The amplifier beam exiting ISO2 is horizontally polarised due to the geometry required with the ISO2 injection port. As a result the amplifier beam retains the highly linear horizontal polarisation after reflection from the fibre coupling mirrors. The fibre coupler key will be aligned horizontally or vertically at the factory to ensure the amplifier beam polarisation is aligned to the fast or slow axis of a polarisation maintaining fibre. Polarisation extinction ratios of greater than 30 dB are typically achieved.

5.4 Common fibre coupling issues

A frequent cause of low coupling efficiency with high powered laser systems is fibre facet damage. Remove the fibre completely from the ILA fibre coupler, inspect the end facets using a fibre microscope inspection tool, and clean/polish as necessary. Try reversing the fibre patchcord if the ends are symmetric, or a new patchcord.

Another common problem is current-dependent variation in laser beam astigmatism. Changing the operating current to vary amplifier diode output power will thus affect the beam collimation and consequently the fibre coupling efficiency. To operate at a substantially different current from the factory optimised typical operating conditions, it will likely be necessary to adjust the fibre coupler collimation, and/or adjust the amplifier diode cylindrical telescope if one is installed.

A. Specifications

Parameter	Specification
-----------	---------------

Wavelength/frequency	
370 – 1560 nm	Diode dependent. Please contact MOGLabs for availability.
Linewidth	Determined by seed
Tuning range	Diode dependent; up to 10 nm

Optical	
Beam	Diode dependent 2 mm × 1 mm (1/e ²) typical
Polarisation	Vertical linear > 100 : 1

Thermal	
TEC	±14.5 V 3.3 A $Q = 23$ W standard
Sensor	NTC thermistor 10 k Ω , $\beta = 3988$, standard AD590, 592 optional
Stability at base	±1 mK (controller dependent)
Cooling	M5x0.8 thread for 4 mm diam quick-fit connections (e.g. SMC KQ2S06-M5A). NOTE: Use distilled water only (not de-ionised). The 6061 aluminium chassis will react with many cooling additives.

Parameter	Specification
-----------	---------------

Electronics	
Protection	Diode short-circuit relay; cover interlock connection; reverse diode
Indicator	Laser ON/OFF (LED)
Connectors	See appendix C

Mechanical & power	
Dimensions	300 × 155 × 92.6 mm (L×W×H), 3 kg
Beam height	58 mm
Shipping	490 × 360 × 270 mm (L×W×H), 5.5 kg

B. Troubleshooting

No light or low output power of the amplifier diode

- Ensure input and output shutters are open.
- Ensure both the seed and amplifier beams are not obstructed in their paths, e.g. clipping the isolator or the beam sampler.
- Check that the amplifier diode current and voltage are as expected (refer to factory test results). The ILD current and voltage supplied can be found through the ILD front panel by selecting *Laser* from the *Settings* menu. If the ILD is driving a high voltage but no current, one of the diode wires may have disconnected. If the ILD is driving the desired current but at a lower than expected voltage, the amplifier diode could be short circuited to the chassis.
- Check whether the power out of the amplifier diode with the waveplate removed is as expected.
- Ensure the amplifier diode polarisation is optimised for transmission through the isolator. Try adjusting the waveplate in front of the amplifier diode mount to optimise transmission.
- Ensure your power meter is set to the correct wavelength, that you are using a power head that is rated to sufficient power, and the detector is not saturating. Silicon detectors are rated for an incident power evenly illuminating the entire sensor region. For example a Thorlabs S121C 500mW sensor begins to saturate at only 150 mW for typical beam sizes of 1 mm x 3 mm.

No positive slope in the injection locking signal

If there is no sharp edge in the injection locking signal, first verify that the amplifier diode current is indeed ramping, and that the photodiode has a signal.

- Block the injected seed beam.
- Run MOGILD and connect to your ILD.
- Ensure the seed and amplifier diodes are running near the recommended operating currents, and the amplifier current is enabled.

You should see a positive gradient slope in the injection locking signal. If not:

- Check that the ramp span on the ILD is set to 1. From the front panel on the ILD go to *Settings - Ramp* and ensure *Ramp span:1.00*.
- Check that the ramp mode on the ILD is set to a negative ramp. From the front panel on the ILD go to *Settings - Ramp* and ensure *Current ramp: -RAMP*. To change, enter *Set current ramp* and select *Negative ramp*.
- Place a card in front of the amplifier beam; the beam should be flashing at about 10 Hz. The variation will be more apparent if the amplifier diode current is close to threshold.

If you have performed the checks above and can see that the amplifier diode current is ramping (the beam is 'flashing') but the injection locking signal is not a positive gradient slope, proceed with the following checks:

- Check that the DE15 cable is fully inserted into both the ILD and the ILA connectors. If the cable is not fully inserted the ILD may still be able to generate current, but cannot communicate with the photodiode. Ensure the cable locking screws are fully tightened.
- Check that the photodiode is connected to the photodiode amplifier with no loose connections.
- Check that the flat flex cable is well seated in the photodiode headboard and the laser headboard underneath.

If you still cannot see a ramping signal, contact MOGLabs.

No step discontinuity in injection locking signal

If you see the amplifier diode current ramping (a positive gradient ramp for the injection locking signal) but you have no sharp discontinuity:

- Check that the seed laser is single mode with either a scanning Fabry-Perot interferometer or wavemeter. If neither is available, slowly adjust the seed laser current and see if a sharp edge appears in the signal.
- Try adjusting the horizontal and vertical adjustment of mirror M2 a *very* small amount.
- Try increasing the amplifier current by 5 mA then reducing the amplifier current back to the desired amplifier current in smaller increments of 0.1 mA. The amplifier current mode has a hysteresis that favours reducing current to settle into a good mode.
- Check that you have the recommended injected power from the seed laser between the amplifier diode mount and the amplifier isolator.
- Check that the seed laser beam is well overlapped with the amplifier beam. Reflect the beam after the amplifier isolator out of the chassis over approximately 4 m and ensure the beams are overlapped both near the isolator output and at 4 m.
- Try adjusting the amplifier diode temperature setpoint up or down by 1°C, and watch the injection locking signal as the temperature changes.
- Check that the collimation of the seed and amplifier beams are matched. First block the injected seed beam and observe the size of the amplifier beam at 4 m from the laser, then switch off the amplifier diode current and unblock the seed beam and observe the size of the seed beam. Adjust focus of seed or amplifier until they match and both are collimated.

- Reduce the current of your amplifier diode to near its bare threshold, and check that power output matches the value listed in the *Amplifier injection* section of your ILA test report.

If you still do not see any sharp features, contact MOGLabs.

Negative gradient

If the injection locking scan has a negative gradient, the photodiode may be connected backwards, or the amplifier current is scanning in the wrong direction.

- Check that the ramp mode on the ILD is set to a negative ramp. From the front panel on the ILD go to *Settings - Ramp* and check that *Current ramp: -RAMP*. If it is not, enter *Set current ramp* and select *Negative Ramp*.
- Check that the injection locking signal increases towards the top of the vertical axis when the amplifier diode is turned off or blocked from reaching the photodiode. If it instead drops, reverse the photodiode wiring.

Injection locking signal discontinuity unsuitable

If the ILD cannot find a suitable discontinuity, it will give the error message *ILA edge unsuitable* in the events log. If this occurs the ILD will not be able to lock the amplifier diode to the seed. If no sharp edge-like feature is visible, refer to the troubleshooting section *No step discontinuity in injection locking signal* above. If an edge is visible, check the following:

- Is the seed single mode? If the seed is not single mode, the edge height and sharpness will be reduced. Try adjusting the seed current by +5 mA then reducing the current back to the desired current in smaller increments. The seed current mode has a hysteresis that favours reducing current to settle into a good mode.

- Is the alignment of the injected beam into the amplifier optimal for your wavelength? Try adjusting mirror M2 a very small amount.
- Is there enough injected power? Refer to your ILA test report for the recommended injected power, and verify you have this power injected from the seed through the amplifier isolator, measured with a power meter between the amplifier diode mount and the amplifier isolator.

C. Electrical connections

The ILA has two electronic head boards, one associated with the seed laser and one for the amplifier. For information on the seed laser, please refer to the seed laser user manual. The information below relates to the amplifier only.

C.1 ILA amplifier headboard

The amplifier is connected via the B1056 headboard (figure C.1) which provides connections to the amplifier diode, TEC, a passive NTC thermistor temperature sensor and the beam sampler photodiode. Connections from the board to the wired components use JST-EH series wire-to-board connectors. The board includes a solid-state protection relay and passive protection filters, and a laser-on LED indicator.

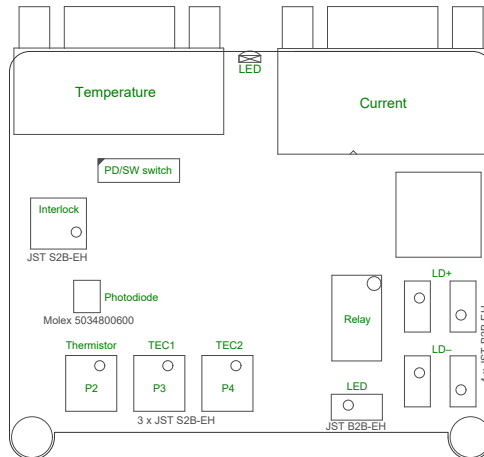


Figure C.1: MOGLabs ILA B1056 laser head board showing connectors for the amplifier diode, temperature sensor, TEC, photodiode headboard and LED.

Name	Description
Temperature	DE9 female (TEMP)
Current	DE15 female (CURRENT)
Photodiode	Photodiode
P2/thermistor	Thermistor
P3/TEC1	TEC connection 1
P4/TEC2	TEC connection 2
LD+	Laser anode
LD-	Laser cathode

Figure C.2: B1056 headboard connectors. The two TEC connections each have +/– polarities and should be connected in parallel to provide greater current-carrying capacity. Each of the laser anode (+) and cathode (–) connectors have two pins connected in parallel.

C.2 Connector pinouts

Note, only high quality cables with 24AWG or larger conductors should be used. Cables generally should be kept to 1.5 m or less.

C.2.1 Current

Pin	Signal	Pin	Signal
1	Relay (-)	9	N/C
2	I2C SDA	10	Laser diode anode (+)
3	Photodiode status	11	+5V
4	Laser diode cathode (-)	12	I2C SCL
5	Laser diode anode (+)	13	Laser diode cathode (-)
6	0V (ground)	14	Laser diode cathode (-)
7	0V (ground)	15	Laser diode anode (+)
8	0V (ground)		

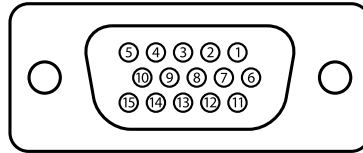


Figure C.3: DE15, female, current supply connector (P6) pinout. Relay (-) should be grounded to open the protection relay and enable operation.

C.2.2 Temperature

Pin	Signal	Pin	Signal
1	Thermistor NTC 10k Ω (+)	6	Thermistor NTC 10k Ω (-)
2	0V (ground)	7	Peltier TEC (-)
3	Peltier TEC (-)	8	Peltier TEC (-)
4	Peltier TEC (+)	9	Peltier TEC (+)
5	Peltier TEC (+)		

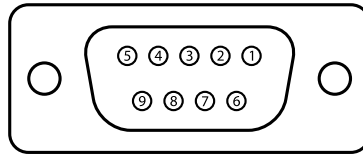
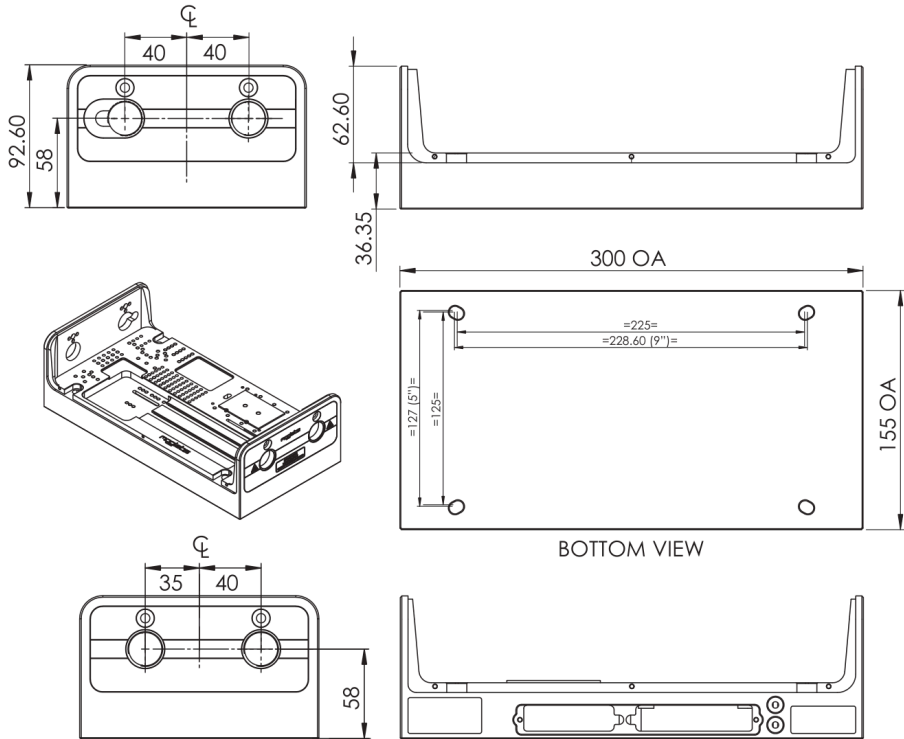


Figure C.4: DE9, female, temperature supply connector (P1) pinout.

D. Chassis dimensions



E. Log messages

The ILD includes an event-logger that permits monitoring of the laser status as well as the injection lock status. In particular, it records when the injection lock fails, suggests a likely cause, and states the action that the controller took in response.

Although the lock can compensate for long-term drift, large external perturbations (e.g. sudden shock) or instability in the seed laser will cause the lock to destabilise. If the cause for the unlock is temporary, the ILD will typically be able to relock the laser within a few seconds. In cases where the seed laser begins multi-moding, the injection locking signal will have an incorrect shape and the log helps to identify the cause.

Log message	Explanation
ILA locking	User initiated injection lock
ILA unlocked	User disabled injection lock
ILA failed to find edge	No locking feature was observed in the injection locking signal
ILA edge unsuitable	A step-feature was observed in the injection locking signal, but it was not large enough to lock to
ILA edge found	An acceptable locking feature was identified
ILA failed to track edge	The laser mode-hopped while isolating the locking feature
ILA locked and stabilised	The algorithm converged and the injection locking was successful
ILA out of bounds	The injection-locking signal went out-of-bounds, causing the lock to fail
ILA mode-hop	The laser was observed to undergo a mode-hop, causing the lock to fail

ILA current drifted too far	Current has drifted from initial lock point; consider relocking to ensure single mode
Too many relock attempts	The auto-relock algorithm has exceeded the maximum number of relock attempts
Laser off; lock aborted	The laser was switched off while the lock was enabled
TEC polarity test start	Automatic test to determine correct TEC polarity
PD capture failed	Signal fidelity from photodiode is low; reduce resistance of head cable (shorter cable, or larger gauge wire cores)

