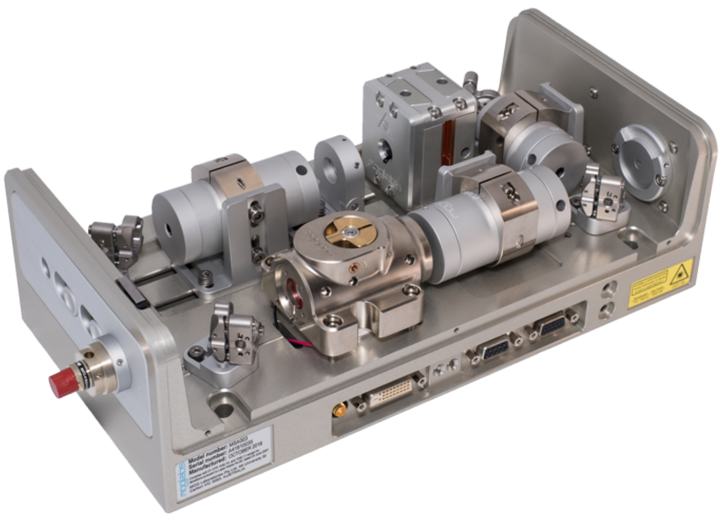
Amplified laser system

Model MSA – internal seed
Model MOA/MOA(L)/MOA(C) – external seed



Revision 2.05

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Preface

The MOGLabs optical amplifier laser system provides up to 6 W of tunable highly coherent optical radiation for atomic cooling, Bose-Einstein condensation, ion trapping, and other spectroscopic applications. It reproduces the optical spectrum of the input seed laser, maintaining the linewidth while increasing the output power by up to 400 times (+26 dB). It can be configured as amplifier only (MOA) or with seed laser (MSA). Configurations may include input and/or output fibre coupling, and input and output Faraday isolators. The MOGLabs DLC and LDD drivers are ideally suited for operating the seed and amplifier components of the amplifier system.

We hope that the MOGLabs optical amplifier system can work well for your application. We are proud of our products and continuously improving them. Please let us know if you have any suggestions for enhancement of the product or this document, so that we can make life in the lab better for all.

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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. Please note several specific and unusual cautionary notes before using the MOGLabs MSA and MOA, in addition to the safety precautions that are standard for any electronic equipment. The directions here apply to both MSA and MOA (amplifier-only) configurations except where explicitly stated otherwise.

> ***WARNING***
> Do not operate the amplifier above the ***Maximum current, unseeded*** without appropriate input seed. Operation exceeding that condition can cause fatal structural degradation of the TA diode. Refer to the ***Maximum current, unseeded*** specified in the amplifier test report.

> 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 MSA and MOA 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. 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 1) and heed their warnings.
- The MSA or MOA must be operated with a controller with keyswitch interlock. The MSA must not be powered unless the keyswitch is inserted and switched on. It should not be possible to remove the keyswitch without turning off the power to the MSA or MOA.
- When the seed laser and amplifier are switched on, there should be a delay of two seconds before the emission of laser radiation, mandated by European laser safety regulations (IEC 60825-1).

WARNING Do not operate the amplifier without sufficient seed laser input. It is important that an injection seed laser beam is coupled into the tapered amplifier (TA) diode so that most of the electrical input energy is converted to optical output rather than lost as heat, which would damage the TA diode.

NOTE The MOGLabs MSA and MOA are designed for use in scientific research laboratories. They should not be used for consumer or medical applications.

Protection Features

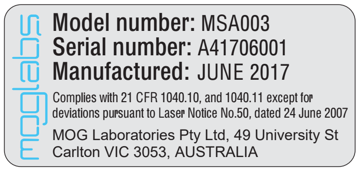
The MOGLabs MSA and MOA include a number of features to protect you and the device. They should be used with a power supply that provides additional safety features such as key lock operation, current limit, temperature limit, cable continuity and short-circuit detection, soft-start and turn-on delay.

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

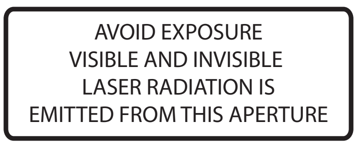
LEDs Separate LED indicators illuminate when the seed laser and amplifier diode current supplies are enabled.

Label identification

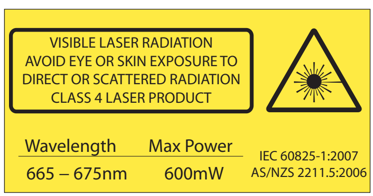
The International Electrotechnical Commission laser safety standard IEC 60825-1:2007 mandates warning labels that provide information on the wavelength and power of emitted laser radiation, and which show the aperture where laser radiation is emitted. Figures 1 and 2 show examples of these labels and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



US FDA compliance



Aperture label engraving



Warning and advisory label
Class 4

Figure 1: Warning advisory and US FDA compliance labels.

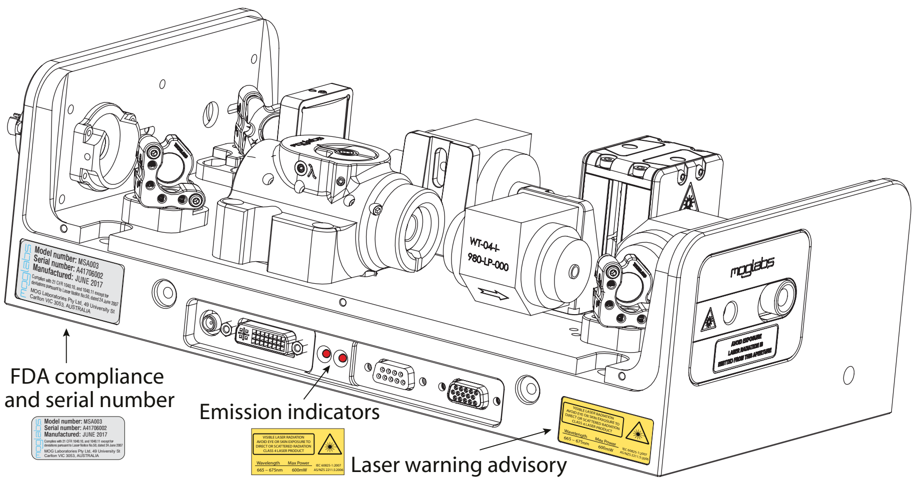


Figure 2: Schematic showing location of warning labels compliant with International Electrotechnical Commission standard IEC 60825-1:2007, and US FDA compliance label. Emission indicator for seed laser (left) and amplifier (right). Aperture label engraved on front and rear apertures; warning advisory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

Contents

1. Introduction

The MOGLabs MSA is a semiconductor laser amplifier with injection seed laser (fig. 1.1). The heart of the system is the amplifier block (fig. 1.2) with semiconductor tapered amplifier (TA) diode. A cylindrical lens provides astigmatism compensation and Faraday isolators protect the TA diode, as well as preventing the amplifier output from disturbing the seed laser.

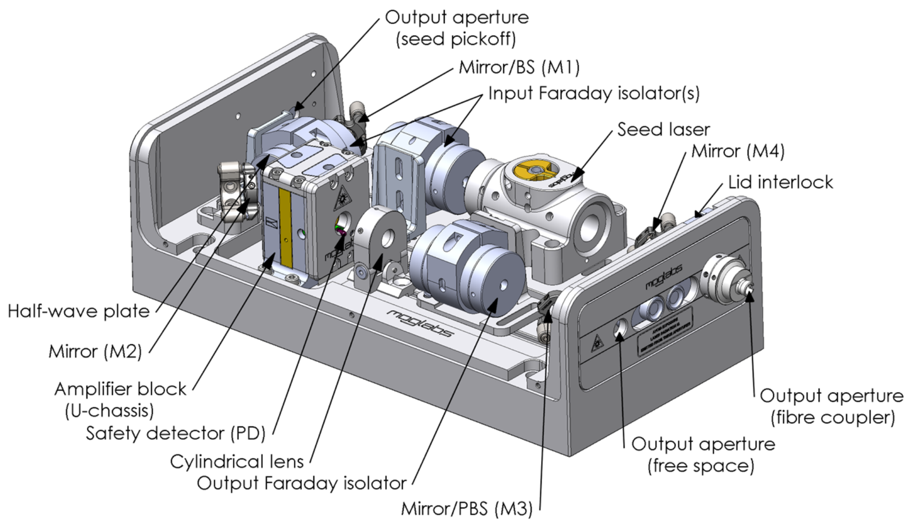


Figure 1.1: Schematic diagram of major components in the MSA.

The MOA is an amplifier-only configuration of the MSA, without built-in seed laser. There are two smaller versions of the MOA; the MOA(L) with one isolator on the TA output and the compact MOA(C) without isolators. Fibre coupling options are available for the MSA/MOA/MOA(L) output and for MOA/MOA(L) input with an external seed laser.

The TA diode is mounted in a block (U-chassis) with aspheric input and output lenses in flexure $x-y$ translation stages (fig. 1.2). The flexure mounts control the transverse positions of the input (focusing) and output (collimation) lenses, providing precise lens alignment with mechanical stability. Finely threaded tubes control the lens positions along the axis of propagation. The U-chassis allows simple user replacement of the TA diode (see chapter 8).

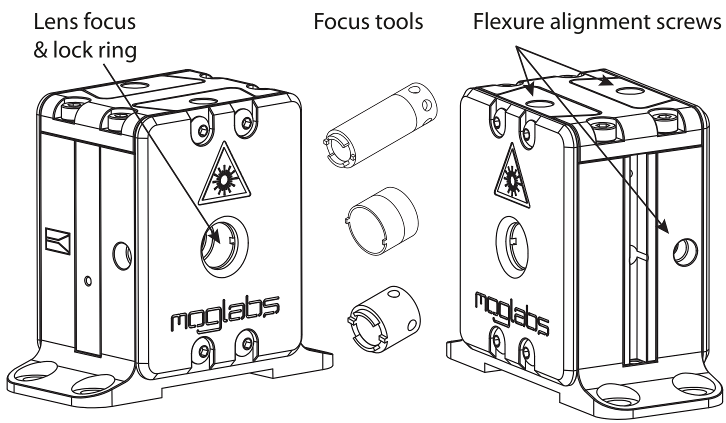


Figure 1.2: TA diode block (U-chassis), showing flexure alignment and focus adjustments for input and output lenses and tools for focus adjust and locking.

The TA diode emits from both input and output facets. Emission from the input-side waveguide can be used for seed laser alignment. A tapered engraving on the side of the U-chassis shows the TA diode orientation, with the small area ridge waveguide on the input side and large area tapered waveguide on the output side.

The input lens focuses the seed laser onto the input waveguide of the TA diode. The output lens collimates the amplified TA laser beam emitted from the output waveguide.

In normal operation, the seed laser should provide a collimated beam of 10 to 60 mW. The minimum seed power requirement depends on the specific TA diode, and will be specified in the laser test report. The seed laser beam should propagate through an input isolator (we recommend > 38dB isolation) and is deflected by mirrors M1 and M2 into the TA diode, with an optional input isolator between M1 and M2. For the MSA, M1 is a fixed beam splitter (or polarising beam splitter (PBS) with a half-wave plate before the

PBS) to pick off a fixed (or variable) free-space beam from the seed laser, which can be used for locking to a frequency reference or monitoring the seed laser. For the MOA series, the seed beam enters through the input aperture either in free-space or via a fibre coupler, and is then deflected by mirrors M1 and M2 into the TA diode.

The seed laser beam must be mode-matched to the TA diode. Mode matching can be optimised by ensuring that the reverse propagating TA beam, emitted from the small area ridge waveguide side of the TA back towards M2 and M1, is overlapped with the seed beam propagating towards the TA. The seed and reverse propagating TA beams should have similar beam size along their paths, and parallel linear polarisation. The MOGLabs amplifiers have a zero-order half-wave plate installed for adjusting the seed polarisation to match the TA diode. Usually the half-wave plate is installed in the end-cap of the input isolator in MSA systems, or on the chassis for MOA systems (see figs. 4.1, 4.3 and 5.1).

The main TA output beam propagates through a high-power Faraday isolator. A photodetector (PD) monitors the TA output to ensure that the TA is properly seeded at high operating currents (see chap. 2 for further information).

The main TA output exits through the free-space output port or is reflected by mirrors M3, M4 to a fibre coupler. Replacing M3 with a PBS allows dual beam output with a variable ratio between free-space and fibre-coupled outputs. See chapter 7 for details on fibre coupling.

For background information on tapered amplifiers, please see Refs. [1, 2].

2. Safety features

> ***WARNING***
> Do not operate the amplifier above the ***Maximum current, unseeded*** without an appropriately coupled input seed. Operation exceeding that condition can cause fatal structural degradation of the TA diode. Refer to the ***Maximum current, unseeded*** specified in the amplifier test report.

MOGLabs amplifiers have interlocks for customer protection and internal power monitoring with a safety shutoff feature to protect the TA diode. The shutoff feature shuts off the TA diode current if simultaneously the amplifier operates above the *Photodiode safety cutout* current specified in the system test report, and the internal power is less than a factory determined threshold.

2.1 Interlock

An interlock switch located along the top edge of the chassis is activated if the cover is removed while the TA injection current is above the *Maximum current, unseeded* current (see fig. 1.1). The interlock can be defeated for alignment and test purposes by holding the switch actuator down, for example with adhesive tape, or by changing the interlock mode under the headboard settings in the LDD menu.

2.2 Photodiode safety cutout

A photodiode monitors the output power of the TA diode. Once the TA injection current is above the photodiode *safety cutout current*, if the output power is measured low for a requested TA diode current, for example because the seed input has been blocked, the diode current supply will be switched off to prevent damage to the TA diode.

Two locations for the photodiode are possible. The first location is inside the exit cover plate of the amplifier U-chassis, which detects light reflected back from the cylindrical lens. The second location is in a separate mount with a dedicated fused silica beam-sampling optic (see sec. 6.2).

Please be aware that any changes in optical alignment that affect the output beam, or changes in the current-power response such as changing seed wavelength, will require adjustment and re-calibration of the photodiode threshold as described in sec. 6.2.

3. First light

> *WARNING*
> Do not operate the amplifier above the ***Maximum current, unseeded*** without an appropriately coupled input seed. Operation exceeding that condition can cause fatal structural degradation of the TA diode. Refer to the ***Maximum current, unseeded*** specified in the amplifier test report.

The initial MSA/MOA installation is typically a matter of mounting the chassis to an optical table, checking the temperature stabilisation and observing emission of light from the TA diode (and seed laser if MSA).

The MSA/MOA includes a water cooling channel for operation at unusually high or low temperatures, or in laboratories with high or unstable air temperature. Quick-fit connectors are provided for connection to 4 mm OD (optionally 6 mm) tubing, but for most applications, water cooling is not required; dissipation to the air and/or optical table is sufficient.

Proceed with the following steps for initial installation (and powering up in general):

1. The MOGLabs amplifier chassis should be firmly mounted to an optical table or other stable surface, using the mounting through-holes, suitable for both metric and imperial tables, accessed by removing the amplifier cover.

2. The amplifier exit aperture should be directed towards a suitable power sensor or a beam block. If fibre coupling is installed on the amplified output, ensure the fibre input coupler is shuttered or protected from the TA input to ensure any fibre facet inserted is not damaged.

3. Connect the laser head to a MOGLabs LDD controller (for MSA, also connect to a MOGLabs DLC) using the provided cables. For alternative electronic controllers use the connector pinout description in appendix A.

4. Enable the temperature controller for the amplifier (and seed laser, whether integrated to the MSA or externally supplied), then check that the temperature readouts are approaching the set points indicated on the controllers as specified in the system test report. Temperature stabilisation usually takes 5 to 10 minutes. Detailed LDD and DLC controller operation instructions are provided separately in their associated user manuals.

5. Choose a TA injection current set point that will provide between 10 mW and 100 mW of output power, but no more than approximately 90% of the *Maximum current, unseeded* current specified (refer to customer test report). Turn on the current and note that light emission should occur from the TA block output aperture.

   NOTE: TA diode operation above *Maximum current, unseeded* without an appropriately coupled seed laser will damage the diode.

6. For future reference, record a power *vs.* current (PI) curve for the main output beam of the unseeded TA diode.

   NOTE: Some power sensors (e.g. Si photodiode) have a highly reflective surface. To avoid damage to the TA diode, ensure the sensor is not close to normal incidence relative to the TA emission.

7. For MSA systems (and externally seeded amplifiers), next power on the seed laser to a suitable current according to the system test report (or according to the seed laser specifications) and wait a minute for thermalisation. Record a PI curve for the free space output beam from the MSA seed, if installed. It should be similar to the PI curve in the system test report (see test report figure *Seed power at TA input, pick off*). Instructions for the integrated seed laser operation are provided separately in the CEL or LDL user manual.

To shutdown the laser system after use, first decrease the TA injection current below the specified *Maximum current, unseeded* for your amplifier (refer to customer test report). Next turn off the seed current. Then turn off the TA injection current. Finally, turn off the temperature controllers for the seed and the TA.

For further operation of MSA systems, proceed to chapter 4.

For further operation of MOA systems, proceed to chapter 5.

4. MSA: internal seed alignment

> ***WARNING***
> Do not operate the amplifier above the ***Maximum current, unseeded*** without an appropriately coupled input seed. Operation exceeding that condition can cause fatal structural degradation of the TA diode. Refer to the ***Maximum current, unseeded*** specified in the amplifier test report.

> ***WARNING***
> The isolators contain very strong magnets – much stronger than expected. Do not bring any e.g. steel objects within 50 mm of the isolators.

4.1 Small adjustment to seed alignment

After initial setup (chapter 3), an MSA system may require a small adjustment to the seed laser alignment. With reference to figure 4.1, optimise the seed alignment using the procedure outlined below.

1. Ensure proper seed laser operation according to the instructions provided in the MOGLabs CEL cateye laser user manual.
2. Take note of the *Maximum current, unseeded* listed in the MSA test report and the maximum expected output power at this TA current.
3. Terminate the TA output beam path with a power sensor rated to at least the power noted in step 2, preferably after the isolator at location *E* in fig. 4.1.

   NOTE: Measuring the TA output power before isolator could damage the TA diode with a back-reflection from the power sensor. Take care to avoid normal incidence reflections.

   NOTE: If a sufficiently slim power sensor is not available, insert a mirror in the beam path after (preferably) or before the output isolator to deflect the beam to a larger sensor.

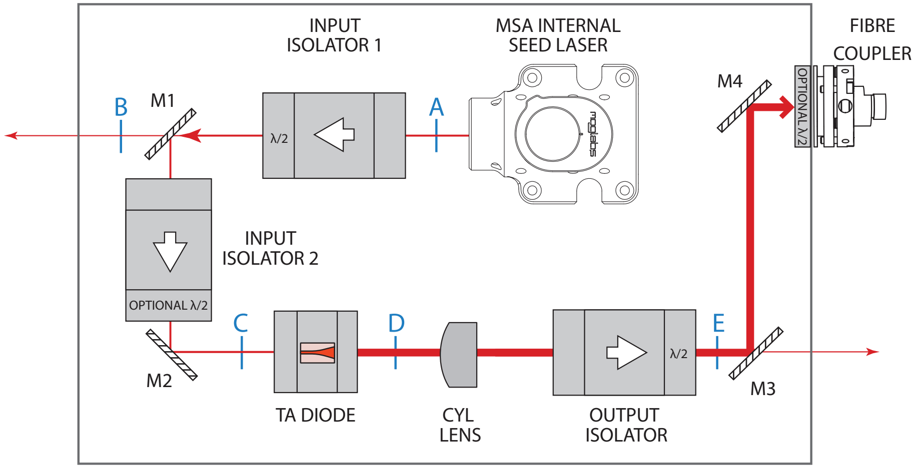


Figure 4.1: Schematic diagram of major components in the MSA.

4. Power on the TA diode with an injection current of 100 mA less than the *Maximum current, unseeded*. Adjust the seed laser current/power so that it matches a listed value from the table *Guide for seed coupling at low and high tapered amplifier current* in the system test report, typically 10 mW (20 mW for some TA diodes).

5. Slightly adjust mirror M2 first horizontally, then vertically, to achieve the maximum possible TA power, P_{REF}. The power should be close to the value in the table *Guide for seed coupling at low and high tapered amplifier current*, either *After isolator* or *Before isolator* column, depending on where the TA output power is measured.

4.1.1 Abbreviated walking procedure

(a) Measure the TA output power while making small (e.g. $\frac{1}{16}$ turn) adjustments to the *horizontal* axis of M1 until the output power is maximised.

(b) Adjust only the horizontal axis of M2 to further optimise P_{REF}.

(c) Repeat above two steps until P_{REF} is optimised.

(d) Repeat the above steps for the vertical axis of M1 and M2 until P_{REF} is optimised.

6. Compare the recorded power of the TA with the appropriate value from the test report. A variation of 5% is acceptable.

7. Record a TA power vs. TA current curve of the seeded TA diode as a future reference for comparison if system performance changes.

If the TA output power is far below the factory measured output indicated in the system test report, proceed to section 4.2.

4.2 Substantial adjustment to seed alignment

Please *do not* proceed with the alignment steps below unless instructed to do so in the previous section, there has been substantial seed misalignment, the TA diode has been replaced or under instruction by MOGLabs support.

For most MSA systems, optical element M1 is a partially reflecting fixed-ratio beam-splitter. The transmitted part of the seed laser beam (location *B* in fig. 4.1) can be used for the following steps in seed alignment. If M1 is instead a mirror, the seed laser beam can be accessed by inserting a mirror directly after the seed laser (location *A* in fig. 4.1) or between the first input isolator and M1. If substantial adjustments are needed, remove M1.

To obtain effective seeding of the TA diode:

1. Take note of the *Maximum current, unseeded* listed in the MSA test report and the maximum expected output power at this TA current.

2. Terminate the TA output beam path with a power sensor rated to at least the power noted in step 1, preferably after the isolator at location *E* in fig. 4.1.

   NOTE: Measuring the TA output power before isolator could damage the TA diode with a back-reflection from the power sensor. Take care to avoid normal incidence reflections.

NOTE: If a sufficiently slim power sensor is not available, insert a mirror in the beam path after (preferably) or before the output isolator to deflect the beam to a larger sensor.

NOTE: Ensure that the TA output propagates through the isolator without clipping.

3. Power on the TA diode with an injection current less than the *Maximum current, unseeded*. Adjust for a few mW in the reverse propagating TA beam at location *C* in fig. 4.1.

4. Adjust the seed laser current/power so that it matches the minimum listed value from the table *Guide for seed coupling at low and high tapered amplifier current* in the system test report, typically 10 mW (20 mW for some TA diodes). The seed laser should be stable in power and frequency, i.e. not near a mode-hop and not ramping the piezo.

5. The divergence of seed reverse propagating TA beams should be matched. Remove M2 and the input side chassis endplate, or use a mirror to deflect the seed beam out of the chassis. Check the collimation of the seed laser using a shear plate (shearing interferometer) or M^2 beam profiler and if necessary adjust the focus of the seed laser to achieve collimation (refer to the CEL manual). If a shear plate or M^2 beam profiler is unavailable, the spot size of the seed laser beam should be minimised at 5 m distance from the seed laser.

6. The reverse propagating TA beam is collimated with an input lens mounted in a flexure translation mount. Allow the reverse propagating beam to propagate about 5 m, again by inserting a mirror into the beam path to deflect the beam as required. Adjust the reverse propagating beam divergence by rotation of the TA input lens mount using the supplied lens tube spanners (see fig. 1.2 and fig 4.2). There is an outer tube spanner for loosening the retaining lock ring and an inner tube spanner for adjusting the lens focus. Make sure to

tighten the retaining ring once the lens position has been adjusted. The beam spot size should be as small as possible at about 5 m propagation distance.

7. Using the flexure alignment screws (see fig. 1.2), adjust the input lens $x - y$ position so that the reverse propagating beam exits parallel to the MSA chassis horizontal plane and parallel with the MSA chassis long edge. It will be necessary to remove the input end plate from the main chassis.

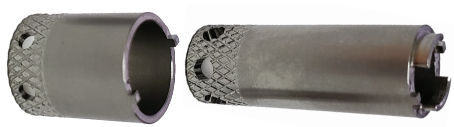


Figure 4.2: Lens tube spanners for adjusting TA collimation lenses.

NOTE: The TA diode injection current should not be more than *Maximum current, unseeded*. Do not allow the TA reverse propagating beam to propagate into the seed laser without a seed isolator installed; it could damage the seed laser diode.

8. Re-install M2, ensuring the incident beams are centred on the mirror and are at 45° angle of incidence.

9. Remove input isolator 2 (if installed between M1 and M2), preferably by removing the entire isolator, ring clamp and right angle bracket as one assembly. First ensure the isolator inputs and outputs are covered to protect against items being magnetically attracted into the isolator optics. Please take care if using steel tools and removing screws, to avoid magnetic attraction into the isolator optics.

10. Pre-align the seed laser beam and the reverse propagating TA beam using M1 and M2. The beams should be collinear and overlapping at locations *A* and *C* in fig. 4.1.

11. Re-install input isolator 2 if applicable, ensuring the seed laser is well-centred on the input and output isolator apertures. The isolator

end faces should generally be orthogonal to the propagating beam direction.

12. Measure the transmission efficiency of the Faraday isolator(s). If the amplifier configuration has two input isolators, the isolator close to the seed laser should be installed first. Compare the isolator efficiency with the efficiency value specified in the system test report. If the value from the test report and the measured efficiency are different by more than 10%, contact MOGLabs customer support.

13. Remeasure the seed laser power before the TA diode (after the input isolator) and adjust the seed laser current to achieve the same power specified in the system test report. The seed laser should still be stable, not near a mode-hop.

14. The TA injection current should now be chosen to match a value in the table *Guide for seed coupling at low and high tapered amplifier current* from column *TA current (mA)* in the test report.

15. Using M1 and M2 accurately align the seed laser beam with the TA reverse propagating beam using the following *walking* procedure:

    (a) Make sure the seed laser is incident and centred on the TA block input aperture by adjusting M1 and M2.

    (b) Install a power sensor after the TA output, preferably after the output isolator.

    (c) For the *horizontal* axis first, adjust M2 to achieve maximum output power from the TA. Call this value P_{REF}.

    (d) Make a small adjustment to the *horizontal* axis of M1 in a clockwise direction such that the output power drops by no more than 25%. Take note of how much adjustment was made e.g. $\frac{1}{16}$ turn clockwise.

    (e) Next adjust only the horizontal axis of M2 to maximise the output power from the TA. The adjustment range should be less than half a turn of the actuator at this step, and this range should reduce upon iteration.

(f) If the new measured power is greater than P_{REF}, this higher power is the new reference power P_{REF}. Iterate steps 15d and 15e until P_{REF} is maximised. It will be necessary to drop the output power by less than 25% as the alignment improves, e.g. 10% or 5%.

(g) If the new measured power after step 15e is instead lower than P_{REF}, readjust the horizontal axis of M1 anti-clockwise to return to the original angle (as noted at step 15d), then reoptimise the horizontal axis of M2 to return to P_{REF}. Now iterate steps 15d and 15e with an *anticlockwise* adjustment at step 15d.

(h) Once P_{REF} is maximised, iterate steps 15d through 15g for the *vertical* direction.

(i) Iterate the horizontal and vertical alignment procedures above until P_{REF} is maximised.

16. Check that the seed laser power before the TA (position *C* in fig. 4.1) has not changed during the adjustment procedure and corresponds to the seed power from the system test report. If it has changed, again adjust the seed laser current so that the power at position *C* matches a listed value in the *Guide for seed coupling at low and high tapered amplifier current* table in the system test report. Iterate the walking procedure from step 15 again (with very small adjustments).

17. Once P_{REF} is optimised, adjust the orientation of the half-wave plate mounted in the endcap of the input isolator (see fig. 4.3) by first loosening the set screw indicated. Rotate the half-wave plate to maximise power out of the TA diode, then re-tighten the set screw.

18. Verify optimum seed alignment by again walking the M1, M2 mirror pair according to step 15 (with very small adjustments).

19. Record the final TA output power, P_{REF}, along with the seed power and injection current. Temporarily block the seed beam and record the unseeded amplifier output power. Compare the measured P_{REF} with the value from the table *Guide for seed coupling at low and*

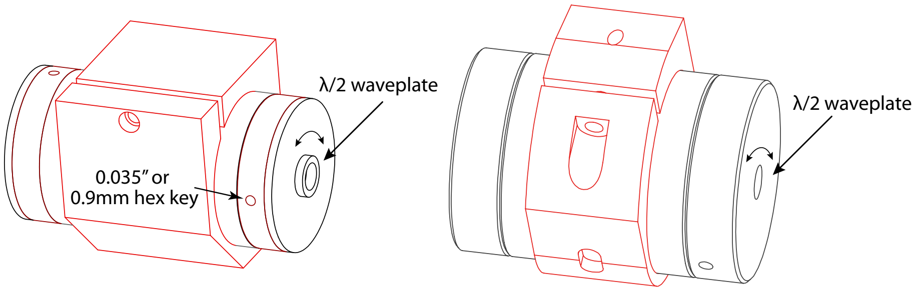


Figure 4.3: Schematic diagram showing location of half-wave plate in isolator endcaps. Ensure set screw is loosened before rotating endcap.

high tapered amplifier current, either *Before isolator* or *After isolator* column in the test report, as appropriate.

20. If P_{REF} has been measured after the output isolator and it is not within 10% of the value given in the system test report, instead measure and compare the TA power before the isolator for agreement. If there is still more than 10% difference from the test report value, slightly adjust the TA input lens focus (z) position to achieve better mode-matching and repeat step 15. It may take a number of iterations to maximise P_{REF}.

21. Measure PI curves before and after the TA output isolator and compare with the curves in the system test report.

22. If the measured and factory curves still differ by more than 10%, contact MOGLabs customer support.

5. MOA: external seed alignment

> *WARNING*
> Do not operate the amplifier above the ***Maximum current, unseeded*** without an appropriately coupled input seed. Operation exceeding that condition can cause fatal structural degradation of the TA diode. Refer to the ***Maximum current, unseeded*** specified in the amplifier test report.

MOA installation requires aligning a seed laser with the TA diode to obtain a power comparable to the value in the MOA test report. The MOA is available in three configurations: MOA, MOA(L) and MOA(C). The MOA(C) does not have provision for an internally mounted output isolator, so the user should provide an external isolator for both input and output beams.

5.1 Seed alignment

To efficiently couple seed light into the TA diode, polarisation and spatial mode matching are required; that is, the seed beam and TA reverse propagating beam should have the same polarisation, beam width, and divergence. The TA input lens in the U-chassis (see chapter 1) is optimised by MOGLabs for a collimated seed laser. Depending on the amplifier configuration, the input seed laser could be fibre coupled or free space.

With reference to figure 5.1, optimise the seed alignment using the procedure below.

1. Take note of the *Maximum current, unseeded* listed in the MOA test report and the maximum expected output power at this TA current.

2. Terminate the TA output beam path with a power sensor rated to at least the power noted in the above step, preferably after the isolator at location *D* in fig. 5.1.

   NOTE: Measuring the TA output power before isolator could damage the TA diode with a back-reflection from the power sensor. Take care

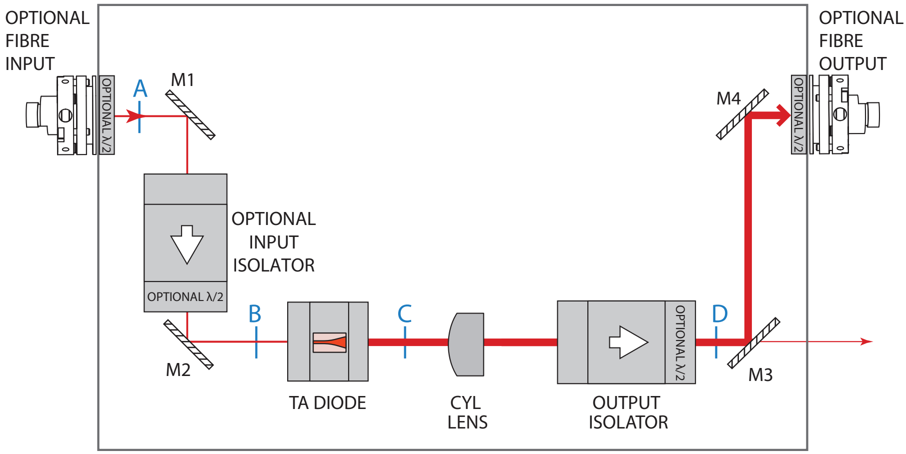


Figure 5.1: Schematic diagram of major components in the MOA.

to avoid normal incidence reflections.

NOTE: If a sufficiently slim power sensor is not available, insert a mirror in the beam path after the output isolator (preferably, otherwise before the isolator) to deflect the beam to a larger sensor.

3. Power on the TA diode with an injection current of 100 mA less than the *Maximum current, unseeded*. The TA injection current should be chosen to match one of the values in the table *Guide for seed coupling at low and high tapered amplifier current* from column *TA current (mA)* on the test report, but still be below *Maximum current, unseeded*.

   NOTE: The TA diode injection current should not be more than *Maximum current, unseeded* (see test report).

   NOTE: Do not allow the TA reverse propagating beam to propagate into the seed laser without an isolator installed between the two diodes; it could damage the seed laser diode.

4. Adjust the seed laser current/power so that the power immediately before the TA diode matches a listed value from the table *Guide for seed coupling at low and high tapered amplifier current* in the

system test report, typically 10 mW (20 mW for some TA diodes). If an input isolator is installed in the MOA, measure between that isolator and the TA diode.

5. The seed laser should be stable in power and frequency, i.e. not near a mode-hop and not ramping the piezo. The divergence of the beam should be similar to the divergence of the reverse propagating TA beam. Check the collimation of the seed laser using a shear plate (shearing interferometer) or M^2 beam profiler and if necessary adjust the focus of the seed laser to achieve collimation (refer to the CEL manual). If a shear plate or M^2 beam profiler is unavailable, the spot size of the seed laser beam should be minimised at 5 m distance from the seed laser. For fibre coupled MOA input, collimation can be adjusted using the focus adjustment tool provided (see Appendix 7).

6. For the MOA and MOA(L) configuration, ensure the seed laser beam is incident at the centre of the chassis input aperture and is both parallel to the long edge of the chassis.

7. Adjust M1 to reflect the seed laser beam into the input isolator aperture (if installed). Ensure that the seed laser beam goes through the centre of the input and output isolator apertures without clipping. Measure the transmission efficiency of the Faraday isolator and (if installed) adjust the half-waveplate installed on the input aperture of the MOA chassis to optimise transmission efficiency. Otherwise, rotate the entire isolator body in its mount to optimise transmission if necessary. Compare the isolator efficiency with the factory efficiency values from the system test report. If the value from the test report and the measured efficiency are different by more than 10%, contact MOGLabs customer support.

   For the MOA(L) and MOA(C), an isolator external to the MOA(L) or MOA(C) should be installed (preferably) immediately after the seed laser.

8. Use M1 and M2 to align the seed laser beam with the TA reverse propagating beam. Both beams should be collinear and overlapping over the longest distance that is practical (if an input isolator is

installed, this distance will be quite short). To optimise the alignment, use a *walking* procedure as follows, where M1 and M2 refer to external mirrors in the case of MOA(C).

(a) Make sure that the seed laser beam is incident and centred at the TA block input aperture by adjusting M1 and M2.

(b) Ensure a power sensor is installed after the TA output, preferably after the output isolator.

(c) For the *horizontal* axis first, adjust M1 to achieve maximum output power from the TA. Next adjust only the horizontal axis of M2 to optimise the output power from the TA. Call this power P_{REF}.

(d) Make a small adjustment to the *horizontal* axis of M1 in a clockwise direction such that the output power drops by no more than 25%. Take note of how much adjustment was made e.g. $\frac{1}{16}$ turn clockwise.

(e) Next adjust only the horizontal axis of M2 to maximise the output power from the TA. The adjustment range should be less than half a turn of the actuator at this step, and this range should reduce upon iteration.

(f) If the new measured power is greater than P_{REF}, this higher power is the new reference power P_{REF}. Iterate steps 8d and 8e until P_{REF} is maximised. It will be necessary to drop the output power by less than 25% as the alignment improves, e.g. 10% or 5%.

(g) If the new measured power after step 8e is instead lower than P_{REF}, readjust the horizontal axis of M1 anti-clockwise to return to the original angle (as noted at step 8d), then reoptimise the horizontal axis of M2 to return to P_{REF}. Now iterate steps 8d and 8e with an *anticlockwise* adjustment at step 8d.

(h) Once P_{REF} is maximised, iterate steps 8d through 8g for the *vertical* direction.

(i) Iterate the horizontal and vertical alignment procedures until P_{REF} is maximised.

9. Check that the seed laser power before the TA (position *B* in fig. 5.1) has not changed during the adjustment procedure and corresponds to the seed power from the system test report. If it has changed, again adjust the seed laser current so that the power at position *B* matches a listed value in the *Guide for seed coupling at low and high tapered amplifier current* table in the system test report. Iterate the walking procedure from step 8 again (with very small adjustments).

10. Once P_{REF} is optimised, adjust the orientation of the half-wave plate mounted in the input isolator endcap for MOA (see fig. 4.3, by first loosening the set screw indicated. Rotate the half-wave plate to maximise power out of the TA diode, then re-tighten the set screw. For MOA(C) (and sometimes MOA, MOA(L)) the half-wave plate is instead mounted on the chassis straight after the input aperture.

11. Verify optimum seed alignment by again walking the M1, M2 mirror pair according to step 8 (with very small adjustments).

12. Record the final TA output power, P_{REF}, along with the seed power and injection current. Temporarily block the seed beam and record the unseeded amplifier output power. Compare the measured P_{REF} with the value from the table *Guide for seed coupling at low and high tapered amplifier current*, either *Before isolator* or *After isolator* column in the test report, as appropriate.

13. If P_{REF} has been measured after the output isolator and it is not within 10% of the value given in the system test report, instead measure and compare the TA power before the isolator for agreement. If there is still more than 10% difference from the test report value, slightly adjust the TA input lens focus (z) position and repeat step 8. It may take a number of iterations to maximise P_{REF}.

14. Measure PI curves before and after the output isolator and compare with the curves in the system test report.

15. If the measured and factory curves differ by more than 10%, contact MOGLabs customer support.

5.2 Reverse propagating TA diode beam collimation

Please **do not** proceed with the TA block adjustment steps below unless there has been substantial misalignment or the TA diode has been replaced.

1. Block any seed light from entering the amplifier chassis. Referring to the *Unseeded* column in the test report table *Guide for seed coupling at low and high tapered amplifier current*, set the TA diode injection current to a few mW.

2. Remove M2. The reverse propagating TA beam is collimated with an input lens mounted in a flexure translation mount. Using the flexure alignment screws (see fig. 1.2), adjust the input lens $x - y$ position so that the reverse propagating beam exits parallel to the chassis horizontal plane and parallel with the chassis long edge. It will be necessary to remove the input end plate from the main chassis. For older MOA chassis this cannot be completed so skip this step.

3. Allow the reverse propagating beam to propagate over 4 to 5 m, inserting a mirror into the beam path to deflect the beam as required. Adjust the reverse propagating beam divergence by rotation of the TA input lens mount using the supplied lens tube spanners (see fig. 1.2 and fig 4.2). There is an outer tube spanner for loosening the retaining lock ring and an inner tube spanner for adjusting the lens focus. Make sure to tighten the retaining ring once the lens position has been adjusted. The criteria for collimation will be a beam spot that is as small as possible at a distance of 4 to 5 m.

4. Re-install M2. For the MOA, remove any input Faraday isolator. Pre-align the seed laser beam and the TA beam using M1 and M2. The beams should be collinear.

   NOTE: Do not allow the TA reverse propagating beam to propagate into the seed laser without an isolator between the TA and the seed laser if there is more than about 1 mW in the reverse propagating beam; it could damage the seed laser diode.

5. For the MOA, re-install the input Faraday isolator, if installed. Make sure the seed laser beam propagates through the centre of the isolator input and output apertures without clipping.

6. Repeat the *walking* procedure from section 5.1, step 8, through to the end of the section.

6. Output beam optimisation

> ***WARNING***
> Do not operate the amplifier above the ***Maximum current, unseeded*** without an appropriately coupled input seed. Operation exceeding that condition can cause fatal structural degradation of the TA diode. Refer to the ***Maximum current, unseeded*** specified in the amplifier test report.

The beam profile of a TA output beam generally looks unpleasant. It is usually irregular, cross-shaped (like two orthogonal ellipses) and may have two or three stripes. To some extent, appearances are deceiving because of the logarithmic response of human vision. For a better appreciation of the output beam, please use a beam profiler or imaging sensor (e.g. a weak reflection, viewed on the CMOS sensor of a webcam with lens removed).

Typically, the TA output will be fibre-coupled to produce a high-quality TEM_{00} Gaussian beam. A simple measure of the beam quality is known as the M^2 factor (or beam quality factor)

$$M^2 = \omega_0 \theta \frac{\pi}{\lambda}$$

where ω_0 is the waist radius and θ is the half-angle of the beam divergence. The beam quality factor provides an indication of how well the beam can be focused, compared to an ideal diffraction-limited Gaussian beam. For a TEM_{00} beam, the value will be one, and beams with larger M^2 will produce larger spot sizes.

MOGLabs can provide measurements of M^2 for your laser system upon request. We find a more meaningful measurement is how much of the total power can be coupled out of a single-mode optical fibre, and hence we measure and optimise the fibre-coupled output as well as the total output power.

Please **do not** proceed with any output beam optimisation unless there has been substantial misalignment (e.g. due to mishandling during shipping, movement of the cylindrical lens, adjustment of the TA output lens) or the TA diode has been replaced. It is non-trivial to achieve equivalent results as represented in the system test report, so seek advice from MOGLabs before proceeding.

6.1 Procedure for output beam optimisation

Please follow these steps to optimise the output beam.

1. Referring to the test report table *Guide for seed coupling at low and high tapered amplifier current*, set the TA diode injection current to a value where you expect a few mW *Unseeded* and no more than 10s of mW *Before isolator*.

2. Cover the ends of the output isolator with e.g. masking tape and carefully (it contains a very very strong magnet) store safely away from metallic objects and optical benches.

3. Confirm that the TA output is incident exactly on the centre of the cylindrical lens and the TA beam passes through the centre of the output aperture on the amplifier chassis. If a photodiode in installed in the TA output plate, the reflection from the cylindrical lens should also be centred on this photodiode. If the TA beam is not centred on the output aperture, adjust the vertical and horizontal alignment of the TA beam with the fine-adjustment set screws on the top and side of the U-chassis respectively (see fig. 1.2). If these adjustments were not sufficient to recentre the beam, a more substantial adjustment will be required as outlined below.

4. Reinstall and align the output Faraday isolator to maximise transmission then set the TA current so that the TA is operating at no more than 20% of full output power. Isolator alignment includes orthogonal translations, tilt (pitch and yaw), and rotation (roll) of the entire isolator body. Transmission is typically 85 to 95% (refer to the system test report).

5. The amplifier laser beam divergence and astigmatism depend on injection current. Output beam optimisation should be conducted at the expected operating current, typically at or near the maximum current specified in the system test report. Increase the TA current to the operating current but do not measure the output beam directly, instead use an external PBS and half-wave plate to decrease the power to a reasonably safe level, for example 100 mW or less.

6. Carefully adjust the TA exit lens focus to collimate the major (fast) axis of the output beam, by using the supplied lens tube spanners (see figs. 1.2 and 4.2). There is an outer tube spanner for loosening the retaining lock ring and an inner tube spanner for adjusting the lens focus. Make sure to retighten the retaining ring once the lens position has been adjusted. Use an M^2 beam profiler, or an external lens with an imaging sensor positioned at the lens focal distance, to achieve the best collimation. The major axis beam waist on the imaging sensor should be minimised. Note that the cylindrical lens will be acting on the minor (slow) axis which is typically the horizontal axis for almost all MOGLabs amplifiers.

7. Once the beam is collimated along the major axis, adjust the position of the cylindrical astigmatism correction lens along the optical axis to achieve the smallest beam waist along the minor axis. This is the most critical adjustment as the beam quality is incredibly sensitive to cylindrical lens rotation (orthogonality of the lens plane to the optical axis), centring (translation along the minor axis) and position (translation along the optical axis).

We strongly recommend using an M^2 measurement system, such as the MOGLabs M2P, to adjust collimation and astigmatism compensation in order to achieve the best quality output beam and hence achieve optimum fibre coupling efficiency.

6.2 Procedure for photodiode (PD) safety cutout optimisation

For MOGLabs TA laser systems used with the LDD controller, a photodiode monitors the TA output to ensure the seed is properly coupled at high operating currents. If the output power is measured low when the TA injection current is above the photodiode safety cutout *interlock current*, for example because the seed input has been blocked, the TA current will be switched off to prevent TA diode damage. The interlock current is set using the LDD menu under Settings → Interlock → Interlock Current. Please refer to your system test report for the recommended interlock current, specified as *Maximum current, unseeded*.

When operating the TA above the interlock current, the photodiode reading (LDD menu item Settings → Interlock → PD reading) must exceed the photodiode setpoint (LDD menu item Settings → Interlock → PD setpoint). The *PD setpoint* is set to about 70% of the typical output power expected at the interlock current, **when the minimum power seed laser is well coupled to the TA**. The *PD setpoint* can be adjusted using the LDD menu item. Please refer to your system test report for the recommended *PD setpoint* specified at item *Photodiode safety cutout*.

The *PD reading* is affected by TA output power, beam shape and mechanical alignment of the photodiode pickoff. Large changes to the seed wavelength will result in substantially different TA power output at a given current due to the wavelength-dependent gain response of the TA diode, requiring recalibration of the *PD setpoint*. If the output beam optimisation procedure from section 6.1 has resulted in a different beam shape, or the incident polarisation at the photodiode pickoff has changed, this can also result in a different measured power at the photodiode for the interlock current.

Minor adjustment

For most situations where the power output or beam shape has only changed a small amount (i.e. the seeding wavelength has not changed), only the photodiode gain will need minor optimisation as follows:

- set the TA curent to the *Maximum current, unseeded* specified in the system test report
- with minimum seed power as specified at *Maximum current, seeded*, ensure the seed coupling is optimised and agrees with the system test report table 1 *Guide for seed coupling at low and high tapered amplifier current*
- check *PD reading* is between 4 to 4.8 V (note that 4.94 V is the saturation voltage)
- if *PD reading* is saturated, reduce TA current by 100 mA and compare again. If the 4 to 4.8 V is now satisfied, no further action is required
- if *PD reading* is low, adjust the gain trimpot so the *PD reading* is between 4 to 4.8 V (see fig. 6.1)

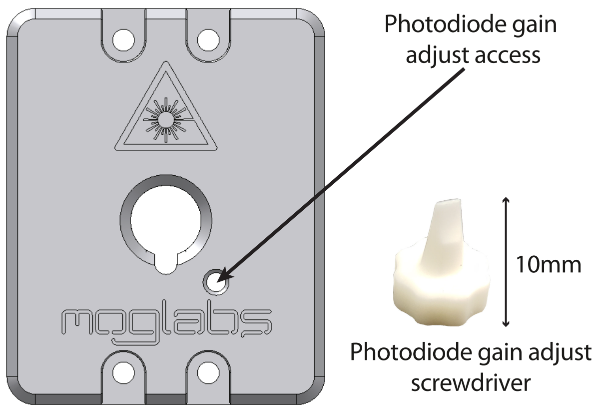


Figure 6.1: Schematic diagram showing location of photodiode gain adjust access hole and photodiode gain adjust screwdriver.

Substantial adjustment

For situations where the TA power output has changed significantly from the system test report, the pickoff can be mechanically optimised as follows:

- set the TA curent to the *Maximum current, unseeded* specified in the system test report
- with minimum seed power as specified at *Maximum current, seeded*, ensure the seed coupling is optimised and agrees with the system test report table 1 *Guide for seed coupling at low and high tapered amplifier current*
- optimise the photodiode pickoff alignment by ensuring the mount is square to the input beam in the horizontal plane (see fig. 6.2)
- transmission through the photodiode pickoff should then be maximised by loosening the M3 socket head screw on the side of the mount to adjust the vertical tilt of the pickoff mount relative to the incident beam (fig. 6.2)
- adjust the gain trimpot (fig. 6.1) so *PD reading* is between 4 to 4.8 V (note that 4.94 V is the saturation voltage)
- adjust *PD setpoint* to about 70% of the voltage reading from the previous step
- ensure *PD reading* drops substantially when the seed laser is blocked from coupling into the TA, e.g. to about 1 to 1.5 V

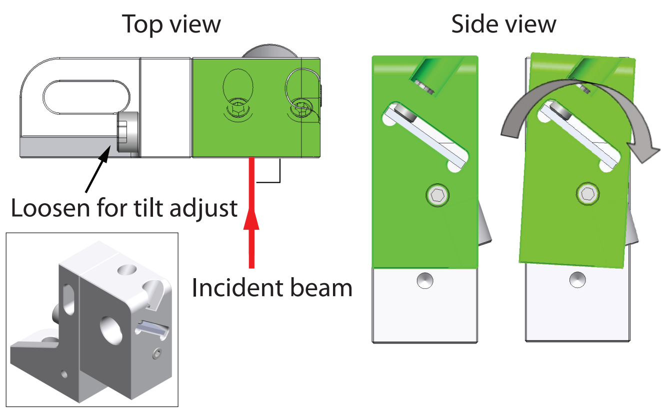


Figure 6.2: Schematic diagram of photodiode pickoff showing top view (left) and side view (right) with isometric view (inset). Loosening the screw indicated allows vertical tilt of the photodiode assembly towards/away from the incident TA beam relative to the base mount.

7. Fibre coupling

The output beam profile of a TA diode can be highly irregular and highly astigmatic. Nevertheless it is still possible to achieve good coupling into a singlemode fibre. Some examples of fibre coupling efficiency are provided in the figure below. Fibre coupling efficiency varies from diode to diode due to many factors, so as a guide net coupling efficiency from fibre coupler (FC) input power to FC output power is generally 50% or better, and 60% is not unusual, despite Fresnel losses at each facet of the fibre (8%).

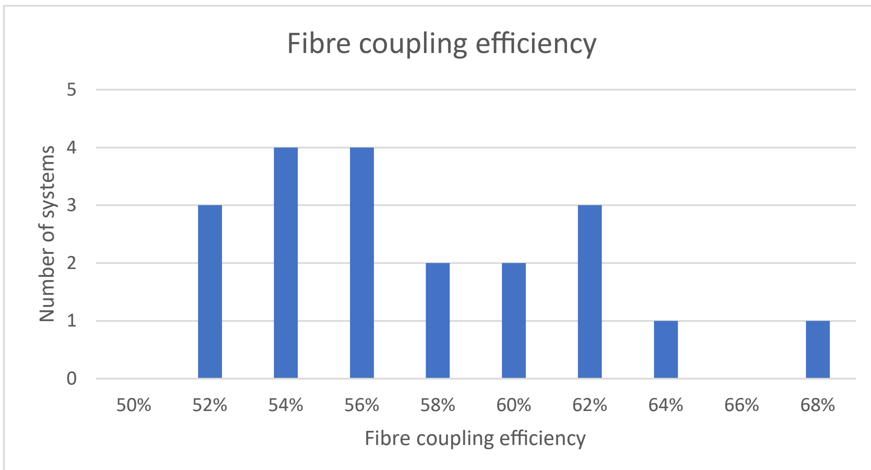


Figure 7.1: Measured fibre coupling efficiency for 20 fibre coupled TA systems ranging from 670nm to 1080nm with input powers from 500mW to 3000mW. The average result is 57% for this sample set.

The TA output beam profile and astigmatism both vary with operating current. It is thus advised to correct TA beam astigmatism at high current (or your desired operation current) *before* attempting fibre coupling (see Chapter 6). Note that TA operating powers typically exceed the damage threshold tolerance at fibre facets and thus it is easy to damage fibre facets if attempting to correct astigmatism at high currents *during* fibre coupling.

Some instruments and tools will be helpful in quickly attaining optimum fibre coupling, including:

1. Suitable fibre patch cord, e.g. end-capped fibre patch cord such as MOGLabs FPC-EC-780-2 (PM780-HP fibre core) for 770 nm to 1100 nm.
2. Optical fibre visual fault locator (VFL, see fig. 7.2).

Figure 7.2: Visual fault locator (VFL). Injects visible laser light into a fibre, allowing initial alignment and mode matching.

3. Power meter and sensor, preferably with integrating sphere to avoid sensor saturation.

Note that power meters with sensors using silicon photodiodes can easily saturate below their maximum rated power and thus give false readings, particularly when the entire sensor surface is not illuminated as for a small beam. Sensors based on integrating spheres are preferred.

Polarisation control

The polarisation of the TA output can be aligned to that of a polarisation-maintaining (PM) singlemode fibre in two ways.

- A half-wave retarder can be used, either mounted in the endcap of the final isolator (see fig. 4.3), or mounted to the chassis just before the fibre coupler using an optional waveplate holder available from MOGLabs. It is unlikely adjustment of the half-wave retarder will require any substantial fibre coupling realignment. If some small adjustment seems necessary, refer to section 7.1.

- The fibre coupler can be rotated about the optical axis to align the FC/APC key of the coupler to the incident TA output, by releasing the three radial mounting screws. After this mechanical rotation, a full realignment of the fibre coupling will likely be required, as per section 7.2.

In both cases a polarimeter measurement is recommended to ensure a polarisation extinction of $> 20\,\mathrm{dB}$ is achieved.

7.1 Fibre alignment touch-up

Minor fibre alignment adjustment may be required when the TA system is first received or any minor or suspected alignment change may have occurred between the TA chip and the fibre coupler.

The amplifier should first be operating normally in free space as described in the previous chapters. In particular, it is assumed the output is well collimated both horizontally and vertically and the astigmatism compensation is optimised for the desired TA diode operating current. The beam cross-section should be approximately circular, but achieving a symmetric aspect ratio may not be possible given the limited range of cylindrical lens focal lengths available, and variations in TA diode astigmatism.

1. The seed power into the TA should be set in the range of seed power recommended in the test report. The TA injection current should be chosen to provide 10 mW before the fibre coupler (or as specified at *Initial FC target* in the test report). The fibre core type should also be the same as specified in the test report, or have an equivalent mode field diameter.
2. Measure P_{REF}, the output power from the correct fibre patch cord connected to the fibre coupler output, and compare to the *Initial FC target* in the test report for the same test conditions.
3. Referring to figures. 4.1 and 5.1, make very small (typically $\frac{1}{16}$ turn or less) adjustments to the *horizontal* axis of M4 until the output power is maximised.

4. Make a very small ($\frac{1}{16}$ turn or less) adjustment to the *horizontal* axis of M3 until the output power is maximised.

5. Again, make very small ($\frac{1}{16}$ turn or less) adjustments to the *horizontal* axis of M4 until the output power is maximised.

6. Repeat above two steps until P_{REF} is optimised.

7. Now for the *vertical* axis of M3 and M4, repeat from step 3 to 6 until P_{REF} is optimised.

8. Compare the TA output power with the appropriate value from *Initial FC target* in the test report. A value within 10 to 15% of the target is suggested before proceeding.

9. Measure the input power to the fibre coupler, carefully inserting a mirror to pick off the beam before the coupler if necessary, and calculate the net fibre coupling efficiency. Use the same power sensor head for the output power measurement where possible and, if used, make sure to allow for any losses due to the mirror. Do not proceed unless the total net efficiency is at least 10%. If this is not possible using the above procedure, review the troubleshooting section 7.4, implement any changes, and repeat steps 3 to 7. If the net efficiency is still not sufficient, skip the remaining steps here and proceed to the advanced fibre alignment procedure in section 7.2.

10. Increase the TA current to a value where you expect about 100 mW of power after the isolator.

11. Repeat steps 3 to 7, being careful to use only the smallest adjustments so that the power does not reduce by more than 50 % for any given adjustment of a particular mirror axis. Net fibre coupling efficiency should remain above 10 % at all times when power incident on the fibre is > 100 mW.

12. Remeasure the new fibre coupling efficiency. The net efficiency should be a little higher than the value determined for 10 mW of input light.

13. Increase the TA current to operating current in at least 4 equal steps, repeating steps 3 to 7 after each current increase. For example if the current required for 100 mW post-isolator is 1 A and the maximum operating current required is 3 A, increase the current by 500 mA at each step. Very carefully (being mindful of the high power before the fibre coupler when inserting mirrors and power sensors) measure the net coupling efficiency after each step. The measured efficiency should be increasing as current increases.

14. Compare the efficiency achieved to the value listed at *Full TA power* in the test report, for the same test conditions. A value within 5% should be expected. If this is not achieved, refer to the troubleshooting section 7.4 or the advanced procedure in section 7.2.

7.2 Fibre alignment procedure

The following procedure can be used when substantial fibre coupling alignment optimisation is required.

1. Ensure the seed power into the TA is set in the range of seed power recommended in the test report. The TA injection current should be chosen to provide 10 mW before the fibre coupler.

2. Adjust M3 (see figs. 4.1 and 5.1) so the TA output is incident at the very centre of the fibre coupler input aperture. The TA output should be reasonably well collimated between the isolator and the fibre coupler, particularly in the vertical axis. If not, check with MOGLabs support for how to proceed.

3. Attach the correct fibre patch cord (refer sec. 7.1, step 1) to the output fibre coupler. Insert the opposite end into the VFL (fig. 7.2) and switch the VFL to glint/blink mode.

4. Adjust M4 so the VFL output is incident at the very centre of the isolator output aperture, through to the isolator input aperture, and if possible, all the way back to the centre of the TA U-chassis output

aperture. The cylindrical lens may prevent a clear VFL output at the U-chassis from being observed. The TA beam and the VFL beams should be overlapping at these points. Note that if the VFL output is very strongly diverging (e.g. larger than 1 cm diameter over 10 to 15 cm propagation), it may be necessary to adjust the fibre coupler lens. See section 7.3 or check with MOGLabs support for how to proceed.

5. Continue alternately adjusting M3 to centre the TA beam on the fibre coupler aperture, and adjusting M4 to centre the VFL beam on the U-chassis output (or isolator input aperture) until no further optimisation can be made. The TA beam and the VFL beams should be collinear.

6. Turn off and remove the VFL from the fibre patch cord. Connect the fibre patch cord output to a power sensor. There should be some nanowatts or more power detected when you block/unblock the TA beam in front of the fibre coupler. If not, check your fibre patch cord end facets (see section 7.4), or contact MOGLabs support for how to proceed.

7. Walk the mirror pair to optimise output power as follows:

   (a) For the *horizontal* axis first, adjust M4 to achieve maximum output power from the fibre. Adjust the *horizontal* axis of M3 to achieve maximum output power from the fibre. Call this value P_{REF}.

   (b) Make a small adjustment to the horizontal axis of M3 in a clockwise direction such that the output power drops by no more than 25%. Take note of how much adjustment was made e.g. $\frac{1}{16}$ turn clockwise.

   (c) Next adjust only the horizontal axis of M4 to optimise the output power from the fibre.

   (d) If the new measured power is greater than P_{REF}, this higher power is the new reference power P_{REF}. Iterate steps 7b and 7c until P_{REF} is maximised. It will be necessary to drop the output power by less than 25% as the alignment improves, e.g. 10% or 5%.

(e) If the new measured power after step 7c is instead lower than P_{REF}, readjust the horizontal axis of M3 anti-clockwise to return to the original angle (as noted at step 7b), then reoptimise the horizontal axis of M4 to return to P_{REF}. Now iterate steps 7b to 7d with an anticlockwise adjustment at step 7b.

(f) Once P_{REF} is maximised, iterate steps 7b through 7e for the *vertical* direction.

(g) Continue to alternately iterate the horizontal and vertical alignment procedures until P_{REF} is maximised.

8. If the final net fibre coupling efficiency obtained is within 5 to 7 % of *Output coupling (FC) - Initial FC target* in the test report, skip to step 10.

9. Taking note of P_{REF}, now make a tiny adjustment to the fibre coupler lens position with the appropriate fibre coupler focus tool provided as part of the system toolkit (see fig. 7.3). Make note of the direction of adjustment. Repeat a single iteration of the horizontal and vertical walking procedure from step 7 and compare the efficiency to P_{REF}. If the efficiency is greater than the original P_{REF}, make another tiny adjustment to the fibre coupler lens position in the same direction, otherwise make a tiny adjustment in the opposite direction and repeat the iteration in either case until P_{REF} has been optimised. The final efficiency after optimising the fibre coupler lens should be within 2–3 % of *Output coupling (FC) - Initial FC target* in the test report, for the same fibre type and test conditions.

10. Return to step 10 of section 7.1 and continue to make adjustments to the fibre coupler lens after each current increase as per step 9 above. Also note that:

    (a) the seed alignment will likely need very small adjustments using M2 after each TA current increase, as changes to seed alignment can affect the profile of the TA output and therefore the coupling efficiency, and;

(b) tiny adjustments to the fibre coupler lens at high current can drop the fibre coupling efficiency very significantly to the point where the fibre tip is likely to be damaged. Take great care and use small well-controlled adjustments to the fibre coupler lens.

7.3 Fibre coupler collimation

If the TA output beam size, astigmatism and/or collimation has changed compared to the original MOGLabs test condition, it will be necessary to adjust the position of the focusing lens inside the fibre coupler to accommodate the changes. Initially when focus is very far from optimised, the fibre coupler lens collimation can be approximately set using the VFL (see fig. 7.2) as a light source.

1. Connect the fibre patch cord to the MSA (MOA) fibre output connector.
2. Connect the *exit* of the fibre to the VFL laser source.
3. Examine the red beam emitted back towards the TA diode from the output fibre coupler.
4. Using the EX-4 eccentric cam tool or MGQA focus tool provided in your toolkit, adjust the fibre coupler lens collimation (see fig. 7.3) such that the light exiting the coupler is well-collimated over at least 4 to 5 m distance. The beam can be deflected outside the chassis by carefully inserting a mirror into the beam path between M4 and the fibre coupler.
5. Refer to section 7.2 to redo the fibre coupling alignment.

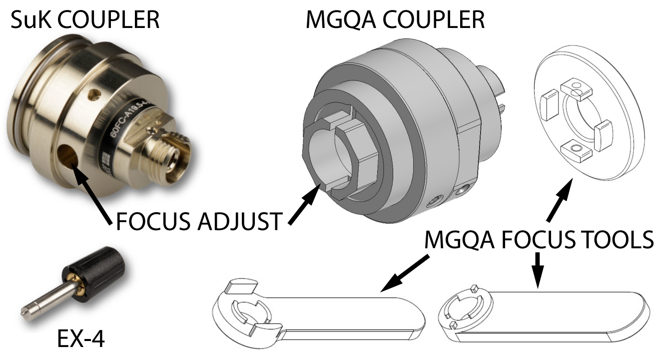


Figure 7.3: Fibre couplers showing access to fibre collimation lens adjustment. There is a slot in the SuK coupler mount for the eccentric focus tool EX-4 off-centre pin to insert into. The MGQA coupler will come with one of three MGQA focus tools indicated to adjust the internal nut acting on the collimation lens.

7.4 Troubleshooting

The most frequent cause of low coupling efficiency is damage to the fibre facet. Inspect the end facets using a fibre microscope inspection tool, and clean/polish if necessary. Also try reversing the fibre patch cord or just try a new patch cord. Note for 780/795 nm, we generally find that PM630 fibres achieve better efficiency and polarisation preservation.

Another frequent problem is the variation in astigmatism, and thus beam collimation, with injection current. Changing the operating current to vary the output power of the TA diode will affect the beam collimation and thus fibre coupling efficiency. At the MOGLabs factory, astigmatism compensation is optimised for high injection current. To operate at a different current and work with a well-corrected output beam, it will be necessary to readjust the cylindrical lens position and then reiterate the fibre coupling optimisation (see chapter 6 for cylindrical lens adjustments).

Damage to the TA chip is also possible. It is highly advisable to record the TA output beam profile regularly, so that any progressive degradation can be monitored.

8. Diode replacement

Replacement tapered amplifier diodes can be purchased from MOGLabs or directly from suppliers (e.g. Eagleyard Photonics or Coherent). The diode is provided in an industry-standard C-mount package, which is then mounted to a proprietary MOGLabs MGM-068 mount (fig. 8.1).

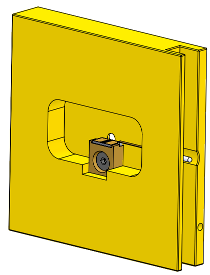


Figure 8.1: MGM-068 copper mount with C-mount TA diode seen from exit aperture side. Cathode pin, groove for cathode wire, and one registration pin hole are on the right.

To replace the diode, ensure the controller is off and head cables disconnected, then follow these steps:

1. Open the PCB cover plate underneath the chassis and disconnect the diode anode and cathode wires at the PCB. The diode connectors are labelled on the PCB. If the diode connectors are laying flat on the PCB (Hirose), lever the connectors up gently from the wire entry end of the connector. If the diode connectors are standing upright from the PCB (JST), gently tilt the connector towards the tall side of the socket, then pull the connector up (see fig. 8.2).

2. Remove the crimp terminals from the connectors by gently levering up the plastic tabs (see fig. 8.3) using a sharp/pointed tool, then slide the crimped wires out of the connector. When reinserting crimp

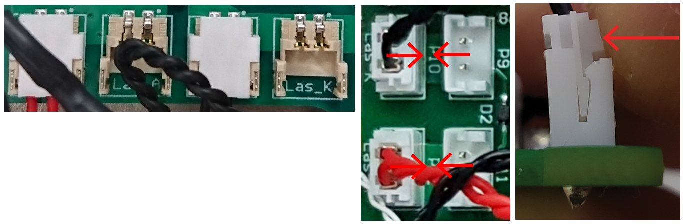


Figure 8.2: Diode wires with Hirose connectors (left) and JST connectors (centre, right). Arrows indicate direction to apply tilt to the JST connectors before pulling out of the socket.

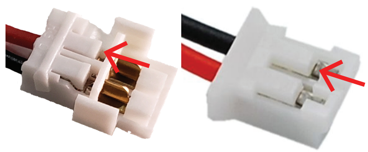


Figure 8.3: Crimp terminal removal with Hirose connectors (left) and JST connectors (right). Arrows indicate plastic tabs that should be levered up to release the crimp terminal.

terminals, ensure the tab 'clicks' back down to lock the crimped wire in the connector – a gentle tug on the wire will reveal whether the crimp has been securely reinserted in the connector.

3. Referring to fig. 8.4, remove the input and output cover plates on each end of the U-chassis (4x screws on each cover plate). Remove the 4x screws securing each flexure translation mount in the U-chassis and remove both flexure assemblies from the U-chassis. Make sure to note the orientation of each flexure assembly as well as which assembly is the TA input and TA output side.

4. Remove the 4x screws securing the H-clamp on top of the U-chassis (see fig. 8.4). Gently slide the MGM-068 mount upwards for removal and pause if any resistance is met. The copper block will be tight but should move when wiggled. If the flexure translation mounts are not removed as in the previous step, the collimation lenses will obstruct the MGM-068 mount. Note that registration dowel pins prevent the

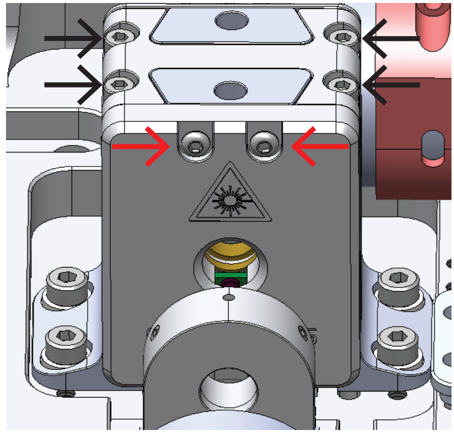


Figure 8.4: Schematic of the U-chassis showing location of screws securing flexure cover plates (red arrows, only two of four screws visible) and the H-clamp (black arrows).

MGM-068 from sliding laterally. Carefully thread the diode wires out of the PCB cavity through the access hole.

5. If replacing the C-mount TA diode rather than the MGM-068 copper block assembly, remove the old TA by desoldering the cathode ribbon from the turret pin, then unscrew the M2 screw holding the anode wire. Replace the indium foil and assemble with the new TA diode. Ensure the TA diode is square and sitting flat on the copper block as you tighten the M2 screw. When soldering the cathode ribbon to the turret pin, use low-temperature silver solder. Do not resolder until the TA diode is firmly attached to the copper to act as a heatsink.

6. Install the new TA diode mounted on the MGM-068 mount by following the steps in reverse, taking care to replace the dowel pins and threading the diode wires (which have crimp terminals but no connectors) through to the PCB cavity. Ensure the H-clamp is reinstalled using a cross pattern to tighten the screws so that tension is evenly applied as the clamp engages. Return the flexure translation mounts to their correct location and orientation, securing all screws firmly and reinstalling the cover plates.

7. At the PCB, insert anode (red) wire crimp pairs into the connectors until they 'click' and cannot be removed from the connector when tugged. Repeat with cathode (black) wire crimp pairs. Reconnect the diode connectors to the PCB underneath.

8. Test operation by reconnecting the controller and powering on the TA temperature controller first, check operation is normal with temperature approaching the set point, followed by powering on the current controller at 100 mA. Referring to the test report table *Guide for seed coupling at low and high tapered amplifier current*, set the TA diode injection current to a value where you expect a few mW of *Unseeded* light and verify that some output light is visible on an IR viewing card.

9. Restore the lens collimation (see Chapter 6). Only a small adjustment should be necessary if the TA diode is the same type or similar size and wavelength. Follow the instructions for aligning either an internal seed laser (Chapter 4) or external seed laser (see Chapter 5).

A. Electrical connections

The MOA has a single electronic circuit board for interfacing between the device and a laser driver/controller, whereas the MSA has an additional board for also operating the seed laser/controller. For information on the seed laser, please refer to the seed laser user manual. The information below relates to the amplifier interface only.

A.1 Amplifier headboard: MOA, MSA

The amplifier is connected to a controller via a B1048, B1055 or B1056 headboard (figs. A.6, A.2) which provides connections to the TA diode, TEC, and a passive NTC thermistor temperature sensor. Connections from the B1048, B1055 boards to the components use Hirose DF59 "swing-lock" wire-to-board connectors; B1056 uses JST EH-series connectors. There is also a photodiode amplifier which can be used to generate a signal for monitoring the laser output. The boards include a solid-state protection relay, passive protection filters, and a laser-on LED indicator.

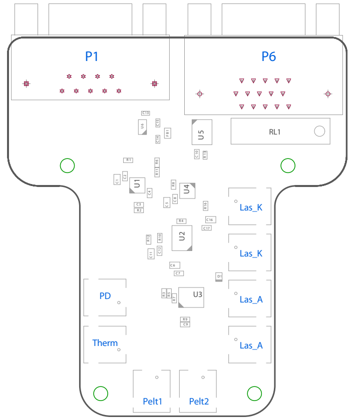


Figure A.1: MOGLabs MOA/MSA B1048 laser head board showing connector locations for tapered amplifier diode, temperature sensor, TEC, photodiode, and head cables.

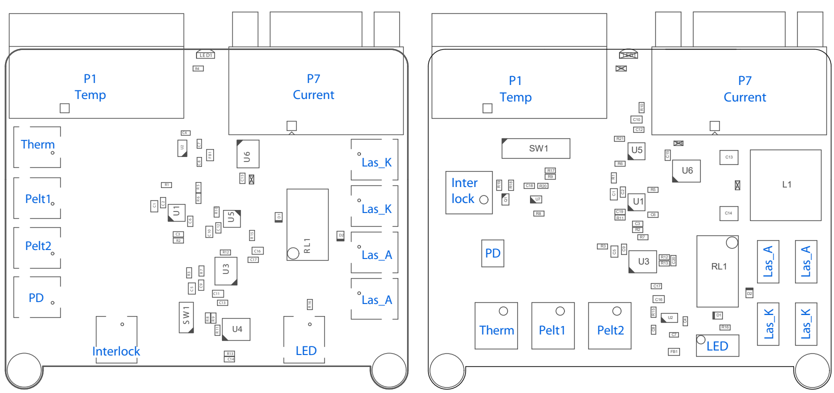


Figure A.2: MOGLabs MOA/MSA B1055 (left) and B1056 (right) laser head board showing connector locations for tapered amplifier diode, temperature sensor, TEC, photodiode, microswitch interlock, LED and head cables.

Name	Description
P1	DE9 female (TEMP)
P6/P7	DE15 female (CURRENT)
PD	Photodiode
Therm	Thermistor
Pelt1	TEC connection 1
Pelt2	TEC connection 2
Las A	Laser anode
Las K	Laser cathode

Figure A.3: B1048 and B1055/B1056 headboard connector legend. 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.

A.2 Connector pinouts

A.2.1 Current

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

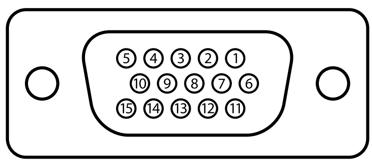


Figure A.4: DE15, female, current supply connector (P6/P7) pinout. Relay (−) should be grounded to open the protection relay and enable operation. Pinout is the same on LDD and headboards. +5 V is output on LDD, input on headboards.

A.2.2 Temperature

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

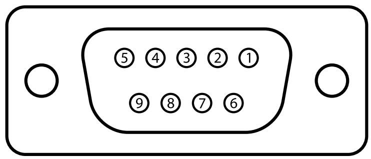


Figure A.5: DE9, female, temperature supply connector (P1) pinout. Pinout is the same on LDD and on headboards, except that pin 2 is not connected on headboards.

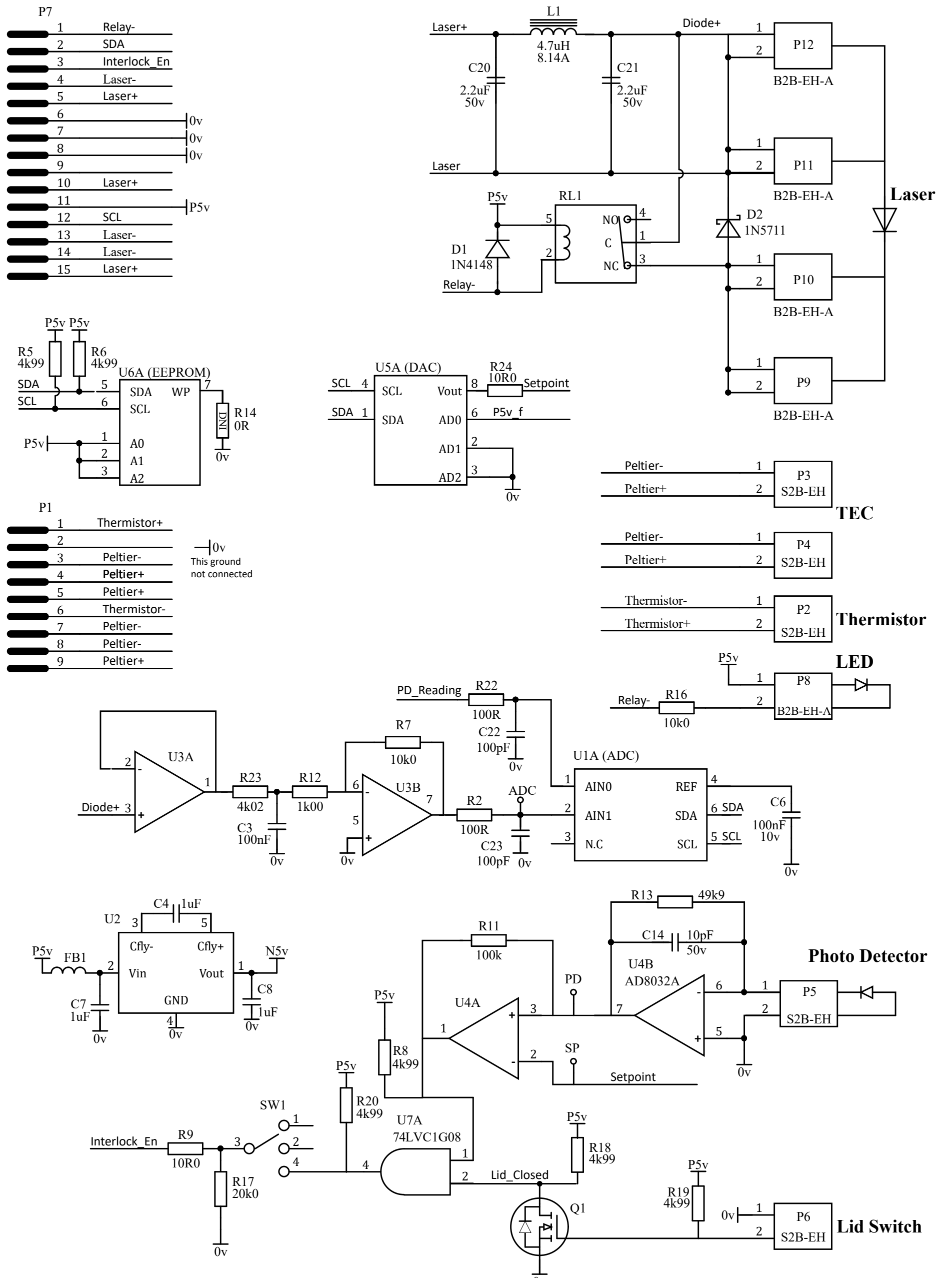
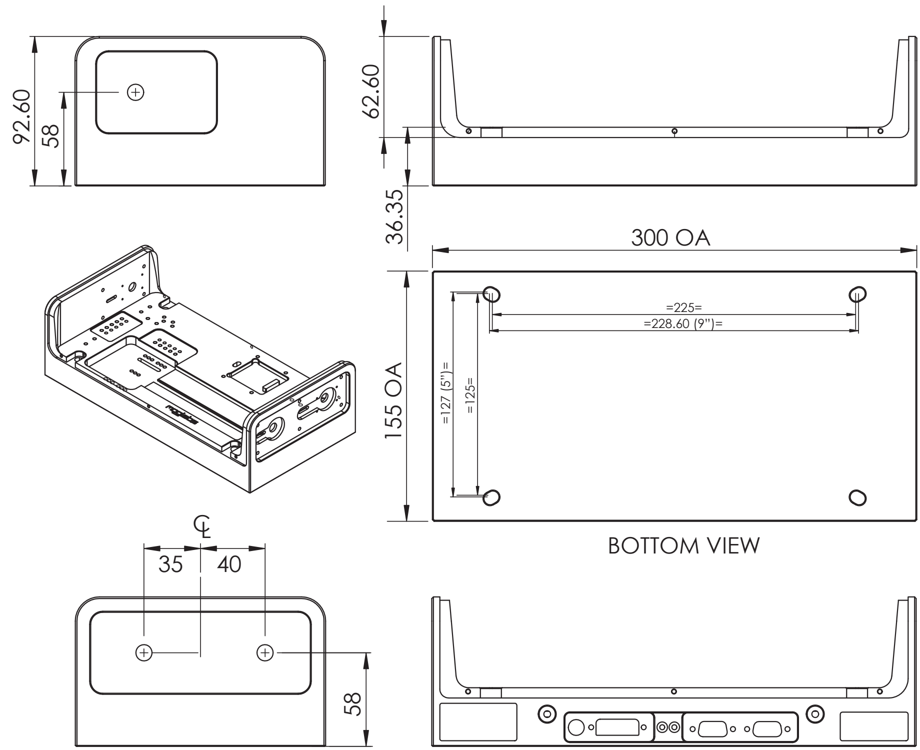


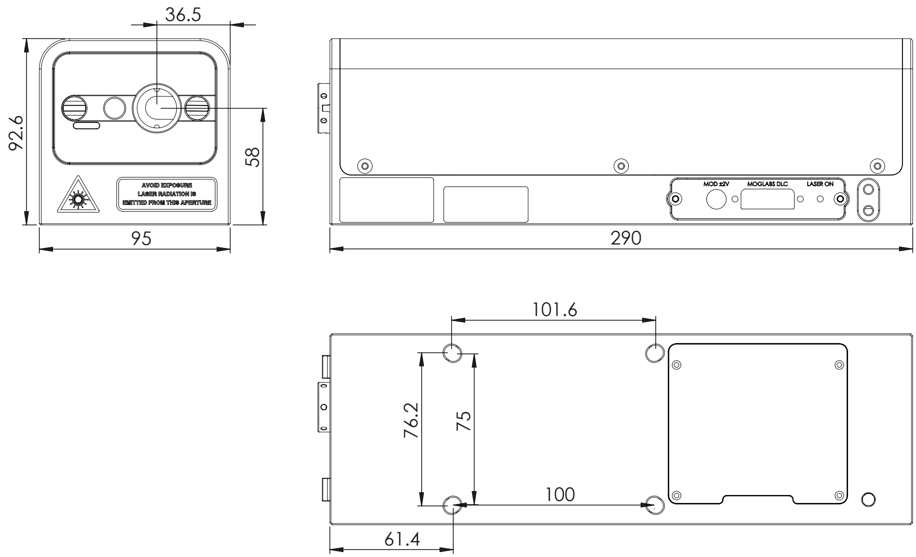
Figure A.6: MOGLabs MOA/MSA laser head board schematic (B1055).

B. Chassis dimensions

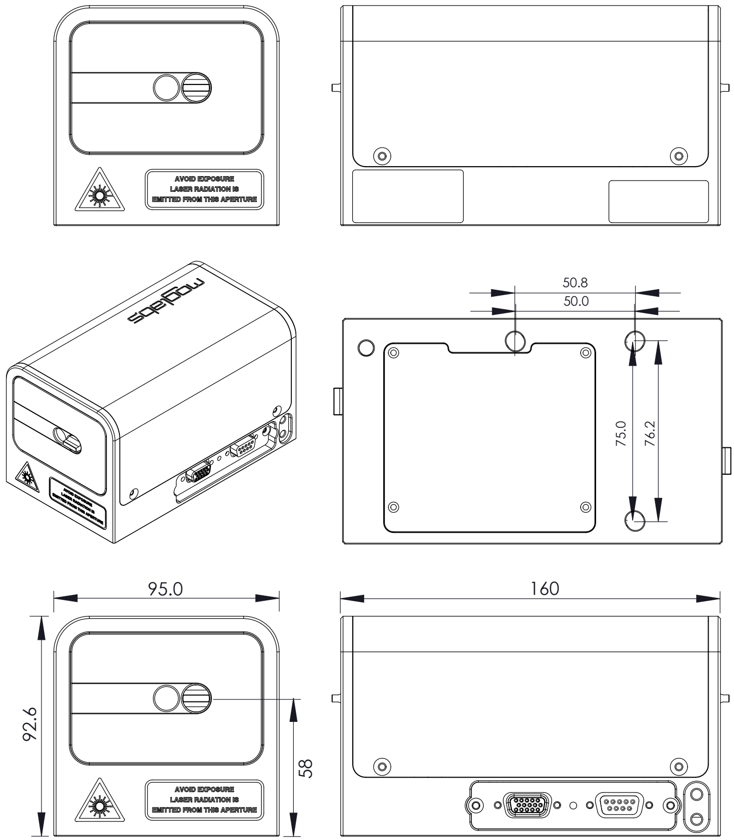
MSA/MOA amplified laser



MOA(L) standard amplifier



MOA(C) compact amplifier



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[2] JCB Kangara, AJ Hachtel, MC Gillette, JT Barkeloo, ER Clements *et al.* Design and construction of cost-effective tapered amplifier systems for laser cooling and trapping experiments, *Am. J. Phys.* **82** 805 (2014) `http://doi.org/10.1119/1.4867376` 3