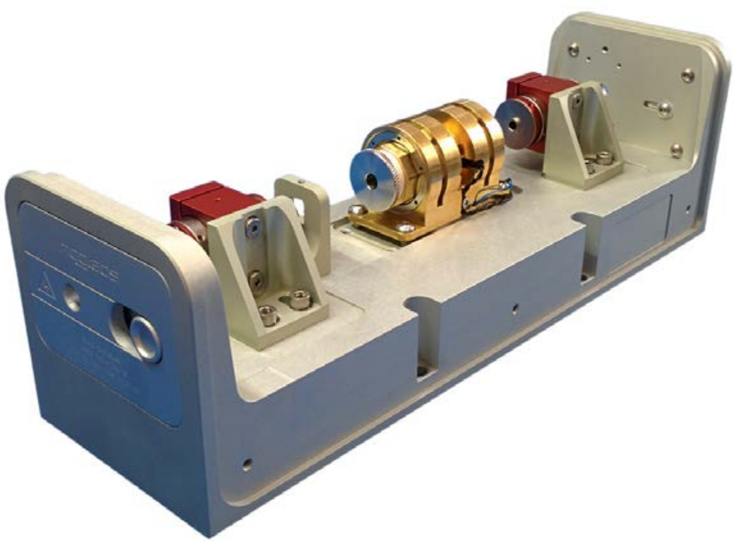
Optical amplifier

Model MOA002



Revision 1.00

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Preface

The MOGLabs MOA002 optical amplifier provides up to 4 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 100 times (+20 dB).

We hope that you enjoy using the MOA002, and please let us know if you have any suggestions for improvement of the MOA002 or this document, so that we can make life in the lab better for all.

MOGLabs, Melbourne, Australia
www.moglabs.com

Safety Precautions

Safe and effective use of this product is very important. Please read the following safety information before attempting to operate. Also please note several specific and unusual cautionary notes before using the MOGLabs MOA002, in addition to the safety precautions that are standard for any electronic equipment.

> ***WARNING***
> Do not operate the MOA002 without input seed laser. The input seed power must be at least 10 mW, and properly mode-matched to the tapered amplifier diode. Operation without appropriate seed will destroy the tapered amplifier diode.

> 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 MOA002 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 below) and heed their warnings.

- The MOA002 must be operated with a controller with keyswitch interlock. The MOA002 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 MOA002.
- When the amplifier is 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 MOA002 without input seed laser. Then input seed power must be at least 10 mW, and properly mode-matched to the tapered amplifier diode. Operation without appropriate seed will destroy the tapered amplifier diode.

WARNING Do not couple more than 10 mW of seed light into the MOA002 with less than 100 mA injection current.

NOTE The MOGLabs MOA002 is designed for use in scientific research laboratories. It should not be used for consumer or medical applications.

Protection Features

The MOGLabs MOA002 includes a number of features to protect you and the unit. It 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 solid-state relay at the laser head board.

Laser LED Indicator LED illuminates when the temperature controller is switched on.

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 MOA002.

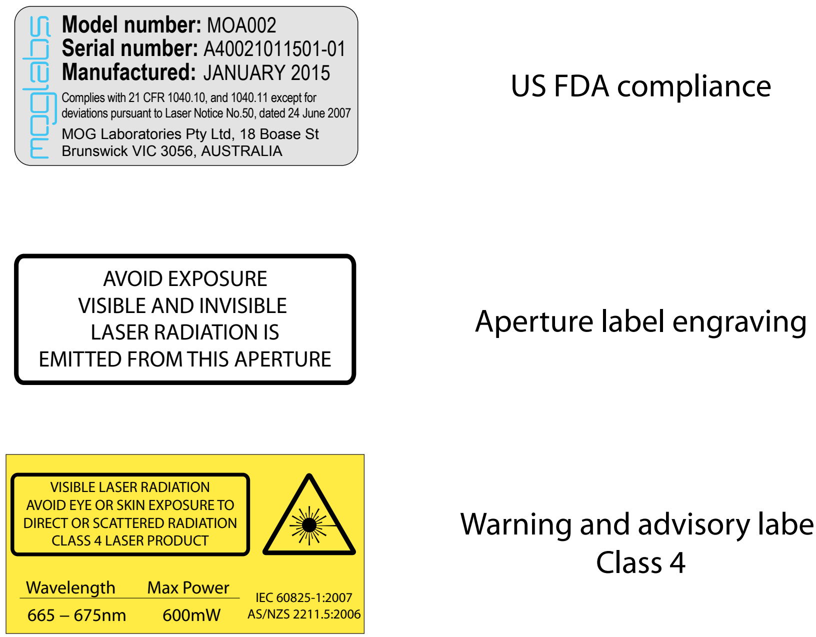

Figure 1: Warning advisory and US FDA compliance labels.

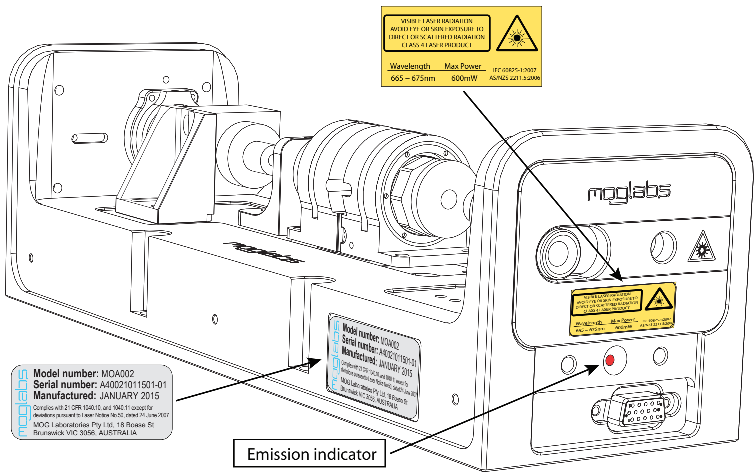

Figure 2: Schematic showing location of warning labels compliant with International Electrotechnical Commission standard IEC 60825-1:2007, and US FDA compliance label. Aperture label engraved on the front of the MOA002 near the exit aperture; warning advisory label on the rear and compliance label beneath.

Contents

1. Introduction

The MOGLabs MOA002 (see figure 1.1) consists of the core semiconductor tapered amplifier diode, aspheric input and output collimation lenses, a cylindrical lens on the output for astigmatism compensation, and two Faraday isolators.

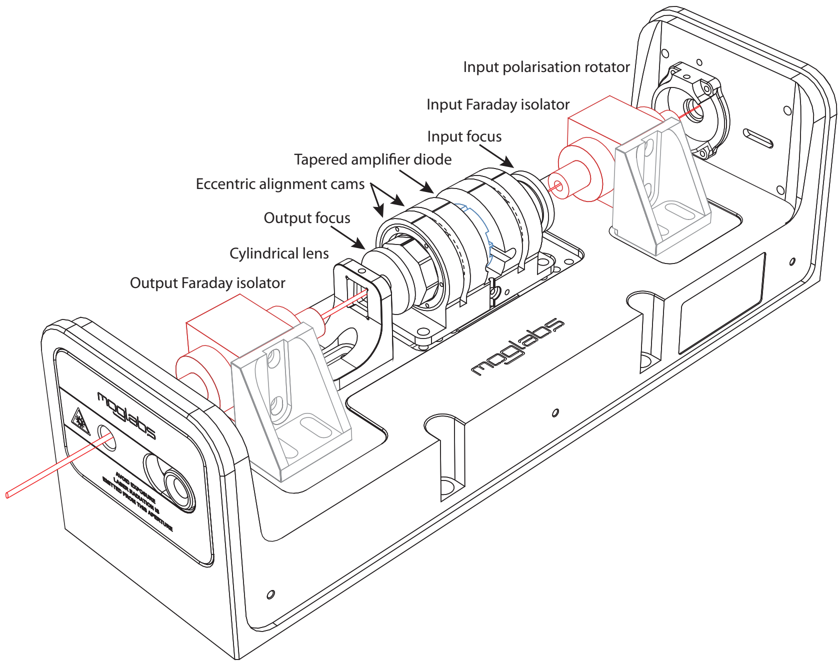

Figure 1.1: Schematic diagram of major components in the MOA002, including tapered amplifier diode, collimation lens eccentric cam alignment mechanism, cylindrical lens astigmatism compensator, Faraday isolators.

The tapered amplifier diode is user-replaceable (see section 2.4). Two eccentric cam arrangements control the transverse position of the input and output collimation lenses, providing precise alignment with mechanical stability. Finely threaded stainless steel knobs with strong spring loading control the focus of the lenses.

1.1 Basic setup

1. The MOA002 should be firmly mounted to an optical table or other stable surface. The MOA002 has through-holes at spacings suitable for most optical tables.

2. The exit aperture should be directed towards a suitable power meter or beam block.

3. Connect the MOA002 to the current source and temperature controller provided, or to an alternative supply using the connector pinout description in appendix B.

4. Enable the temperature controller and check that the temperature is approaching the set temperature (see below).

2. Alignment

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2.1 Seed alignment

If the tapered amplifier (TA) diode is operated without injection seed, all of the electrical input energy is lost as heat, and at high current there is significant risk of damaging the diode. At currents over 300 to 700 mA (device dependent), it is important that an injection seed laser beam is coupled into the TA diode so that some of the input energy is converted to optical output rather than heat. Follow these steps to align the seed into the TA.

1. Adjust the seed laser collimation such that the beam is well collimated, or weakly focusing at a distance of at least 4 m from the seed laser.

2. Remove the MOA002 input isolator. Ensure the input and output of the isolator are covered to protect against items being magnetically attracted into the isolator optics.

3. Adjust the TA diode injection current until a weak alignment beam can be detected exiting from the *input* aperture. Do not exceed the maximum unseeded current specified in the test data for your device (300 to 700 mA). It may be necessary to use a video camera (e.g. webcam with IR filter removed), or an infrared upconversion card, to see the alignment beam.

4. Monitor the *output* power of the amplifier and record your data (current, power).

5. Using the input pair of eccentric cams (see fig. 2.1), adjust the input collimation lens position so that the weak alignment beam exits (from the input side of the MOA002) parallel to your optical table and aligned with the MOA002.

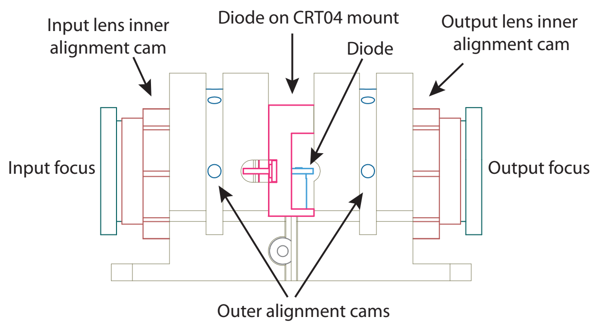

Figure 2.1: Eccentric cam sub-assembly.

There are two adjustment cams. The octagonal brass "nut" controls the inner cam, and the second larger diameter cam can be rotated using a screwdriver inserted into one of the radial holes accessed through a gap in the outer brass housing.

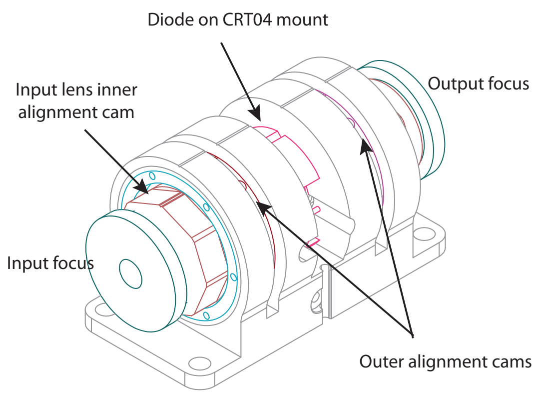

Figure 2.2: Eccentric cam sub-assembly.

6. Align a pair of iris apertures with the weak alignment beam

(see figure 2.3). The irises should be separated by at least 150 mm and be almost closed, with aperture diameter of 2 or 3 mm.

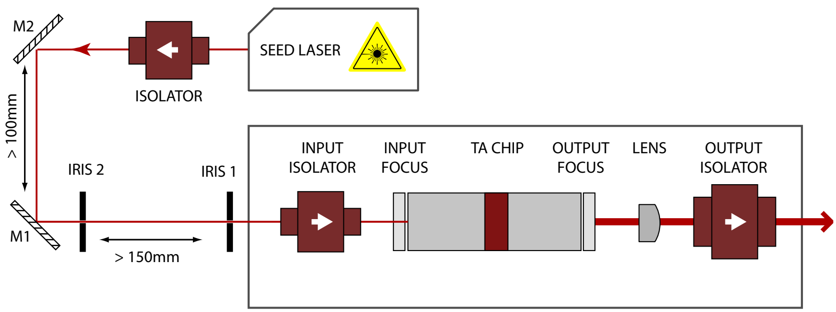

Figure 2.3: Alignment setup for aligning MOA002 to seed laser.

7. Turn on your seed laser and ensure about 15 mW of power will be available at the amplifier input. Record the seed laser power.

8. Using a pair of mirrors on kinematic mounts, align your seed laser beam with the amplifier alignment beam, without moving the irises. Both beams should be colinear and collimated.

9. You should observe an increase of at least 50% in the amplifier output power as the seed alignment improves. The focus of the MOA002 input collimation lens may require small adjustment to mode-match the seed and amplifier.

10. Adjust the seed polarisation to match the amplifier polarisation, preferably using a half-waveplate in a rotation mount. The amplifier polarisation can be horizontal or vertical, depending on TA diode. Please refer to your datasheet. You should observe that the output power maximises when the seed polarisation matches the amplifier polarisation.

11. (Optional) The TA diode will act as a photodiode which can be used to optimise the alignment of the seed laser. This

step is optional and alignment can instead be optimised by monitoring the amplifier output power (see below). To use the TA diode as a photodiode:

(a) Disconnect the TA cathode, directly at the diode or on the circuit board on the underside of the amplifier.

(b) Connect the TA cathode to a nano-ammeter.

(c) Adjust the seed alignment by walking the seed beam with the mirror pair, and the focus, to optimise the photocurrent from the TA.

Refer to `http://www.eagleyard.com/fileadmin/downloads/app_notes/AppNote_TPA_2-0.pdf` for more detail on this procedure.

12. Verify optimum seed alignment by optimising the amplifier output power, again walking the beam with the mirror pair and adjusting focus.

13. The recommended procedure for walking the mirror pair is as follows:

    (a) For the horizontal axis first, find the maximum output power/photocurrent by adjusting the mirror closest to the amplifier (furthest from the seed), mirror M1.

    (b) Take note of the output power/photocurrent.

    (c) Adjust the horizontal axis of the mirror furthest from the amplifier (closest to the seed, mirror M2) clockwise such that the output power/photocurrent drops by no more than 25%. Take note of roughly how many degrees rotation were required.

    (d) Adjust the horizontal axis of mirror M1 and maximise for amplifier output power. Compare the new maximum amplifier output power/photocurrent you have obtained to the output power/photocurrent you obtained at step (b).

    (e) If your new power/photocurrent is greater, repeat steps (c) and (d). If your new power/photocurrent is lower, adjust the horizontal axis of mirror M2 anti-clockwise to return it to its original angle (as you noted at the end of step (c)), then optimise the horizontal axis of mirror M1 to regain the output power/photocurrent you noted in step (b). If your first horizontal clockwise adjustment of both mirrors (steps (b) and (c)) resulted in a decrease in output power/photocurrent, repeat steps (c) and (d) using an anti-clockwise adjustment instead.

(f) Once horizontal alignment is optimized, repeat steps (c) through (e) for the vertical alignment.

(g) Iterate the horizontal and vertical alignment procedure until you can no longer increase the output power. You may need to drop the output power/photocurrent by less than 25% as your alignment improves, e.g. 10% or 5%.

(h) Record the maximum amplifier output power and the seed power and injection current. Close the input MOA002 shutter and record the unseeded amplifier output power. Reopen the input shutter.

14. Reinstall the input isolator and align the isolator to maximise the amplifier output power. You will need to adjust height, translation, and (to a very small degree) tilt of the isolator/isolator mount. You will also need to ensure the seed polarisation is 45° to the amplifier polarisation, as the isolator rotates the polarisation by 45°. A half-wave retarder between the seed laser and amplifier can be useful to optimise the polarisation. It may also be necessary to adjust the rotation of the isolator about the optical axis to match the polarisations.

15. Repeat step 12, walking the mirrors.

16. At the maximum unseeded injection current, ensure the MOA002 is amplifying the seed by comparing the output power seeded and unseeded. You should observe at least a 50% increase in output power when the seed is aligned correctly. Compare also to the MOGLabs MOA002 test data.

2.2 Measure PI curve

It is important to verify proper seed injection by measuring the output power (P) against input current (I) and comparing to the PI curve measured at MOGLabs.

1. Reconnect the TA power supply if necessary.

2. With TA current of 0.3 A (500 mW devices), 0.5 A (1000 mW devices) or 0.7 A (2000 mW devices), increase the seed power and verify significant output from the TA (see figure 2.4). The TA output is predominantly ASE (amplified spontaneous emission) until the seed power is increased to several milliwatts. The TA output will normally saturate with seed power of 10 mW to 50 mW depending on the specific TA diode and the efficiency of coupling of seed into the amplifier.

3. Carefully optimise the seed alignment and focus at the recommended initial TA current. Note that both will depend on the TA current due to thermal lensing.

4. Repeat alignment at a current above the initial low injection current, for example at 1 A for 1000 mW devices, to ensure optimum alignment under near-normal operating conditions.

5. Measure the PI curve (see figure 2.5). Make sure that the output power is comparable to the factory test results. Do not increase the TA current significantly if the threshold current (i.e. the current at which the TA output power is more than a few milliwatts) and the slope are not comparable to the factory test results. Further optimisation of the seed alignment and focus may be necessary.

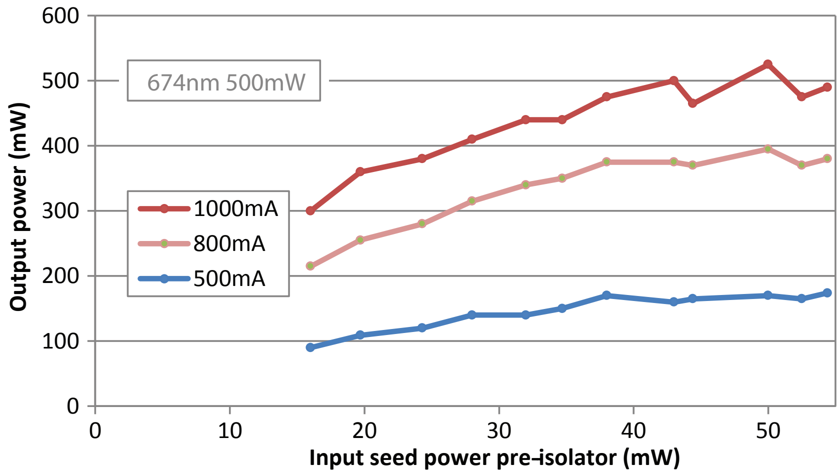

Figure 2.4: TA output against seed power, for several injection current values.

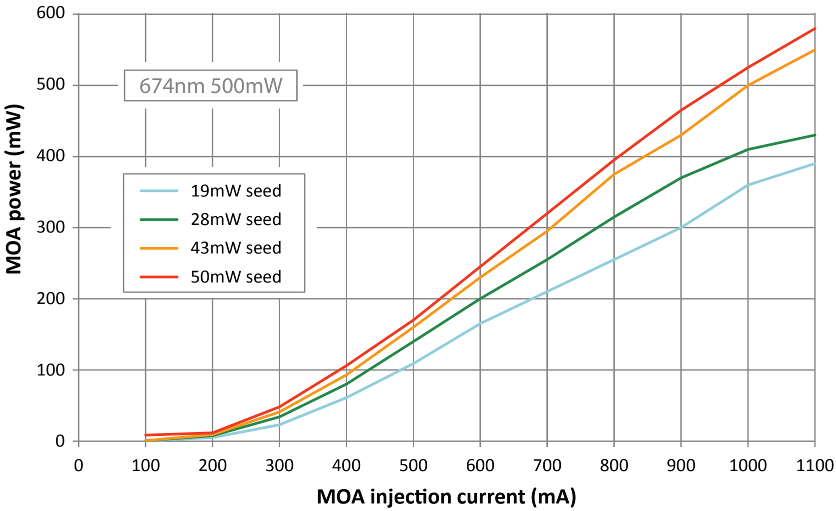

Figure 2.5: TA output against diode current, for several different injection seed laser powers (measured pre-isolator).

2.3 Output beam optimisation

The beam profile of a tapered amplifier output beam generally looks awful. It is usually mishapen, cross-shaped (like two orthogonal ellipses) and may have 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).

Typically, the output will be fibre-coupled to produce a high-quality TEM_{00} Gaussian beam. The simplest measure of the beam quality is known as the M^2 parameter, which is loosely defined as the ratio of total beam power to that component in the TEM_{00} mode. For example, $M^2 = 1.7$ means that for a total beam power of P, after removing the higher-order modes which make the beam non-TEM_{00}, the TEM_{00} beam power will be $P/1.7$.

At MOGLabs, we believe that a more meaningful measure is how much of the total power can be extracted from a single-mode optical fibre, and hence we measure and optimise the fibre-coupled output as well as the total output.

Please follow these steps to optimise the output beam.

1. Operating at no more than 20% of full output power, align the output Faraday isolator to maximise transmission. Alignment includes translation, tilt, and rotation. Transmission is typically 80 to 90% but please refer to the factory test results for your amplifier.

2. View the output beam at a large propagation distance, for example by reflecting from a mirror at several metres away, back to the MOA002, with a beam profiler or imaging sensor.

3. Carefully adjust the exit collimator lens focus to collimate the exit beam. The beam size on exit from the MOA002 and after long propagation distance should be similar.

4. Some adjustment of the focus of the astigmatism compensation lens may be needed so that the output is collimated along horizontal and vertical directions.

5. Increase to full power. Thermal lensing may affect the input and output collimation slightly, so it is best to carefully adjust both with the TA operating at the preferred output power.

6. If coupling to a fibre, first reduce the output power to a few mW to avoid fibre end facet damage. Unfortunately there are substantial changes to the TA output beam when varying between the lower power needed for fibre coupling adjustment, and the high power needed for experiments, and hence some iteration is needed. It is helpful to introduce a neutral density filter before the fibre so that fibre alignment can be optimised at relatively high power. Then optimise the fibre coupling and increase the output power iteratively until the desired operating power is reached. It is normally safe then to switch off the MOA002 and restart without multistep fibre alignment each time.

2.4 Diode replacement

Replacement tapered amplifier diodes can be purchased from MOGLabs or directly from suppliers, in particular Eagleyard Photonics. The diode semiconductor chip is mounted to an industry-standard C-mount, which is then mounted to a proprietary CRT04 mount developed in conjunction with Eagleyard Photonics.

To replace the diode:

1. Disconnect the diode anode and cathode wires and pull the thermistor from the eccentric cam sub-assembly. The cathode (black wire) may be press-fit or soldered to the pin on the CRT04 mounted diode. The anode (red wire) is connected to the eccentric cam sub-assembly with a small screw.

2. Rotate the focus knobs to pull the input and output collimation lenses away from the diode. Turn each anti-clockwise until the lenses retract fully into the eccentric cam assembly on each side of the diode. It will be helpful to mark the focus knob and count the turns, so that the operation can be reversed when re-assembling.

3. Two screws hold the diode to the sub-assembly. These screws are accessed from underneath and hence the sub-assembly must be detached from the thermoelectric cooler (TEC) and main chassis by removing the four screws at the corners.

4. After removing the two screws from the bottom side of the assembly, the diode can slide sideways for removal. Take care that the collimation lenses are retracted (see above) so that they do not obstruct the diode.

5. Re-assemble by following the steps in reverse.

6. The cathode pin on the CRT04 mount is usually too long and should be (carefully) cut short, to about 3 mm. Then the cathode wire (red) can be push-fit onto the pin, or soldered. Heat-shrink tubing should be used to prevent short-circuits to the main body of the eccentric cam assembly.

7. Take care to maintain a very thin layer of thermal paste between the TEC and the eccentric cam assembly.

8. When tightening the four corner screws, first hold the assembly down firmly against the TEC, then tension each screw evenly until firm. The wave spring washers should be flat.

9. Don't forget to reconnect anode and cathode wires, and to re-insert the thermistor.

10. Restore the lens focus knobs. This should be done while monitoring the two exit beams for collimation as described above.

A. Troubleshooting

No light or low output power

- Ensure input and output shutters are open.
- Check that the TA diode current and voltage drop are as expected (refer to factory test results).
- Is ASE apparent from input and output sides of TA? If not, diode is probably damaged. Remove and inspect under a microscope.
- Is input seed mode-matched to TA diode? Refer to alignment instructions.

Output unstable

For example, output power varies substantially with small changes of input seed frequency.

- Check for sufficient optical isolation between seed and amplifier. Two Faraday isolators, or a double-stage isolator, may be required.
- Adjust angular alignment of Faraday isolators very slightly to reduce direct back-reflection from first optical surface into TA diode.

B. Connector pinouts

B.1 MOA amplifier

The MOA002 is connected via a standard 15-pin DE15 high-density D-sub connector .

Pin	Signal	Pin	Signal
1	Laser diode anode (+)	9	+5 V
2	Laser diode anode (+)	10	0 V (ground)
3	Peltier TEC (+)	11	Relay (−)
4	Peltier TEC (+)	12	Photodetector signal (0 − 5 V)
5	Peltier TEC (−)	13	NC
6	Laser diode cathode (−)	14	Thermistor NTC 10 kΩ (+)
7	Laser diode cathode (−)	15	Thermistor NTC 10 kΩ (−)
8	Peltier TEC (−)		

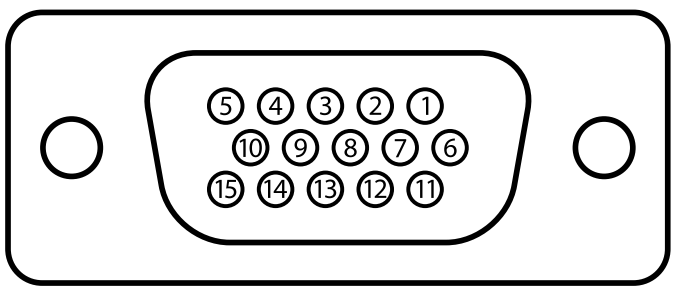

Figure B.1: Connector pinout. Relay (−) should be grounded to open the protection relay and enable operation.

B.2 Headboard

The amplifier head interface board provides connection breakout to the amplifier diode, TEC, temperature sensor, and photodetector amplifier. It also includes a solid-state protection relay and passive protection filters, and a laser-on LED indicator. The internal connections are made with Hirose DF59 "swing-lock" wire-to-board connectors.

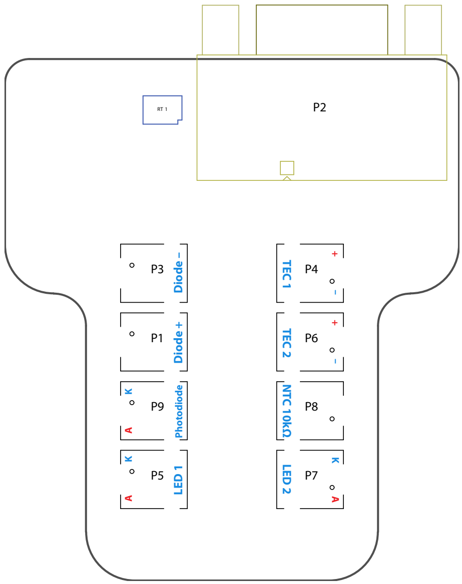

Figure B.2: MOGLabs MOA002 laser head board showing connectors for tapered amplifier diode, temperature sensor, TEC and LEDs.

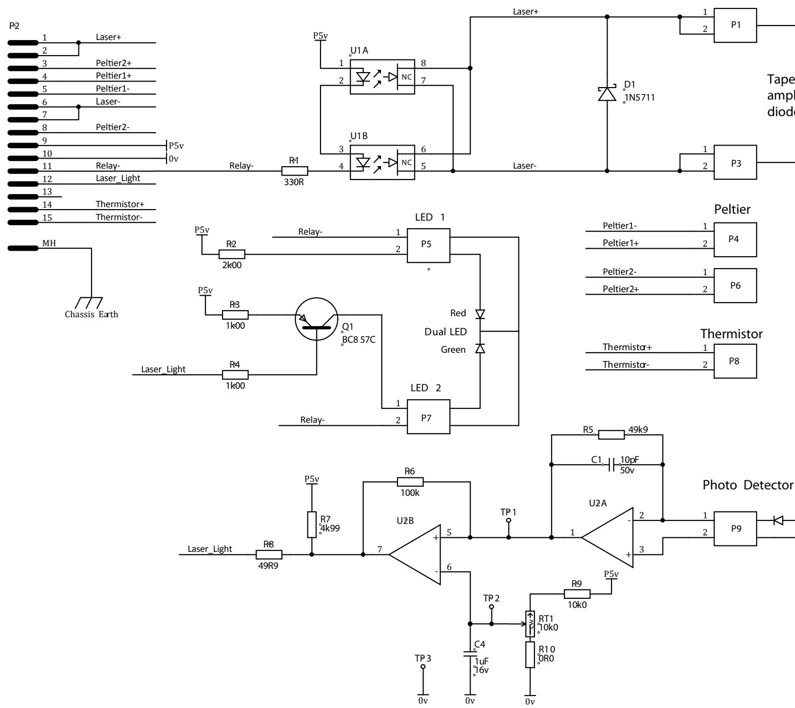

Figure B.3: MOA002 headboard schematic.

C. Arroyo power supply

> *WARNING*
> Do not operate the MOA002 without input seed laser. The input seed power must be at least 10 mW, and properly mode-matched to the tapered amplifier diode. Operation without appropriate seed will destroy the tapered amplifier diode.

The MOA002 can be supplied with many different current and temperature controllers. ARROYO offer several versatile and ergonomic options, such as the 6340 combined current and temperature controllers, supporting front panel and remote operation via an RS232 or USB communications channel.

ARROYO manuals are available at http://arroyoinstruments.com. If purchased with your MOA002, the ARROYO will be pre-configured with appropriate current limit and other settings for your device.

C.1 Before powering on

1. The MOA002 requires +5 V for operation of the diode protection circuitry. Please configure the ARROYO to provide this via the FAN output, which is part of the TEC functions and available on the TEC output cable. Using RS232 or USB communications, or via the front panel menu, configure as:

   ```
   EXT FAN: CUSTOM
   EXT FAN PWR: 5V
   EXT FAN MODE: ON
   ```

2. Connect according to the table in section C.3 below.

3. Set the current limit, TEC, and temperature according to the test data provided with your MOA002.

C.2 Starting the MOA002 optical amplifier

Enable active temperature control with the TEC On/Off switch.

Adjust the amplifier current target. Initially, the current should be set to a safe level for alignment: high enough to see some ASE (amplified spontaneous emission) but not high enough to cause damage without seed laser injected. Typical values are 300/500/700 mA for 500/1000/2000 mW devices

With appropriate target current set, activate the current driver with the Laser Enable keyswitch andLaser On/Off switch.

C.3 Arroyo/MOA cable

The ARROYO 6340 is connected via 9-pin LASER OUTPUT and 15-pin TEC OUTPUT standard density D-sub connectors. ARROYO provide good quality cables at reasonable cost, which can easily be connected to the MOGLabs MOA002. We suggest one each of 1221B LaserSource Cable and 1261B TECSource Cable.

DB-9	DB-15	Function	MOA Pin	Function
1,2		Interlock		Short-circuit
3		Earth ground	10, 11	0 V, relay (–)
4		Laser cathode sense	6	Laser (–)
5		Laser cathode	7	Laser (–)
6		PD cathode	10, 11	0 V, relay (–)
8		Laser anode sense	1	Laser anode (+)
9		Laser anode	2	Laser anode (+)
	1,2,9	TEC (+)	3,4	TEC 2 (+)
	3,4,10	TEC (–)	5,8	TEC 2 (–)
	5,6	Earth ground	10,11	0 V, relay (–)
	7	Sensor (+)	14	Thermistor (+)
	8	Sensor (–)	15	Thermistor (–)
	11	Fan (+)	9	+5 V
	12	Fan (–)	10,11	0 V, relay (–)

C.4 Arroyo 6340 pinout

C.4.1 Laser Output Connector

DB-9 Pin	Signal
1	Interlock (+)
2	Interlock (−)
3	Earth ground
4	Laser cathode (−) voltage sense
5	Laser cathode (−)
6	Photodiode cathode (−)
7	Photodiode anode (+)
8	Laser anode (+) voltage sense
9	Laser anode (+)

C.4.2 TEC Output Connector

DB-15 Pin	Signal
1, 2, 9	TEC (+)
3, 4, 10	TEC (−)
5, 6	Earth ground
7	Sensor (+)
8	Sensor (−)
11	Fan (+)
12	Fan (−)
13	No contact
14	Remote sensor (+)
15	Remote sensor (−)

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