Laser Diode Driver

LDD605

Revision 2.04

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Preface

The MOGLabs LDD Laser Diode Driver is a compact high-power laser diode driver. It provides up to 8 A diode injection current with low noise, a temperature controller, a 60 W Peltier TEC driver, and a 160 V piezo driver. It can be operated via front-panel controls, or using a computer communications interface (TCP/IP or USB) with simple text-based commands. It has been designed for tapered amplifier and broad area laser diodes commonly used in atomic physics research laboratories, where stability and low noise are essential.

We hope that the LDD meets and exceeds your expectations. Please let us know if you have any suggestions for improvement in the LDD or in this document, and check our website from time to time for updated information.

MOGLabs 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 your laser. Also please note several specific and unusual cautionary notes before using the MOGLabs LDD, in addition to the safety precautions that are standard for any electronic equipment or for laser-related instrumentation.

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

Laser output 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 your laser. Please:

- Avoid direct exposure to the beam.
- Avoid looking directly into the beam.
- Note the safety labels and heed their warnings.
- When the laser is switched on, there will be a short delay of two seconds before the emission of laser radiation, mandated by European laser safety regulations (IEC 60825-1).
- The STANDBY/RUN keyswitch must be turned to RUN before the laser can be switched on. The laser will not operate if the keyswitch is in the STANDBY position. The key cannot be

removed from the controller when it is in the clockwise (RUN) position.

- To completely shut off power to the unit, turn the keyswitch anti-clockwise (STANDBY position), switch the mains power switch at rear of unit to OFF, and unplug the unit.
- When the STANDBY/RUN keyswitch is on STANDBY, there cannot be power to the laser diode, but power can still be supplied to the laser head for temperature control.

CAUTION The supply must include a good ground connection.

CAUTION To ensure correct cooling airflow, the unit should not be operated with cover removed.

WARNING The internal circuit boards and many of the mounted components are at high voltage, with exposed conductors, in particular mains supply to various sections of the power supply. The unit should not be operated with cover removed.

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

Protection Features

The MOGLabs LDD includes a number of features to protect you and your laser.

Softstart A time delay (3 s) followed by linearly ramping the diode current at < 1 A/s.

Circuit shutdown When not in use, relevant parts of the circuitry are immediately powered down when the system is in standby, an interlock is opened, or a fault detected. This includes the diode current supplies, the TEC driver and the high-voltage piezo driver.

Current limit A user-configurable maximum current can be specified to prevent damage to the laser diode or the TEC.

Cable continuity The system checks for an open-circuit condition on the laser diode, TEC or temperature to ensure.

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

Temperature If the measured temperature exceeds the bounds of normal operation, the system enters a failsafe state.

Protection relay Unless the user has signalled the laser to turn on, the laser diode is shorted via a normally-closed solid-state relay at the laser head.

Emission indicator The MOGLabs controller will illuminate the current warning indicator LED immediately when the laser is switched on. There will then be a delay of at least 3 seconds before actual laser emission.

Mains filter The device is protected against transient peaks in the mains voltage supply.

Key-operated The laser cannot be powered on unless the key-operated STANDBY switch is in the RUN position, to prevent unauthorised or accidental use. The key cannot be removed from the controller when it is in the RUN position.

Interlocks The main unit has an external interlock to allow the laser to be disabled via a remote switch, and a laser head cover interlock can be connected to disable laser output if the cover is removed.

Seeding A photodetector in the laser headboard can be used to detect sudden drops in output power, preventing damage to the tapered amplifier from running unseeded.

Contents

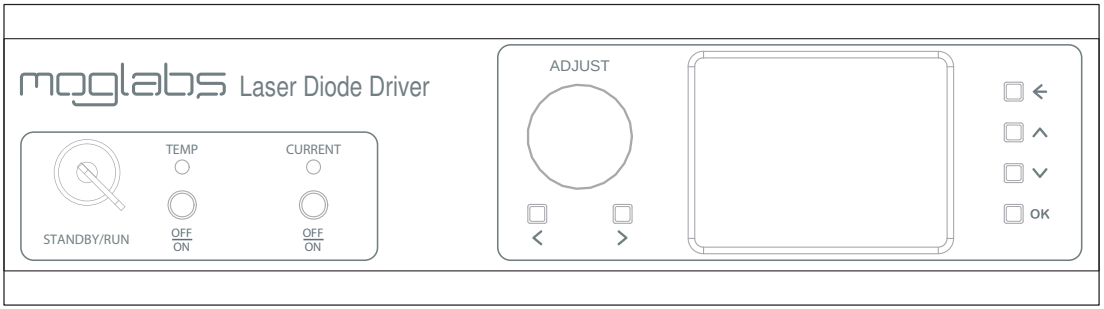
1. Introduction

The MOGLabs LDD is a compact high-power laser diode driver, providing low-noise injection current for the diode, a temperature controller with Peltier TEC output, and a high voltage piezo driver.

Connections between the LDD and laser are split across three cables: one for temperature control and power, one for diode current, and a third for the piezo. The connections are designed to interface directly with MOGLabs MOA and MSA optical amplifiers. See Appendix C for interfacing the LDD with non-MOGLabs laser products.

The device can be controlled via the front-panel controls and display (see below) or remotely via simple text commands communicated through USB or ethernet. Please refer to appendix F for further information on setting up computer communications, and appendix E for details on the control commands and their syntax.

1.1 Front panel controls



STANDBY/RUN

In STANDBY mode, both the temperature controller and diode current are disabled.

In RUN mode, the temperature controller is placed into standby, ready to be activated. On first power-up and during the boot pro-

cedure the LDD will halt if the key is already in the RUN position, to ensure that the laser cannot be accidentally powered if there is a power failure. The keyswitch should be set to STANDBY and then to RUN to initiate user control. Place the unit back into STANDBY if further operation is not desired.

TEMP OFF/ON Temperature controller enable. The STANDBY/RUN key switch must first be in the RUN position. If the unit fails to start the temperature controller on (indicator does not show green), see Appendix B.

CURRENT OFF/ON Diode current enable. The STANDBY/RUN key switch must first be in the RUN position. The temperature controller must also be on and operating.

If the current controller fails to switch to STANDBY mode (indicator does not show yellow), see Appendix B.

ADJUST The ADJUST rotary encoder allows variation of any editable value on the display. The knob can be pressed to step through different digits of the value being edited, to allow for fine and coarse control.

←, → The two buttons below the adjust knob allow selection of the digit of a value being edited.

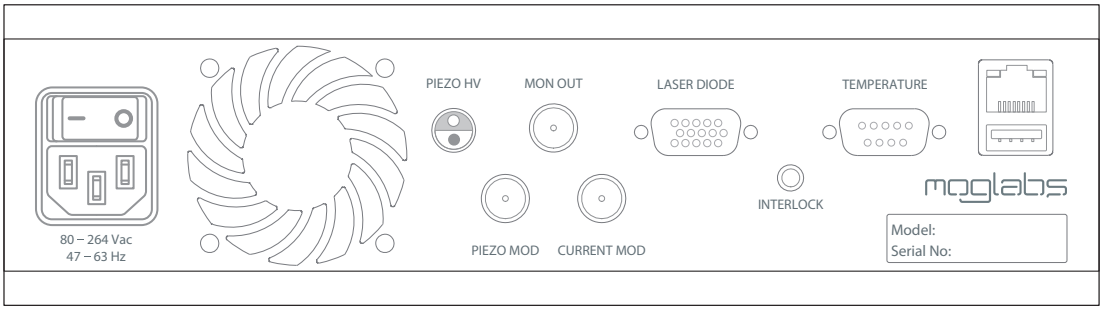
←, ↑ , ↓, OK Menu control buttons. These are used to navigate the menu system allowing users to go back one menu level (←), up and down between lines on any given menu (↑ or ↓), and to move forward in the menu system or to run system functions (OK).

1.2 Rear panel connections

IEC power in The unit supports a wide range of input voltages and frequencies from 80-264VAC 47-63Hz.

Fan The fan speed is temperature-controlled.

Piezo HV Lemo connector. 160 V HV piezo supply.



Piezo Mod — SMA connector. Control input for analogue piezo modulation. ±10 V input max, 12.5 V/V sensitivity (modulation depth of 150V) and bandwidth of 10 kHz.

Mon Out — SMA connector. Represents the ramp applied to the piezo, when that functionality is enabled.

Current Mod — SMA connector. Control input for analogue diode current modulation. ±10 V input max, 40 mA/V sensitivity (modulation depth of 400mA) and bandwidth of 40 kHz.

Laser Diode — Female DE15 port to laser head. Provides diode current, I2C, 5 V and other control lines to the laser headboard.

Interlock — The LDD will not power on the laser unless the pins on this port are **shorted**. A standard 3.5 mm audio plug is provided; see appendix D for pinout. The pins should be shorted using a relay for integration with laboratory interlock system; do not apply a voltage directly across the pins.

Temperature — Female DE9 port to laser head. TEC current and temperature sensor.

Ethernet — RJ45 10/100 twisted pair ethernet port.

USB — USB-A hi-speed (USB2) port.

1.3 Internal DIP switches

Special functions can be accessed by changing the state of dip switches within the unit. Note that these settings take effect on boot.

All DIP switches should be set to ON in normal operation. Setting a DIP switch to OFF will activate the associated functionality.

DIP 1	Enter firmware update mode, for use when firmware will not boot normally. Instructions for installing updates are in section 4.4.
DIP 2	Internal use only.
DIP 3	Internal use only.
DIP 4	Activate factory reset. The firmware and settings will be reverted to the original factory versions. Any user settings (including safety limits) must then be changed as required by the user.

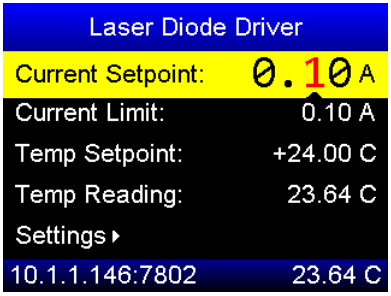
2. Menus

The MOGLabs LDD can be controlled via a detailed on-screen menu system. There are four push buttons to the right of the LCD display, to step through the menus. The large encoder knob can be rotated to change a value, and also acts as a push-button to change which character or digit is being changed.

The LCD display provides status and control information in the following pages:

Main	Critical values and settings
Settings	Main menu structure
TEC	Temperature-related values and settings
Laser	Laser values and settings
Piezo	Piezo values and settings
Headboard	Headboard interlock settings
Ethernet	Ethernet (TCP/IP) configuration
System	System settings and debug information

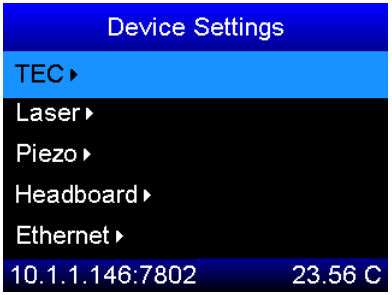
2.1 Main menu

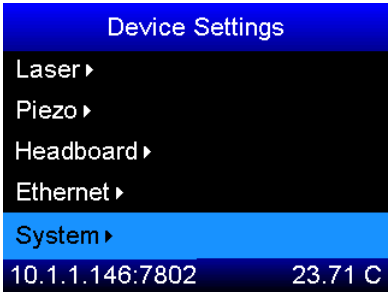


The default screen on power-up, showing diode set current, current limit, set temperature, actual temperature. The color box shows that the LD current is selected for adjustment. Rotate the adjust knob to

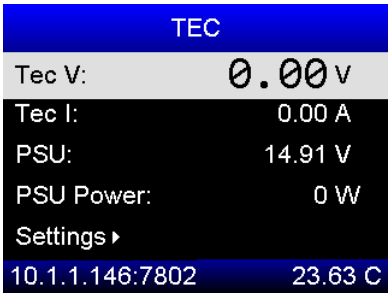
change the current; use the ↓ button to select a different parameter, or to move the cursor down to the Settings→ line and press OK to enter into other menus.

2.2 Settings menu



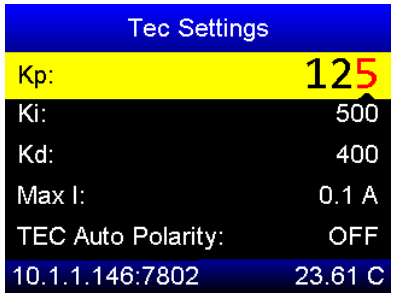


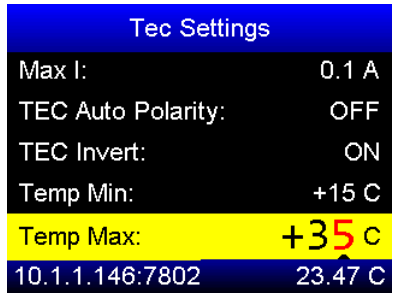
2.3 TEC menu



The TEC menu provides access to key operating parameters of the temperature controller, and a sub-menu to change TEC settings.

2.4 TEC settings

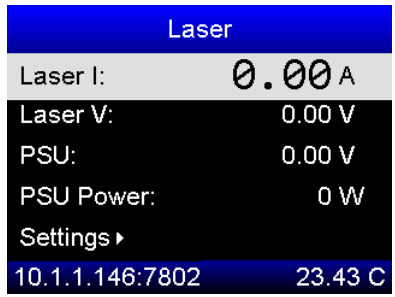




PID coefficients can be adjusted here if needed. *Max Current* sets an upper limit to the current to the TEC. T_{min} and T_{max} are limits; if the temperature falls outside this range, the temperature controller is disabled and current to the TEC is set to zero.

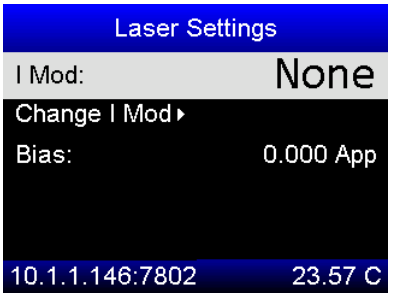
By default, the LDD will auto-detect the TEC polarity. Auto-polarity can be disabled and the polarity manually inverted with the *TEC Invert* menu option.

2.5 Laser menu



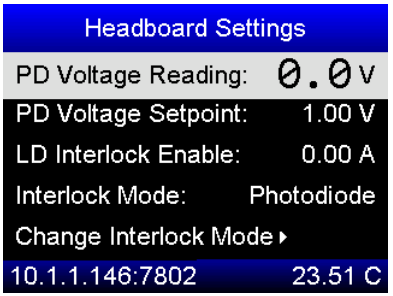
Laser I and *Laser V* display the diode voltage and current measured at the LDD unit. PSU voltage and PSU Power reflect the internal operating voltage and power of the current driver.

2.6 Laser settings



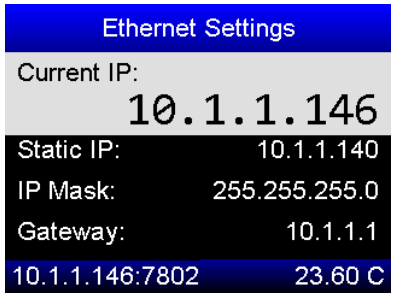
I Mod indicates if any modulation is currently affecting the laser current. Selecting "Change I MOD" allows you to change the modulation source or disable it. Bias indicates the maximum peak to peak current bias added to the laser when the piezo is being used.

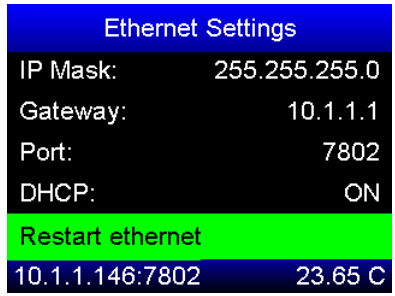
2.7 Headboard settings



The LDD supports a headboard-based interlock in the form of a case-switch or monitor photodiode (section 3.2), which is activated when the output current is greater than the *Interlock Enable* current. When using a monitor photodiode, the interlock will trip if the monitor reading falls below the specified setpoint value.

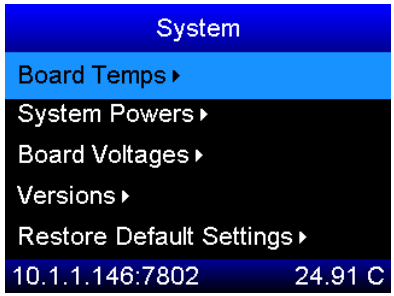
2.8 Ethernet settings

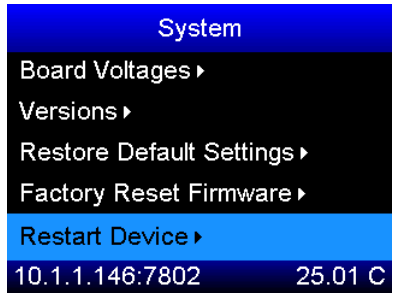




TCP/IP network parameters. Note for these settings to take effect select the *Restart ethernet* menu option which is initially off-screen at the bottom.

2.9 System information





The System menu allows access to infrequently required information, including internal temperature readings and supply voltages form the main board as well as firmware versions. There are also options to restore default settings, Factory reset the settings and firmware, as well as restart the device.

3. Operation

3.1 Getting started

The MOGLabs LDD should be connected to the laser diode and TEC using heavy gauge screened cables, one for each of the current and temperature functions.

To operate the LDD:

1. Ensure the rear power switch is on, and the STANDBY/RUN switch is in the STANDBY position. In this mode, the current and temperature controller are disabled.
2. Switch from STANDBY to RUN. The TEC LED should turn yellow indicating that the temperature controller can now be enabled. If the indicator is still off, this indicates that an interlock or connection to the laser is missing.
3. If the key is switched back to STANDBY, both laser current and temperature controllers will be disabled.
4. Adjust the temperature setpoint as required, using the display or `mogldd` application. If the LDD was purchased as part of a laser system, this will already have been factory-set as required.

   To use the display, move the cursor down to *Temp Setpoint* using the buttons on the right-hand side, and then turn the rotary encoder (ADJUST) to adjust the value.
5. Start the temperature controller by pressing the ON/OFF button below the TEMP LED. The LED below TEMP may briefly turn blue indicating that the the temperature controller is testing the polarity of the TEC. This process takes approximately three seconds. Once the temperature controller is running the LED will turn green.

6. Adjust the current setpoint as required. It may be necessary to change the *Current Limit* to permit the desired setpoint current.
7. Switch the laser on by pressing the ON/OFF button below the CURRENT LED. The LED below CURRENT will turn blue, indicating that the current supply is starting. After three seconds the output current will ramp up to the desired setpoint value.
8. Once the current has hit the setpoint the LED will turn green, indicating the laser is operational.

Note that the temperature controller must be running, all interlocks must be enabled, and no errors can be present for the laser current to be enabled. Consult Appendix B for assistance with diagnosing issues.

3.2 Interlocks

The LDD includes a number of safety features for the protection of both personnel and equipment. These interlocks must be active during normal operation, as even a momentary interruption will trigger the safety procedure and disable the laser output.

The laser headboard interlocks (case switch and photodiode) only activate above an *interlock threshold current*, allowing for diagnostics and laser tuning to be carried out at low power. These settings can be adjusted in the *Headboard Settings* menu on the device, or through the headboard commands (section E.4).

3.2.1 Rear-panel interlock

The back-panel interlock connector is a 3.5 mm audio plug whose pins must be shorted to enable the LDD. Intended for integration with controlled-entry systems such as door interlocks.

3.2.2 Key switch

The key switch on the front-panel must be set to *Run* before the LDD output can be enabled. As a safety procedure, it is necessary to manually toggle the key switch after power-cycling the unit; it cannot simply be left in the ON position.

For integration into control systems, toggling the key switch can be performed through the command `TOGOVERRIDE`, however to be compliant with safety regulations this function should only ever be used in accordance with a user prompt confirming manual override.

3.2.3 Case interlock

High-power laser amplifiers produce a lot of scattered light, and are generally considered unsafe to operate with the lid open. The laser headboard includes a switch that detects when the case is open and prevents the laser from being run above the interlock threshold current.

3.2.4 Photodiode interlock

Some laser amplifiers include a photodiode sensor that monitors the approximate laser output power. An unexpected decrease in output power at a given current is an indication that the amplifier is operating unseeded, which can irreversibly damage the amplifier at high drive currents.

A threshold photodiode voltage can be specified (e.g. corresponding to 80% of the typical output power), below which the interlock will be tripped, helping to prevent damage from occurring. This setpoint can be specified using the `HB,VSET` command, and the currently-measured photodiode voltage can be queried using `HB,PDV`.

3.3 Ramping

The LDD includes a ramp generator that interfaces with the high-voltage piezo driver and current controller, allowing the frequency of an attached laser to be swept. This functionality is potentially of use for high-power ECDLs as well as self-seeded tapered amplifiers. However, please note that the internal ramp functionality is not compatible with external modulation.

The ramp generator produces an adjustable sawtooth wave with versatile control parameters (Figure 3.1) to customise the sweep. The ramp frequency can be from 0.01 Hz to 100 Hz which may be useful in a number of contexts. The output of the ramp generator is available on the "MON OUT" SMA connector on the LDD backpanel for monitoring and scope-triggering purposes.

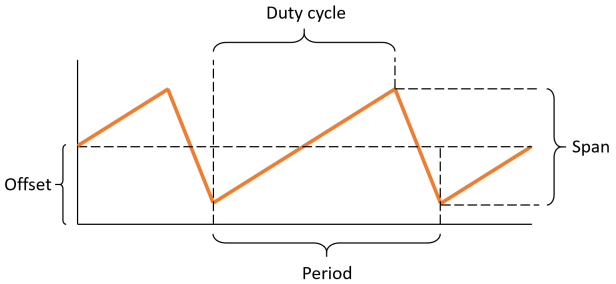


Figure 3.1: Schematic of ramp generator output, showing the meaning of the control parameters.

In order to scan the piezo, the high-voltage driver must be powered on (`HV,ONOFF,ON`) and set to ramp mode (`HV,MOD,RAMP`). Effective inversion of the piezo ramp polarity can be achieved by changing the ramp generator duty cycle[1]. The span and offset can either be specified in Volts using the `HV` commands (section E.5), or the normalised (unitless) `RAMP` commands (section E.6).

[1] For example. changing from 0.2 to 0.8 effectively inverts the polarity.

The current can be swept by setting the current modulation mode to either "+" or "-" depending on the desired polarity[2] (e.g. using the commands `CURRENT,MOD,+` or `CURRENT,MOD,-`). This function can be activated with or without the piezo scan enabled. The change in current is equal to the normalised ramp span times the bias current.

Where the piezo controller is active, the current and piezo sweeps are synchronised. Typically the bias current value and polarity must be optimised to match the piezo ramp to achieve improved mode-hop free scan ranges in applicable systems.

Note that the span and offset are software-limited such that the peak and trough of the generated ramp remain within bounds. This is to prevent undefined behaviour caused by clipping the control range.

[2]Negative polarity is only available in Rev 7+ devices.

4. MOGLDD application

The host software program `mogldd` provides a graphical user interface that allows remote control of the LDD laser diode driver.

It may be necessary to install a firmware update (section 4.4) before being able to use the `mogldd` software. If the software detects an incompatibility it will offer to install the update, which can be obtained from the MOGLabs website.

4.1 Device discovery

Upon starting `mogldd`, a device discoverer is displayed (Figure 4.1) which searches for LDD devices. Simply select the device with the correct serial number and click *Connect*.

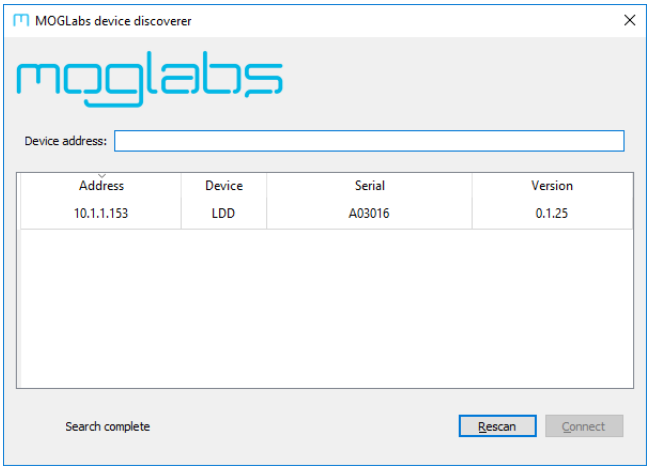
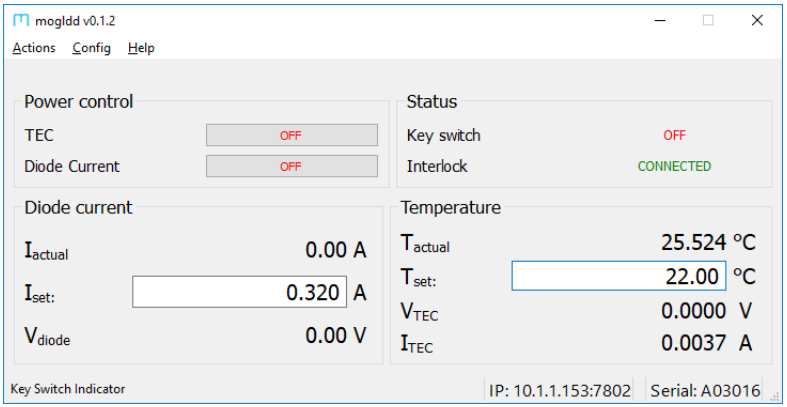


Figure 4.1: Example of the *device discoverer* window.

If the network does not permit device discovery and/or your LDD does not appear in the list, type the IP address of the unit (as displayed on the LCD screen) in the *Device address* box and click *Connect*.

4.2 Main display



The main window is divided into sections displaying the state of different aspects of the device, as follows. Values are periodically read from the unit and updated.

Power control Two buttons allow control of the TEC and laser diode current and show their status.

TEC Activates the TEC output and temperature feedback control.

Diode current Activates the laser diode output with soft start: the current increases slowly after a short delay.

Status Status of the front panel keyswitch and interlock, which must both be enabled to initiate the current controller.

Diode current

I_{actual} Measured current through laser diode.

I_{set} Desired output value of the current controller.

V_{diode} Measured voltage across laser diode.

Temperature The measured temperature of the laser, and the current and voltage of the TEC.

T_{actual} Measured temperature determined from the temperature sensor (either a thermistor or AD590 sensor).

T_{set} The setpoint temperature of the TEC controller.

I_{TEC} Measured current through TEC.

V_{TEC} Measured voltage across TEC.

4.3 Menu options

4.3.1 Actions

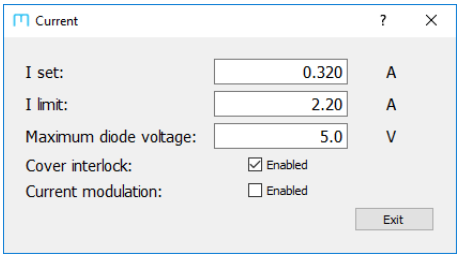
Command This opens a new dialogue for interactive command access to the device (Appendix E).

Restart LDD Resets the LDD device. Communications will be suspended. `mogldd` will attempt to reconnect to the device for up to 10 seconds.

Restore factory Initiates restore of factory settings from EEPROM on the LDD device. **Note that this process is irreversible and will erase all user settings.**

4.3.2 Config

Current Options for configuring the current controller, including features to prevent damage to attached devices.



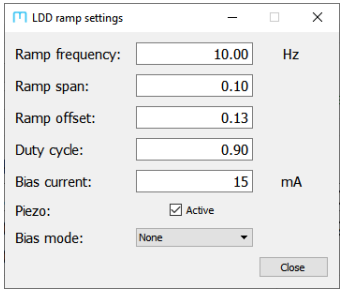
I set An alternative control for setting the desired laser diode current.

I limit Defines an upper limit for the entered diode current on the LDD device.

Max voltage Defines upper limit on the diode voltage on the LDD device. On newer revision units, this is adjusted automatically.

Current mod Enables external analogue modulation of the laser diode current via the rear panel modulation input. **Using external current modulation may cause the current to exceed the programmed limit in some scenarios**.

Ramp Options related to the piezo/current ramp functionality, as described in section 3.3.



Ramp frequency The frequency of the sweep, from 0.01 Hz to 100 Hz.

Ramp span The peak-to-peak span of the ramp from $[0, 1]$.

Ramp offset The offset of the middle of the ramp, in the range $[-1, +1]$

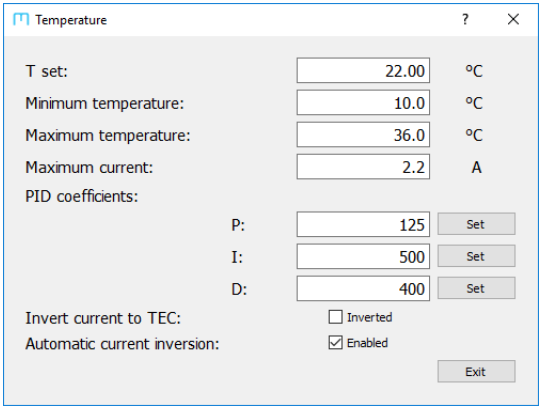
Duty cycle The fraction of the ramp with positive slope.

Bias current The amplitude of the bias current applied at a maximum ramp amplitude.

Piezo Enables the high-voltage piezo driver and sets it to ramp mode.

Bias mode Enables/disables the bias current, and sets its polarity.

Temperature The temperature settings dialogue allows setting critical temperature controller parameters.



T set An alternative control for setting the desired temperature.

Min/Max temp Define the limits on the permitted setpoint temperature. Exceeding these limits is indicative of incorrect TEC polarity or failure of the TEC to remove heat, causing the device to be disabled as a safety feature.

Max TEC current The upper limit on TEC current in regular operation. Running the TEC at too high current reduces the efficiency of the TEC and can lead to runaway heating, destabilising the temperature control loop.

PID coefficients The LDD controls the laser temperature with a standard PID (proportional integral differential) function:

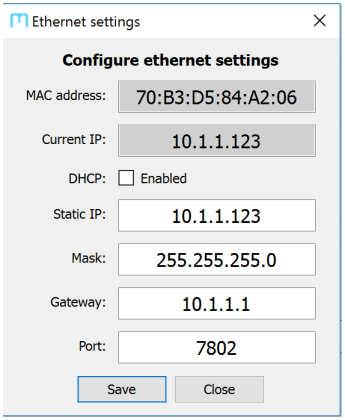
$$u(t) = k_p e(t) + k_i \int_0^t e(\tau)d\tau + k_d \frac{de}{dt}.$$

$e(t)$ is the input error signal and $u(t)$ is the feedback response. k_p, k_i, k_d are scaled positive proportional (P), integral (I) and differential (D) gain coefficients. Typical values are $P = 125$, $I = 500$ and $D = 400$. New coefficients can be entered but are not activated until the adjacent Set button is pressed.

Invert current Allows application of the LDD with a reverse polarity TEC.

Auto inversion Instructs the LDD to determine the TEC polarity after boot by checking which polarity causes a temperature decrease.

Network Allows configuration of network connection settings (IP address, mask, gateway and port). Particularly useful for configuring the network settings over USB. Note that changing the *Static IP* only has an effect if DHCP is disabled, or if DHCP name resolution fails. Note



that changing the ethernet settings will require the application to be restarted, and may also require the device to be rebooted. The port should be unchanged at 7802 to ensure that the `mogldd` suite of programs can continue to communicate with the device.

Reconnect Initiates device reconnection following communication interruption.

4.3.3 Help

About Displays device information.

Update Initiates firmware update (section 4.4).

Manual Opens web browser pointed at the MOGLabs support website to read the most up-to-date version of the manual.

4.4 Firmware update

From time to time, MOGLabs will release a firmware update that improves the device's functionality. The update is available from the MOGLabs website and should be installed on the device using the `mogldd` application.

The firmware update procedure is started by selecting *Update* from the *Help* menu, or will be automatically activated if the software detects incompatibility with the current firmware version (Figure 4.2).

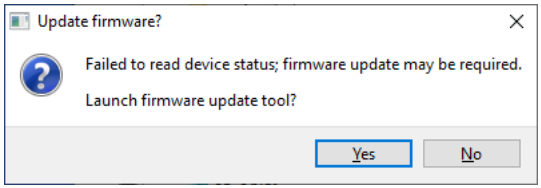


Figure 4.2: When `mogldd` detects a version incompatibility it will offer to install a firmware update. Alternatively the *Update* option can be selected from the *Help* menu.

The update process depends on the hardware revision of the unit. Only Rev 4+ units are described by this manual, which are easily identified by the presence of a colour screen. A separate manual describes legacy units, which is available from the website.

It is strongly recommended to update the firmware using Ethernet, but it is possible to update over USB. When using USB it may be necessary to unplug the USB cable when the process appears to have become stalled at the "Waiting for reboot..." stage.

The LDD should not be in use while applying a firmware update; neither the front-panel interface nor a separate device connection should be used to interact with the unit simultaneously. The LDD must not be powered off or interrupted during the firmware update or the firmware could become corrupted.

Firmware for Rev 4+ units is distributed as a ZIP file that contains different firmware components. Upon opening the firmware update

tool (Figure 4.3), click the *Select* button and browse for this file. The tool will identify the components that need upgrading, which will by installed by clicking the *Update all* button.

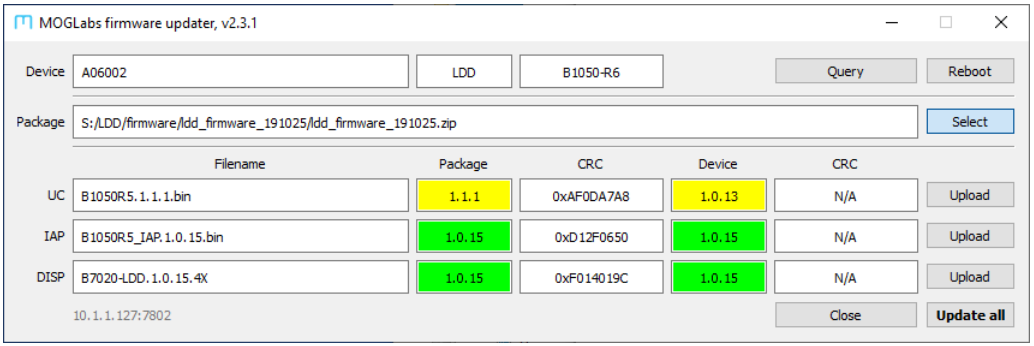


Figure 4.3: The firmware update tool shows the current versions of the firmware components, indicating which are up-to-date (green) and which require updating (yellow or red).

The firmware update process typically requires the device to reboot several times. A prompt is displayed once the process is complete. Closing the firmware update tool will then allow `mogldd` to be used.

A. Specifications

Parameter	Specification
Current regulator	
Output current	0 to 8 A
Max diode voltage	5 V up to 6 A
Display resolution	±1 mA
Noise	TBD (10 Hz – 1 MHz)
Stability	Warmup time: 15 minutes
Analogue mod	40 mA/V, ±10 V max, 40 kHz bandwidth

Temperature controller	
TEC current max	±5 A
TEC voltage max	±12 V
TEC power max	60 W
Stability	±10 mK/°C
Sensor	NTC 10 kΩ
Range	−20 to +80°C standard
Display resolution	±0.01°

Note: The TEC is controlled with a linear regulator, which may overheat if the current load is high and the TEC voltage is low. Choose a TEC with 2 to 4 Ω resistance for optimal performance.

Parameter	Specification
Piezo driver	
Output	0 to 150 V, 10 mA
Bandwidth	1 kHz
Control	External analogue 12.5 V/V Internal 12-bit DAC (4096 steps)
Computer interface	
Ethernet	10/100 TP, RJ45
USB	USB2, plug type USB-A
Display type	2.8" 240x320 TFT
Connectors	
Current	DE15 high density 15-pin female
Temperature	DE9 9-pin female
Piezo	LEMO EPL.0S.302.HLN
Protection	
External interlock	3.5 mm audio plug (provided)
Cover interlock	Laser head cover interlock
Key interlock	STANDBY/RUN
Delayed soft-start	3 s delay + 1 s/A ramp (to 6A)
Open circuit	Laser cable, TEC, temperature sensor
Diode current	Digital setpoint limit I_{lim}
Photodetector	Seed failsafe

Parameter	Specification
Mechanical & power	
Fan	Dual 12 V DC ball-bearing
IEC input	80 to 264 47-63Hz
Dimensions	WxHxD = 250 × 79 × 292 mm
Weight	2.4 kg (excluding cables, laser head board)
Power	18 W (standby) 30 W to 100 W (low/high diode/TEC load)

B. Troubleshooting

The MOGLabs LDD detects a wide range of fault conditions and deactivates related circuitry accordingly. The front-panel LEDs provide indication of the state of these functions.

B.1 TEMP indicator

Colour	Status
DARK	Deactivated; check interlock and key switch
YELLOW	Standby mode, ready to be enabled
BLUE	Testing TEC direction
GREEN	Operational
RED	Error state; check screen for more information

B.2 CURRENT indicator

Colour	Status
DARK	Deactivated; check TEC controller
YELLOW	Standby mode, ready to be enabled
BLUE	Current ramping up to setpoint
GREEN	Current stable at setpoint
RED	Error state; check screen for more information

B.3 Error states

If an error is detected, the LCD display will provide an explanatory message from the table below.

Error Message	Solution
Internal PCB too hot	The internal circuit board has overheated. Check ventilation and ensure fan is not blocked.
Laser driver too hot	
TEC driver too hot	
Error reading temperature sensor	Unable to measure laser temperature. Check connections between LDD and laser headboard.
Laser temperature too high	TEC could not regulate temperature. Indicates incorrect TEC polarity, insufficient chassis cooling, or electrical failure of the TEC.
Laser temperature too low	
TEC error	Error controlling TEC
TEC open circuit	The TEC is not correctly connected, or has failed
TEC short circuit	
TEC max current too high	The voltage required to achieve the TEC current is too high, indicating the max TEC current must be reduced
Laser voltage too high	The voltage supplied to the laser diode has exceeded the maximum permitted voltage
Current control error	The current driver could not supply the required current.
Laser lid open	The laser lid has been opened, triggering the interlock (section 3.2)
Optical power too low	The photodiode is below threshold, triggering the interlock (section 3.2).

Error Message	Solution
Laser open circuit	The laser diode is open circuit. Check laser cable is correctly connected.
No interlock	The rear interlock is open circuit. Make sure the rear-panel interlock is shorted.
Remote interlock removed	Rear interlock was removed during operation.
Activate key first	Key needs to be in the RUN position.
Toggle key switch	The key needs to be turned off and on again before operation.
Key switch disabled	Key switch was turned off during operation.
Laser short circuit	The laser diode is short circuit. Check laser cable and diode.

For additional assistance please contact MOGLabs support describing the problem. Please ensure to include the device serial number and firmware versions.

C. Laser head board

A laser head interface board provides connection breakout to the laser diode, TEC, temperature sensor, and laser head interlock. It also includes a laser diode protection relay, a passive protection filter and a laser-on LED indicator.

Three headboards are available: B1048, B1055 and B1056. They provide the same functionality but in slightly different form factors depending on the requirements of the laser mechanics. Each provides current capacity of 8 A for diode and 5 A for TEC. They also include a transimpedance amplifier for a photodiode which can be used to verify proper laser diode output as part of the interlock system (section 3.2).

C.1 B1048 headboard

The B1048 provides connection to a passive NTC thermistor temperature sensor, TEC, laser diode and photodiode, using Hirose DF59 "swing-lock" wire-to-board connectors.

C.2 B1055 headboard

The B1055 is used in most MOGLabs optical amplifiers. It includes connections to a case interlock (whose pins must be shorted to enable the laser diode current output). The switch SW selects between cover-only and photodiode-augmented modes of interlock operation. Contact MOGLabs for further details if required.

C.3 B1056 headboard

The B1056 is an evolution of the B1055 that uses more mechanically robust connectors. It includes integrated current noise filters and is less susceptible to magnetic interference than previous designs.

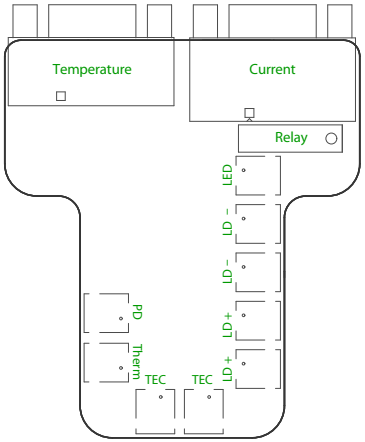


Figure C.1: B1048 laser head board layout.

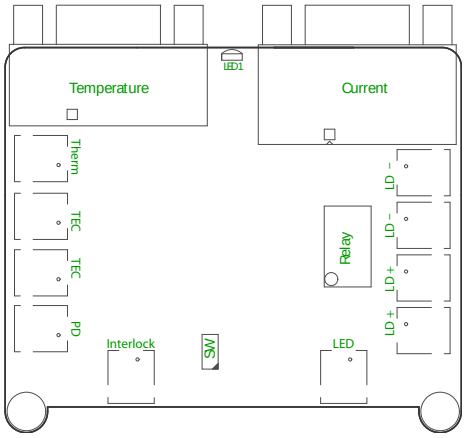


Figure C.2: B1055 laser head board layout.

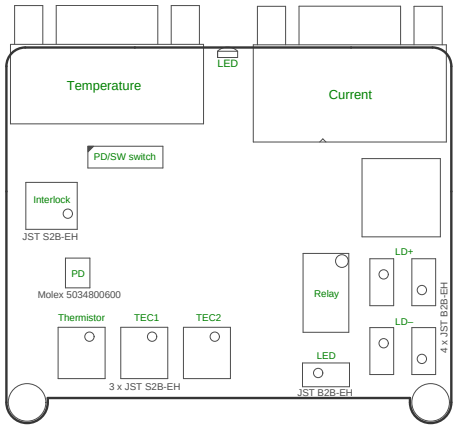


Figure C.3: B1056 laser head board layout.

D. Connector pinouts

WARNING: The CURRENT and TEMP connectors are intended for connection to a MOGLabs laser head board. They can provide high currents that may damage other devices. Considerable care should be taken if connecting to non-MOGLabs equipment.

Only high quality cables with 24 AWG or larger conductors should be used.

D.1 Temperature

Pin	Signal
1	Thermistor +
2	GND
3	TEC -
4	TEC +
5	TEC +
6	Thermistor -
7	TEC -
8	TEC -
9	TEC +

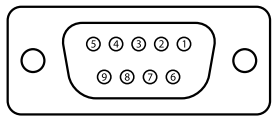


Figure D.1: Female DE9 TEMP connector on rear panel.

D.2 Current

Pin	Signal
1	Relay -
2	I2C SDA
3	Photodiode status
4	Diode cathode
5	Diode anode
6	GND
7	GND
8	GND
9	N/C
10	Diode anode
11	5v
12	I2C SCL
13	Diode cathode
14	Diode cathode
15	Diode anode

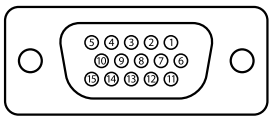
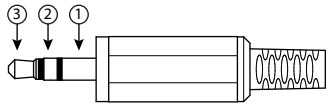


Figure D.2: Female DE15 CURRENT connector on rear panel.

D.3 Interlock



1	+3.3 V via 5 kΩ
2	No contact
3	Ground

Figure D.3: 3.5 mm plug for Interlock. Either mono or stereo plug can be used. In both cases the tip and shell should be used, with the central connector unused for stereo plugs. Tip (pin 3) and shell (pin 1) should be short-circuited to enable current to the laser diode.

Note: Do not apply a voltage across the interlock pins, or the LDD may be irreversibly damaged!

D.4 Piezo

1	0 – 150 V
2	Ground

Figure D.4: LEMO EPL.0S.302.HLN connector for high voltage piezo actuator driver. Plug type FFA.0S.302.

E. Command language

The LDD is controlled via a CRLF-terminated text-based communications protocol which allows it to be easily integrated into existing control systems.

Commands are formed by a comma-separated list of parameters, as listed below. The parameters shown in square brackets are optional, and commands that are called without parameters are treated as queries.

Commands respond with a string that begins with either "OK" or "ERR" to indicate whether it was successful. Queries (such as measured temperature) return a value with units.

In some cases, the *actual* value may be different from the *requested* value due to parameter limits.

The below commands are for Rev 4+ hardware and have a different structure to the legacy firmware. It is recommended to use these new commands, even where older commands are still recognised for backwards-compatibility purposes.

E.1 General functions

INFO `INFO`

Report device identification, including running firmware version and serial number. Please include this information in all correspondance with technical support.

VER `VER`

Report currently running firmware versions.

HELP `HELP[,cmd]`

Returns a list of available commands and short descriptive messages. Commands that have subcommands are indicated with >>, and the

subcommands can be listed by specifying the `cmd` parameter.

STATUS `STATUS`
Responds with a description of the most recent error that occurred (as listed in Appendix B.3) or "No error".

CLEAR `CLEARERROR`
Clears the most recent error as displayed on the screen and as returned by the `STATUS` query.

REPORT `REPORT`
Returns a dictionary (comma-separated list of key-value pairs) of present device settings. The order of entries in the dictionary is subject to change at any time.

INTERLOCK `INTERLOCK`
Report remote interlock status. Returns either ON indicating the interlock is present, or OFF when the interlock is missing.

KEY `KEY`
Report keyswitch status. Responds ON if the keyswitch is set to RUN, OFF if the keyswitch is set to STANDBY, or TOGGLE if the keyswitch must be manually toggled in accordance with safety guidelines.

TOGOVER `TOGOVERRIDE`
Overrides the requirement to toggle the keyswitch. In order to remain compliant with safety regulations, this command should only ever be issued in response to direct user intervention, such as a interactive alert or prompt.

BKLIGHT `BKLIGHT[,value]`
Screen back-light auto off time. `value` can be any number of seconds from 0 to 255. The back-light will remain on indefinitely with a setting of 0.

BTEMP `BTEMP`
Report measured board temperature.

FAN `FAN`
Report current fan speed, as a percentage of maximum.

E.2 Temperature control settings

TEC,ONOFF `TEC,ONOFF[,onoff]`

Activates the temperature controller (TEC) if `onoff` is ON, deactivates it if `onoff` is OFF, and reports the current status if `onoff` is not specified. Returns the string "AUTOPOLARITY" when performing the autopolarity test.

The keyswitch must be ON before the controller can be activated. Disabling the temperature controller will automatically disable the current supply.

TEC,TEMP `TEC,TEMP`

Reports laser temperature as measured by the headboard thermistor.

TEC,PID `TEC,PID,{P, I, D}[,value]`

Set or query the P, I or D gain constants used in regulating the temperature. These parameters should only need to be modified if the temperature sensor is physically relocated away from its factory position. `value` is rounded to the nearest whole number.

TEC,INVERT `TEC,INVERT[,value]`

Set or query whether to invert current to TEC. If the polarity of the TEC is incorrect, the device will heat when it is supposed to cool and the temperature will diverge. It is therefore important to ensure that current is inverted when the polarity is reversed from the default.

TEC,AUTOPOL `TEC,AUTOPOLARITY[,onoff]`

Enable/disable automatic determination of TEC polarity. This check takes approximately three seconds and is performed during the first activation of the temperature controller after power-up, as indicated by a blue LED on the front-panel.

TEC,TSET `TEC,TSET[,value]`

Set or query the desired temperature setpoint of the laser, as rounded to two decimal places. The optimal operating temperature is typically included as part of the laser diode specifications.

TEC,TMIN `TEC,TMIN[,value]`
Set the minimum permitted laser temperature, to prevent damage to the laser diode in case of control failure. `value` is a whole number. This temperature should never be reached if the TEC polarity is correct.

TEC,TMAX `TEC,TMAX[,value]`
Set the maximum permitted laser temperature, to prevent damage to the laser diode in case of control failure. `value` is a whole number. This temperature should never be reached if the TEC polarity is correct.

TEC,ILIM `TEC,ILIM[,value]`
Set the maximum TEC current or reports maximum TEC current if no value specified. A higher limit current may permit faster control convergence, but will require more heat to be dissipated through the baseplate.

TEC,ITEC `TEC,ITEC`
Reports the current measured through the TEC.

TEC,VTEC `TEC,VTEC`
Reports the voltage measured across the TEC.

E.3 Current control settings

CURRENT,ONOFF `CURRENT,ONOFF[,onoff]`
Activates the diode laser current supply if `onoff` is ON, deactivates it if `onoff` is OFF, and reports the status of the controller if `onoff` is not specified. The temperature controller must be running before the current supply can be activated.

CURRENT,ISET `CURRENT,ISET[,value]`
Set or query the setpoint current to be generated by the controller.

CURRENT,ILIM `CURRENT,ILIM[,value]`
Set or query the current limit. This limit is applied in hardware, and prevents damage to the laser diode by overdriving it.

CURRENT,MEAS `CURRENT,MEAS`
Reports the actual measured current through the laser. May differ from the setpoint current by a small amount.

CURRENT,MOD `CURRENT,MODULATION[,value]`
Set or query the current modulation mode. `value` can be one of the following options:

0, OFF, NONE No modulation

1, EXT, SMA External input (SMA connector)

+, INT Internal ramp (positive bias)

-, NEG Internal ramp (negative bias)

CURRENT,BIAS `CURRENT,BIAS[,value]`
Level of feedforward ("bias") applied to the current during the ramp. `value` is the current shift in mA applied at maximum span, and is a floating point value between 0 and 1000.

E.4 Headboard settings

HB,HAS `HB,HAS`
Responds with whether the headboard is interlock-compatible.

HB,ISET `HB,ISET,[value]`
Threshold current above which the headboard interlock is activated. Below this current the headboard interlock is not active, allowing for diagnostics and adjustments to be carried out.

HB,INTER `HB,INTERLOCK[,mode]`
Set or query the headboard interlock mode. `mode` is one of the following strings

NONE Interlock disabled

CASE Case switch interlock

PD Photodiode interlock

If `mode` is not specified, the response includes the present interlock state, for example

- `PD,1` indicates the photodiode interlock is active, and the interlock condition is currently being met (i.e. the measured optical power exceeds the threshold at this current).
- `CASE,0` indicates the case interlock is in use, and the interlock condition is currently being violated (i.e. the case is open)

HB,PDV `HB,PDV`
Currently measured photodiode voltage (on compatible headboards).

HB,VSET `HB,VSET,[value]`
Minimum permitted measured photodiode voltage when drive current is above the threshold current.

E.5 Piezo driver settings

HV,ONOFF `HV,ONOFF[,onoff]`
Activates the high-voltage (piezo) driver. `onoff` can be ON or OFF; reports status of the piezo driver if parameter absent.

HV,SPAN `HV,SPAN[,value]`
Set or query the span of the piezo ramp, in Volts. `value` should be between 0–120V.

HV,OFFSET `HV,OFFSET[,value]`
Set or query the voltage offset of the **centre** of the ramp. `value` can be any integer from 0 to 160, as permitted by the span.

HV,MOD `HV,MOD[,value]`
Set or query the piezo modulation mode. `value` is one of:

NONE No modulation

RAMP Internal ramp

EXT External input (via SMA connector)

HV,FREQ `HV,FREQ[,value]`
Piezo ramp frequency. `value` can be 0.01 to 100Hz; reports current value if parameter absent.

E.6 Ramp settings

These commands control the ramp settings (section 3.3) in normalised units. In particular this is beneficial when the current ramp is used without the piezo ramp.

RAMP,SPAN `RAMP,SPAN[,value]`
The normalised peak-to-peak span of the scan. A `value` of 0 corresponds to no scan, and 1 corresponds to the maximum possible span amplitude (as permitted by the offset).

RAMP,OFFSET `RAMP,OFFSET[,value]`
The normalised offset of the centre of the scan. A floating point number in $[-1, 1]$.

RAMP,DUTY `RAMP,DUTY[,value]`
The normalised duty cycle of the ramp.

RAMP,FREQ Synonym for `HV,FREQ`.

RAMP,BIAS Synonym for `CURRENT,BIAS`.

E.7 Ethernet settings

ETH,STATIC `ETH,STATIC["xxx.xxx.xxx.xxx"]`
Set IP default address based on decimal dotted-quad string (for example "10.1.1.180"). The double-quotes are required.

ETH,MASK `ETH,MASK["xxx.xxx.xxx.xxx"]`
Set IP mask based on dotted-quad string (for example "255.255.255.0").

ETH,GATE `ETH,GATE["xxx.xxx.xxx.xxx"]`
Set IP gateway based on dotted-quad string (for example "10.1.1.1").

ETH,PORT `ETH,PORT[,port]`
Set the TCP/IP port number for device communication.

ETH,DHCP `ETH,DHCP[,onoff]`
Enable or disable DHCP. Set to non-zero to enable DHCP; zero to use static IP address.

F. Communications

The LDD can be connected to a computer by USB or ethernet (TCP/IP) and integrated into existing control software. If you are experiencing difficulty in connecting to your LDD, please review the detailed instructions available at `www.moglabs.com/ldd-software.html`

F.1 Protocol

Communication follows a query/response protocol, where the user sends an ASCII string to the unit, and the unit sends an ASCII response to the originating source.

Messages are CRLF-terminated, so all statements must end with the carriage return (ASCII code 0x0D) followed by a new-line character (ASCII code 0x0A). Most terminal applications automatically append these characters. Responses from the unit should be buffered until CRLF is received. It is strongly recommended to check this response before continuing to ensure it does not indicate an error.

Statements are either **commands** or **queries**. A command is a statement that causes some action to occur, and the unit will respond with either "`OK`" or "`ERR`" depending on whether the command succeeded or not. For example,

```
> CURRENT,ON
< ERR: TEC must be enabled first

> TEC,ON
< OK

> CURRENT,ON
< OK
```

Queries are statements to return a value, either returning the value requested or a message beginning with "ERR". For example,

```
> TEMP
< 22.635 C

> TEMP
< ERR: Temperature sensor missing
```

F.2 TCP/IP

When ethernet is connected, the LDD will attempt to connect to the network using saved values, which can be altered using the front-panel menu system. If DHCP is enabled the device will first try to obtain an IP address via DHCP. If DHCP fails, the static settings will then be used. In both cases, the current address will be shown on the display.

F.2.1 Changing IP address

If your network does not use a DHCP server, you may need to manually change the IP address. This is easily done via the front-panel menu system in *Settings* → *Ethernet*.

F.3 USB

The LDD can be directly connected to a host computer using a USB cable (type A-male). The STM32 Virtual COM Port Driver device driver for the Windows™ operating system is available from the MOGLabs website.

Connecting the LDD will install a new COM port on the machine. To determine the port number of the device, go to Device Manager (Start, then type `Device Manager` into the Search box). You should see a list of devices including "Ports" (Figure F.1).

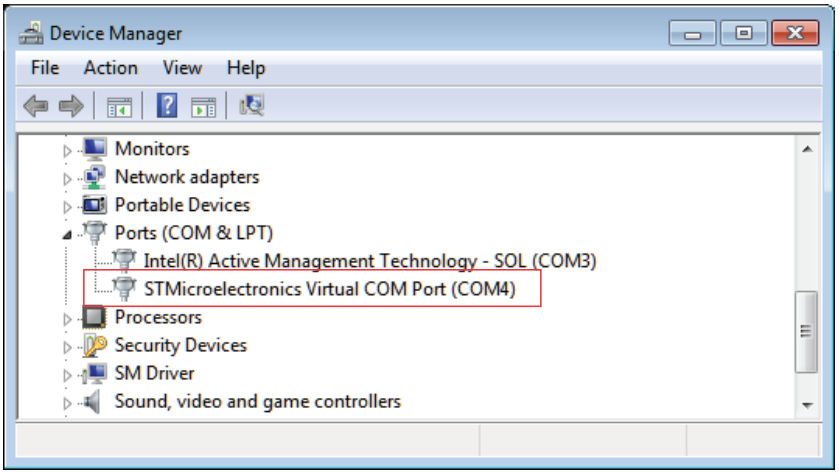


Figure F.1: Screenshot of Device Manager, showing that the LDD can be communicated with using COM4. The port number might change when plugging into a different USB port, or after applying a firmware update.

The LDD can be identified as a COM port with the following name,

`STMicroelectronics Virtual COM Port (COMxx)`

where `xx` is a number (typically between 4 and 15).

If the port appears in Device Manager with a different name, then the driver was not successfully installed. If this occurs, disconnect the LDD from the host computer and reinstall the device driver.

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