

Handling, Mounting, and Operating D2 High-Power Pump Lasers

A thick diagonal line spanning the page from the bottom-left to the top-right. It features a color gradient, starting with a blue-green hue at the bottom-left and transitioning to a bright yellow-green at the top-right.

This technical note provides guidelines to ensure the maximum device performance and reliability of high-power pump laser modules.

This note includes special handling requirements for D2 products that differ from Sparta pump requirements due to a low-profile butterfly package design. D2 products operate the thermoelectric coolers (TECs) at 45°C, requiring new techniques for safely turning on the pump module. A separate application note describes ways to reduce low-power noise.

Actual operational configurations for pump modules and their reliability requirements depend on customer-specific applications. Therefore, Lumentum does not guarantee the module attachment or control method reliability within customer-specific configurations and can only recommend good engineering practices. Customers must confirm the final reliability and quality of any system using a pump or pumps within the associated architectures and controls.

Topics addressed in this application note include:

- Precautions
- Fiber contamination and cleaning
- Mounting
- Power supply and control
- TEC control and operation
- MPD control and operation
- Appendix A: HEPCO Model 3000-2 basic preform machine

Precautions

Safety

The ex-fiber-coupled power that Lumentum pump lasers offer represents significant optical power in the infrared region. Follow standard safety protocols for eye and skin for Class III & IV IR lasers.

Electrostatic Discharge

Electrostatic discharge (ESD) damage to a laser diode is induced from the rapid flow of electrical charge between two bodies at different potentials, either through direct contact or through an induced electric field. ESD can cause catastrophic or latent damage and is of particular concern for the pump module's laser diode and monitor-photo-diode (MPD).

Latent ESD damage is also possible when an ESD event occurs below that required to exhibit immediate degradation, but may manifest itself during deployment.

A human body model (HBM) ESD test is used to determine the pump module's damage threshold which is tested in accordance with GR-468-CORE section 5.22 (MIL-STD-883, method 3015.7) from the electrode "pin-to-ground." Refer to pump module specifications for ESD voltage limits. A number of industry specifications are available to make the work area ESD safe (for example, EIA-625, JEDEC 108-A).

These are commonly recommended guidelines for preventing pump module ESD damage:

- Refer to the pump module specification sheet for ESD voltage ratings.
- Use the provided shorting clips on 14-pin butterfly packages when the modules are disconnected from the operational circuit.
- Ensure that operators, equipment, WIP transport trays, work surfaces, pump modules, and systems are grounded to eliminate static electricity.
- Use only confirmed ESD dissipative coatings or surface finishes on fixtures or tools used to assemble the pump modules.
- When manipulating pump modules, use ESD-protective smocks, gloves, and shoes or covers, dissipative bench-top mats, and ESD-protective flooring or matting.
- Remove or control static-generating sources to voltages below the specified maximum for safe ESD handling.
- Install air ionizers as necessary for additional environmental control.
- Use electrically grounded soldering irons for soldering the pump module to the mounting surface.
- Use electrostatic shielding containers and antistatic or dissipative carriers.

Fiber Contamination and Cleaning

Fiber contamination is a key concern for high-power pump modules. Optical power that is not coupled into the fiber core is propagated by the fiber cladding layer a short distance from the snout or boot. Fiber contamination, especially dark color contamination, causes the temperature to increase as the cladding absorbs light.

Wear gloves when handling fiber:

- To avoid fiber contamination
- If contamination occurs, clean the fiber; be especially careful with approximately the first 2 inches of the buffer
- No dark color contamination with an area larger than 100 μm is allowed within approximately the first 2 inches of the buffer, and it should be avoided along the entire length of the fiber.

Fiber cleaning materials and procedures that follow are for informational purposes only and are not meant to recommend, endorse, or discredit any existing procedures. Users should evaluate any procedure or product before using it in applications where damage or failure may result. As always, exercise safety precautions at all times when using glass, chemicals, and lasers.

Many materials are commercially available for cleaning fibers. Some are marketed specifically for the fiber optic industry, while others are considered "raw materials" or generic; however, they can be used for this purpose. Materials discussed in this technical note include:

- Swabs
- Alcohol
- Wipes
- Adhesive
- Air

Swabs

There are applications for each type of swab. Choose the proper type of swab after experimenting with its results. Manufacturers sometimes recommend using swabs multiple times. This may be suitable for some applications; but other uses suggest only a single use prior to disposal.

Cotton tipped –Various swab sizes are available that are made from different materials and come in various stick lengths. Whether used dry or wetted with a cleaning solution, these swabs are not the best solution for tight or unseen areas as the cotton swab fibers can come off and adhere to connectors or become lodged in small openings.

Foam tipped – These swabs are designed for use with different cleaning fluids. The tips range in size and materials and come in various stick lengths. Take care to wet it properly and to dry the freshly cleaned surface.

Felt style tipped – Similar to the foam-tipped swab, except the tip is stiffer. A hard felt-type tip softens and swells with wetting. Take care to wet it properly and to dry the freshly cleaned surface.

Film – This is probably the newest style of cleaning material or fabric. This swab uses a woven film that is wrapped to the end of a stick and can be used wet or dry. The film removes both particles and oils well.

Alcohol

Isopropyl alcohol is the most commonly used of all alcohols in fiber optic cleaning because of its low cost and safety qualities (toxicity, flammability, environmental/disposal). Alcohol will loosen particulates and help remove oils. It is used on swabs and wipes, by directly spraying on surfaces, in soaking tubs, and in ultrasonic cleaners. Higher concentration (lower water content) is preferable and 99 percent is readily available in bulk, small bottles, and pressurized spray cans with nozzle extensions.

Replace the caps on bottles or risk degrading the concentration due to humidity absorption. Also do not re-dip a wipe into the same alcohol container for multiple cleanings. Storing a bottle with just a little fluid loses efficacy more quickly; therefore, it should be discarded. Spotting on a cleaned surface indicates alcohol degradation due to moisture absorption.

Wipes

Natural fiber – Cotton wipes are available in various weaves and come in different absorbencies, thicknesses, and pad sizes.

Synthetic – Synthetic wipes are similar to cotton wipes, but they are stiffer and sometimes less absorbent.

Moist – Premoistened wipes are available in tear-off tubs or are prepackaged individually. Be sure to close tubs after each use to keep the wipes from drying out. Individually packaged wipes are single-use only and often contain lower alcohol concentrations, like 40 to 60 percent.

Dry film – Woven film, designed for single wipe use, and are used to clean connector tips and end faces to remove both particles and oil contamination.

Adhesive

Adhesive-type cleaners can remove particle contamination. Select an adhesive in-line with the particular application so that the adhesive itself does not become a new contamination source or cause damage (whether it is the adhesive itself that adheres to a surface, or a contaminant that was on the adhesive prior to cleaning causing cross-contamination or scratching and dig-type damage).

Tape – A high-quality common adhesive tape can be used; however, it should adhere to common MIL standards.

Pads and sheets – Available in pocket-sized sheets, this product has individual pads for single-use tip or end-face cleaning. Failure to keep the adhesive pads covered can cause contamination..

Air

Air is used to dry and clear surfaces and other areas of contaminants, separately or after cleaning with a fluid or wipe. Open-air drying can be used, but it can also be problematic because it can leave water spots on surfaces.

Air used in fiber optics must be free of particulates and oil contaminants and should not generate increased susceptibility to ESD. Test canned air before using it to ensure its cleanliness, especially to avoid any problems from residual film. Use proper filters when using house air. Canned air is most commonly used because of its portability and reliability for cleanliness.

System or house air – Pressurized air that is piped through the lab or building supplied through a compressor is called system or house air. Use proper filters and test to certify that the air is free of particles and oil contaminants.

Canned air – Choose a high-quality, canned pressurized air that leaves no residual film or oil when tested on a dark glass or a shiny plastic surface. Do not spray from a can that has been shaken or inverted within the last half hour because inadvertently spraying some propellant can potentially contaminate the surface being cleaned.

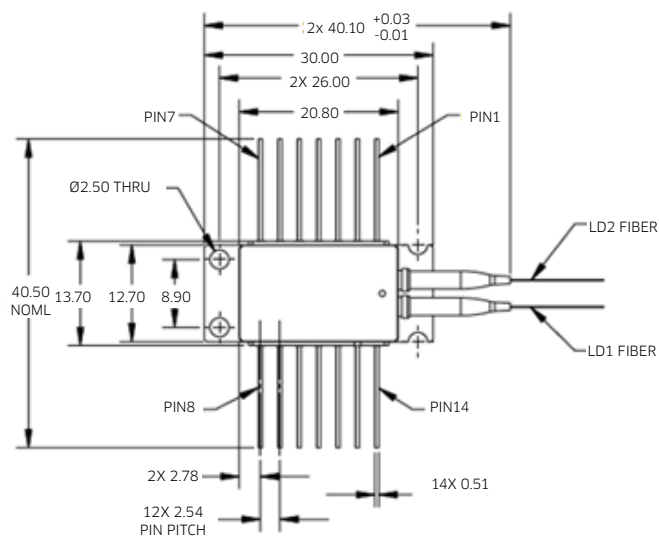
Mounting

Mounting topics include:

- Butterfly package
- Heat sinks
- Thermal interface materials
- Soldering module package leads
- Fiber handling
- Fiber lay sensitivity–polarization effects
- Lead bending

Butterfly Package

When mounting the D2 14-pin butterfly package, ensure that the butterfly pins are properly oriented and are not inadvertently rotated 180 degrees. Figures 1a to 1b show the module's mechanical and electrical schematics.



Pin	Description
1	TEC+
2	Thermistor
3	MPD Anode(+)
4	MPD Cathode(-)
5	Thermistor
6	LD2 Cathode(-)
7	LD2 Anode(+)
8	Not Connected
9	Not Connected
10	LD1 Anode(+)
11	LD1 Cathode(-)
12	Not Connected
13	Case ground
14	TEC-

Figure 1a. Example top view and electrical schematic for a D2 pump module

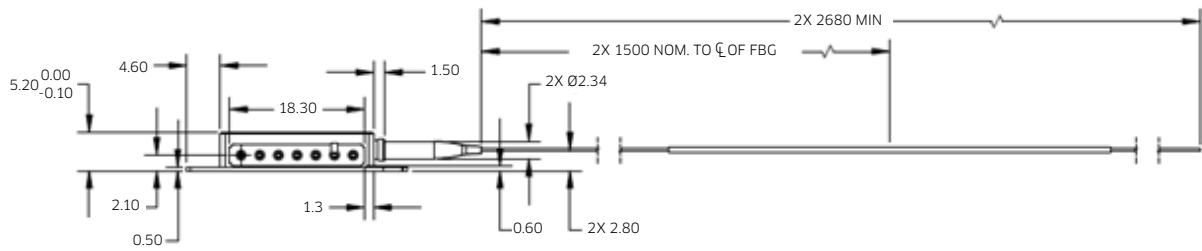


Figure 1b Example side view and electrical schematic for a D2 pump module

Heat Sinks

The receiving heat sink design is intended to dissipate heat pumped by the TEC, which is crucial for the overall pump module's performance and reliability. All pump modules that use a TEC to control LD temperature require heat sinks, and they will fail catastrophically if operated without one. The heat sink design helps it to dissipate heat from the package base with minimal thermal resistance.

Heat sink performance is usually specified in terms of thermal resistance (Q):

$$Q_s = (T_s - T_a) / Q$$

where:

Q_s = Thermal resistance in °C per watt

T_s = Heat sink temperature in °C

T_a = Ambient or coolant temperature in °C

Q = Heat input to heat sink in watts

Each thermoelectric cooling application has a unique heat sink requirement and frequently will have various mechanical constraints that may complicate the overall design. Therefore, no single heat sink configuration is suitable for all situations.

A well-designed heat sink combined with a high-performance thermal interface material and package-mounting technique should guarantee that the pump module case temperature does not exceed the maximum temperature specified for each series (refer again to the absolute maximum specifications). Failure to keep a package base below the specified maximum temperature will lead the pump module to overheat resulting in module damage.

Important note: Mount the butterfly pump module on a heat sink with a flatness of 50 microns or less over the entire mating surface.

The D2 low profile package are vulnerable to the mechanical stress that will be transmitted through the package when the base is not bolted to a flat surface meeting these specification limits.

The following general heat sink guidelines are recommended for all SP products:

- Mount the pump module on a heat sink with 0.8 microns or less surface finish.
- The heat sink should accommodate the maximum heat dissipation over the product life. Refer to the module specifications for total module power dissipation. Maximum heat dissipation is approximately equal to total power consumption (laser diode and TEC) minus the ex-fiber optical power.
- Design a heat sink that can maintain the pump module case temperature below the maximum-rated temperature for all operating conditions. Refer to the pump module specification for the maximum package base temperature,

Thermal Interface Materials

Thermally-conductive materials are applied to the interface

between a pump module and the heat sink to accommodate any flatness/smoothness gaps between both sides. Suitable thermally-conductive materials include phase-change materials, greases, thermal compounds, elastomers, and adhesive films. All of these materials are designed to conform to surface irregularities, thereby eliminating air voids for better heat flow between interfaces.

Specific thermal interface materials and implementation depend on the customer's specific application and reliability considerations.

Use thermal grease to minimize thermal resistance. If using a semi-rigid thermal-interface material, such as a phase-change material or thermal pad, it must cover the entire base Bracket, including the bolt-hole area to avoid warping the base during bolt down.

Failure to follow proper pump module mounting procedures to a properly prepared heat sink can result in high thermal resistances or a warped module, both of which can impact performance and long-term reliability.

Important note: Bolt down the pump module to the heat sink in an X-style fashion with the initial torque set to 0.75 in-lb and a final X-style bolt-down at 1.5 in-lb.

- Use a thermal interface material that is sufficiently thick to compensate for a maximum non-planarity of 100 microns between the pump module base and the heat sink mounting surface.
- Ensure that the thermal interface material follows the outline of the base, including the four mounting screws. Excluding the mounting hole area can cause high stress and may crack the glass feedthroughs.
- Use a thermal interface material with 1 W/mK or better thermal conductivity.
- Prevent contaminating the pump module's fiber strain relief (boot) and fiber buffer with any thermal interface materials.
- Follow 1~4 sequence to mount screw to fix the pump module, as shown in Figure 2.
- Ensure the screw & screw driver non-touching on boot.

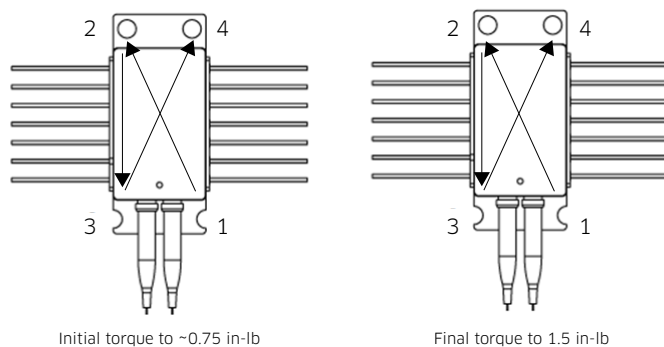


Figure 2 Bolting pattern and torque specifications for mounting a D2 module

Soldering Module Package Leads

Pump module leads can be soldered to a mounting surface using localized solder reflow techniques. A handheld iron can be used if it meets the solder temperature dwell time requirements, maximum temperature, and force applied at the joint area.

- Use a handheld iron with a tip small enough to achieve reflow in less than 3 seconds to prevent damage to module components.
- Do not exceed a lead temperature of 300°C during soldering and properly heat sink the pump module base to avoid overheating the inside components.
- Allow the module to cool down to ambient temperatures after soldering the pump module leads to the mounting surface.
- Ensure that the fiber temperature does not exceed 85°C either through exposure to the soldering iron or other hot surfaces during any soldering operations. A fiber-coupled pump module can be easily damaged if a hot solder iron touches the fiber. While this may not immediately break the fiber, it increases loss due to local stresses and will compromise the fiber's physical strength and the recoat buffer's integrity. A fiber damaged by a hot soldering iron is no longer a reliable device and should be replaced.
- Prevent heating the fiber above 85°C when performing any lead-soldering operation.

Fiber Handling

Both the fiber buffer and grating sections are heat sensitive and susceptible to buffer damage. Take care during the setup and qualification in handling and assembling the pump modules as the buffer is highly susceptible to damage. For example, coiling the fiber during product assembly and securing it with sections of solder or wire is common and is known to cause optical buffer compression and delamination damage.

Fiber manufacturers' recommended a maximum 85°C storage and exposure temperature for the optical buffer. Exposing the buffer to temperatures above 85°C can permanently damage the pigtail. If it must be exposure to temperatures above 85°C, it is critical for users to understand the risks associated with the optical fiber's reliability.

The optical buffer is susceptible to buffer damage and is typically classified under 10 to 40X magnifications as:

- M0: Surface contamination (for example, by debris or epoxy) that should not be removed using solvents or mechanical force. Instead, remove it by gently swabbing the surface with a foam-tipped probe.
- M1: Delamination of the buffer from the glass fiber without compromising the buffer integrity while the diameter remains fixed. Delamination can be caused by compressing the optical fiber. Small sections of delamination (for example, one mm long) may not pose a reliability risk; however, it implies over-handling or processing and can potentially cause buffer damage.

- M2: Buffer compression occurs when something presses on the fiber pinching the buffer's physical diameter, which typically appears as an indentation or 'dent' and may be accompanied by delamination. Again, a compression defect will not breach the buffer's integrity and presents no immediate reliability risk. However, it raises concern about the pump module's processing and handling.
- M3: Cracked acrylate buffer sections can become damaged. Even though no glass fiber is exposed, buffer integrity is compromised and presents a reliability hazard. Lumentum screens for this type of defect prior to shipping modules because of the reliability risks.
- M4: Exposed glass fiber sections present the highest reliability risk and severely reduce the optical fiber's inherent proof-test strength. Lumentum also screens for this type of damage because of its reliability hazard.

Follow the proper procedure for handling fiber to avoid catastrophic fiber damage in high-power pump lasers:

- Do not expose fiber to temperatures above 85°C.
- Always wear finger cots or gloves when handling fiber to avoid fiber contamination.
- Whenever possible, handle fiber in loops to prevent damaging the fiber.
- Do not drag fiber over equipment.
- Avoid fiber coming into contact with any sharp objects.
- Never let the fiber support the weight of the laser pump. Always handle pumps with two hands, one holding a package and the other handling the fiber coil.
- Do not allow kinks or knots to develop in the fiber. Carefully work out any tangles, because pulling on the fiber can cause kinks or curls to tighten and exceed the minimum bend radius.
- Do not bend a fiber with a radius smaller than specified as the minimum bending radius for each specific pump module series. Refer to the module specification for this specific value.

Bending the fiber smaller than the specified minimum radius can increase the fiber's temperature due to a bend loss and subsequent optical absorption by the fiber and its buffer. Catastrophic fiber damage can occur due to a growing crack induced by the increased temperature. In less severe bend situations, a temperature increase can degrade the coating and present long-term reliability issues.

Fiber Lay Sensitivity—Polarization Effects

Pump module wavelength stabilization is realized by writing a slightly reflective, narrow-band fiber Bragg grating (FBG) into the module pigtail roughly one meter away from the butterfly package. Most pump laser light passes through the FBG, but a low percentage reflects back into the laser diode (LD). Optical feedback ensures that the laser operates only at the FBG wavelength, even with wide variations in the drive current or temperature.

The key to effective wavelength stabilization is maintaining adequate optical feedback into the LD cavity. The laser chip is TE-polarized; consequently, only the TE-polarized component of the FBG feedback can influence the laser diode. Any birefringence in the round-trip optical path from the LD to the FBG reduces the amount of TE-polarized feedback. Under worst-case 90-degree rotation, there is negligible optical feedback that will cause the LD to spectrally “unlock”.

Extrinsic-induced pigtail birefringence must be minimized by the EDFA assembler through proper fiber handling techniques and production controls. Birefringence can arise if the pigtail is twisted during spooling, bent to too tight at the radius, or if how the pigtail is secured places any micro-bend stress on the fiber or lets it move during pump laser operation.

Note: Lumentum recommends that customers spool the pump module pigtail to a radius above the specified minimum and minimizing axial fiber rotation during the process.

Following these guidelines will minimize birefringence and optimize the pump module's spectral performance. If poor spectral performance occurs after the original spooling or unspooling, repeat the spooling process.

Lead Bending

If the external leads require bending into a preferred shape (for example, bending leads upwards or downwards 90 degrees as Figures 3a and 3b show), the following simple and low-cost lead-forming tool is recommended.

Important note: Do not apply more than 0.227 kg (8 ounces) of tensile force on the leads to prevent cracking the housing's lead seal.

Model: HEPCO Model 3000-2 Basic Preform Machine (Appendix A). Dies are customized to the desired lead shape.

Company: HEPCO, INC.

Address: 150 San Lazaro Ave., Sunnyvale, CA 94086 Contact:

Mr. Bill Manfroy

Tel: (408)738-1880

Fax: (408)732-4456

e-mail: info@hepcoblue.com

Web address: www.hepcoblue.com

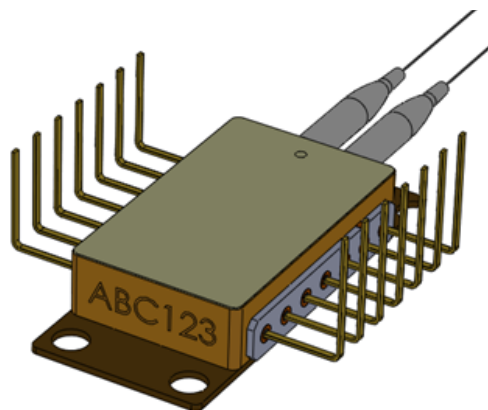


Figure 3a. Leads bent upwards 90 degrees

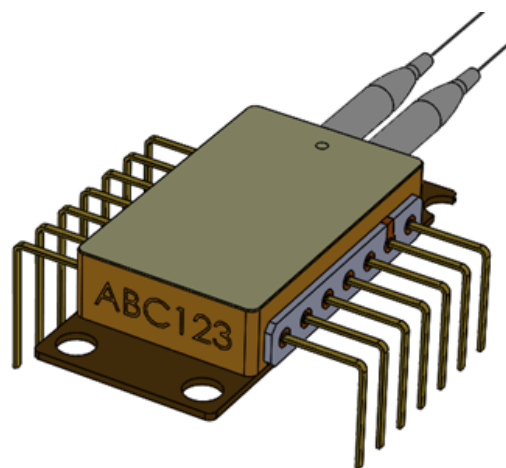


Figure 3b Leads bent downwards 90 degrees

Power Supply and Control

General LD power supply design requirements apply to high-power pump modules. Failure to follow these requirements can cause pump module degradation or failure. When designing or using an LD or TEC power supply, designers should refer to the specified absolute maximum ratings specified for each series of high-power pump lasers.

Product Family	LD Reverse Voltage	LD Forward Current
D2	2 V	1800 mA

Electrical overstress (EOS) damage occurs when a pump module is subjected to voltage or current levels beyond its surge-absorbing capacity. The location and degree of damage depends on the magnitude and duration of the voltage, current, total energy, polarity, and EOS waveform.

Power supplies and test equipment can induce EOS. Recommended guidelines for preventing pump module EOS includes:

- Avoid or minimize transient electrical stress to the pump module throughout its operational life. Never exceed the maximum specified transient current time for a pump module while operating a LD; refer to the absolute maximum ratings (AMR) in the pump module specifications.
- Use transient suppression for power supplies.
- Use over voltage protection for power supplies and fuses at critical locations.
- Confirm that modules are mounted with the correct electrical pin configurations as specified.
- Ensure that all operational and assembly equipment is properly grounded with no loose connections, which can lead to intermittent connections.
- Always ensure the TEC controller is enabled and that the pump module is being actively cooled prior to turning on the laser diode controller. Allow the pump module's internal temperature to stabilize at 45°C ±2°C for D2 before turning on the LD.

TEC Control and Operation

Large-capacity TECs are used to control cooled pump module temperature for high-power operation. Proper operational procedures for the TECs are critical for reliable lifetime module performance. Pump module TECs typically are operated with closed-loop temperature controllers/power supply circuits. Closed-loop circuits can maintain 45°C (nominally) internal pump module temperatures for varying ambient temperatures. The TEC can be switched from cooling mode to heating mode by reversing the current's flow direction.

Power Supply

The pump module TEC operates from a DC power source. Using filtered DC current is important for reliable module operation. DC ripple affects the TEC performance and subsequently affects module performance and lifetime.

Limit the TEC power supply to the absolute maximum TEC current as specified for each pump module model. The TEC can run at the absolute maximum current for a very limited time without impacting the module's reliability. The pump TEC operates more efficiently in heat mode. Therefore, the forward and reverse TEC current absolute maximum ratings (TEC I AMR) are not the same absolute value. Using symmetric current limits that exceed the recommended TEC I AMR values can compromise pump reliability and cause a thermal overshoot.

When first turning on the pump module, the feedback circuit will supply a transient current to the TEC as it stabilizes. Note that the absolute maximum TEC current differs from the maximum operating current, which is the current at which a TEC can operate safely for up to 25 years. The maximum operating current is specified for each pump module series.

Turning on heating transients with incorrect gain and ITEC limit settings will damage the pump module. ITEC EOL must be limited to the maximum EOL value for the specific product rating.

In summary:

- Limit the maximum TEC current to less than or equal to the EOL current (ITEC EOL) to avoid TEC thermal runaway.
- Limit the TEC power supply ripple factor to less than 10 percent.
- Do not operate the TEC at its maximum rated current, except as transient applied current during module start-up.
- Set asymmetric TEC control limits in the pump laser thermal control circuitry.

Product Family	TEC Current (Minimum)	TEC Current (Maximum)
D2	– 2.2 A (note 1)	4.0 A

Note 1: When turn on TEC at heating mode, make sure internal temperature no more than 85°C

- Operate the TEC in constant temperature mode rather than in constant current mode using temperature feedback from the module thermistor.

Temperature Controller

Pump module TECs operate with closed-loop temperature controller/power supply circuits. A thermistor can control the LD temperature within the pump module to the specified LD operating temperature for a specific product series through the specified operational ambient temperature range.

The D2 “closed-loop response time” is defined as the time for the system to attain the target temperature within $\pm 2^{\circ}\text{C}$ is approximately 1.5 to 2 seconds for a well-tuned system. Tuning the control system depends on several factors such as the PI control loop, laser diode, TEC capacity, TEC time constant, heat sink, air flow, laser diode current, and case temperature.

Note that if the 14-pin butterfly package thermistor leads are not in electrical contact when it is mounted and operated, the temperature controller/power supply loop will remain open. This will cause it to run at its maximum available power supply current and can permanently damage the module. For example, this situation can arise if the pump module is placed into an active TEC-powered circuit board with pins 1 and 14 on the butterfly package placed first.

- Ensure that the electrical circuit connected to the pump module is correctly oriented for mounting the 14-pin butterfly package. The pump module is symmetrical, so it can be connected backwards by 180 degrees (see Figure 1 for example mechanical and electrical schematics).
- Ensure that all 14-pin butterfly leads have electrical contacts to avoid open controller/power supply circuits.
- Ensure the TEC leads are connected to the proper electrical polarity and that the TEC power supply is turned off prior to mounting or un-mounting the pump module.
- Wait until the internal temperature stabilizes to within $\pm 2^{\circ}\text{C}$ after turning on the LD before making any TEC control changes.
- Do not leave a module operating without ensuring that the internal laser temperature is within $\pm 2^{\circ}\text{C}$.

MPD Control and Operation

Monitor-photo diodes (MPDs) are used to monitor and/or control pump module output power. The InGaAs photodiodes used in Lumentum pumps must be reversed biased (typically -5 V) in order to respond linearly per the specifications. The MPD cannot function adequately to be used without being reversed biased. Also, MPDs are highly sensitive to ESD.

Appendix A: HEPKO Model 3000-2 Basic Preform Machine



Single Machine to Trim and/or Form All These Components and More:

Capacitors
Transistors
Flat packs
Headers

Hall cells
Resistors
Crystals
Connectors

Triacs
LEDs
DIPs
SIPs

- Die changes in under 1 minute / Versatile
- Steel base for extremely long life / Durable
- Large variety of dies available
- Slash labor costs over hand tool use
- Precision dies to protect components during form
- Virtually no operator / Simple to use
- Maintenance-free / Accurate
- Special dies to meet customer specifications
- Rapid payback / Efficient
- Immediate delivery

Quality and Durability Proven by Years of Production Use

Specifications	
Power	50-90 PSI compressed air
Volume	0.1 CFM max.
Size (W x H x L)	8 x 5 x 15 inches
Weight	25 lb
Average production rate	2-Leaded = ~1,250/hr 3-Leaded = ~900/hr



North America
Toll Free: 844 810 LITE (5483)

Outside North America
Toll Free: 800 000 LITE (5483)

China
Toll Free: 400 120 LITE (5483)

© 2020 Lumentum Operations LLC
Product specifications and descriptions in this document are subject to change without notice.