D2 Series
Product Manual

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General Warnings and Cautions

The following general warnings and cautions are applicable to this instrument.

WARNING

This instrument is intended for use by qualified personnel who recognize shock hazards or laser hazards and are familiar with safety precautions required to avoid possible injury. Read the instruction manual thoroughly before using to become familiar with the instrument's operations and capabilities.

CAUTION

There are no serviceable parts inside the instrument. Work performed by persons not authorized by Vescent Photonics may void the warranty.

CAUTION

Although ESD protection is designed into the instrument, operation in a static-fee work area is recommended.

WARNING

To avoid electrical shock hazard, connect the instrument to properly earth-grounded, 3-prong receptacles only. Failure to observe this precaution can result in severe injury or death.

WARNING

Do not clean outside surfaces of any Vescent Photonics products with solvents such as acetone. Front panels on electronics modules may be cleaned with a mild soap and water solution. Do not clean optics modules.

Limited Warranty

Vescent Photonics warrants this product to be free from defects in materials and workmanship for a period of one year from the date of shipment. If this product proves defective during the applicable warranty period, Vescent Photonics, at its option, either will repair the defective product without charge or will provide a replacement in exchange for the defective product. The customer must notify Vescent of the defective product within the warranty period and prior to product return. The customer will be responsible for packaging and shipping the defective product back to Vescent Photonics, with shipping charges prepaid.

Vescent Photonics shall not be obligated to furnish service under this warranty from damage caused by service or repair attempts made without authorization by Vescent Photonics; from damage caused by operation of equipment outside of its specified range as stated in either the product specification or operators manual; from damage due to improper connection to other equipment or power supplies.

This warranty is in lieu of all other warranties including any implied warranty concerning the suitability or fitness of the product for a particular use. Vescent Photonics shall only be liable for cost of repairs or replacement of the defective product within the warranty period. Vescent Photonics shall not be liable for any damages to persons or property resulting from the use of the product or caused by the defect or failure of this product. Vescent Photonics' liability is expressly limited to the warranty set out above. By accepting delivery of this product, the purchaser expressly agrees to the terms of this limited warranty.

Vescent Photonics

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Absolute Maximum Ratings

Note: All modules designed to be operated in laboratory environment

Parameter	Rating
Environmental Temperature	>15°C and <30°C
Environmental Humidity	<60%
Environmental Dew Point	<15°C
Stage 2 Temperature of DBR Laser Diode	>15°C and <40°C
Laser Diode Current	150mA

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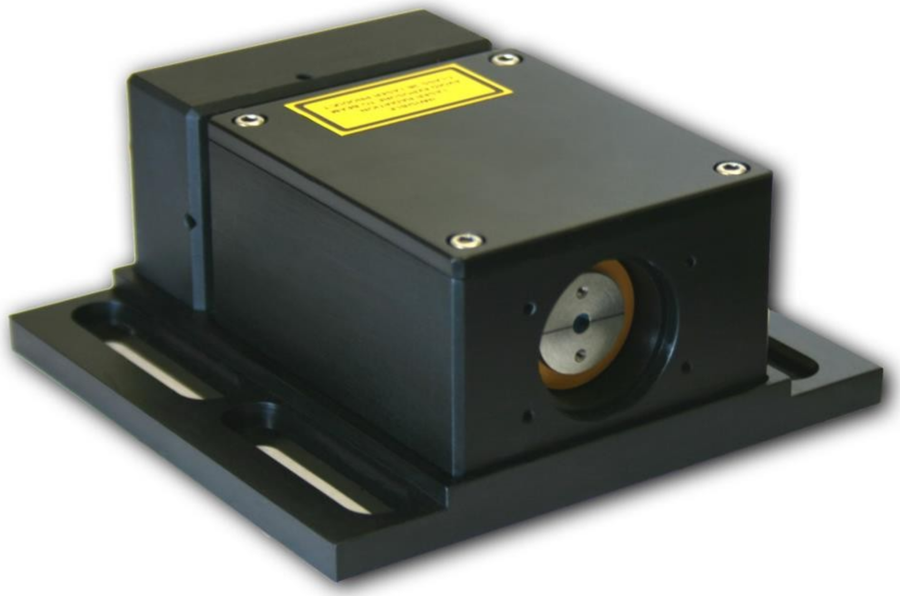
1. DBR Laser Module

Model No. D2-100

Document Revision: 1



1.1. Description

The DBR laser module is comprised of a distributed feedback (DBR) laser diode in a precision temperature-controlled housing with beam conditioning optics and an optical isolator. DBR laser diodes are fabricated with the feedback grating patterned directly over the gain section of the diode. They are highly immune to vibrations and by virtue of a very short cavity (~ 1 mm), they can be current tuned over more than 50 GHz. The result is a robust laser capable of very fast servo control for easy locking to atomic transitions. The module contains no moving parts or piezo-electrics and is therefore inherently robust and rugged.

DBR lasers have 2-3 times larger temperature and current tuning coefficients as compared to external-cavity diode lasers. Vescent carefully controls these parameters with two stages of temperature control and a precision low-noise current controller with fast servo input.

The DBR laser is collimated by a 0.55 NA lens mounted to a movable plate for pointing adjustments. The module also comes with a 35 dB optical isolator and a pair of anamorphic prisms. (Note that prior to fiber coupling we recommend a second stage of isolation.)

The temperature controllers use an 8-pin circular connector on the back of the DBR subassembly. The injection current connection to the laser diode is through an SMA connector also on the back of the DBR subassembly.

The DBR laser chip is contained in a thermal package allowing temperature control between 0° to 50° C. Vescent can replace the package if it exceeds its lifetime.

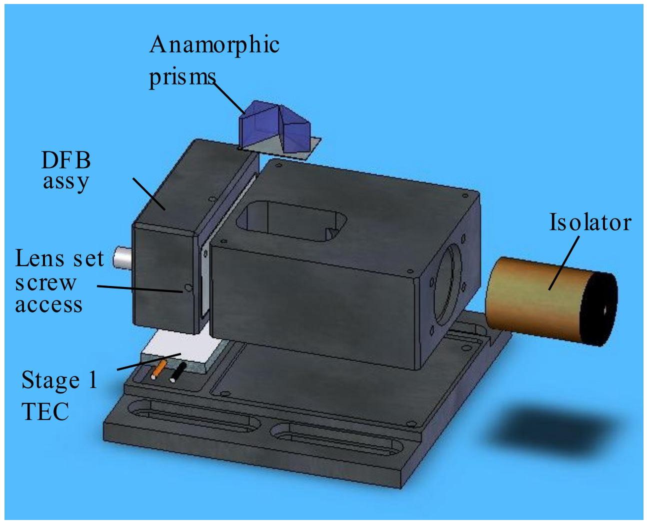


Figure 1: The DBR laser module.

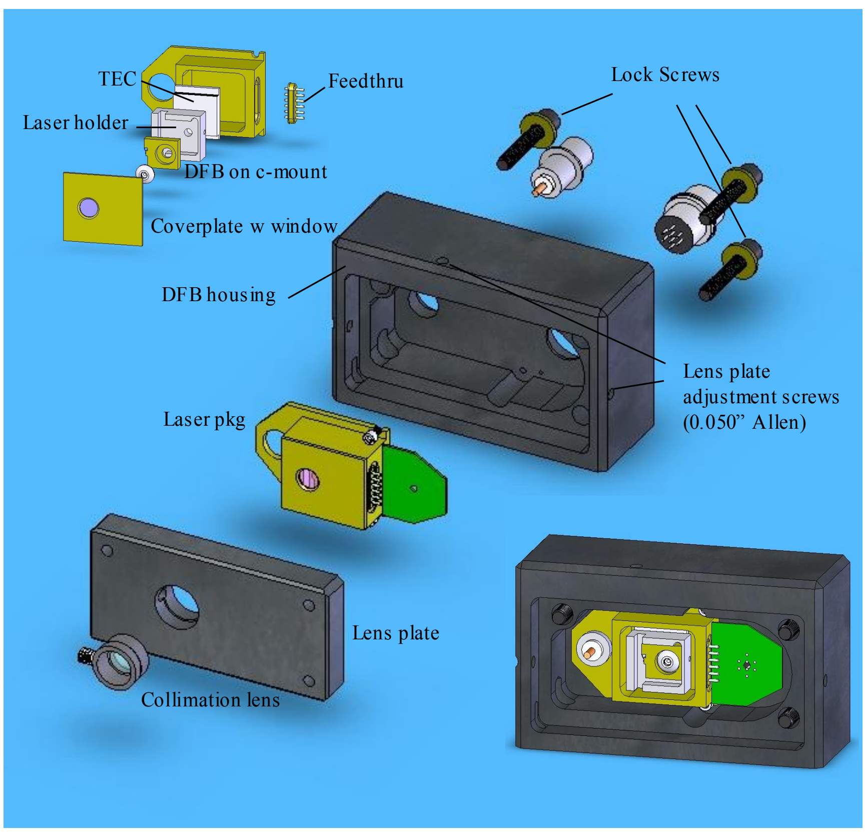


Figure 2: Exploded view of the DBR subassembly.

1.2. Specifications

	Min.	Typical	Max.	Units
Wavelength	780.24			nm
Output power	30	40	50	mW
Beam diameter	0.8	1.1	1.7	mm (1/e^2 dia.)
Polarization	Horizontal			
Optical isolation		35		dB
Operating current		150	180	mA
Threshold Current	40	50	70	mA
Temperature range Stage 1, housing Stage 2, laser	 15 0	 20 15	 40 50 [(1)]	°C
Temperature stability	See Laser Controller, Model No. D2-105			
Safety Class	3B			
Beam height	0.95			inches
Total package Size (L x W x H)	3.75 x 4 x 2			inches

1.3. Inputs, Outputs, and Controls

Vertical and horizontal pointing

The vertical and horizontal alignment of the laser system is factory set and should not need adjustment. However, if your specific application requires it or the system is misaligned, the DBR subassembly has adjustments to steer the beam for alignment to the spectroscopy module or other modules. The beam pointing is adjusted by loosening the three lock screws ½ turn past the crack point and adjusting the x and y positioning setscrews on the top and left side (facing out along the laser beam) of the module (see Figure 3). For more detailed instructions, see section 1.4.

[1]Operation above 40° C can reduce the lifetime of the laser diode

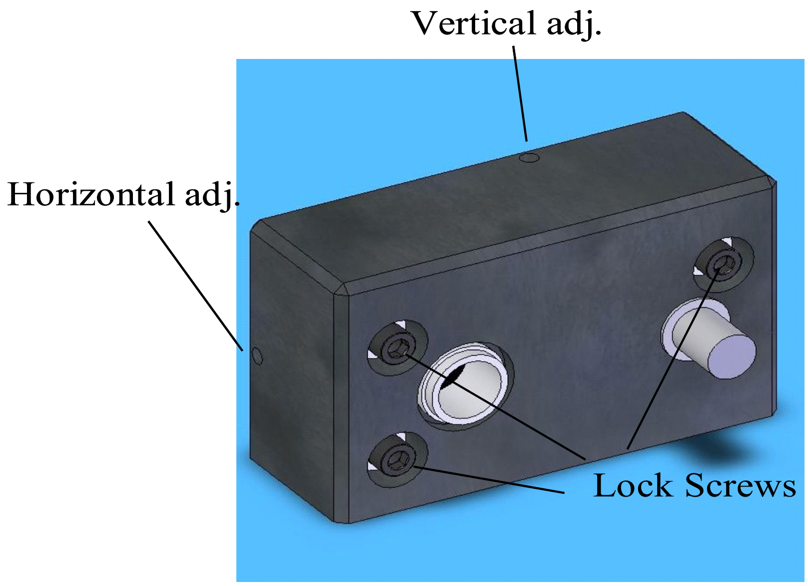


Figure 3: Lock screws and beam pointing controls.

Beam Conditioning

The collimation of the output beam is set at the factory and should not be adjusted unless absolutely necessary. Remove the isolator subassembly from the baseplate with the 4 screws accessible from the bottom. The locking set screw on the right side of the DBR subassembly can then be loosened and the lens repositioned with a 9 mm spanner wrench (Thorlabs, SPW301). Tighten the locking screw and reattach the isolator subassembly.

Laser diodes all have astigmatism, which means the horizontal and vertical axis have different foci. Vescent uses a powerful asphere with a short focal length and an anamorphic prism pair to create a small diameter circular beam. This reduces the costs of the isolator and other downstream modules by reducing the clear aperture requirements. While the aspheres and anamorphic prisms produce a circular beam, astigmatism dictates that a single lens will not simultaneously collimate both orthogonal axes of the beam with the result that in the far field the beam is again elliptical.

The far-field pattern is the most important for ascertaining the quality of the diode output. The near-field pattern often shows stray light from the diode waveguide and ASE that doesn't propagate as part of the primary beam. However, aberrations and beam clipping due to an insufficient lens NA will show up as fringes-on the far field pattern. Vescent has taken care in the design of the DBR laser module to keep aberrations and clipping to a minimum, resulting in a clean beam in the far field.

Cable Connector

The connections to the TECs and thermisters are made to an 8-pin circular connector. The pin definitions are:

Pin	Signal
1	TEC1+
2	TEC1-
3	Rth-1
4	Rth1-RTN
5	TEC2+
6	TEC2-
7	Rth2
8	Rth2-RTN

NOTE: Earlier models use a push-pull connector for the 8-pin connector to the DBR module. To remove take care to apply opposition forces with the thumb and forefinger knuckles against the housing. Excessive force could displace the output beam and require realignment.

Laser Current (SMA)

Current is provided to the DBR chip through an SMA connector. The central conductor of the SMA connects to the laser anode, and the shield connects to the laser cathode. *This is a direct, unprotected connection to the DBR chip, so care must be taken to avoid ESD damage.*

1.4. Aligning the DBR Laser Module

The module should not need adjustments, but if necessary the following procedure can be used to fine tune the beam positioning.

1. Loosen the three locking screws on the back of the DBR module ½ turn past the crack point.
2. With a 0.050” Allen driver, adjust the vertical adjustment setscrew on the top of the DBR housing to level the beam.
3. Adjust the horizontal adjustment 4-40 set screw on the left side of the DBR housing (See Figure 3).
4. Alternatively, use the spectroscopy module as a beam target. Place the spectroscopy module as far down the table as possible, bolt it down, and center the beam to the input hole.
5. Gently retighten the three locking screws.

2. Spectroscopy Module

Model No. D2-110

Document Revision: 1

2.1. Description

The spectroscopy module provides saturated absorption spectroscopy to atomic rubidium. It contains a rubidium absorption cell, TEC, balanced photodetector, and associated mirrors and beamsplitting optics. Nominally, it takes two 1% samples from the input beam. Temperature control stabilizes the number density of atoms in the cell, and a balanced photodetection circuit compensates for intensity drifts giving stable control over the lock point for side locking applications. Two beamsteering adjustments are provided for optimizing overlap of the counter-propagating beams, and positioning on the signal photodiode. The photodiode output is shot-noise limited out to ~12 MHz for photocurrents of 50 µA and above. The high bandwidth of the feedback enables tight solid locking that is immune to vibrations and shock.

Note: The spectroscopy module should not be placed closer than 3" from the DBR laser module because the magnetic fields from the isolator can interfere with the hyperfine transitions causing lock instability and dc shifts.

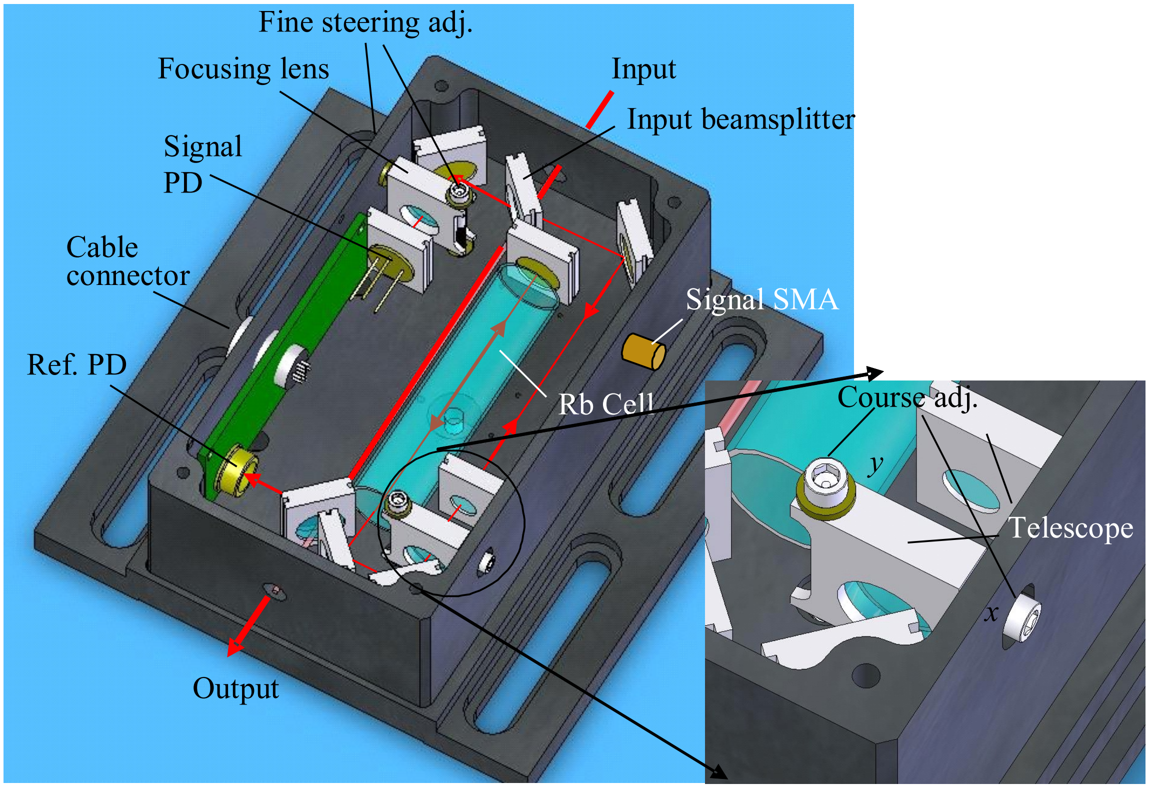


Figure 4: Spectroscopy Module with cover removed.

2.2. Specifications

	Value	Units
Photodiode Amplifier		
Transimpedance (signal)	20,000	Ω
Bandwidth (signal)	12	MHz
Noise @ 10 MHz (shot level)	80	nV/√Hz
Set Temperature	~35	°C
Temperature Stability	~0.01	°C
Beam Height	0.95	inches
Total package Size (L x W x H)	4.25 x 4 x 2	inches

2.3. Inputs, Outputs, and Controls

Input Connector (8-pin circular)

Power and temperature control signals from the Laser Servo are made through an 8-pin circular connector. The pin definitions (pin numbers are marked on the connectors) are listed below, where Rth and Rth_Rtn are the two ends of the thermistor.

Pin	Signal
1	TEC+
2	TEC-
3	+15 V
4	Rth_Rtn
5	Rth
6	-15
7	NC
8	GND

Signal Output (SMA)

To minimize electro-magnetic interference, the photodiode signal to the Laser Servo is output through an SMA connector.

Course vertical and horizontal beam positioning

The spectroscopy module contains a 3x Galilean beam expander. The output lens is mounted on a spring-loaded mount with 2-56 screws that serve as a course adjustment for the beam positioning onto the signal photodiode and also to control the retro reflection of the reflecting mirror (Figure 4, inset).

Fine vertical and horizontal beam positioning

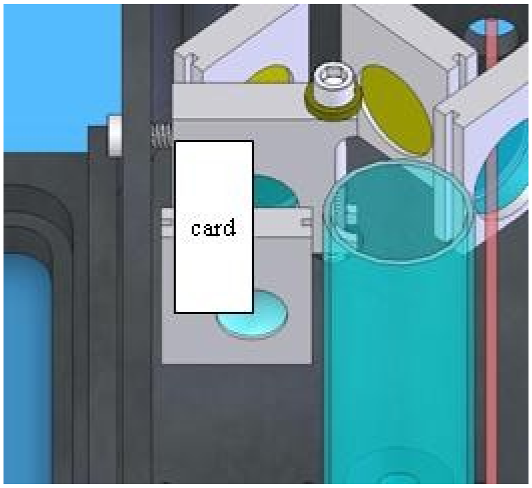
The spectroscopy module contains a focusing lens for the signal photodiode on a spring-loaded mount with 2-56 screws for fine adjustment of the beam onto the photodiode (Figure 4).

2.4. Aligning the Spectroscopy Module

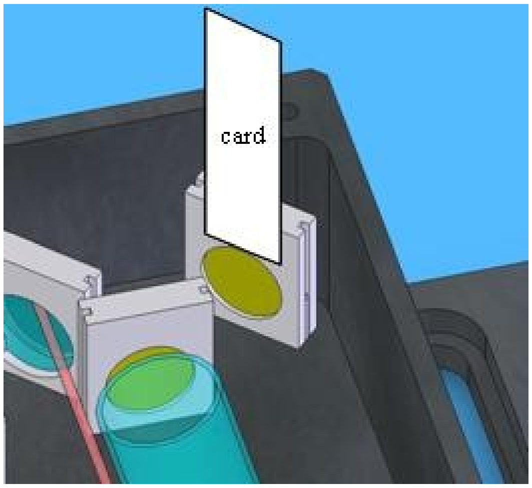
The spectroscopy module is shipped factory aligned and should need only minor adjustment. However, it is not uncommon that alignment is required after initial set up. To realign, follow this procedure:

1. Loosen the three locking screws on the back of the DBR module ½ turn past the crack point.
2. Fashion two small 1 cm x 3 cm cards from an index card for use as viewing screens.
3. Remove the cover on the Spectroscopy Module.
4. Use the card and the vertical and horizontal positioning controls on the DBR module to center the beam onto the 6 mm diverging lens. This is the most critical alignment.

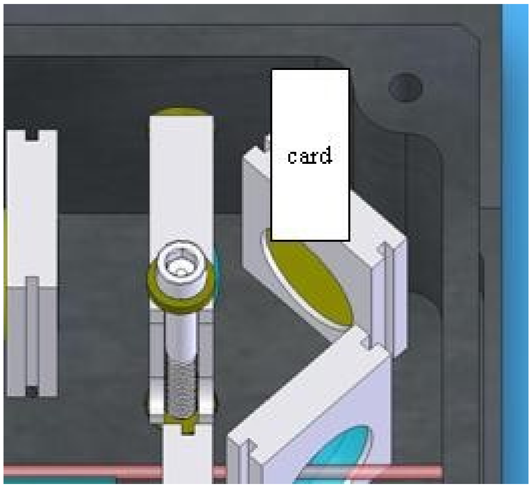
5. At this point the beam should be going through the center of the input and output apertures on the module, the center of the 6 mm lens, and the second pick off should be impinging on the reference photodiode (see Figure 4). Make adjustments as necessary.



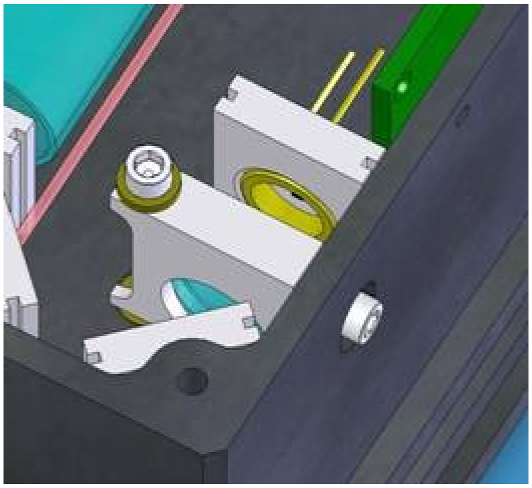
6. Retighten the locking screws on the DBR module.
7. Use the card to ascertain the position of the returned beam on the first corner mirror.



8. Use the course positioning controls to place the retro-reflected beam as close as possible to the incoming beam.
9. Use the card to probe the opposite corner mirror (along short side) to see if the retro beam is now passing back through the input beamsplitter.



10. If the beam is visible on the card, center it with the course positioning controls. If not, repeat from Step 8.
11. Check to see that the beam is relatively well centered on the retro reflecting mirror at the end of the Rb cell. If not, the beam is not centered well enough on the 6 mm divergent lens. Start again from Step 4.
12. Fold the second card lengthwise (light goes through a single layer) and block the reference photodiode while monitoring the SMA OUTPUT on an oscilloscope or voltmeter.
13. Use the Course and fine steering controls to maximize the signal (actual signal is negative) on the voltmeter. Generally, the fine steering controls have little effect. You might find them useful if you wish to use the course controls to center the beam on the retro mirror and find this moves the beam off center from the signal diode.



The fine steering controls and signal PD

14. Remove the card from the reference photodiode.

15. Adjust the trimpot until a desired lockpoint for sidelocking crosses zero volts (with oscilloscope connected to the ERROR INPUT monitor, or until an eyeball average of the hyperfine transitions lies near zero volts. This step determines how well the balancing circuit cancels intensity drifts. (Note: for peak locking applications this is not important since dc drifts have no affect on the lockpoint.)

16. The spectroscopy module is now ready for use. Replace the cover.

3. Laser Controller

Model No. D2-105

Document Revision: 2

3.1. Description

The laser controller has two temperature controllers capable of sub-mK stability[2] and a 200 mA precision current source based on the Libbrecht-Hall[3] circuit. The laser controller is designed for very fast current modulation via the servo input enabling high-speed servo control of the laser's frequency. The current servo input can accommodate input frequencies well over 10 MHz and is limited by reflections due to the 1 kΩ input impedance. Additionally, an RF port is available for higher frequency modulation.

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[2] Sub-mK stability requires a proper thermal design and proper tuning of the temperature controller to the thermal plant. If you did not purchase the Laser Controller with a Laser Diode, please read the section on tuning the temperature controller.

[3] Libbrecht and Hall, *A Low-Noise, High-Speed Current Controller,* Rev. Sci. Inst. 64, pp. 2133-2135 (1993).

3.2. Turning on the Laser Diode

In compliance with FDA requirements for a Class 3B laser, the Laser Controller has two safety interlocks. If either interlock is tripped, the laser will turn off and stay off until the interlocks are reset AND the laser switch is switched from the “reset” position to the “on” position. Additionally, the Laser Controller loses power, the laser diode will turn off.

To turn on the laser diode, follow these instructions:

1) Flip the Laser switch into “off/reset” position
2) Insert the key into the keyhole and rotate the key 90 degrees (keyhole located on back panel)
3) Place grounding BNC terminator on “Remote Interlock” BNC (located on back panel)
4) Flip the Laser switch into the “on” position. The green light above the switch should turn on and after a 5 second delay, the laser will turn on.

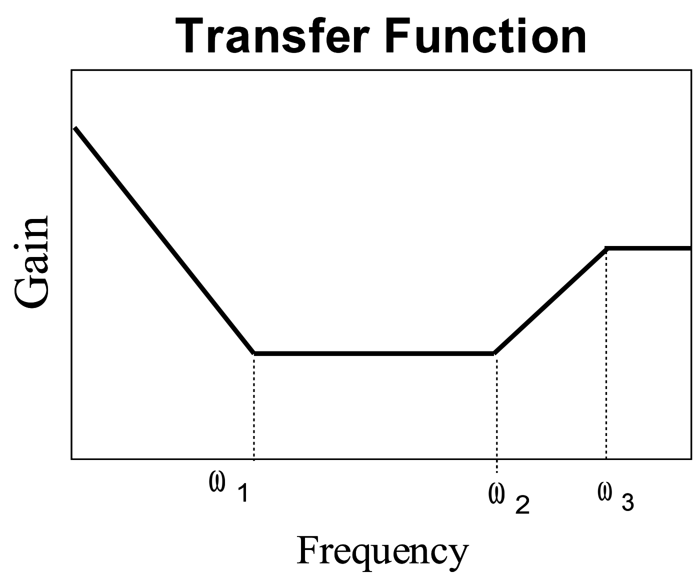
3.3. Tuning the Temperature Controller

If you purchased the Laser Controller with a Laser Module, then the Laser Controller is properly tuned for the Laser Module's thermal load and you can skip this section. This section will describe the basic theory about tuning the temperature servo response and provide step-by-step instructions for tuning the servo response to your thermal load.

To get good temperature stability, the temperature servo response needs to be tuned to match the thermal load. Access to tuning the temperature response is provided on the right side panel of the Laser Controller and requires removing that side panel to access the controls. The Laser Controller provides two independent temperature controllers that are nominally identical. However, stage 2 has front panel adjustment of the temperature set-point, while the stage 1 temperature set-point is a side-panel adjustment. Additionally, the front panel TEMP SERVO INPUT adjusts the stage 2 set-point while stage 1 does not have an equivalent function. Stage 2 is accessed in the middle of the side-panel, while stage 1 is near the back of the side panel. Typically, stage 2 is used to control the laser temperature and stage 1 is used to control the temperature surrounding stage 2. In this way temperature gradients between the laser diode and the thermistor measuring the laser temperature are stabilized and temperature changes caused by room temperature drift is greatly reduced.

3.3.1. Transfer Function and Poles

Each stage of temperature control has a transfer function shown below:



The three poles (ω_1, ω_2, ω_3) and the overall gain can be adjusted using trimpots and click-switches on the side panel. The first pole (ω_1,) is the Proportional-Integrator (PI) pole, or the frequency where the gain switches from being an integrator to proportional. The second pole (ω_2,) is the Differential (D) pole, or the frequency where the gain becomes differential. The final pole, (ω_3,) is where the differential gain ends and the gain becomes proportional again.

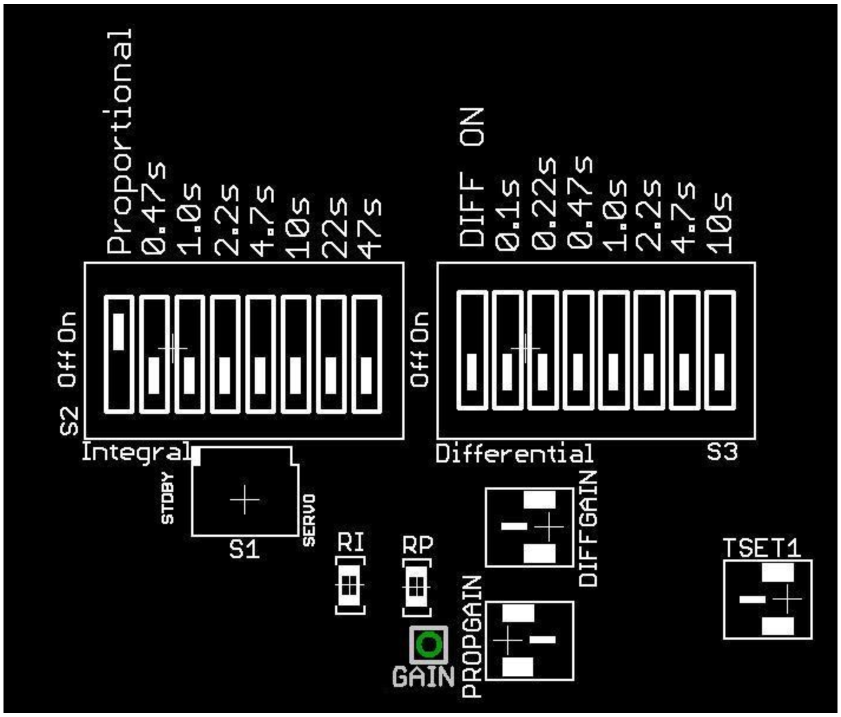


Figure5: Side Panel Adjustments for Temperature Control.

3.3.2. User Control of the Poles and Gain

If you remove the right side panel on the Laser Controller, for each stage of temperature control, you will see the panel shown in Figure5. The set of click switches labeled "Integral" control the PI (ω_1,) pole. Clicking the first switch, labeled "proportional", into the on position removes the integral gain. If the "proportional" switch is in the off position, then the sum of the times for all switches in the on position gives the RC time-constant for the PI pole. For example, if the 2nd (0.47s) switch and the 4th (2.2s) switch are in the on position (and the rest off), then the time constant is 2.7s and $\omega_1 = 1/2.7\text{s} = 0.37$ Hz.

Similarly, the switches labeled "Differential" control the D (ω_1,) pole. If the first switch, labeled "Diff On" is in the off position, then there is no differential pole. If the "Diff On" switch is on, then the D pole has an RC time-constant given by the sum of the times of all the switches in the on position, same as with the Integral bank of switches.

The "DiffGain" trimpot tunes the third pole (ω_1,) from $\omega_2/1.25$ to $\omega_2/25$. Turning up (CW) the trimpot moves the pole to a higher frequency, yielding more differential gain.

The "PROPGAIN" trimpot tunes the overall gain of the system and is adjustable by a factor of 200.

Additionally, the TSET1 trimpot is used to adjust the set-point temperature for stage 1 (stage 2 is controlled on the front panel).

The "STBY / SERVO" switch can disable temperature controller for either stage by placing the switch into STBY (standby) mode. In this mode, a red light will be shown on the front-panel to show that the stage has been disabled.

3.3.3. Tuning the Thermal Loop

Although there are numerous methods for tuning the loop parameters, these instructions will use the Ziegler-Nichols tuning method.

For nested stages (one stage is inside a housing whose temperature is controller by another stage), we recommend tuning the outside stage first with the inside stage turned off. Then tune the inside stage while the outside stage is turned on. For the stage directly controlling the laser temperature, we recommend running the tuning procedure while the laser is on. For each stage, follow the below steps to tune the plants according to the Ziegler-Nichols tuning method:

1) Connect thermal load to Laser Controller
2) Place Loop in proportional-only mode: Switch labeled “Proportional” is on, switch labeled “Diff On” is off
3) Turn the gain all the way down (trimpot labeled “PROPGAIN” all the way CCW)
4) Turn on temperature loop
5) Adjust set-point to approximately desired temperature
6) Turn up the gain. Keep increasing the gain until the temperature error (difference between temperature set-point and the actual temperature) oscillates with an peak-to-peak amplitude <500mW. If oscillation too large, reduce gain. Measure the period of oscillation.
7) Turn off Laser Controller. Measure resistance between “GAIN” testpoint and “GND” testpoint. 7. Turn down the “PROPGRAIN” until this resistance reads 1.7 time less than its original value (i.ei from 500Ω to 295Ω)
8) Take the measured oscillation period in step 6 and divide by two. Set the Integrator time constant to this value. If you measured a period of oscillation of 14 seconds, turn on the 4th (2.2s) and 5th (4.7s) switches in the integrator bank, to get a time constant of 6.9s.
9) Turn off the “proportional” switch.
10) Turn the “DiffGain” trimpot all the way CW.
11) Set the “Differential” switches to the same position as the “integral” one. This works out to setting a D time-constant roughly equal to 1/8 of the period of oscillation. For the previous example, set the 4th (0.47s) and 5th (1.0s) switches on to get a time constant of 1.5s
12) Turn on the “Diff On” switch
13) Your thermal loop is now tuned. Power and Laser Controller wait for temperature to stabilize. Change the setpoint and observe the temperature error and verify that the oscillations of damped and the temperature stabilizes. You may be able to get better performance by tweaking the poles and gain.

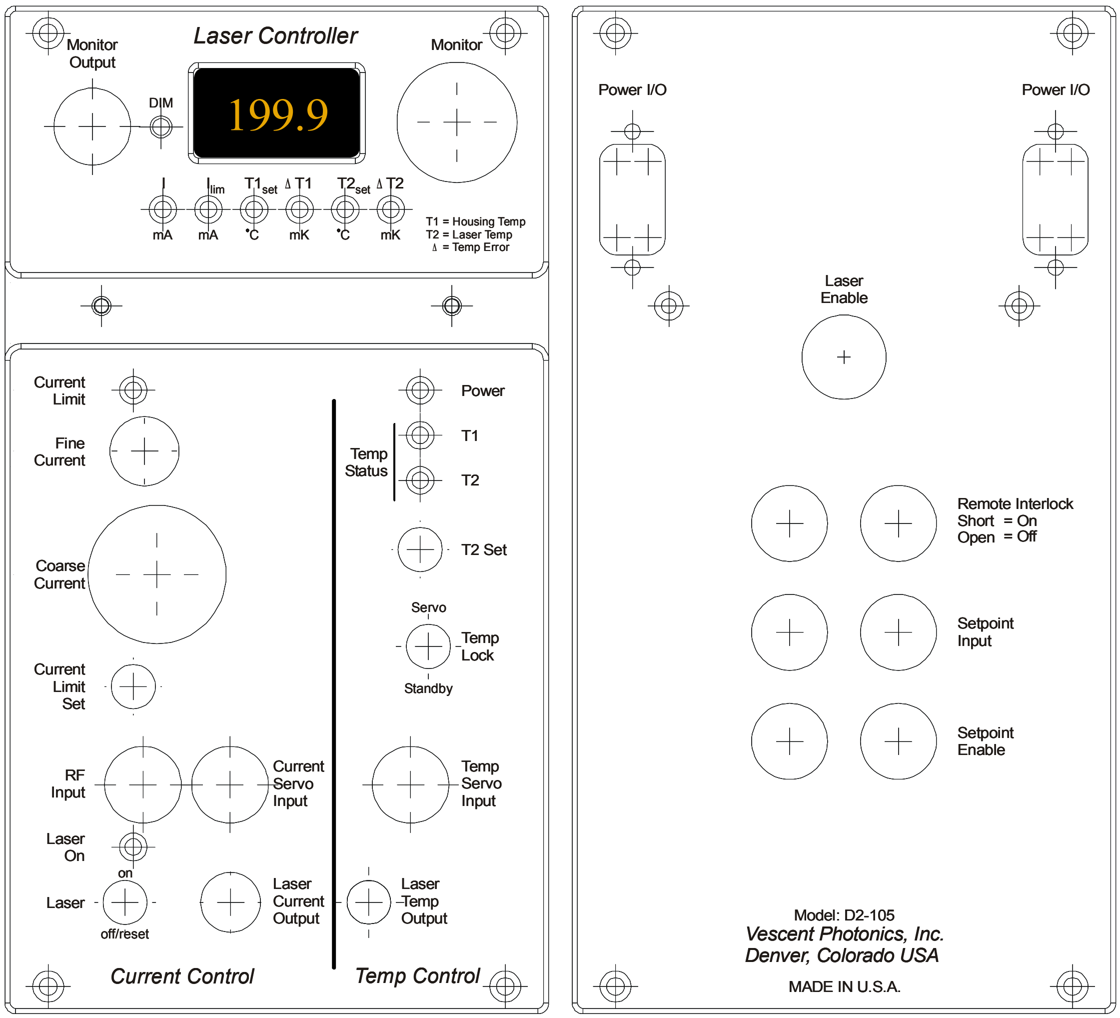
NOTE: Depending on the thermal design, nested temperature loops can fight each other, causing oscillations and instability. If you observe this, you will need to reduce the gain and/or increase the time-constants on the slower stage.

3.4. Specifications

		Units
Current Source		
Current range	0-200	mA
Current noise density	<100	$pA/\sqrt{Hz}$
RMS Noise (10Hz - 100kHz)	<50	nA
RMS Noise (10Hz - 1MHz)	<100	nA
RMS Noise (10Hz - 10MHz)	<300	nA
Monitor Resolution (Display)	100	µA
Absolute accuracy	2	%
Temperature coefficient	<1	µA/°C
Current Servo Input		
Input impedance	1000	Ω
Bandwidth	>10	MHz
Modulation coefficient	1	mA/V
	~1.4	GHz/V
RF Input Bandwidth	0.001 - TBD	GHz
Temp Servo Input		
Input impedance	100	kΩ
Temp modulation coefficient		
Gain = Low	-20	mK/V
Gain = High	-600	mK/V
Temperature Control		
Temperature setpoint range	1-50	°C
Temperature isolation (T2)[4]	TBD	mK/°C
Long term stability (T2)	~1	mK/day
Temperature coefficient [5] (controller, T2)	TBD	mK/°C
Max TEC current (voltage)	1 (4)	A (V)

[4]DBR module temperature changed while Laser Controller module held fixed.
[5]DBR module temperature fixed while Laser Controller temperature change.

3.5. Inputs, Outputs, and Controls



Front Back

3.5.1. Monitor Section

The monitor section contains a 3 ½ digit display and an output BNC for monitoring by an oscilloscope or voltmeter. A selector knob controls which of six signals are relayed to the display and BNC. An LED indicator is below the display to show which signal is being displayed and its units.

Name	Symbol	Units	Resolution
Current	I	mA	0.1 mA
Current limit	I_{lim}	mA	0.1 mA
Housing Temperature Set	$T1_{set}$	°C	0.1 °C
Housing Temperature Error	ΔT1	mK	0.1 mK
Laser Temperature Set	$T2_{set}$	°C	0.1 °C
Laser Temperature Error	ΔT2	mK	0.1 mK

NOTE: When the Laser Switch is in the "Off / Reset" position, the laser diode is shorted to ground and no current is flowing through the laser diode. However, the Current Monitor will read up to 30 mA of current flowing through the short. This is normal. When the switch is in the "ON" position, the current monitor accurately measures the current flowing through the laser diode.

3.5.2. Current Control

Current Lim (LED)

The current limit indicator lights when the current limit circuit is activated. If the user attempts to set the current over the current limit setpoint the circuit shunts the excess current through a transistor to ground

Fine Current (knob)

The fine current adjusts the diode injection current by ½-1 % of the course control setting. Use this control for fine positioning of the laser frequency prior to locking.

Course Current (Scale Dial)

The course current control sets the laser diode injection current between 0 to about 220 mA maximum (199.9 mA maximum on the display output). To set the current, switch the selector knob in the monitor section so that the current LED *(I)* is lit. Then adjust the course current to the desired setting.

Current Limit Set (Trimpot)

The current limit set is a front panel trimpot adjustment. Set the selector knob to the I_{lim} position and adjust the trimpot to the desired value. Note that the DBR Laser Module has a maximum current of 180 mA.

RF Input (BNC)

The RF input is ac coupled to the laser diode through a 10 nF capacitor. Over ~3 MHz the impedance of this input will approach the ac impedance of the laser diode of ~5Ω. This input is normally connected to the RF output from the Laser Servo module, which applies FM sidebands at 4 MHz to the laser output.

Note: a large voltage transient to this input could possibly cause damage to the laser diode. If you are connecting other equipment to this input do not exceed 0.25 Vrms from a 50 Ω source or 1 mW of power.

Current Servo Input (BNC)

The current servo input adds or subtracts current though 1 k Ω connected to the laser diode giving a modulation coefficient of 1 mA/V. A bias circuit sets the voltage of the current servo input to zero volts. (Normally, a connection to the laser diode would place this voltage at ~ 2V or equal to the forward diode drop.) Therefore, leaving the input open or grounded does not alter the current to the laser diode.

The bandwidth of the current servo input is >10 MHz.

Laser On (LED indicator)

Turns ON 5 seconds before laser light turns on. If light is on, laser is on (or will be in <5secs).

Laser ON-Off/Reset (switch)

When the switch is in the Off/Reset position, the laser diode is turned off and the laser is shorted to ground. When flipped into the On position, the Laser ON (LED indicator) will turn on and 5s later, the laser will turn on. If the laser diode is turned off from the laser enable or remote interlock, this switch must to placed into the Off/Reset position and then into the ON position to turn the laser back on.

Laser Out (SMA)

The laser current is output through an SMA connector and returns through the cable shielding to ground.

3.5.3. Temperature Control

Power (LED indicator)

All electronic modules have a blue LED power indicator on the top right side of the front panel control section. The LED requires +15V and 5V in order to light.

Temp Status (dual LED indicators)

The temperature status LED indicators turn red whenever the temperature servo loop has been disengaged. The temperature servo loop will disengage when the temperature is below -1°C, above 50°C, or the thermistor is shorted or open. Additionally, when the TEMP LOCK is in standby mode, the servo loop is off and the LED's will be red.

The temperature status LED indicators will turn green when the temperature is within a narrow temperature window of the setpoint. The window is usually set to a 10's of mK. See spec sheet included with your order for the setting of this window.

T2 Set (Trimpot)

The temperature of the laser diode (T2) is set with a front panel trimpot. T2 is factory set to put the laser on transition with the Rb D2 hyperfine lines and should not need trimming. However, as the diode ages the user might need to adjust this value. Set the display selector knob to read $T2_{set}$ and set to the desired value.

T1 is also set at the factory and should not require further adjustment. However, the T1 trimpot can be accessed by removing the right panel from the enclosure.

Temp Lock (Dual position switch)

The temperature servo can be placed into standby mode if desired. In this mode no current is supplied to the TEC elements.

Temp Servo Input (BNC)

The temperature servo input is summed to the T2 temperature setpoint signal and can be used to make electronic perturbations to the laser diode temperature. The Temp Servo Input, has two settings: “Low” and “High” gain. The default settings in “Low” but can be changed by a switch accessible on the right side panel.

When the gain is set to “LOW”, the slope for changing the setpoint is ~-20 mK/V.

When the gain is set to "HIGH", turn the setpoint to the lowest desired temperature. Apply a voltage between 0V and 10V to TEMP SERVO INPUT to raise the setpoint temperature. With this configuration, you can sweep the setpoint all the way from the low temperature limit (-1°C) to the high temperature limit (58°C). *NOTE that the Vescent Photonics DBR Laser should not be operated above 50°C.* The slope for changing the setpoint is ~-600 mK/V.

The "Low" mode is designed for slow temperature feedback for long-term (days) stability of the locked laser. Normally the Temp Servo Input is used to drive the dc value from the Current Servo Ouput on the Laser Servo to zero over long time scales. In other words, temperature tuning is used to remove large, slow variations in the laser frequency. To accomplish this connect the Temp Servo Output from the Laser Servo module to the Temp Servo Input of the Laser Controller (with TEMP SERVO INPUT Gain is set to "Low"). This connection is only important if the user is trying to maintain a laser lock continuously over many days or even weeks. Without feedback to Temp Servo In the Laser Servo can eventually run out of range. (The Current Servo output of the Laser Servo is clamped at 1.2 V. See discussion in the Laser Servo manual.)

Laser Temp Output (8-pin connector)

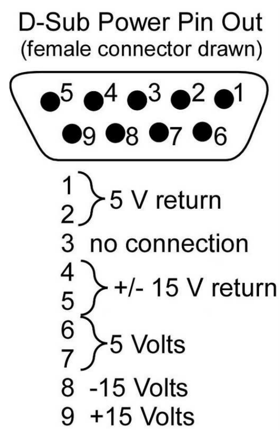
An 8-pin connector carries the signals for the temperature control of the DBR module. The wiring diagrams are shown in the table below, where 1 (2) refer to stage 1 (2) temperature control, which stabilizes the DBR Housing (DBR Laser Diode). Rth and Rth_Rtn are the two ends of the thermistor.

Pin	Signal
1	TEC1+
2	TEC1-
3	Rth1
4	Rth1-RTN
5	TEC2+
6	TEC2-
7	Rth2
8	Rth2-RTN

3.5.4. Back panel I/O

Power I/O (9-pin D-sub)

The power to each electronics module is through a 9-pin D-sub connecter through a power bridge unit. The unit can also be powered through any serial cable with 9-pin D-sub connectors, which is convenient when the unit must be taken out of line for access to the side panels. The pin outs are shown in the following figure:



Laser Enable

This key-switch is required to be in the enable position for the laser to turn on. Normally, the key is left in the enable position.

Remote Interlock

The remote interlock can be used to disable the laser diode output via an interlock control. When this input is shorted the laser diode output is ON. When the input is open the diode output is OFF. If not used, leave a shorting cap over this BNC. Once the interlock has been tripped, the laser will stay off until it is manually reset with the front panel switch.

Setpoint In

SETOINT IN is an analog input. When the SETPOINT ENABLE is LOW (0V) the SETPOINT IN voltage value sets the injection current instead of the front panel dial. Zero volts sets zero current and 6V sets the maximum value of 200 mA. A Zener diode protects the input if more than 6.8 V are input.

This input is rolled off at 1 kHz, which is a much higher frequency than the front panel dial, which rolls off at 8 Hz, with a second pole at 4 Hz. Therefore, noise can enter the circuit at this point and this input should be used with caution. It is primarily intended for sweeping the current in order to measure PI curves and threshold values of laser diodes. We do not recommend using this input for computer control of the injection current.

Setpoint Enable

SETPOINT ENABLE is a TTL input. 5V puts the front panel dial in control of the injection current and 0V gives control to SETPOINT IN.

When disconnected, the SETPOINT ENABLE is at 5V.

4. Laser Servo

Model No. D2-115

Document Revision: 1

4.1. Description

The Laser Servo contains a PI^{2}D loop filter for tight locking to an error signal. The error signal is either an amplified version in the Error Input signal (Side-Lock mode) or a demodulated signal based on the Error Input signal. Additionally, the Laser Servo has an internal ramp generator for sweeping the output, a temperature controller, and computer control to break lock and directly control the output voltage.

The Laser Servo is optimized for use with the other D2-Series modules (the Laser Controller, the Laser Module, and the Spectroscopy Module). When used with these other modules the Laser Servo takes an input from the Spectroscopy Module and outputs to the Laser Controller. It was designed for high-speed and low noise. The Laser Servo contains a PI^{2}D loop filter, which means it has standard proportional, integral, and differential feedback with a second integral feedback to boost gain at low frequencies. The Laser Servo can be switched into either peak-lock mode or side-lock mode. Peak locking is useful for locking the laser to a specific hyperfine transition, such as a Master laser in a Master/slave configuration, or as a repump, pump or probe laser in magneto-optical trapping experiments, where the laser frequency must be accurately positioned at line center of a fringe or optical transition. In peak-lock mode the Laser Servo can also be used for Pound-Drever-Hall locking to an optical cavity. Side lock mode is useful when the laser is to be used as the primary trapping laser or for locking to the side of interferometer fringes.

The Laser Servo can be unlocked by a computer and the laser diode frequency can be jumped by as much as ±1 GHz and then relocked to the same or a different transition or fringe. This feature can be exploited to reduce the number of lasers required in neutral atom trapping experiments and can be used in auto-locking or relocking routines.

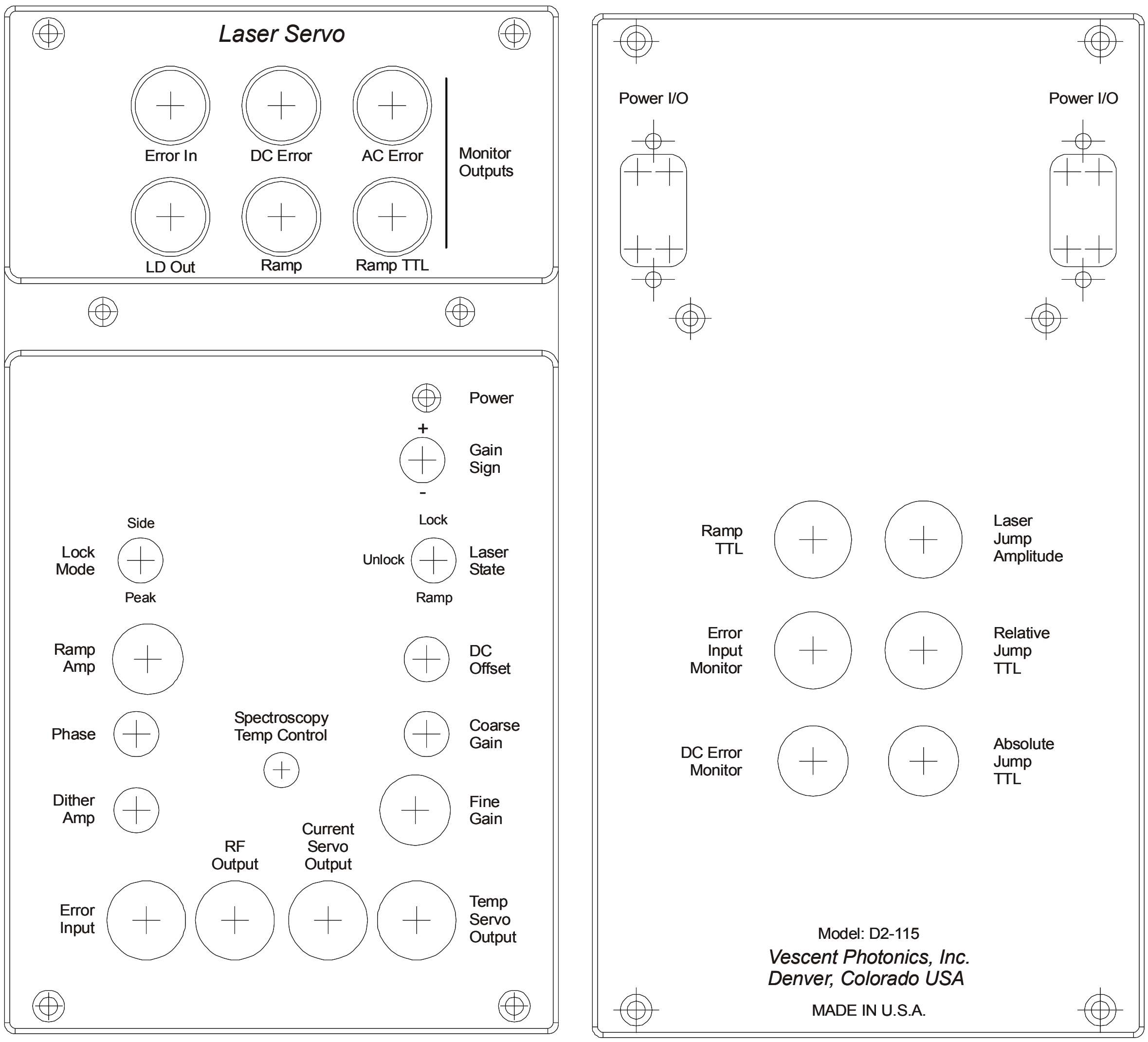
The Laser Servo has an internal sweep generator to aid in transition identification during locking. It also contains a temperature control circuit to maintain constant temperature for the Spectroscopy Module.

4.2. Specifications

	Value	**Units**
Input voltage noise	<5	nV/√Hz
Bandwidth[6]	9	MHz
Proportional Gain	-25 to +26	dB
Input impedance	50	Ω
Laser Freq. Jump		
Input impedance	100	k Ω
Tuning coefficient	~140	MHz/V
Lock -> Jump Time	<50	µs
Jump -> Lock time	<50	µs

[6] Oscillation frequency when Laser Servo side-locked to itself.

4.3. Inputs, Outputs, and Controls



4.3.1. Monitor Section

The monitor section contains 6 BNC outputs. Each output is described below.

Error In

The ERROR IN monitor is generated by passing the ERROR IN from the Spectroscopy Module through a low pass filter set to about 300 kHz to remove dither and other high frequency noise. In PEAK LOCK mode the ERROR IN signal shows the raw spectroscopy signal and the DC ERROR gives the resulting derivative signal.

DC Error

The DC ERROR monitors the ERROR IN after the first 26 dB (x 20) amplification stage. In PEAK LOCK mode, the DC ERROR is the derivative signal derived from ERROR IN. DC ERROR is passed through a low pass filter with a roll off of 200 kHz, so that high frequency noise does not obfuscate the signal. The DC ERROR signal is used to adjust the DC OFFSET on the Laser Servo front panel. When locked, the Laser Servo acts to drive the DC ERROR to zero.

AC Error

The AC ERROR monitors ERROR IN after the first 26 dB (x 20) amplification stage. In PEAK LOCK mode, the AC ERROR is the derivative signal derived from ERROR IN. It is coupled through a high pass filter to remove dc components (< 10 Hz). It is designed for spectrum analysis and is also useful for crude estimates of the laser linewidth. The bandwidth of the AC ERROR is limited by the preceding amplifier stages (~12 MHz for the photodiode amplifier, 60 MHz for the input stage amplifier).

LD OUT

The LD OUT monitors the CURRENT SERVO OUTPUT, which is fed back to the CURRENT SERVO INPUT on the laser controller. This is the correction signal that is fed back to the laser diode. When locked, it is useful to check this signal to ensure that the CURRENT SERVO OUTPUT has sufficient range to stay locked. LD OUT should stay between +1V and -1V.

If the Laser Servo goes out of lock this signal will rail at ±1.2 Volts and thus can serve as an indicator of lock status.

Ramp Mon

The RAMP MON is a monitor for the unattenuated actual ramp signal sent to the CURRENT SERVO OUTPUT when the laser is in RAMP mode. Unlike the output at CURRENT SERVO OUTPUT, Ramp Mon is not attenuated by the RAMP AMP knob.

Ramp TTL

The RAMP TTL is a trigger synchronous with the internal ramp generator. It is used to trigger an oscilloscope while viewing transitions or fringes probed during the ramp. The RAMP TTL signal is also available on the back panel as a dedicated trigger output.

4.3.2. Front Panel

Power (LED indicator)

All electronic modules have a blue LED power indicator on the top right side of the front panel control section. The LED requires +15V and -15V in order to light.

Lock Mode (two-position switch)

When set to the PEAK LOCK position, this switch routes the ERROR IN to an FM demodulation circuit that extracts the error signal, which is then passed to the Loop Filter circuit. In the SIDE LOCK position, the demodulation circuit is bypassed and the signal is fed directly to the Loop Filter circuit. Additionally, the RF OUTPUT is disabled in SIDE LOCK.

Ramp Amp (1-turn knob)

The RAMP AMPLITUDE sets the amplitude of the internal ramp generator. At maximum setting the DBR laser will sweep about 7 GHz and should cover nearly all 4 hyperfine transitions in Rb 87 and Rb 85.

Phase (25-turn trimpot)

The PHASE control is set at the factory and should not require further adjustment unless the Laser Servo is being used outside the original DBR laser system. The PHASE control adjusts the phase between the dither signal at RF OUTPUT and the local oscillator used to demodulate the signal coming in at ERROR INPUT. It is used to maximize the DC ERROR signal while the laser is sweeping across the desired transition(s). The dither frequency is 4 MHz.

Dither Amp (25-turn trimpot)

The DITHER AMPLITUDE control is used to set the amplitude of the dither signal. It is set at the factory and should not require further adjustment unless the Laser Servo is being used outside the original DBR laser system. The dither signal is output from RF OUTPUT and should be connected to the Laser Controller at the RF INPUT.

Error Input (BNC)

The ERROR INPUT is provided by the Spectroscopy Module.

RF Output (BNC)

The RF OUTPUT signal is the dither or FM modulation signal. In the PEAK LOCK mode it should be connected to the RF INPUT on the Laser Controller. In SIDE LOCK mode the dither to the RF OUTPUT is turned off.

Gain Sign (two-position switch)

The GAIN SIGN reverses the sign of the input amplifier to the Laser Servo and should be used if the servo is providing positive feedback instead of negative. Upon switching GAIN SIGN the pattern of DC ERROR while ramping is inverted relative to ERROR IN. When triggering an O-scope with the RAMP TTL signal on a positive edge, the Laser Servo locks to a positive slope.

Laser State (three-position switch)

The lock switch has three positions. In the lowest is the RAMP, which connects the internal ramp to the CURENT SERVO OUTPUT causing the laser to sweep. The amplitude of the sweep is controlled with RAMP AMP. In the center position (UNLOCK) the ramp is disconnected and zero volts is output to CURRENT SERVO OUTPUT. In the top position (LOCK) the loop filter is engaged.

DC Offset (trimpot)

The DC OFFSET adds a dc offset to the ERROR IN at the input amplifier. For side locking DC OFFSET can be used to control where on the fringe or transition the laser will lock. In peak locking mode one normally sets DC OFFSET to zero to center the lockpoint at line center. To set DC ERROR to zero, disconnect the ERROR IN, and adjust the DC Offset trimpot until the DC Error reads zero. Reconnect the ERROR IN.

Coarse Gain (trimpot)

The COURSE GAIN sets the overall proportional gain of the circuit without changing the location of the any poles that define the loop filter. The COURSE GAIN is a resistor divider after the input gain stage. The input amplifier stage has +26 dB of proportional gain. The Coarse Gain adjusts the gain from +26 dB to -14 dB.

The overall loop gain (set by both the COARSE GAIN and the FINE GAIN) should be set around the point that minimizes the RMS noise on the DC ERROR MONITOR. This can sometimes result in setting the gain too high because the DC ERROR MONITOR filters high frequencies and thus hides some of the gain peaking with high gain. To precisely set the gain, look at the noise with a spectrum analyzer through the AC ERROR MONITOR.

Fine Gain (1-turn knob)

The FINE GAIN control adjusts the proportional gain by 0 to -12 dB.

Current Servo Output

The CURRENT SERVO OUTPUT is fed into the CURRENT SERVO INPUT on the Laser Controller with a front panel BNC cable. The CURRENT SERVO OUTPUT is the output from the loop filters when in LOCK mode, zero volts when in UNLOCK mode, and a DC balanced triangle wave when in RAMP mode.

When in LOCK mode, the CURRENT SERVO OUTPUT is clamped at ±1.2 V, so that if the laser does become unlocked a large current offset is not conveyed to the laser diode (due to railing of the loop filter). This prevents heating of the laser diode during unlock events and associated frequency offsets and speeds the recovery of the diode for relocking.

Temp Servo Output

The TEMP SERVO OUTPUT is generated from the CURRENT SERVO OUTPUT and is passed through a trimpot attenuator and a slow integrator with a ~5s time constant. Its purpose is to supply a correction signal to the temperature of the laser diode to drive the dc value of the CURRENT SERVO OUTPUT to zero. TEMP SERVO OUTPUT is connected via a front panel BNC cable to the TEMP SERVO INPUT on the Laser Controller. This feedback loop acts to remove large slow frequency fluctuations with the laser temperature control. It is only necessary when long term locking (days) is desired.

The magnitude of the proportional gain for the TEMP SERVO loop and its sign are set at the factory. However, the proportional gain trimpot (R109 in VPN00156.3 and R112 in VPN00156.4) and a slider switch (S3) to control gain sign are accessible by removing the right panel of the Laser Servo.

Spectroscopy Temp Control

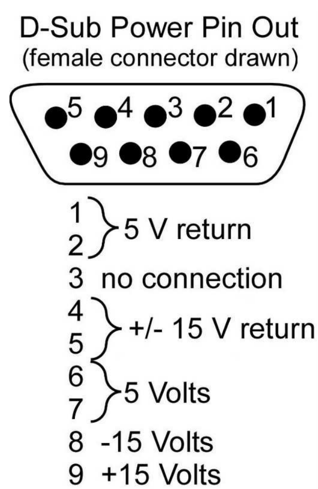
This is an 8-pin connector for the cable to the Spectroscopy Module. It provides power to the photodiode board, thermister, and TECs. The pin definitions are listed below where Rth and Rth_Rtn are the two ends of the thermistor.

Pin	Signal
1	TEC+
2	TEC-
3	+15 V
4	Rth_Rtn
5	Rth
6	-15 V
7	NC
8	GND

4.3.3. Rear Panel

Power I/O (9-pin D-sub)

The power to each electronics module is through a 9-pin D-sub connector through a power bridge unit. The unit can also be powered through any serial cable with 9-pin D-sub connectors, which is convenient when the unit must be taken out of line for access to the side panels. The pin outs are shown in the following figure:



Ramp TTL

Same as the front panel signal. This output is useful for dedicated oscilloscope triggering.

Error Input Monitor

Same as the front panel monitor. This output is useful for computer monitoring of the lock status. In PEAK LOCK, a discontinuous jump can be an indication of an unlock event that can then be corrected with jump controls.

DC Error Monitor

Same as the front panel monitor. This output is useful for computer monitoring of the lock status. A non-zero value, or a change in the RMS noise is an indication of an unlock event.

Absolute Jump TTL (BNC)

When asserted HIGH in LOCK mode, ABSOLUTE JUMP takes the Laser Servo out of lock and conveys the voltage on LASER JUMP AMPLITUDE to CURRENT SERVO OUTPUT with a 10:1 attenuation ratio. Thus, a 10 V input to LASER JUMP AMPLITUDE applies 1 V absolute to CURRENT SERVO OUTPUT. ABSOLUTE JUMP is useful when one wants to control the absolute voltage on the integration stages of the loop filter, or for zeroing the integrators during autolocking routines. When returned to LOW, the loop filter is engaged.

When asserted HIGH in RAMP mode, ABSOLULTE JUMP applies a DC offset equal to the LASER JUMP AMPLITUDE divided by 10 to the ramp signal at CURRENT SERVO OUTPUT. When asserted LOW, the ramp signal is DC balanced.

When disconnected, ABSOLULTE JUMP is low.

Relative Jump TTL (BNC)

When asserted HIGH in LOCK mode, RELATIVE JUMP engages a sample-and-hold circuit and takes the Laser Servo out of lock. The voltage on the CURRENT SERVO OUTPUT is the sample-and-hold value summed in with the LASER JUMP AMPLITUDE with a 10:1 attenuation factor. For example, if the laser is locked and the CURRENT SERVO OUTPUT is -200 mV, then engaging the RELATIVE JUMP and putting 3V on the LASER JUMP APPLITUDE will make the CURRENT SERVO OUTPUT 100mV (-200mV + 3V / 10). This feature is useful for jumping the laser relative to its current lock point (say +200 MHz from a locked transition). When returned to LOW, the loop filter is engaged, enabling the laser to be relocked to its original position (by returning LASER JUMP AMP to zero), or to a new lock point.

When asserted HIGH in RAMP mode, RELATIVE JUMP applies a DC offset equal to the LASER JUMP AMPLITUDE divided by 10 to the ramp signal at CURRENT SERVO OUTPUT. When asserted LOW, the ramp signal is DC balanced.

When disconnected, RELATIVE JUMP is low.

Laser Jump Amp (BNC)

The LASER JUMP AMPLITUDE is an analog signal that is used to jump the frequency of the diode laser. See preceding sections for RELATIVE JUMP and ABSOLUTE JUMP.

4.4. Laser Lock Troubleshooting

Most laser locking problems can be attributed to the following:

- **Gain set too high (or too low).** Reduce the course and fine gain all the way and try locking. Increase the course gain by one turn at a time.

- **Gain sign wrong** (trying to lock to the wrong slope).
    - Make sure the oscilloscope is triggering to positive slope.
    - Make sure oscilloscope is not in inverting mode.
    - If all else fails, flip the gain sign and try again.

Note: sometimes the laser will lock even if the slope is wrong because there are legitimate lockpoints nearby. This can fool you into thinking you are locking properly.

- **DC OFFSET not adjusted properly.**
    - When monitoring DC ERROR make sure you're not ac coupled to the oscilloscope!
    - Ramping fast through the transition changes the dc value on the scope (due to atom transit time through laser beam coupling to optical pumping rates). Reduce RAMP AMPLITUDE towards zero on the desired transition until the dc value is not affected.
- **The ramp center is not located at the center of the oscilloscope**. In theory, the lockpoint is where the RAMP signal goes through zero; however, there is a small offset from this point due to atom transit time effects in the spectroscopy cell. Use the procedure in the Quick Setup Instructions. If the oscilloscope is set up properly, then when switching to LOCK pause at UNLOCK. You should see a very noisy signal centered at zero. The goal is to get the laser within the capture range when the laser is in UNLOCK.
- **Magnetic fields are interfering with the spectroscopy signal**. Even though the spectrum might look okay, we have noticed that strong magnetic fields can affect the effective transfer function of the spectroscopy error signal in a negative way making locking difficult. Make sure the DBR module is at least three inches away from the spectroscopy module as discussed earlier. In some cases, strong magnetic fields can emanate from the optics table (if magnetic clamps are in use). Look at the F=1 to F' transitions in ^{87}Rb. If there are any inverted peaks you could have magnetic field interference.

If you are having problems locking the laser, it is a good idea to unplug the BNC connecting the TEMP SERVO INPUT on the Laser Controller to the TEMP SERVO OUTPUT on the Laser Servo. This will reduce how much the laser frequency changes when you lock the laser to an undesired transition and then take the laser out of lock. Once you get the locking to work properly, you can reconnect this cable.

If you still cannot lock the laser, please call Vescent Photonics at (303)-296-6766 and ask to speak with either Mike or Ben.

5. Power Supply

Model No. D2-005

Document Revision: 1

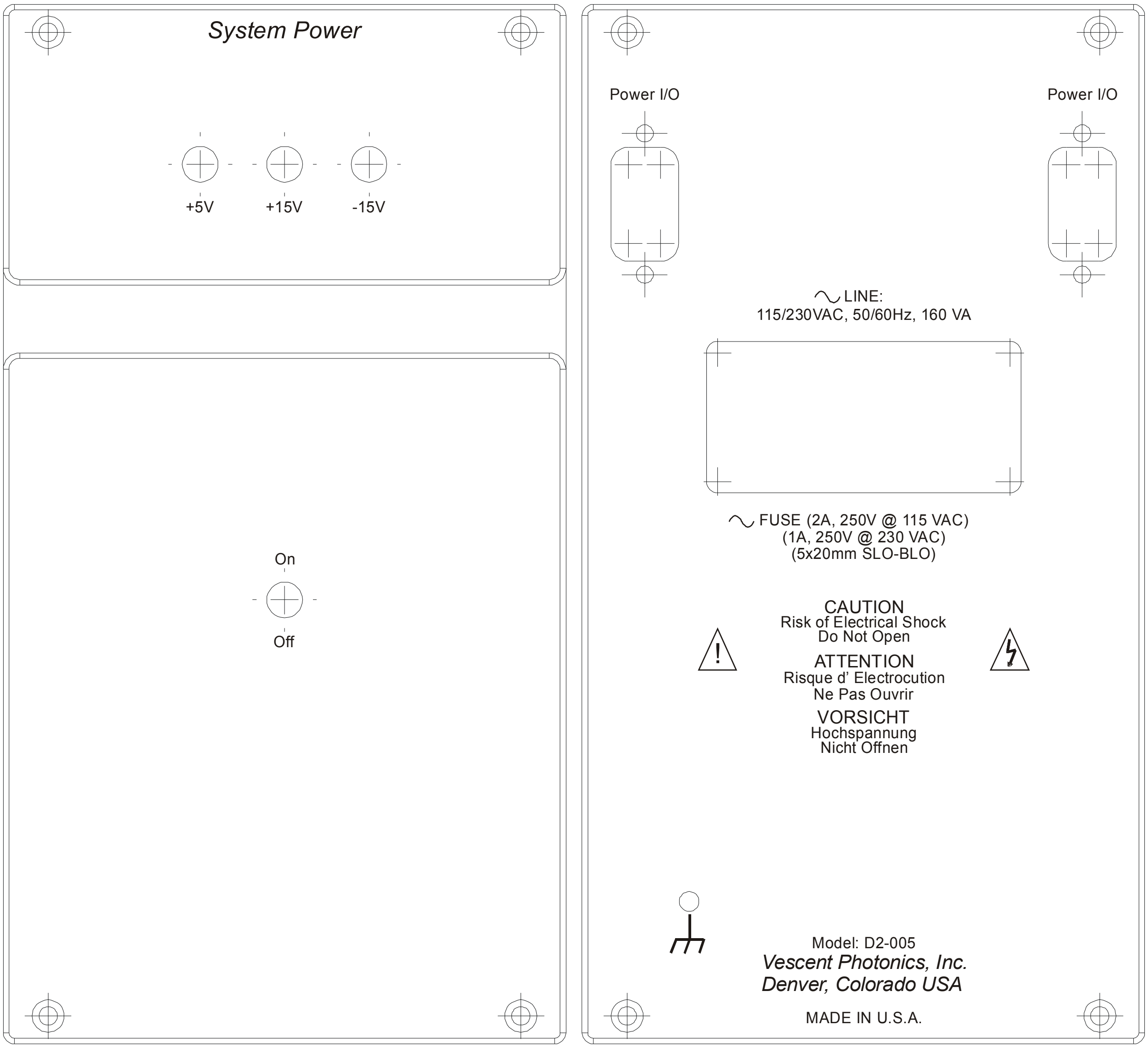
5.1. Description

The Power Supply is a quiet, linear power supply providing +/-15V and 5V. It is in a separate box to isolate 60 Hz and EM interference. One power supply can power two complete laser systems, or four electronics modules.

5.2. Specifications

		Units
Current Limit		
+15V	1.5	A
-15V	1.5	A
+5V	6	A
Output Regulation	0.05	%

5.3. Inputs, Outputs, and Controls



Front Back

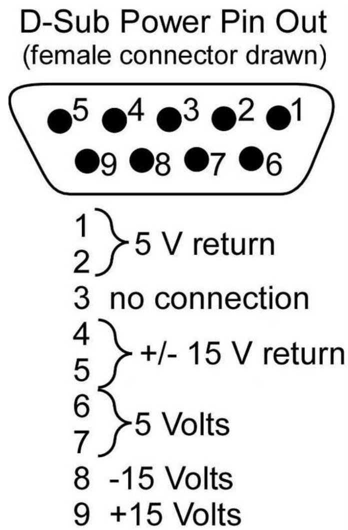
5.3.1. Monitor Section

The monitor section contains three blue status LEDs indicating proper voltage on the +15,-15, and 5V power lines. In there is a voltage sag on any of the power lines, the blue status LED will turn off.

5.3.2. Back panel I/O

Power I/O (9-pin D-sub)

The power to each electronics module is through a 9-pin D-sub connector through a power bridge unit. The unit can also be powered through any serial cable with 9-pin D-sub connectors, which is convenient when the unit must be taken out of line for access to the side panels. The pin outs are shown in the following figure:



6. Quick Setup Instructions

6.1. Electronic Modules Initial Setup

Place the three electronics modules (System Power, Laser Controller and Laser Servo) in a row as shown on the right (order is not important).

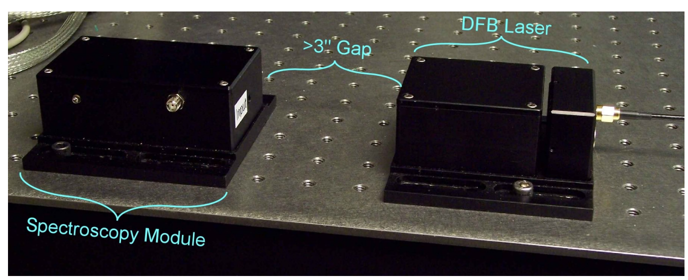
On the back of the modules, attach the two power bridges across adjacent modules. See picture below.

On the Laser Controller, in the bottom left corner, make sure that the LASER switch is in the OFF/RESET (down) position.

Make sure the power switch on the System Power module is in the OFF (down) position. Plug power cable into back of System Power module.

6.2. Optic Modules Initial Setup

Place the DBR Module on an optics table and bolt to table with 4 1/4-20 screws.

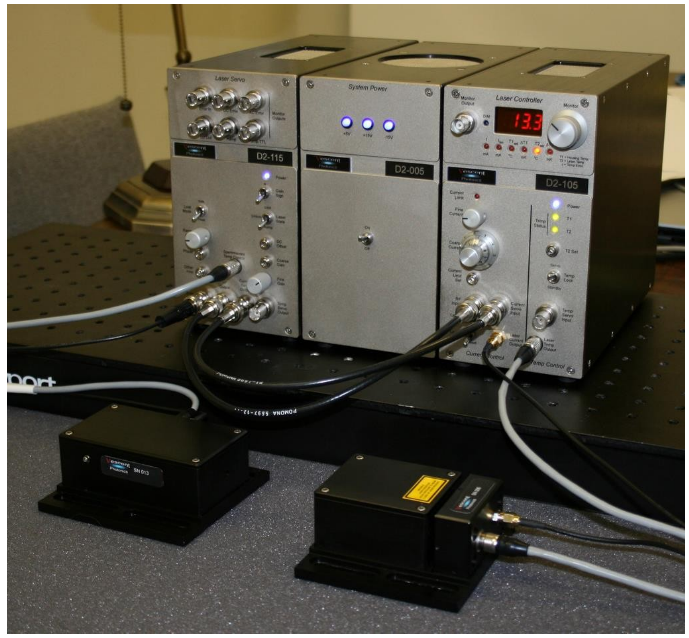


Align the Spectroscopy Module to the DBR Module, but place Spectroscopy Module at least 3" away from the DBR Module.

To help with optical alignment, loosen the four screws that hold each module and gently register the modules by pushing against the screws in the same direction. (This is how they were aligned at Vescent.)

6.3. Cabling & Power

Locate the 6ft SMA cable circular connector cable assembly. Plug the SMA connector into the LASER CURRENT OUTPUT plug and LASER TEMP OUTPUT on the Laser Controller. Make sure that the nearby Laser switch is in the OFF/RESET position (down). While grounded, remove the SMA terminator connected to the DBR Laser. Connect the other end of the SMA cable and circular connector to the DBR module.



Find the 6ft SMA / BNC cable and circular connector cable assembly. Plug the BNC end into the ERROR INPUT on the Laser Servo. Plug the SMA end into the Spectroscopy Module. Connect the circular connectors.

Take one short (~1ft) BNC cable and connect it from the CURRENT SERVO INTPUT on the Laser Controller to the CURRENT SERVO OUTPUT on the Laser Servo.

For Peak-Lock Only: Connect one short (~1ft) BNC from the RF INPUT on the Laser Controller to the RF OUTPUT on the Laser Servo.

Optional: For greater long-term stability, connect one short (~1ft) BNC from the TEMP SERVO INPUT on the Laser Controller to the TEMP SERVO OUTPUT on the Laser Servo. This shifts long term drift to the temperature servo.

Flip the switch on the System Power Module to the ON position. Three LED's (+5V, +15V, -15V) on the System Power modules should glow blue.

Both the Laser Controller module and the Laser Servo module should have a blue LED glowing next to the label POWER. If not, check that the power bridges are properly connected on the back.

6.4. Laser Controller

Flip the TEMP LOCK switch on the Laser Controller into the SERVO position. A green light next to T2 should turn on in ~30 seconds. In ~3 minutes, the T1 green light should also turn on. You may use the laser before stage 1 temperature (T1) is fully stabilized. The LEDs turn red if the temperature servo senses an error condition, or if the laser is not between 0 and 50°C. They will show red until LASER TEMP OUTPUT is connected (open condition), and when the TEMP LOCK is in the STANDBY position.

Rotate the display selector knob in the upper right corner of the Laser Controller until the “I_{lim}” indicator is lit. Make sure the current limit value shown is below 180 mA.

The Laser Controller has two safety interlocks. If either interlock is tripped, the laser will turn off and stay off until the interlock condition has been fixed AND the Laser switch has been moved from “off/reset” position to the “on” position. To turn the laser on for the first time follow the subsequent procedure:

1. Place the front panel Laser switch in the “off/reset” position.
2. Place the included terminator on to the back-panel “remote interlock” BNC.

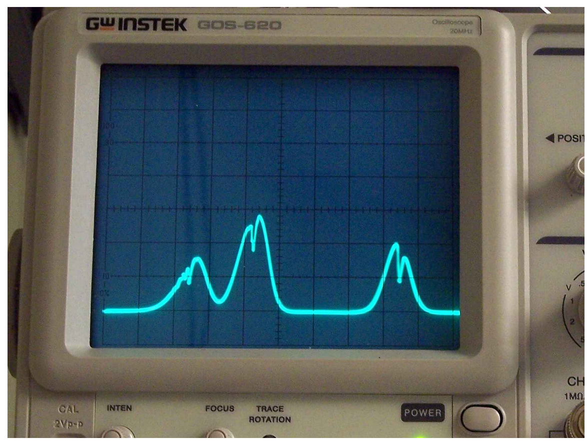
3. Take the key that was taped to back of the Laser Controller and place it in the back-panel Laser Enable keyhole and rotate the key 90 degrees (the key should be horizontal).
4. Now that both interlocks are enabled, flip the Laser switch into the “on” position. The green “Laser On” light should turn on and 5 seconds later the laser should turn on.

Rotate the display selector knob in the upper right corner of the Laser Controller until the LED underneath the label “I” is lit. Adjust the COURSE CURRENT to the value given in the accompanying paperwork to place the laser on the D2 hyperfine transitions.

6.5. Laser Servo

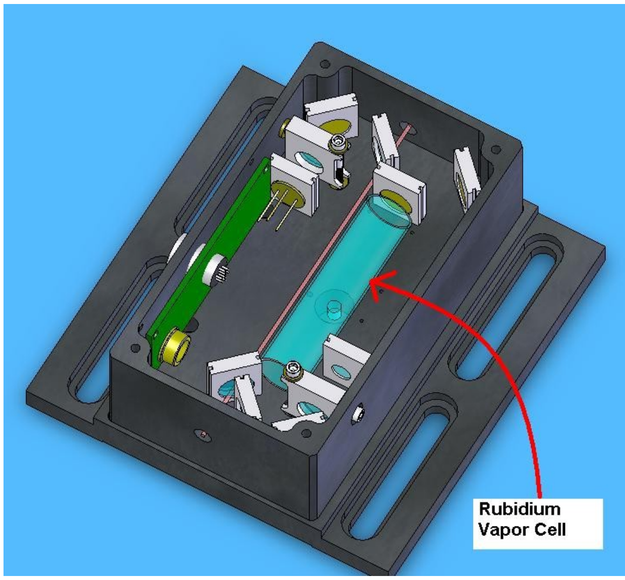
On the Laser Servo, place the LASER STATE switch into the RAMP position. Turn the RAMP AMP knob to max (clockwise). Connect a BNC cable from RAMP TTL on the **back** of the Laser Servo to the trigger input on your oscilloscope. Set trigger to ***positive*** slope.

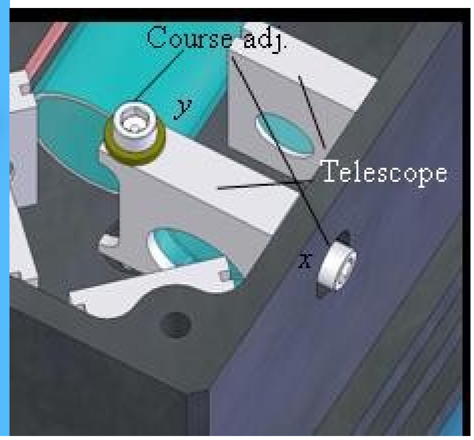
You should see the rubidium hyperfine transitions on the ERROR IN monitor. Adjust the laser current to move the transitions to the left and right. You should see something similar to the figure on the right. There are four Doppler broadened peaks. (The picture shows three of them.)



If you don’t see the hyperfine transitions don’t panic. More than likely the pickoff beams in the spectroscopy module need adjustment. Make sure all four screws are holding down the DBR and spectroscopy modules. Loosen the spectroscopy module screws and try making small adjustments while looking at the ERROR IN signal. You can also try scanning the laser current.

If you still cannot get spectroscopy, remove the screws to the top of the spectroscopy module and adjust the course steering mirror (see below).





If you still cannot get the right signal strength, see the full instructions on aligning the spectroscopy module in the Spectroscopy Manual.

6.6. Locking the laser

6.6.1. Setting up the oscilloscope for locking.

Connect a BNC cable from RAMP TTL on the **back** of the Laser Servo to the trigger input on your oscilloscope. Set trigger to ***positive*** slope. Connect a BNC cable from the DC ERROR to your oscilloscope. Connect a BNC cable from ERROR INPUT to your oscilloscope.

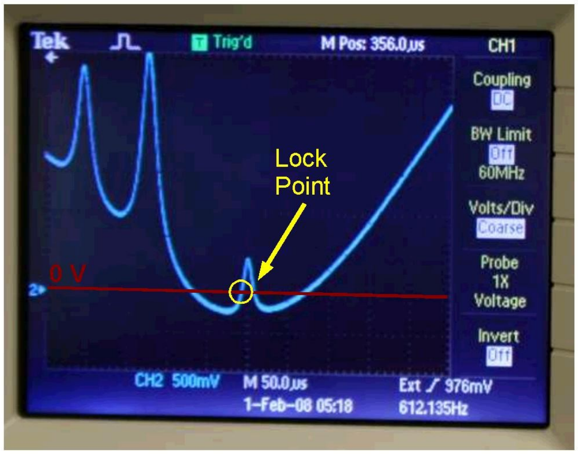
Adjust the Coarse and Fine Current control to place a transition peak at the center of the oscilloscope screen. Reduce the ramp amplitude so you can clearly see the hyperfine transitions (adjust fine current as necessary). As you lower the ramp amplitude and bring it back, you will see the spectroscopy on the oscilloscope expand and contract about a single point on the oscilloscope. The point should be near the center of the oscilloscope. Adjust the horizontal position on the oscilloscope to put this point in the ***exact middle*** of the oscilloscope screen. If you move the spectroscopy so that a hyperfine peak is centered on the oscilloscope, it will be easier to see exactly where this point is. Now as you change the ramp amplitude, the value of the trace at the center of the oscilloscope should not change. Adjust the horizontal position again if necessary.

6.6.2. Side Lock

Note: The laser locks to the point where DC ERROR crosses zero voltage with a ***positive*** slope and when the oscilloscope is triggering to the RAMP TTL with positive slope.

Adjust the laser current and ramp amplitude so you can clearly see the transition that you want to side lock to. Do not ramp too far. The desired transition should occupy most of the screen. You might see that while near a transition the value of DC ERROR moves up and down slightly as the ramp value is changed. Lower the ramp until this effect is gone.

Optional: For long term frequency stability on side lock, monitor ERROR IN on the oscilloscope, open up the top of the Spectroscopy Module, and adjust the trimpot such that your desired lock point crosses 0V on the oscilloscope.



Flip the LOCK MODE switch into the SIDE LOCK position. The laser will lock to a positive (upward) slope at the zero crossing point. If the spot you want to lock to has a negative slope, flip the GAIN SIGN switch on the Laser Servo to make the slope positive. The figure shows the lockpoint on the DC ERROR signal. (Note: the GAIN SIGN switch flips the entire spectrum upsidedown.) Adjust the DC Offset with the pot tweaker until the desired lock point is at zero volts.

Adjust the COURSE gain pot to roughly the number of turns transition you are locking, shown in the accompanying paperwork shipped with your laser system. (Turn to left till it clicks, then turn to the right the specified number of turns.)

Center the spectroscopy such that the lock point is exactly in the center of the oscilloscope. Flip the lock switch on the right from RAMP to LOCK. The DC error signal should now be reading 0V with visible noise.

Adjust the COURSE and FINE GAIN knob to minimize the noise in the DC ERROR. Too high a gain usually kicks the laser out of lock or gives rise to sustained oscillations.

Look at the LD OUT monitor. If the value is less than about 50mV then the laser successfully locked to the desired transition. If it is greater then 50mV the servo jumped to another lock point or is railed.

If the laser did not properly lock see the Laser Lock trouble-shooting section (4.4) on page 34.

6.6.3. Peak Lock

Note: The laser locks to the point where the DC ERROR crosses zero voltage with a ***positive*** slope and when the oscilloscope is triggering to the RAMP TTL with positive slope.

Adjust the laser current and ramp amplitude so you can clearly see the transition that you want to lock to.

If not connected, connect one of the short (~1ft) BNC's from RF OUTPUT on the Laser Servo to the RF INPUT on the Laser Controller. This is the RF dither signal.

Monitor DC ERROR. Flip the LOCK MODE switch to the PEAK position. You should see a signal that is the derivative of the spectroscopy signal. It may have a large DC offset that you will have to adjust with the DC Offset trimpot.

Note: The PHASE and DITHER AMP adjustments are factory set. You do not need to adjust these values.

The laser will lock to where the error signal crosses zero voltage with a positive slope. If your desired lock point has a negative slope, flip the GAIN SIGN switch on the Laser Servo to invert the signal and make the slope positive.

The figure shows an oscilloscope trace of DC ERROR (blue) and ERROR IN (yellow) for the ^{87}Rb F=2→ F'=2, 3 hyperfine crossover transition. Using the DC OFFSET, center the DC ERROR signal vertically about zero to insure that the lock point is at the center of the peak.

Adjust the COURSE gain pot to roughly the number of turns transition you are locking, shown in the accompanying paperwork shipped with your laser system. (Turn to left till it clicks, then turn to the right the specified number of turns.)

Adjust the laser current such that the center of the desired peak is exactly in the center of the oscilloscope. Switch LASER STATE from RAMP to LOCK. The ERROR IN signal should be held constant at the height of the desired peak and DC ERROR should be at zero volts with visible noise. If the ERROR IN value jumped when you clicked LOCK, then the laser jumped to the wrong transition or the servo is railed.

Adjust the COURSE and FINE GAIN knob to minimize the noise in the DC ERROR. Too high a gain usually kicks the laser out of lock or gives rise to sustained oscillations.

If the laser did not properly lock see the Laser Lock trouble-shooting section (4.4) on page 34.