Laser Servo

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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

1. Laser Servo

Model No. D2-115

1.1. 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.

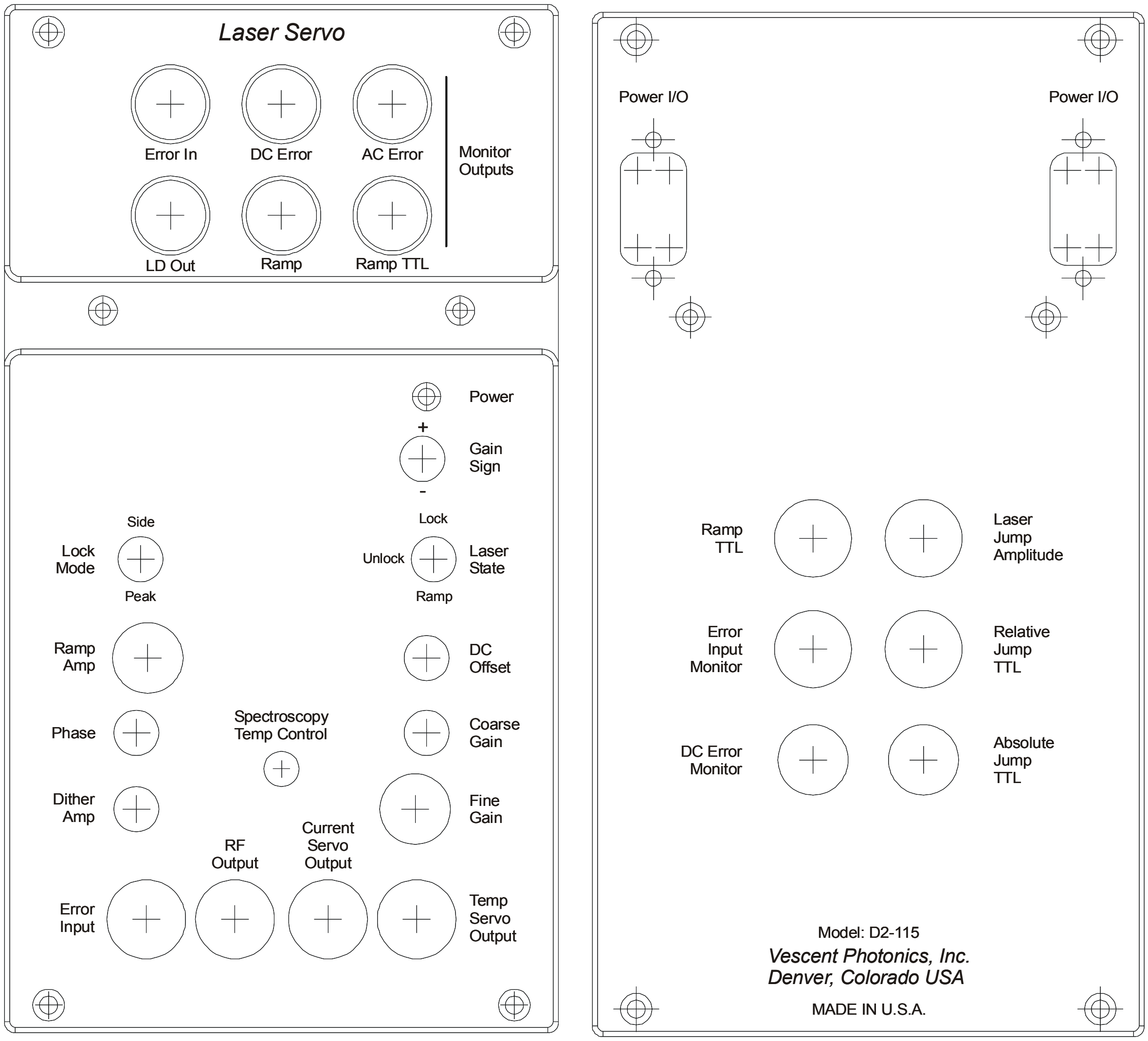
The Laser Servo has an internal sweep generator to aid in transition identification during locking. It also contains a temperature control circuit to maintain constant temperature for the Spectroscopy Module.

1.2. Specifications

	Value	Units
Input voltage noise	<5	nV/√Hz
Bandwidth[1]	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

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

1.3. Inputs, Outputs, and Controls



1.3.1. 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.

1.3.2. 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

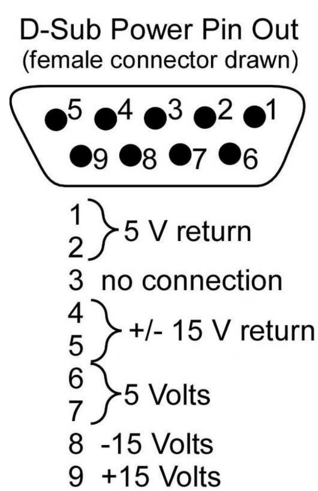
This is an 8-pin connector for the cable to the Spectroscopy Module. It provides power to the photodiode board, thermister, and TECs. The pin definitions are listed below where Rth and Rth_Rtn are the two ends of the thermistor.

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

1.3.3. 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.

1.4. 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.