Operator's Manual

ClarityPlus™ Full C Band Tunable Laser and Reference Standard

Laser Locked to Molecular Absorption Lines

Operating Manual WRD-19020-1

Wavelength References
1800 SW 3rd Street, #140
Corvallis, OR 97333

Voice (541)738-0528
Fax (541)-738-0998
E-mail: sales@wavelengthreferences.com

Warranty

Wavelength References warrants that this product will be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If this product proves defective during the warranty period Wavelength References, at its option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product.

In order to obtain service under this warranty Customer must notify Wavelength References of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. It is important that you, in advance of returning a unit, receive a Return Material Authorization Number (RMA). This will ensure the prompt handling of the repair, as well as provide important tracking information. Customer shall be responsible for the packaging and shipping the defective product to the service center designated by Wavelength References with shipping charges prepaid. Wavelength References shall pay for the return of the product to Customer if the shipment is within the United States or Canada. Customer shall be responsible for paying all shipping charges, duties, taxes, and any other charges for products returned to other locations.

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1 Safety and Regulatory Compliance Information

1.1 Laser Classification

This laser product is listed as a Class IIIb device per the US Code of Federal Regulations 21CFR §1040.10. Laser glasses are suggested while laser is in use. While the beam outputting from the instrument readily diffuses, avoid looking directly into the aperture.

1.2 Power Requirements

Line Power: 90-250 VAC, 50/60 Hz, 0.5 amp

Power Input Connection: style IEC 320-C14

Fuse: Accepts 5mm x 20mm cartridge fuse, 2A current rating (Example: Eaton Technologies, S506 series, MPN BK/S506-2-R)

Compliance:The DC power supplies used in the product comply with IEC 62368-1, GC4943.1 and EAC TPTC004.

1.3 Reference Gas

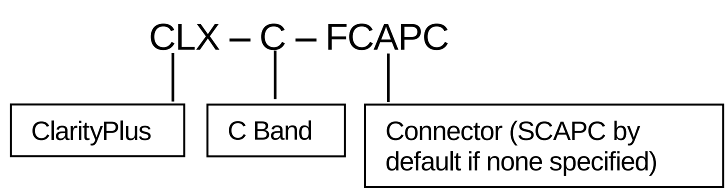
Hydrogen cyanide gas: Occupational Safety and Health Administration (OSHA) lists a Permissable Exposure Limit (PEL) for HCN of 11mg/m^3 over an 8-hour period (time-weighted average). The reference cell within the laser instrument contains < 0.14mg of $H^{13}CN$, well below the 8 hour continuous exposure limit.

These lasers may be shipped by ordinary means.

2 Ordering Information

For ordering or questions, please contact us at sales@wavelengthreferences.com or visit our website.

The ClarityPlus is currently available as a C-band instrument with standard SCAPC covered output. An FCAPC output is available upon request.



The following accessories are also available through Wavelength References:

PM jumper cable, 1 meter length, SCAPC input, FCAPC output: Optipow PMJP-15-X-C-1-R or equivalent.

RS-232 to USB serial adapter: U.S. Connectors XS8801 or equivalnet.

3 Introduction

This manual contains useful operating and background information about the ClarityPlus™ C Band Tunable Laser. It contains all the information you will need to operate and maintain your laser.

If you have just received your laser, refer to Section 3.2 for instructions on initial inspection. For routine front panel operation, refer to Section 4.

This manual is intended to coincide with firmware versions 1.2 through 1.9. For other firmware versions, please consult the appropriate manual or contact Wavelength References for information.

3.1 Product Overview

The ClarityPlus contains a Distributed Feedback (DFB) Laser Diode Array (LDA) coupled with an $H^{13}CN$ Molecular Absorption Cell. The laser is capable to stabilizing its output wavelength to any of the $H^{13}CN$ reference lines published in NIST's Special Publication 260-137 (see section 7.1 and bibliography). Furthermore, the laser self-calibrates to these reference lines allowing high accuracy wavelengths ANYWHERE in the C band.

The ClarityPlus ships with three modes:

1. **Reference Lock**: Allows wavelength stabilization to any of the published NIST $H^{13}CN$ Reference Lines. Refer to Section 7.1 for a list of available lines. This can be considered as a primary frequency standard, treating the reference cell as traceable to a physical constant (see Section 8.4 for a traceability statement).
2. **Wavelength Lock**: Allows wavelength stabilization to any wavelength in the C band by first calibrating to available reference lines.
3. **Channel Frequency Lock**: Allows frequency stabilization anywhere in the ITU grid. The user selects a frequency channel, resolution and offset to arrive at a precise frequency for stabilization. Laser calibrates to available references lines first, as in Wavelength Lock. Channel Frequency Lock Mode also includes a live update feature (when the laser is locked):

the user is able to adjust the target frequency by up to +/- 50 GHz without initializing a new calibration.

3.2 Visual and Operational Inspection

The ClarityPlus laser is packed in a carton designed to give adequate protection during shipment. If the outside of the shipping carton is damaged, notify your shipping department and carrier immediately. If the external packaging is not damaged carefully remove the contents. The contents should include:

- ClarityPlus instrument
- Power cord
- Certificate of Compliance and manual (manual may be emailed separately).
- BNC rear interlock short (affixed to instrument rear panel).

Optional accessories may include:

- Optical fiber jumper cables
- RS-232 to USB adapter and driver software

3.3 Operating Environment

The ClarityPlus laser should be used in an area which satisfies the following conditions:

- Ambient Temperature: 15°C to 45°C (operating temperature)
- Relative Humidity: <85% non-condensing
- Low noise area. While the Clarity laser is designed for noise immunity the best performance will be achieved in a low EMF area. Please use a noise line filter in an area where high noise is unavoidable

4 Connections

Front Panel:

The front panel connection is the fiber optic laser output. The standard output has a spring hinged door to shield the laser output when no fiber connection is made. The standard fiber connector is SCAPC although an adaptor for FCAPC is available. Take care to clean all fiber connections to the laser well before making connection. This will help keep the internal ferrule clean and undamaged. If the internal ferrule is dirty you can attempt to clean it using ferrule cleaning tools available from a number of vendors. It is suggested that if repeated connection to the laser is planned that a jumper be left connected to the laser and repeated connection made to the jumper and not the laser.

Rear Panel:

The rear panel has three connections: a standard IEC universal power connection with integral fuse, a BNC connector for laser interlock (ships with BNC short for laser operation – see Section 5.1.3) and a 9 pin D-Sub socket connector for the RS-232 interface. See Section 6 for more information about the serial interface.

5 Operating Instructions

5.1 Getting Started

5.1.1 Password

At instrument power-on, the user must enter a password.

The default factory set password is **5000** and the user should only have to press ENTER to proceed.

If necessary, press the directional buttons (▲ and ▼) to reach the target password (press and hold for continuous scrolling). Once password is reached, press ENTER. The instrument is now ready to be used.

Should the user wish to change the password, press MENU until the Main Menu Display is reached (shown below – you may have to press MENU multiple times, depending on the current display).

```
1. Reference Lock
2. Wavelength Lock
3. Channel Frequency Lock
4. Instrument Settings
↑, ↓, and ENTER or MENU to exit.
```

Press the directional keys to highlight Instrument Settings and press ENTER. From the new list of selections, press the directional keys to highlight "Change Password" and press ENTER. Press the directional buttons to reach the desired new password (press and hold for continuous scrolling).

Press ENTER, then ENTER again to confirm (or press MENU to cancel).

5.1.2 Initial Warm Up

When the user locks to a reference line, wavelength or frequency from a disabled state (no drive current to the laser), the instrument will begin a lock sequence but there will be no optical power for several seconds. This is completely normal behavior. The laser first stabilizes to a target temperature. Once thermally stabilized, the drive current is supplied to the internal laser diodes and SOA. At this point, the user will note the output power quickly rises to the expected value.

5.1.3 Interlock

The ClarityPlus ships with a BNC short on the Remote Interlock input located on the rear panel. If the connection at the Interlock port is opened the laser will automatically disable. If the BNC short is replaced with an interlock circuit (for example, a door sensor), ensure the circuit is closed prior to laser operation.

5.2 Front Panel Operation and Displays

The user can access the full functionality of the ClarityPlus via the four front panel buttons. Specific functionality is given in the following subsections. Generally, the user can expect the following operation:

- UP/DOWN: directional buttons will move up and down a list or increase/decrease a displayed value.

- ENTER: Moves forward in the selection process. Stores the selected value and updates the display based on selection.

- MENU: Moves back out of the selection process, eventually reaching the main menu display.

5.2.1 The Main Menu

The Main Menu display is accessed by pressing the (blue) MENU button. Note this may require multiple pressings depending on the current display.

The Main Menu lists the three Lock Modes and provides access to the Instrument Settings sub-menu. (shown in Section 5.1.1). Button behavior is described below:

- UP/DOWN moves through the list of options.

- ENTER goes to the appropriate sub-menu (specific mode settings or instrument settings).

- MENU returns user to the Mode display for the current laser lock mode.

5.2.2 The Mode Settings Display

The Mode Settings display is accessed either by pressing MENU from the Mode Display or by pressing ENTER from the Main Menu Display when a Lock Mode is selected. An exception: pressing MENU from the Channel Frequency Lock while the laser is locked enters a Live Update sub-menu – see Section 5.2.3.4 for information.

5.2.2.1 Reference Lock Settings Display

```
Line: R19
Wavelength: 1530.7859 nm
Frequency: 195.84219 THz

↑, ↓, and ENTER or MENU to exit.
```

Press the directional buttons to cycle through the available reference lines (see Section 7.1 for a list of reference lines). Press ENTER to store the target reference line and update the screen to the Reference Lock display. Press MENU to escape out of the settings and return to the Main Menu.

5.2.2.2 Wavelength Lock Settings Display

```
Wavelength: 1530.7859 nm
Frequency: 195.84219 THz


↑, ↓, and ENTER or MENU to exit.
```

The Wavelength Lock Settings display first highlights the nanometer resolution of the target wavelength. Press the directional buttons to set the nanometer resolution of the target wavelength. Press and hold for continuous scrolling.

Press ENTER to move to the sub-picometer resolution and use the directional buttons.

Press ENTER again to store the target wavelength and update the screen to the Wavelength display.

Press MENU at any time to escape out of the settings and return to the Main Menu.

Note on available wavelengths: The specified list of available wavelengths is 1528.773nm to 1566.723nm. The laser instrument can extend 1-1.5 nm beyond the specified limits but the precise range will vary from instrument to instrument. These extended wavelengths are available to the user but are not explicitly specified.

5.2.2.3 Channel Frequency Lock Settings Display

```
Channel Spacing: 100 GHz
Channel Frequency: 193.700 THz
Offset:   0.0 GHz

↑, ↓, and ENTER or MENU to exit.
```

The Channel Frequency Lock Settings first highlights the Channel Spacing / Channel Resolution parameter. Press the directional buttons to choose between 100 GHz, 50 GHz and 25 GHz.

Press ENTER to store the resolution and highlight the Channel Frequency. Press the directional buttons to increase/decrease the frequency by the amount set in the Channel Spacing.

Press ENTER again to store the Channel Frequency and highlight the Offset. Press the directional buttons to choose an offset from -50.0GHz to +50GHz with 0.1GHz resolution.

Press ENTER a final time to store target data and update the display to the Channel Frequency Mode display.

Press MENU at any time to escape out of the settings and return to the Main Menu.

5.2.3 The Mode Display

This display will depend on the current laser lock mode. The bottom right displays the lock status (OFF, Locking, Locked). The bottom left remains clear or displays an error message if present (see Section 5.4 for error details).

Press ENTER to either enable or disable the laser. Enabling the laser changes the locking status from OFF to Locking (then Locked). Disabling the laser changes the locking status from Locked (or Locking) to OFF. Additionally, a green LED illuminates when the laser is enabled. The LED is underneath the connector for output fiber.

Pressing MENU brings user to the Mode Settings display EXCEPT when laser is in Channel Frequency Lock Mode and locked. In this case, the user is able to update the offset without forcing a new calibration sequence. See Section 5.2.3.4 for more information.

5.2.3.1 Reference Lock Mode

```
Line: R19
Wavelength: 1530.7859 nm
Frequency: 195.84219 THz

                                  OFF
```

Reference Lock displays the reference line and corresponding wavelength and frequency.

5.2.3.2 Wavelength Lock Mode

```
Wavelength: 1530.7859 nm
Frequency: 195.84219 THz


                                  OFF
```

Wavelength Lock displays the target wavelength and corresponding frequency.

5.2.3.3 Channel Frequency Lock Mode

```
Lock Frequency: 193.7100 THz
Channel Frequency: 193.700 THz
Offset:   10.0 GHz

                                  OFF
```

Channel Frequency Lock displays the target lock frequency, channel frequency and offset. Target lock frequency is the sum of the channel frequency and the offset.

Pressing MENU while locked allows the user to update the Offset without initiating a new calibration, entering the Live Update display.

5.2.3.4 Live Update Display (Channel Frequency Lock)

```
Lock Frequency: 193.7100 THz
Channel Frequency: 193.700 THz
Offset:    10.0 GHz

                                  Locked
```

To access, press MENU while in Channel Frequency Lock with the laser locked.

Press the directional buttons to adjust the offset. The corresponding locking frequency will simultaneously update. The lock status will update as necessary.

Press ENTER to return to the Channel Frequency Mode display.

Press MENU to enter the Channel Frequency Mode Settings display.

5.3 Front Panel Instrument Settings Display

The ClarityPlus includes access to additional instrument-wide settings. To access, select Instrument Settings from the Main Menu display and press ENTER.

```
1. Secure Laser
2. Change Password
3. RS-232 Settings

↑, ↓, and ENTER or MENU to exit.
```

5.3.1 Secure Laser Display

Press directional buttons until Select Laser is highlighted, then press ENTER. This disables the laser and displays the password screen. The user must enter the password to be able to again use the instrument.

5.3.2 Change Password Display

This is treated in Section 5.1.1

5.3.3 RS-232 Settings Display

```
1. Baud Rate: 115200
2. Tx Term: LF


↑, ↓, and ENTER or MENU to exit.
```

RS-232 settings include the Baud Rate and the Transmit Terminator.

When first entering the display, the baud rate is highlighted. Press the directional buttons to update the baud rate to one of five options: 9600, 19200, 38400, 57600 or 115200.

Press ENTER to store the baud rate and highlight the Transmit Terminator. Press the directional buttons to update the Transmit Terminator to one of four options: LF, LFCR, CR or CRLF.

5.4 Instrument Error Status:

Instrument error statuses are displayed in the Mode display in the lower left hand corner of the display. They are listed below and report errors associated with instrument operation. If there are no errors, the field is blank.

1. "Interlock": The interlock circuit attached to the rear panel BNC output is open. The laser automatically disables. Closing the interlock circuit removes the display and allows the user to re-enable the laser.

2. "Cal Error": Occurs when the laser is unable to locate the reference line during a calibration sweep. Laser will automatically disable. Power-cycle instrument and try again, waiting several seconds between power-off and power-on. If problem persists, consult factory.

3. “Drive Error”: Occurs when the drive current for the laser forward current or SOA current is out of range. Laser will automatically disable. Power-cycle instrument and try again, waiting several seconds between power-off and power-on. If problem persists, consult factory.

4. "Temp Error": Occurs when the laser temperature exceeds specifications. Laser will automatically disable. Power-cycle instrument and try again, waiting several seconds between power-off and power-on. If problem persists, consult factory.

5.5 Troubleshooting

The Clarity should be relatively trouble free. The laser used is somewhat sensitive to back reflections. The best performance will be delivered if the return loss of the connection is >30dB. Excessive back reflection will be evidenced by a roughly 0.04 picometer random fluctuation of the wavelength which may be difficult to see. The output power will also exhibit minor fluctuations in this condition.

Keep the optical connector clean. Use swabs designed for cleaning optical connectors if the connector becomes soiled.

6 Serial Interface

Serial interface to the Clarity laser is provided by means of the RS-232 connector. To use, connect the instrument through a suitable RS-232 session, such as CoolTerm or PuTTY in Windows. Baud rate is initially set to 115200, and the transmitter terminator to LF.

The command set is listed below with the following notes on syntax:

- Bracketed words are optional. SOURCE:FREQUENCY:FIXED? and FREQUENCY? are both valid, for example.
- Commands can be entered either as full (verbose) words or in their shortened form (noted below in uppercase). FREQUENCY? and FREQ? are both valid commands, for example. Note: the commands are not case-specific. Upper- and lower-case are used below only to denote differentiate between the shortened and long (verbose) forms.

6.1 RS232 Commands and Responses

Command	Parameter Form	Notes
Source Subsystem		
[SOURce:]FREQuency[:FIXed]?		Queries target frequency. Returns [xxx.xxxxxxTHz]
[SOURce:]MODe:FREQuency	xxx.xxxxx (Opt.)	Sets mode to Channel Frequency Lock. Optional: enter target frequency in THz.
[SOURce:]MODe:FREQuency?		Queries lock mode. Returns mode and target value.
[SOURce:]MODe:FREQuency:RESolution	<25|50|100>	Sets Channel Frequency Lock Mode channel resolution (GHz).
[SOURce:]MODe:FREQuency:RESolution?		Queries channel resolution. Returns 25, 50 or 100 GHz.
[SOURce:]MODe:REFerence	<0-53> (Opt.)	Sets mode to Reference Lock mode. Optional: enter target reference Line # (see sec. 5.1)
[SOURce:]MODe:REFerence?		Queries current reference line for Reference Lock Mode. Returns 0 to 53 (see Sec. 5.1).
[SOURce:]MODe:WAVelength	xxxx.xxxxx (Opt.)	Sets mode to Wavelength Lock mode. Optional: enter target wavelength in nm.
[SOURce:]MODe:WAVelength?		Queries current wavelength in Wavelength Lock mode. Returns wavelength in nm.
[SOURce:]MODe?		Queries Lock Mode. Returns FREQuency, WAVelength or REFerence.
[SOURce:]STATe	<0|1|OFF|ON>	Sets laser state to disabled / enabled
[SOURce:]STATe?		Queries laser state. Returns OFF or ON.
[SOURce]WAVelength?	xxxx.xxxxxnm	Queries target wavelength
System Subsystem		
SYSTem:ERRor:IMMediate	<0|1|OFF|ON>	Enables/disables error reporting to terminal window.
SYSTem:ERRor:IMMediate?		Queries error reporting to terminal. Returns OFF or ON.

<table>
<tr><td>SYSTem:ERRor[:NEXT]?</td><td></td><td>Queries error from queue (LIFO). Refer to Section 6.2 for list of error codes.</td></tr>
<tr><td>[SYSTem:]HEADer</td><td><0|1|OFF|ON></td><td>Header strings disabled/enabled in query responses. Units, when applicable are also disabled/enabled (e.g. nm or THz).</td></tr>
<tr><td>[SYSTem:]HEADer?</td><td></td><td>Queries header string state. Returns OFF or ON</td></tr>
<tr><td>[SYSTem:]INTerlock?</td><td></td><td>Queries interlock state. Returns OFF or ON.</td></tr>
<tr><td>SYSTem:KLOCk</td><td><0|1|OFF|ON></td><td>Sets front-panel operation to unlocked/locked.</td></tr>
<tr><td>SYSTem:KLOCk?</td><td></td><td>Queries front panel lock state. Returns OFF or ON.</td></tr>
<tr><td>SYSTem:PASSword[:ENABle]</td><td>(####)</td><td>Enables laser system via current 4-digit password. Include parenthesis when entering.</td></tr>
<tr><td>SYSTem:SECure[:LASer]</td><td></td><td>Disables laser and goes to password screen.</td></tr>
<tr><td>SYSTem:SECure[:LASer]?</td><td></td><td>Queries whether laser is in the password screen or not. Returns ON or OFF.</td></tr>
<tr><td>SYSTem:SERial:BAUD</td><td><9600|19200|38400|57600|115200></td><td>Sets baud rate.</td></tr>
<tr><td>SYSTem:SERial:BAUD?</td><td></td><td>Queries baud rate.</td></tr>
<tr><td>SYSTem:SERial:TERMinator</td><td><CRLF|LF|LFCR|CR></td><td>Sets serial transmit termination character.</td></tr>
<tr><td>SYSTem:SERial:TERMinator?</td><td></td><td>Queries termination character.</td></tr>
<tr><td>SYSTem:STATus?</td><td><0|1|2></td><td>Queries laser lock state <OFF|LOCKING|LOCKED></td></tr>
<tr><td>[SYSTem:]VERBose</td><td><0|1|OFF|ON></td><td>Sets verbose (long form) disabled/enabled.</td></tr>
<tr><td>[SYSTem:]VERBose?</td><td></td><td>Queries verbose state. Returns OFF or ON.</td></tr>
<tr><td>IEEE 488.2 Requirements</td><td></td><td></td></tr>
<tr><td>*CLS</td><td></td><td>Clear status command</td></tr>
<tr><td>*ESE</td><td><numeric value></td><td>Standard event status register</td></tr>
<tr><td>*ESE?</td><td></td><td></td></tr>
<tr><td>*ESR?</td><td></td><td></td></tr>
<tr><td>*IDN?</td><td></td><td>Identification query. Returns Model and firmware information.</td></tr>
<tr><td>*OPC</td><td></td><td>Operation complete enable</td></tr>
<tr><td>*OPC?</td><td></td><td>Queries Operation complete status.</td></tr>
<tr><td>*RST</td><td></td><td>Reset command</td></tr>
<tr><td>*STB?</td><td></td><td>Read status byte query</td></tr>
<tr><td>*WAI</td><td></td><td>Wait for calibration to complete</td></tr>
</table>

6.2 Error and Event Codes

The eight most recent error and event codes are stored in an array and can be queried with the command “SYSTem:ERRor:[NEXt]?”. Query repeatedly to produce the full array.

Error Code Definitions:

```
//No event messages
    "0, "No error”                                   // No error
    "1, "Empty input buffer”                         // No input command to parse
    "2, "Too many numeric suffixes”                  // Too many numeric suffices in Command Spec
//Command error messages
    "-100, "Command error”                           // Command error message
    "-103, "Invalid separator”                       // Unmatched bracket
    "-104, "Data type error”                         // Wrong type of parameter(s)
    "-108, "Parameter not allowed”                   // Invalid number of dimensions in a channel list
    "-110, "Command header error”                    // Command keywords were not recognized
    "-115, "Unexpected number of parameters”         // Wrong number of parameters
    "-120, "Numeric data error”                      // Invalid value in numeric or channel list, e.g. out of range
    "-131, "Invalid suffix”                          // Numeric suffix is invalid value
    "-150, "String data error”                       // Unmatched quotation mark (single/double) in parameters
//Execution error messages
    "-200, "Execution error”                         // Execution error message
    "-203, "Command protected”                       // Command password protected
    "-220, "Parameter error”                         // No entry in list to retrieve (number list or channel list)
    "-221, "Settings conflict;Check rear interlock”  // Settings Conflict - Check rear interlock
    "-222, "Data out of range”                       // Data out-of-range
    "-223, "Too much data”                           // Parameter of type Numeric Value overflowed its storage
"-224, "Illegal parameter value”                     // Too many dimensions in entry to be returned in parameters
    "-240, "Hardware error;Temperature”              // Temperature error
    "-241, "Hardware missing;Rear interlock opened”  // Warning - Rear interlock opened
    "-294, "Incompatiable type”                      // Wrong units for parameter
//Device-specific error messages
    "-300, "Device-specific error”                   // Device-specific error message
    "-310, "System error;Invalid password”           // System Error - Invalid password
    "-313, "Calibration memory lost”                 // Non-volatile calibration data corrupted
    "-315, "Configuration memory lost”               // Non-volatile configuration data corrupted
    "-340, "Calibration failed”                      // Internal calibration error
    "-350, "Queue overflow”                          // Queue overflow error
//Query error messages
    "-400, "Query error”                             // Query error message
//Power-on event
    "-500, "Power on”                                // Power-on event message
//User-request event
    "-600, "User request”                            // User request event message
//Request control event
    "-700, "Request control”                         // Request control event message
//Operation complete event
    "-800, "Operation complete”                      // Operation complete event message
```

7 Specifications

7.1 Reference Lines for $H^{13}CN$

Reference Lines are obtained from NIST's Special Publication 260-137 (see Bib.). The final wavelength is derived from the extrapolated 'vacuum' wavelengths and pressure shift information. Vacuum wavelengths are calculated from NIST's reported reference lines and pressure shift information (see SRM Tables 1 through 3).

Absolute Accuracy Uncertainty is reported parenthetically as 2-sigma values and is applied to the least significant digit(s). Uncertainty is added in quadrature and combines pressure uncertainty, base wavelength uncertainty, SRM repeatability, shift uncertainty and, where applicable, additional nearby line uncertainty.

A line number precedes each reference line. Use this number when selecting a specific line via software command.

Note that the ClarityPlus reports wavelength to the nearest 0.1pm.

Line #	Line ID	Vacuum Wavelength (nm)	Pressure Shift (pm/kPa)	Reference Cell Wavelength (nm)
0	R26	1527.633278	0.043	1527.63329(5)
1	R25	1528.054582	0.048	1528.05460(12)
2	R24	1528.485562	0.054	1528.48558(4)
3	R23	1528.926232	0.060	1528.92625(4)
4	R22	1529.376596	0.065	1529.37662(4)
5	R21	1529.836646	0.071	1529.83667(4)
6	R20	1530.306409	0.076	1530.30643(4)
7	R19	1530.785886	0.080	1530.78591(4)
8	R18	1531.27509	0.085	1531.27512(4)
9	R17	1531.77402	0.085	1531.77405(4)
10	R16	1532.2827	0.085	1532.28273(4)
11	R15	1532.80111	0.085	1532.80114(4)
12	R14	1533.329289	0.076	1533.32931(4)
13	R13	1533.867229	0.067	1533.86725(4)
14	R12	1534.414949	0.058	1534.41497(4)
15	R11	1534.972441	0.042	1534.97245(4)
16	R10	1535.539724	0.026	1535.53973(4)
17	R9	1536.116814	0.005	1536.11682(4)
18	R8	1536.703709	-0.021	1536.70370(5)
19	R7	1537.300402	-0.034	1537.30039(5)
20	R6	1537.906941	-0.058	1537.90692(5)
21	R5	1538.523324	-0.083	1538.52330(4)
22	R4	1539.14953	-0.097	1539.14950(8)

23	R3	1539.785596	-0.111	1539.78556(4)
24	R2	1540.431537	-0.102	1540.43150(4)
25	R1	1541.087334	-0.092	1541.08730(8)
26	R0	1541.753018	-0.066	1541.75300(4)
27	P1	1543.114088	0.043	1543.11410(4)
28	P2	1543.809475	0.059	1543.80949(17)
29	P3	1544.514783	0.075	1544.51481(4)
30	P4	1545.23003	0.091	1545.23006(4)
31	P5	1545.955213	0.084	1545.95524(4)
32	P6	1546.690342	0.063	1546.69036(4)
33	P7	1547.435438	0.043	1547.43545(23)
34	P8	1548.190497	0.022	1548.19050(4)
35	P9	1548.955547	0.001	1548.95555(4)
36	P10	1549.730589	-0.024	1549.73058(4)
37	P11	1550.515625	-0.050	1550.51561(4)
38	P12	1551.310684	-0.071	1551.31066(4)
39	P13	1552.11576	-0.091	1552.11573(5)
40	P14	1552.93088	-0.112	1552.93084(4)
41	P15	1553.756036	-0.126	1553.75600(5)
42	P16	1554.591249	-0.139	1554.59120(5)
43	P17	1555.436532	-0.146	1555.43649(5)
44	P18	1556.291895	-0.147	1556.29185(5)
45	P19	1557.157352	-0.149	1557.15730(5)
46	P20	1558.032898	-0.151	1558.03285(12)
47	P21	1558.918559	-0.145	1558.91851(5)
48	P22	1559.814349	-0.139	1559.81430(5)
49	P23	1560.720272	-0.134	1560.72023(5)
50	P24	1561.636346	-0.126	1561.63631(4)
51	P25	1562.562569	-0.118	1562.56253(5)
52	P26	1563.498953	-0.110	1563.49892(5)
53	P27	1564.445527	-0.102	1564.44549(5)

7.2 Table of Specifications

Specifications[1]	Performance	Notes
Wavelength Range	1528.773-1566.723nm	C-band
Reference Mode Absolute Accuracy	±0.1pm ±0.1pm typical	Reference Lines[2] Other gas lines
Wavelength/ITU Mode Absolute Accuracy	±1pm typical	1 hour[3]
Allan Deviation (100 sec)	<1x10-9	Reference Mode
Laser Linewidth	<500 KHz typical	
ITU Grid Resolution	100, 50, 25 GHz	ITU Mode
ITU Frequency Offset	0-50 GHz	Live
Operating Temperature	15-45 degC	
Side Mode Suppression	>35 dB typical	
RIN	<-140dB typical	
Output Power	10 dBm typical	
Power Stability	±0.015 dB typical ±0.025dB typical	1 hour 24 hours
FiberType, interface	PM Panda, SCAPC	
Serial Interface	RS-232	SCPI Compliant
Power Requirements	90-250 VAC, 50/60 Hz, 0.5 amp	Universal AC socket

1. Specifications reported at 25 ± 3 °C.
2. R8 and P11 lines. See Section 7.1 for wavelengths.
3. Within 1 hour of initial setting.

8 Additional Information

8.1 Applications

A typical application for the ClarityPlus laser is to provide an extremely accurate and stable wavelength standard in the DWDM band. This can be used as a calibration source for an OSA (optical spectrum analyzer) or to verify operation of a wavelength meter.

Most wavelength meters are actually frequency ratio meters which measure the wavelength of the unknown signal as a ratio to the built-in standard. Generally, the built-in standard is a helium neon laser. These lasers are available with absolute frequency accuracy nearly as accurate as the ClarityPlus but the wavelength at 632nm is very far from the DWDM band. Vendors of wavelength meters have developed correction algorithms to compensate for the difference of index of refraction of air and other factors that might affect the transfer of this accuracy to the DWDM band by the wavelength meter. These techniques all add a measure of uncertainty. The ClarityPlus provides a means to verify the correct operation of a wavemeter up to its full capabilities with a signal in the DWDM band.

8.2 Operating Principles

The ClarityPlus primarily consists of a semiconductor laser diode array, an internal reference gas cell and controlling circuitry. Laser chip temperature, drive current and SOA current are all controlled in concert while local ambient temperature and the gas cell output are monitored and accounted for. By incorporating the gas cell in its control loops, the ClarityPlus builds on the inherent physical standard asserted by the internal reference gas cell.

At the start of all lock modes, the laser first stabilizes to a molecular absorption line. These lines are relatively insensitive to ambient temperature conditions and long-term aging effects – both for the gas cell and the laser diode array. Thermal and current control loops maintain a wavelength output at the peak of the absorption line, and once the laser is stabilized, characterization data is recorded. If in Reference Lock, the process is complete. If in Wavelength or Channel Frequency Lock, the laser instrument applies the characterization data as calibration data to the new target wavelength or frequency.

To achieve longer term stability in Wavelength or Channel Frequency Lock, ambient temperature is monitored and compensated for.

8.3 Accuracy

Line location and accuracy are determined by applying NIST pressure shift data (measurement and uncertainty) to the extrapolated "zero-pressure" line position. Uncertainties are added in quadrature.

Pressure uncertainty in the gas fill also contributes to the line location and uncertainty, though not by a measureable amount. A 1 Torr change in pressure, well above our pressure uncertainty, shifts the line by -.02 to +0.01pm.

Locked lasers are measured in-house with an Agilent 86122C wavemeter to ensure locking and stability. The fundamental reference line lock routine has been verified by measurements at NIST to be well within 0.1pm accuracy.

8.4 NIST Traceability

The ClarityPlus is considered NIST traceable by virtue of the internal reference gas cell used for calibration and locking stabilization.

NIST traceability describes a process by which an instrument is referenced to a NIST SRM (Standard Reference Material). This can be due to a direct measurement with the SRM or through an unbroken chain of instrumentation that ends with a NIST SRM. This often applies to laser instruments and metrology instruments such as wavemeters and spectrum analyzers.

NIST traceability of gas cells is obtained instead through verification of the gas sample within the reference cell. The absorption lines seen in the gas cell (NIST or Wavelength References) are based on fundamental energy levels of molecules and as a result are not subject to calibration, only verification. The specified accuracy of the gas cell lines also generally exceeds the accuracy of the measurement equipment.

The principle variations in gas cell environment are chemical purity and pressure. Each are treated below:

1. Chemical Purity:

We purchase raw gas with a purity assay to assure purity of the raw material. The depth of a gas cell line for a particular gas cell length gives an independent measure of contamination when compared to published results.

2. Pressure:

Gauges are periodically calibrated. In addition, the measured width of the gas cell line gives an independent measure of the gas cell pressure. NIST has performed a detailed error analysis of gas cell lines for their SRMs. By far the dominant source of error is pressure uncertainty due to variations in the filling process. For example, the data on the NIST SRM2517A acetylene gas cell assumes a pressure of 50Torr ±10Torr or ±20%. When we analyze results from production over a long term at Wavelength References we see that we hold the pressure uncertainty to <±5%(1σ).

All tubes are manufactured with melted, sealed glass to ensure long term stability of the gas cell environment. The leak rate from this type of seal is extremely slow, making the tubes effectively hermetically sealed (good for > 10 yrs). This seal is also extremely robust to temperature and humidity unlike, for example, an epoxy seal.

NIST Traceability, then, is achieved through documented chemical purity, known pressures, stable cell environment, and finally, the underlying fundamental properties of molecular absorption itself.

9 Bibliography

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Revision History		
WRD-19020-0	10/18/2019	Initial Draft
WRD-19020-1		Clarified RS-232 connection