OM2210
Coherent Receiver Calibration Source

User Manual

Tektronix

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Contacting Tektronix

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- In North America, call 1-800-833-9200.
- Worldwide, visit www.tektronix.com to find contacts in your area.

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Important safety information

This manual contains information and warnings that must be followed by the user for safe operation and to keep the product in a safe condition.

To safely perform service on this product, additional information is provided at the end of this section. (See page vi, *Service safety summary*.)

General safety summary

Use the product only as specified. Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. Carefully read all instructions. Retain these instructions for future reference.

Comply with local and national safety codes.

For correct and safe operation of the product, it is essential that you follow generally accepted safety procedures in addition to the safety precautions specified in this manual.

The product is designed to be used by trained personnel only.

Only qualified personnel who are aware of the hazards involved should remove the cover for repair, maintenance, or adjustment.

Before use, always check the product with a known source to be sure it is operating correctly.

This product is not intended for detection of hazardous voltages.

Use personal protective equipment to prevent shock and arc blast injury where hazardous live conductors are exposed.

When incorporating this equipment into a system, the safety of that system is the responsibility of the assembler of the system.

To avoid fire or personal injury

Use proper power cord. Use only the power cord specified for this product and certified for the country of use.

Do not use the provided power cord for other products.

Ground the product. This product is grounded through the grounding conductor of the power cord. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making connections to the input or output terminals of the product, make sure that the product is properly grounded.

Do not disable the power cord grounding connection.

Power disconnect. The power cord disconnects the product from the power source. See instructions for the location. Do not position the equipment so that it

is difficult to disconnect the power cord; it must remain accessible to the user at all times to allow for quick disconnection if needed.

Observe all terminal ratings. To avoid fire or shock hazard, observe all ratings and markings on the product. Consult the product manual for further ratings information before making connections to the product.

Do not apply a potential to any terminal, including the common terminal, that exceeds the maximum rating of that terminal.

Do not float the common terminal above the rated voltage for that terminal.

The measuring terminals on this product are not rated for connection to mains or Category II, III, or IV circuits.

Do not operate without covers. Do not operate this product with covers or panels removed, or with the case open. Hazardous voltage exposure is possible.

Avoid exposed circuitry. Do not touch exposed connections and components when power is present.

Do not operate with suspected failures. If you suspect that there is damage to this product, have it inspected by qualified service personnel.

Disable the product if it is damaged. Do not use the product if it is damaged or operates incorrectly. If in doubt about safety of the product, turn it off and disconnect the power cord. Clearly mark the product to prevent its further operation.

Examine the exterior of the product before you use it. Look for cracks or missing pieces.

Use only specified replacement parts.

Replace batteries properly. Replace batteries only with the specified type and rating.

Use proper fuse. Use only the fuse type and rating specified for this product.

Wear eye protection. Wear eye protection if exposure to high-intensity rays or laser radiation exists.

Do not operate in wet/damp conditions. Be aware that condensation may occur if a unit is moved from a cold to a warm environment.

Do not operate in an explosive atmosphere.

Keep product surfaces clean and dry. Remove the input signals before you clean the product.

Provide proper ventilation. Refer to the installation instructions in the manual for details on installing the product so it has proper ventilation.

Slots and openings are provided for ventilation and should never be covered or otherwise obstructed. Do not push objects into any of the openings.

Provide a safe working environment. Always place the product in a location convenient for viewing the display and indicators.

Avoid improper or prolonged use of keyboards, pointers, and button pads. Improper or prolonged keyboard or pointer use may result in serious injury.

Be sure your work area meets applicable ergonomic standards. Consult with an ergonomics professional to avoid stress injuries.

Use care when lifting and carrying the product.

Warning- Use correct controls and procedures. Use of controls, adjustments, or procedures other than those listed in this document may result in hazardous radiation exposure.

Do not directly view laser output. Under no circumstances should you use any optical instruments to view the laser output directly.

Service safety summary

The *Service safety summary* section contains additional information required to safely perform service on the product. Only qualified personnel should perform service procedures. Read this *Service safety summary* and the *General safety summary* before performing any service procedures.

To avoid electric shock. Do not touch exposed connections.

Do not service alone. Do not perform internal service or adjustments of this product unless another person capable of rendering first aid and resuscitation is present.

Disconnect power. To avoid electric shock, switch off the product power and disconnect the power cord from the mains power before removing any covers or panels, or opening the case for servicing.

Use care when servicing with power on. Dangerous voltages or currents may exist in this product. Disconnect power, remove battery (if applicable), and disconnect test leads before removing protective panels, soldering, or replacing components.

Verify safety after repair. Always recheck ground continuity and mains dielectric strength after performing a repair.

Terms in this manual

These terms may appear in this manual:

⚠ **WARNING.** *Warning statements identify conditions or practices that could result in injury or loss of life.*

⚠ **CAUTION.** *Caution statements identify conditions or practices that could result in damage to this product or other property.*

Symbols and terms on the product

These terms may appear on the product:

- DANGER indicates an injury hazard immediately accessible as you read the marking.

- WARNING indicates an injury hazard not immediately accessible as you read the marking.

- CAUTION indicates a hazard to property including the product.

⚠ When this symbol is marked on the product, be sure to consult the manual to find out the nature of the potential hazards and any actions which have to be taken to avoid them. (This symbol may also be used to refer the user to ratings in the manual.)

The following symbol(s) may appear on the product:

⚠ CAUTION Refer to Manual   Protective Ground (Earth) Terminal   Mains Disconnected OFF (Power)   Mains Connected ON (Power)   Invisible Laser Radiation

Front panel label locations

Item	Description
1	Indicates the location of laser apertures
2	INVISIBLE LASER RADIATION; DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS, CLASS 1M LASER PRODUCT EMISSION DE RAYONS LASER INVISIBLES DE CLASSE 1M, NE PAS OBSERVER A L'AIDE D'INSTRUMENTS OPTIQUES

Rear panel label locations
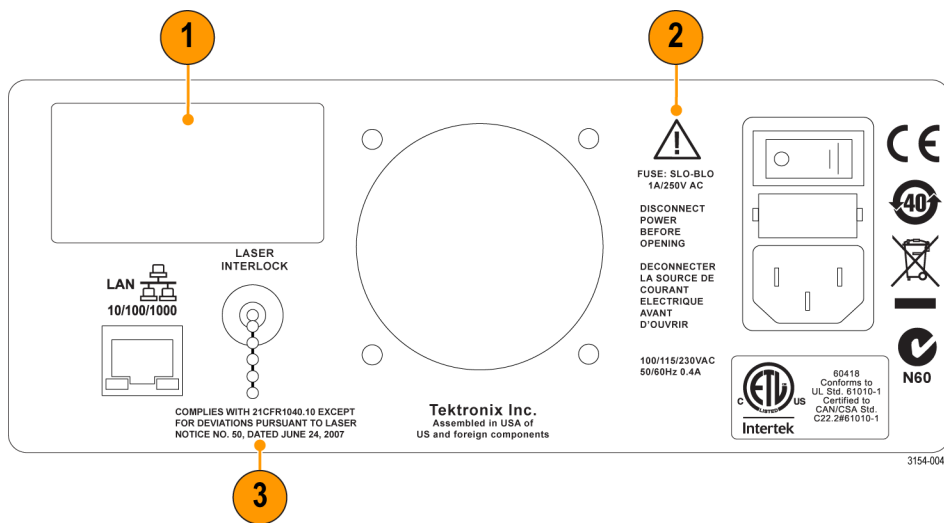
Item	Description
1	Instrument model and serial number label
2	Fuse safety information label
3	**COMPLIES WITH 21CFR1040.10 EXCEPT FOR DEVIATIONS PURSUANT TO LASER NOTICE NO. 50, DATED JUNE 24, 2007**

Compliance information

This section lists the EMC (electromagnetic compliance), safety, and environmental standards with which the instrument complies.

EMC compliance

EC Declaration of Conformity – EMC

Meets intent of Directive 2004/108/EC for Electromagnetic Compatibility. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:

EN 61326-1 2006. EMC requirements for electrical equipment for measurement, control, and laboratory use. [1] [2] [3]

- CISPR 11:2003. Radiated and conducted emissions, Group 1, Class A

- IEC 61000-4-2:2001. Electrostatic discharge immunity

- IEC 61000-4-3:2002. RF electromagnetic field immunity [4]

- IEC 61000-4-4:2004. Electrical fast transient / burst immunity

- IEC 61000-4-5:2001. Power line surge immunity

- IEC 61000-4-6:2003. Conducted RF immunity [5]

- IEC 61000-4-11:2004. Voltage dips and interruptions immunity

EN 61000-3-2:2006. AC power line harmonic emissions

EN 61000-3-3:1995. Voltage changes, fluctuations, and flicker

European contact.
Tektronix UK, Ltd.
Western Peninsula
Western Road
Bracknell, RG12 1RF
United Kingdom

[1] This product is intended for use in nonresidential areas only. Use in residential areas may cause electromagnetic interference.

[2] Emissions which exceed the levels required by this standard may occur when this equipment is connected to a test object.

[3] For compliance with the EMC standards listed here, high quality shielded interface cables should be used.

[4] When subjected to interference in accordance with the IEC 61000-4-3 tests, Power Position 1 and 2 Variation < 1 dB, and Extinction Power Max > 40 dBm.

[5] When subjected to interference in accordance with the IEC 61000-4-6 tests, Power Position 1 and 2 Variation < 1 dB, and Extinction Power Max > 40 dBm.

Australia / New Zealand Declaration of Conformity – EMC	Complies with the EMC provision of the Radiocommunications Act per the following standard, in accordance with ACMA:

- CISPR 11:2003. Radiated and Conducted Emissions, Group 1, Class A, in accordance with EN 61326-1:2006.

Australia / New Zealand contact.

Baker & McKenzie
Level 27, AMP Centre
50 Bridge Street
Sydney NSW 2000, Australia

Safety compliance

This section lists the safety standards with which the product complies and other safety compliance information.

EU declaration of conformity – low voltage	Compliance was demonstrated to the following specification as listed in the Official Journal of the European Union:

Low Voltage Directive 2006/95/EC.

- EN 61010-1. Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements.

- EN 60825-1. Safety of Laser Products - Part 1: Equipment classification and requirements.

U.S. nationally recognized testing laboratory listing	- UL 61010-1. Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements.

Canadian certification	- CAN/CSA-C22.2 No. 61010-1. Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements.

Additional compliances	- IEC 61010-1. Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements.

- IEC 60825-1. Safety of Laser Products - Part 1: Equipment classification and requirements.

- This laser product complies with 21CFR1040.10 except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.

Equipment type	Test and measuring equipment.

Safety class Class 1 – grounded product.

Pollution degree descriptions A measure of the contaminants that could occur in the environment around and within a product. Typically the internal environment inside a product is considered to be the same as the external. Products should be used only in the environment for which they are rated.

- Pollution degree 1. No pollution or only dry, nonconductive pollution occurs. Products in this category are generally encapsulated, hermetically sealed, or located in clean rooms.

- Pollution degree 2. Normally only dry, nonconductive pollution occurs. Occasionally a temporary conductivity that is caused by condensation must be expected. This location is a typical office/home environment. Temporary condensation occurs only when the product is out of service.

- Pollution degree 3. Conductive pollution, or dry, nonconductive pollution that becomes conductive due to condensation. These are sheltered locations where neither temperature nor humidity is controlled. The area is protected from direct sunshine, rain, or direct wind.

- Pollution degree 4. Pollution that generates persistent conductivity through conductive dust, rain, or snow. Typical outdoor locations.

Pollution degree rating Pollution degree 2 (as defined in IEC 61010-1). Rated for indoor, dry location use only.

IP rating IP20 (as defined in IEC 60529).

Measurement and overvoltage category descriptions Measurement terminals on this product may be rated for measuring mains voltages from one or more of the following categories (see specific ratings marked on the product and in the manual).

- Category II. Circuits directly connected to the building wiring at utilization points (socket outlets and similar points).

- Category III. In the building wiring and distribution system.

- Category IV. At the source of the electrical supply to the building.

NOTE. Only mains power supply circuits have an overvoltage category rating. Only measurement circuits have a measurement category rating. Other circuits within the product do not have either rating.

Mains overvoltage category rating Overvoltage category II (as defined in IEC 61010-1).

Environmental considerations

This section provides information about the environmental impact of the product.

Product end-of-life handling

Observe the following guidelines when recycling an instrument or component:

Equipment recycling. Production of this equipment required the extraction and use of natural resources. The equipment may contain substances that could be harmful to the environment or human health if improperly handled at the product's end of life. To avoid release of such substances into the environment and to reduce the use of natural resources, we encourage you to recycle this product in an appropriate system that will ensure that most of the materials are reused or recycled appropriately.

This symbol indicates that this product complies with the applicable European Union requirements according to Directives 2002/96/EC and 2006/66/EC on waste electrical and electronic equipment (WEEE) and batteries. For information about recycling options, check the Support/Service section of the Tektronix Web site (www.tektronix.com).

Perchlorate materials. This product contains one or more type CR lithium batteries. According to the state of California, CR lithium batteries are classified as perchlorate materials and require special handling. See www.dtsc.ca.gov/hazardouswaste/perchlorate for additional information.

Restriction of hazardous substances

This product is classified as an industrial monitoring and control instrument, and is not required to comply with the substance restrictions of the recast RoHS Directive 2011/65/EU until July 22, 2017.

Preface

This manual describes how to install and operate the OM2210 Coherent Receiver Calibration Source.

Supported products

The information in this manual applies to the following Tektronix products:

- OM2210 Coherent Receiver Calibration Source

- OM4006D Coherent Lightwave Signal Analyzer

- OM4106D Coherent Lightwave Signal Analyzer

- OM1106 Coherent Lightwave Signal Analyzer stand-alone software (OUI software; included with OM4000 Series)

About this manual

This manual contains the following sections:

- *Getting started* shows you how to install and configure the OM2210 instrument.

- *Operating basics* provides an overview of the front- and rear-panel controls and connections, and basic operations.

- *Reference* provides a MATLAB® function listing.

Getting started

This section contains the following information to get you started using the OM2210 Coherent Receiver Calibration Source:

- Product description
- List of instrument accessories and options
- Initial product inspection
- Operating requirements (environmental, power)
- Software, network, and hardware setup

Product description

The OM2210 Coherent Receiver Calibration Source and associated Hybrid Calibration Software (HRC) software are used in laboratory or industrial facilities to calibrate coherent fiber optic receivers. This product is primarily targeted for calibrating polarization-diverse, phase-diverse receivers that are linear or can be set in a linear mode.

The end result is a transfer matrix, measured at a particular heterodyne frequency over a specified wavelength range, that describes the optical-to-electrical transfer function of the analog portion of the receiver. The transfer matrix is then used to compute critical receiver specifications such as quadrature phase angle, polarization cross-talk, and path gains. This information can be used for quantitative evaluation of the receiver, or to provide calibrated optical field measurements when used with the OM4000 signal analysis software.

Optical communications signals are the combination of a continuous laser field (cw) and a modulation field that carries the data. In the case of polarization multiplexed signals, there can be as many as two independent lasers and modulators that are polarization-multiplexed together.

The OM4000 signal processing software is designed to extract the cw and modulation for each polarization from which data and signal-quality metrics may be extracted. Since the software extracts fields, not just data, it is necessary to have independent measurements of the receiver properties so that the effect of the receiver may be removed. This process consists of a low-frequency measurement of the linear OE transfer matrix relating the input field vector, E, to the output voltages, V, and a separate frequency response measurement. The OM2210 can measure the linear OE transfer matrix, H, at frequencies well within the oscilloscope bandwidth.

$V=[H]E$

This process can be applied both to linear receivers like the OM4000 Series as well as receivers with automatic gain control (AGC) such as commercial coherent receivers. The AGC must be turned off during the calibration so that the software can measure the linear portion of the transfer function. The matrix can then be normalized to simulate the AGC operation.

The calibration software extracts the hybrid matrix, H, by applying a heterodyne signal with different polarizations and then measuring the resulting sine wave outputs on the oscilloscope while separately monitoring the power. Proprietary calculations are performed to extract the hybrid matrix in the presence of receiver impairments, heterodyne phase fluctuations, and channel skews.

This process is directed by the OM2210 Hybrid Receiver Calibration (HRC) Software. The HRC software controls the heterodyne source through the Laser Receiver Control Panel (LRCP) software and collects data from the oscilloscope with the OM4000 User Interface (OUI) software.
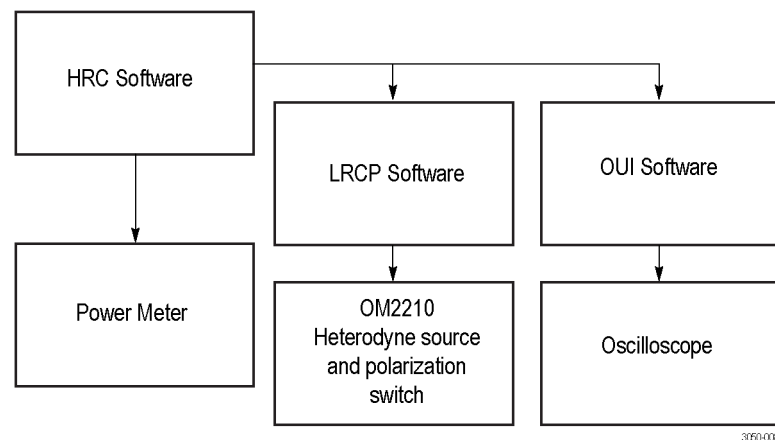
The final results are provided in .mat, .csv, and .xls file formats. The .mat format is used by the OM4000 OUI software hybrid calibration function. The other formats are provided for viewing the results. The results and configurations are also stored in an SQL database.

Key features

- ■ Measure key performance parameters for coherent receivers such as quadrature phase angle, path gains, and channel skew

- ■ Obtain calibration data over wavelength for use in calibrated optical field measurements

- ■ Calibrate any sufficiently stable coherent receiver to make it capable of optical field measurements

- ■ Measure receiver hybrid parameters at any heterodyne frequency within the oscilloscope bandwidth

- ■ Measure optical hybrid properties in higher-level receiver modules

Tunable laser features

- Full C-band and/or L-band tunable continuous wave laser

- Integrated wavelength locker to support 50 GHz ITU wavelength grid

- Settable grid down to 10 GHz

- Off-grid tuning for custom wavelength applications

- User-adjustable transmit power output (+6 to +14.5 dBm) and wavelength adjustment during operation

- Supports advanced features for DWDM networks such as SBS Dither and TxTrace Tone

NOTE. The OM2210 can be configured with up to 2 tunable lasers in addition to the polarization switch. Order the OM2012 if you need just a tunable laser source (without the polarization switch).

Applications

- Calibration of coherent receiver front-end characteristics for use in calibrated optical signal measurements

- Integrated dual polarization intradyne coherent receiver frequency-domain characterization

- Tunable lasers for design and manufacturing test of 2.5, 10, 40, and 100 Gb/s optical networking equipment, including the following:

    - Multi-Service Provisioning Platform (MSSP)

    - Cross connects

    - Optical switches

    - Optical add/drop multiplexers

    - Dense Wavelength Division Multiplex (DWDM) terminals

    - Other Wavelength Division Multiplex (WDM) metro system equipment

Accessories

The following table lists the standard accessories provided with the OM2210.

Table 1: Standard accessories

Accessory	Tektronix part number
OM2210 Coherent Receiver Calibration Source instrument	Varies by option
OM2210 Coherent Receiver Calibration Source User Manual (this manual)	071-3050-xx
OM4000 Series Coherent Lightwave Signal Analyzer User Manual	071-3160-xx
HRC and LRCP software flash drive	650-5660-00
HASP USB key	650-5642-00
Ethernet cable, 7 ft.	174-6230-00
Shorting cap for BNC interlock connector	131-8925-00
Optical power meter	119-8008-00
10/90 Optical coupler	119-8028-00
Power sensor	119-8031-00
Power cord (See page 5, *International power cord options*.)	Varies by option

Options

The following table lists the options that can be ordered with the OM2210.

Table 2: OM2210 options

Option	Description
C	One C-band laser and polarization switch. Use this option when C-band receiver has an OM instrument reference laser.
CC	Two C-band lasers and polarization switch. Use this option when the C-band receiver has no OM instrument sources.
CL	Coupled C- and L-band lasers and polarization switch.
L	One L-band laser and polarization switch. Use this option when L-band receiver has an OM instrument reference laser.
LL	Two L-band lasers and polarization switch. Use this option when the L-band receiver has no OM instrument sources.
NL	C+L polarization switch only (no lasers). Use this option when receiver has 2 OM instrument sources for reference and signal.

International power cord options

All of the available power cord options listed below include a lock mechanism except as otherwise noted.

- Opt. A0 – North America power (standard)
- Opt. A1 – Universal EURO power
- Opt. A2 – United Kingdom power
- Opt. A3 – Australia power
- Opt. A4 – North America power (240 V)
- Opt. A5 – Switzerland power
- Opt. A6 – Japan power
- Opt. A10 – China power
- Opt. A11 – India power (no locking cable)
- Opt. A12 – Brazil power (no locking cable)

Initial product inspection

Do the following when you receive your instrument:

1. Inspect the shipping carton for external damage, which may indicate damage to the instrument.

2. Remove the OM2210 from the shipping carton and check that the instrument has not been damaged in transit. Prior to shipment the instrument is thoroughly inspected for mechanical defects. The exterior should not have any scratches or impact marks.

NOTE. Save the shipping carton and packaging materials for instrument repackaging in case shipment becomes necessary.

3. Verify that the shipping carton contains the basic instrument, the standard accessories and any optional accessories that you ordered listed in the table. (See Table 1 on page 4.)

Contact your local Tektronix Field Office or representative if there is a problem with your instrument or if your shipment is incomplete.

Environmental operating requirements

Check that the location of your installation has the proper operating environment. (See Table 3.)

⚠ **CAUTION.** *Damage to the instrument can occur if this instrument is powered on at temperatures outside the specified temperature range.*

Table 3: OM2210 environmental requirements

Parameter		Description
Temperature	Operating	+10 °C to +35 °C
	Nonoperating	−20 °C to +70 °C
Relative Humidity	Operating	15% to 80% (No condensation)
Altitude	Operating	To 2,000 m (6,560 feet)
		Maximum operating temperature decreases 1 °C each 300 m above 1.5 km.
	Nonoperating	To 15,000 m (49,212 feet)

Do not obstruct the fan so that there is an adequate flow of cooling air to the electronics compartment whenever the unit is operating. Leave space for cooling by providing at least 2 inches (5.1 cm) at rear of instrument for benchtop use. Also, provide sufficient rear clearance (approximately 2 inches) so that any cables are not damaged by sharp bends.

Power requirements

Table 4: AC line power requirements

Parameter	Description
Line Voltage Range	100/115 VAC single phase
	230 VAC single phase
Line frequency	50/60 Hz
Maximum current	0.4 A

⚠ **WARNING.** *To reduce the risk of fire and shock, ensure that the AC supply voltage fluctuations do not exceed 10% of the operating voltage range.*

⚠ **WARNING.** *Always connect the unit directly to a grounded power outlet. Operating the OM instrument without connection to a grounded power source could result in serious electrical shock.*

Connecting the power cable. Connect the power cable to the instrument first, and then connect the power cable to the AC power source. Install or position the OM2210 so that you can easily access the rear-panel power switch.

Power on the instrument (rear-panel power switch and front-panel standby power switch). After powering on, make sure that the fan on the rear panel is working. If the fan is not working, turn off the power by disconnecting the power cable from the AC power source, and then contact your local Tektronix Field Office or representative.

PC requirements

The equipment and DUT used with the OM2210 determine the controller PC requirements. Following are the PC requirements to use the OM2210 with the Tektronix OM4000 instruments:

Item	Description
Operating system	U.S.A. Microsoft Windows 7 64-bit
	U.S.A. Microsoft Windows XP Service Pack 3 32-bit (.NET 4.0 required)
Processor	Intel i7, i5 or equivalent; min clock speed 2 GHz
	Minimum: Intel Pentium 4 or equivalent
RAM	Minimum: 4 GB
	64-bit releases benefit from as much memory as is available

Item	Description
Hard Drive Space	Minimum: 20 GB
	>300 GB recommended for large data sets (for OM4000 OUI software ony)
Video Card	nVidia dedicated graphics board w/ 512+ MB minimum. graphics memory (for OM4000 OUI software ony)
	NOTE. The OUI color grade display feature, the MCS option, and the equivalent-time (ET) oscilloscope mode require that the oscilloscope or PC running the OM software have an nVidia graphics card installed
Networking	Gigabit Ethernet (1 Gb/s) or Fast Ethernet (100 Mb/s)
Display	20" minimum, flat screen recommended for displaying multiple graph types when using with the OM4000 Software
Other Hardware	DVD Optical drive
	Two USB 2.0 ports
MATLAB Software	For Windows 7 (64-bit): MATLAB version 2011b (64-bit)
(for use with OM4000 OUI software ony)	For Windows XP (32-bit): MATLAB version 2009a (32-bit), .NET version 4 or later.
Adobe Reader	Adobe reader required for viewing PDF format files (release notes, installation instructions, user manuals).

Software installation

The OM2210 requires programs and drivers to be installed on your controlling PC (separate Windows 7 or XP-based PC or oscilloscope) for proper operation. Install the programs listed in the following table, in the order listed (starting from the top of table). All programs are on the OM2210 software USB memory drive unless otherwise noted.

NOTE. Read the installation notes or instructions that are in each application installation folder before installing each item of software. Only install the software that is appropriate for your OM instrument, PC, and oscilloscope configuration.

NOTE. If you are going to use the OM2210 as part of a test/calibration system including OM4000 instruments and measurement oscilloscopes, do not install the software listed in the following table. Instead, use the software installation instructions that are in the "OM4106D and OM4006D Coherent Lightwave Signal Analyzer User Manual."

Install software on the controller PC

Table 5: Software install: controller PC

Program	Description	Path (from root directory of USB drive)
TekVISA	Instrument USB and Ethernet connectivity software.	OUI\ISSetupPrerequisites\TekVISA_v3.3.8\TekVISA\setup.exe *NOTE. TekVISA is only required when using MSO/DSO70000 or 70000B series oscilloscopes, or when using the HRC software.*
LRCP	Laser Receiver Control Panel. Detects OM instruments on a network, controls laser and other hardware settings.	LRCP\LRCPSetup x.x.x.x.msi
MATLAB	Required for OUI. Not part of the OM4000, OM2210, or OM2102 software distribution. Contact The Mathworks, Inc. to obtain the MATLAB software. See the PC requirements section to determine the correct version of MATLAB for your PC.	
OUI	OM4000 User Interface. The interface for using the OM4000 instrument to take and display measurements.	OUI\SetupOUI_x.x.x.x 32-bit OS.exe (Windows 7 32-bit or Windows XP 32-bit; assumes MATLAB 2009a installed) OUI\SetupOUI_x.x.x.x.exe (Windows 7 64-bit)
Power meter	Software and drivers to communicate with the instrument optical power meter. Install in the order listed. Only required if you install the HRC software.	HRC\ISSetupPrerequisites\ThorPowerMeter\setup.exe HRC\ISSetupPrerequisites\ThorPowerMeterDriver\setup.exe
HRC	Hybrid-Receiver Calibration software. Uses SQL to keep track of calibration configurations. SQL software installed automatically if not present on the PC.	HRC\Setup Optametra HRC_x.x.x.x.exe

Set the instrument IP address

Use the Laser Receiver Control Panel (LRCP) application to verify and/or set the IP address of OM instruments (OM2210, OM2012, OM4000) if required for your network test setup. All OM instruments must be set to the same network subnet (DHCP-enabled networks do this automatically) to communicate with each other using the LRCP and other OM instrument software.
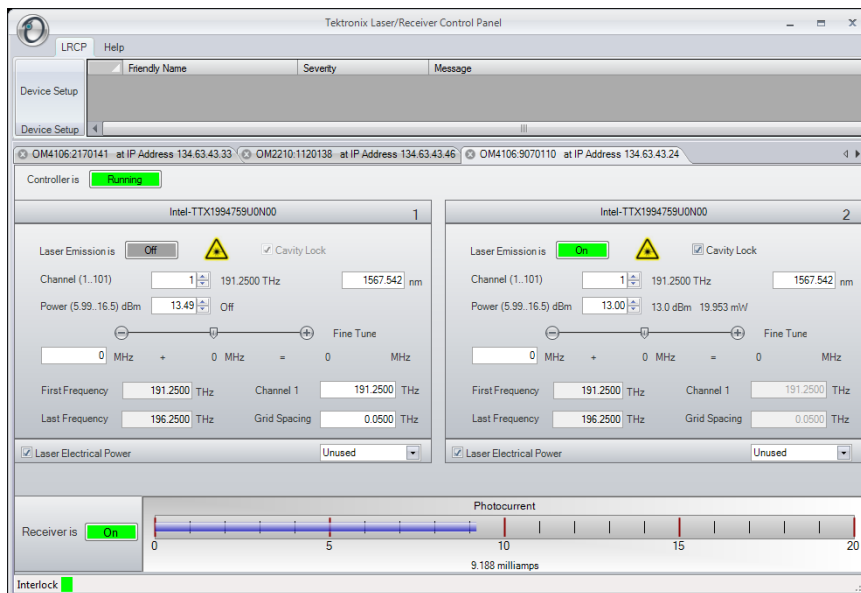
Before using LRCP, you must make sure that IP addresses of the OM series instruments are set correctly to communicate with LRCP on your network. The following sections describe how to set the OM instrument IP addresses for use on DHCP and non-DHCP networks.

Set IP address for DHCP-enabled network

The OM instrument is set with automatic IP assignment (DHCP) enabled by default. Therefore you do not need to specifically set the instrument IP address, as the DHCP server automatically assigns an IP address during instrument power-on.

The following procedure describes how to use LRCP software to verify connectivity of the OM instrument to a DHCP-enabled network.

Prerequisite: OM instrument, and a controller PC (with LRCP software installed), both connected to the same DHCP-enabled network.

1. Connect the OM instrument to the DHCP-enabled network.

2. Power on the OM instrument with the rear power switch (set to **1**). The instrument queries the DHCP server to obtain an IP address. Wait until the front panel Power button light turns off.

3. On a PC connected to the same network as the OM instrument, start the **LRCP** program.

4. Enter password **1234** when requested.

5. When running LRCP for the first time after installation, click on the **Configuration/Device Setup** link on the application screen to open the Device Setup window. Otherwise click the **Device Setup** button (upper left of application window).

6. In the **Device Setup** dialog box, click the **Auto Configure** button. LRCP searches the network and lists any OM instruments that it detects. If no devices are detected, work with you IT resource to resolve the connection problem.

7. (optional) Use the **Friendly Name** field to create a custom label for each instrument. There is no limit to the size of the name you enter.

8. Click **OK** to close the configuration dialog box and return to the LRCP main window. The main LRCP window displays a tab for each instrument detected. Click on a tab to display the laser controls for that instrument.

Set IP address for a non-DHCP network

To connect the OM series instrument to a non-DCHP network, you must reset the default IP address and related settings on the OM instrument to match those of your non-DHCP network. All devices on this network (OM instruments, PCs and other remotely accessed instruments such as oscilloscopes) need the same subnet values (first three number groups of the IP address) to communicate, and a unique instrument identifier (the fourth number group of the IP address) to identify each instrument.

Work with your network administrator to obtain a unique IP address for each device. Your network administrator may need the MAC addresses of the computer, oscilloscope, and OM instrument. The MAC address for the OM instrument is located on the rear panel label.

NOTE. Make sure to record the IP addresses used for each OM instrument, or attach a label with the new IP address to the instrument.

If you are setting up a new isolated network just for controlling OM and associated instruments, Tektronix recommends using the OM instrument default IP subnet address of **172.17.200.XXX**, where XXX is any number between 0 and 255. Use the operating systems of the oscilloscope and computer to set their IP addresses.

NOTE. If you need to change the default IP address of more than one OM instrument, you must connect each instrument separately to change the IP address.

There are two ways to change the IP address of an OM series instrument:

- Use LRCP on a PC connected to a DHCP-enabled network (easiest)

- Use LRCP on a PC set to the same IP address as the OM instrument to change the OM instrument IP address

Use DHCP network to change IP address. To use a DHCP network to change the IP address of an OM instrument:

1. Do steps 1 through 6 of the *Set network access (DHCP network)* procedure.

2. Click the **Set IP** button in the instrument list.

3. Use the dialog box to enter the new IP address and related parameters for the OM instrument.

4. Click **OK** to close the dialog box and set the IP address.

5. Exit the LRCP program.

6. Power off the OM instrument and connect it to the non-DHCP network.

7. Run LRCP and use the **Auto Config** button in the Device Setup dialog box to verify that the instrument is listed.

Use direct PC connection to change IP address. To use a direct PC connection to change the default IP address of an OM series instrument, you need to:

- Install LRPC on the PC

- Use the Windows Network tools to get the IP address of the PC to match that of the current subnet setting of the OM series instrument whose IP address you need to change

- Connect the OM instrument directly to the PC (not over a network)

- Use LRCP to change the OM instrument IP address

Do the following steps to use a direct PC connection to change the IP address of an OM series instrument:

NOTE. The following instructions are for Windows 7.

NOTE. If you need to change the default IP address of more than one OM instrument using this procedure, you must connect each instrument separately to change the IP address.

1. On the PC with LRCP installed, click **Start > Control Panel**.

2. Open the **Network and Sharing Center** link.

3. Click the **Manage Network Connections** link to list connections for your PC

4. Right-click the **Local Area Connection** entry for the Ethernet connection and select **Properties** to open the Properties dialog box.

5. Select **Internet Protocol Version 4** and click **Properties**.

6. Enter a new IP address for your PC, using the same first three numbers as used by the OM instrument. For example, **172.17.200.200**. This sets your PC to the same subnet (first three number groups) as the default IP address setting for the OM series instruments.

7. Click **OK** to set the new IP address.

8. Click **OK** to exit the Local Area Connection dialog box.

9. Exit the **Control Panel** window.

10. Connect the OM instrument to the PC.

11. Power on the OM instrument with the rear power switch (set to **1**). Wait until front panel Power button light turns off.

12. On the PC connected to the same network as the OM instrument, start the **LRCP** program.

13. Enter password **1234** when requested.

14. Click **Device Setup** to open the Device Setup window.

15. Click the **Auto Configure** button. LRCP detects and lists all OM instruments connected to the PC or network. If LRCP does not list the connected instrument, verify that you entered a correct IP address into the PC and your Ethernet cable is good. If the IP address was entered correctly, you may need to connect the OM instrument to a DHCP network to determine if the IP address you used to set the computer was correct.

16. (optional) Use the **Friendly Name** field to create a custom label for each instrument. There is no limit to the size of the name you enter. Friendly Names are retained and are associated with the MAC address of each instrument.

17. Click the **IP address** button in the list.

18. Click **OK** to continue to the **Set IP Address** dialog box.

19. Set the address to an IP Address that is compatible with your network. For example, **172.17.200.040**

20. Edit the Gateway and Net Mask (obtain this information from your network support person).

21. Click **Set IP** to exit the IP address dialog and return to the LRCP main window.

NOTE. If you change the instrument to an IP address that is different than the Subnet of the current PC, and click Set IP, the OM series instrument is no longer detectable or viewable to that PC and the LRCP application.

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22. Exit the LRCP program.

23. Unplug the network cable from between the PC and the OM instrument.

24. Connect the OM instrument to the target network.

25. Run the LRCP software on the PC connected to the same network as the OM instrument.

26. Click **Device Setup**. Click **Auto Config** and verify that the instrument is detected and listed on the display.

Typical setup configurations

The following figure shows how to set up the OM2210 (Option NL) to calibrate the OM4000 Series Coherent Lightwave Signal Analyzer.
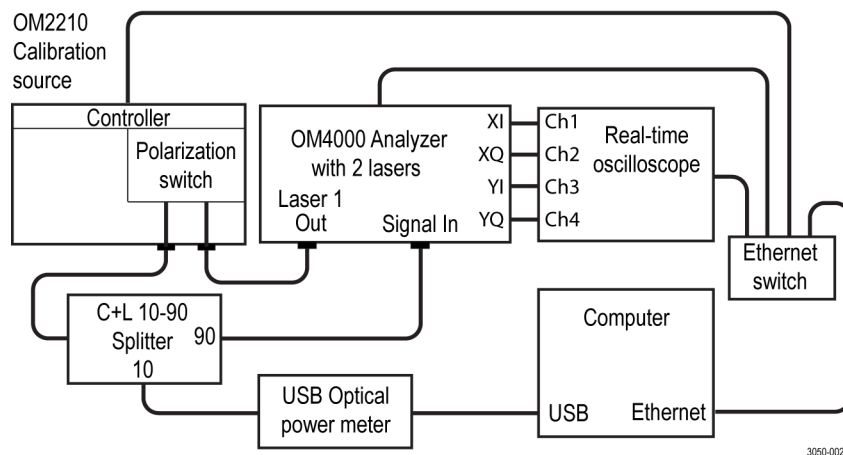
Connect the Polarization Switch Output to the input fiber of the optical splitter (provided).

Connect the 90% output fiber of the splitter to the OM4000 Signal Input.

Connect the 10% output fiber of the splitter to the optical power meter (provided).

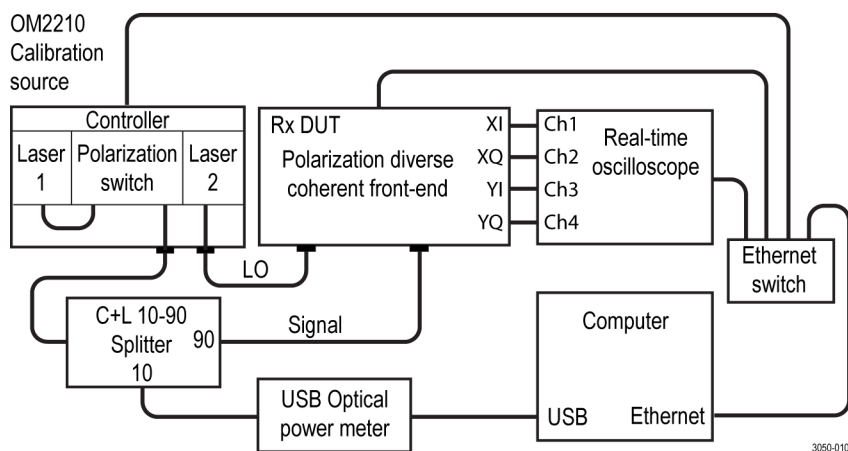Connect the power meter to the computer used to run the calibration.

Connect the OM4000 X and Y I/Q outputs to the oscilloscope using high-quality SMA cables of equal electrical length.

Connect the OM2210, OM4000 Analyzer, oscilloscope, and computer to an Ethernet router switch or over a network.

The OM4000 User Interface (OUI) running on the computer controls the oscilloscope, while the Laser-Receiver Control Panel (LRCP) controls the OM4000 and the OM2210.

NOTE. A password is required to turn on the lasers from the Laser Receiver Control Panel software. The default password is 1234.
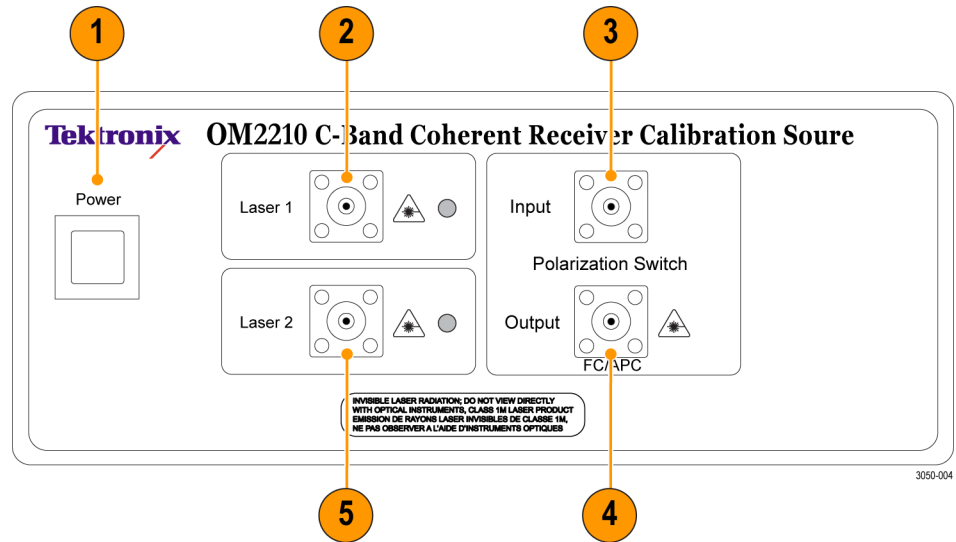
The following is the setup configuration for receiver testing (OM2210 option CC or LL):

OM2210 Calibration Source

Operating basics

OM2210 controls and connectors

Front panel

OM2210 C-Band Coherent Receiver Calibration Source

Tektronix

Power

Laser 1

Laser 2

Input

Polarization Switch

Output

FC/APC

INVISIBLE LASER RADIATION; DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS, CLASS 1M LASER PRODUCT EMISSION DE RAYONS LASER INVISIBLES DE CLASSE 1M, NE PAS OBSERVER A L'AIDE D'INSTRUMENTS OPTIQUES

3050-004

1. On/Off standby switch

2. Laser 1 output (with LED indicator)

3. Polarization switch input

4. Polarization switch output
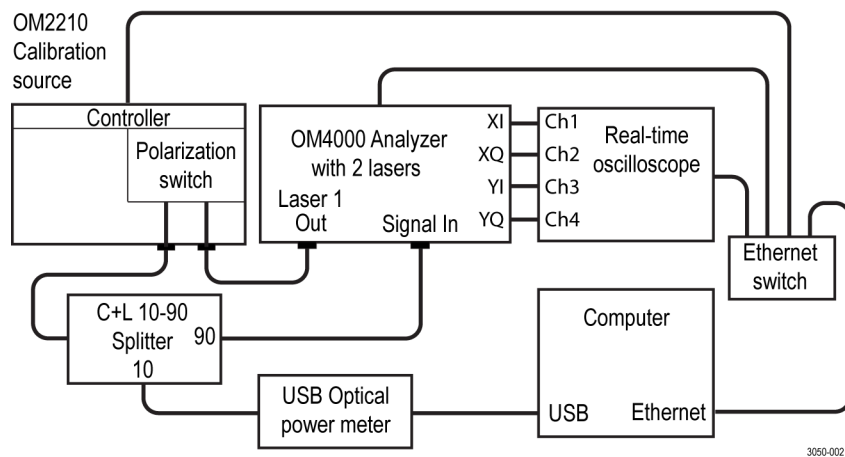
5. Laser 2 output (with LED indicator)

Rear panel
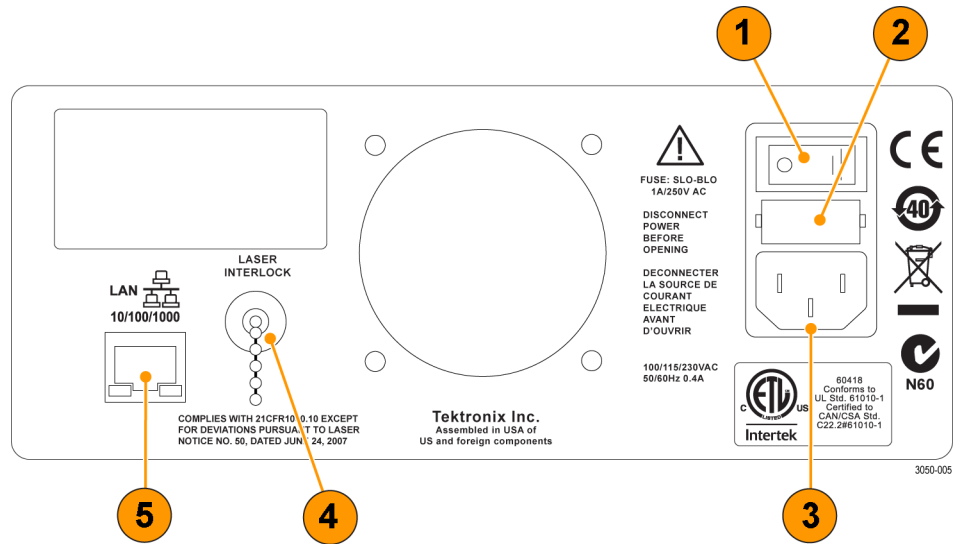
1. Main power switch

2. Fuse holder

3. Power cable connector

4. BNC shorting plug for optional laser remote interlock connector

5. Ethernet port

Equipment setup

Refer to the following diagram to connect the OM2210 to calibrate the OM4000 Series analyzer.

Once everything is securely placed, make electrical connections in the following order:

1. Ethernet connections and other computer connections.

2. Power connections for the OM2210 and other equipment.

3. RF connections from the DUT to oscilloscope.

4. Fiber optic patch cable connections from the OM2210 to the DUT.

5. Store all dust covers and coaxial connector caps for future use.

Once the equipment is connected, turn on the computer, the oscilloscope, the DUT, and the main power switch on the back of the OM2210. The OM2210 front-panel power button will light briefly after main power is applied indicating it is searching for a DHCP server. When an IP address has been assigned or when the search fails in the case of an isolated network, the power light will go off.

Press the power button one time to enable the unit. The steady power button light indicates the OM2210 is ready for use and that lasers may be activated at any time if a user connects via the Ethernet connection. The light will go out and the unit will be disabled any time main power is removed or the IP address is changed. Press the power button to re-enable. This feature prevents a remote user from activating the lasers when the local user may not be ready.

NOTE. Ethernet only allows devices on the same subnet to communicate.

You should now have four devices on an Ethernet network: computer, oscilloscope, DUT, and OM2210. This little network may be connected to your corporate network or router or you may choose to leave it isolated. IP setup is normally done at the time of installation. You should only need the following instructions if you are reconfiguring your network.

OM2210 Hybrid Receiver Calibration (HRC) software

Installation

Please see the software installation instructions when installing the software. You should have an up-to-date installation of the OM4000 OUI Software before installing the Hybrid-Receiver Calibration (HRC) software.(See page 8, *Software installation*.)

An important part of the OM instrument software is the copy protection provided by the USB HASP key. The HASP key:

■ Prevents the software from being run in more places than there are HASP keys

■ Enables options such as QAM and hybrid calibration

When the software installation is complete, see which features are available on your key by plugging it in to your computer and directing a web browser to http://localhost:1947. Click on **HASP Keys and Features**. The following table lists possible features, the actual displayed list depends on your purchased options:

| Feature number	Description
3	OM4000 User Interface (OUI)
4	OM4000 Signal Analysis Software
14	QAM and advanced formats
15	Hybrid Calibration
16	MCS Multicarrier support

Using the HRC software

The OM2210 Hybrid Receiver Calibration (HRC) program controls the OM4000 User Interface (OUI) and the Laser Receiver Control Panel (LRCP) software. The OUI in turn controls the oscilloscope, while the LRCP controls the OM4000 hardware. To launch the complete application, do the following:

1. Follow the instructions in the *Getting Started* section to install software and get the hardware configured properly and powered up.

2. Insert the HASP USB key into the controller PC before starting up the OUI or HRC software.

3. Launch the **OUI** software (from the desktop shortcut or the Start > All Programs menu).

4. Click the **Setup** tab and do the following (for more information on the OUI software, see the *OM4106D and OM4006D Coherent Lightwave Signal Analyzer User Manual*):

   a. Select the **Use Visa** box.

   b. Click **Connect**.

   c. Use the dialog box to select four oscilloscope channels.

   d. Enable all four channels.

   e. Click **Disconnect**.

5. Launch the **LRCP** application (from the desktop shortcut or the Start > All Programs menu).

6. Connect to the OM instrument hardware that will be used for the calibration. Turn on the lasers that will be used for the calibration and tune them to the appropriate wavelength. (See page 29, *The Laser Receiver Control Panel (LRCP) user interface*.)

7. Connect the USB Power Meter to the computer that is running the HRC. Be sure both lights on the Power Meter are on.

8. Launch the HRC software (from the desktop shortcut or the Start > All Programs menu).
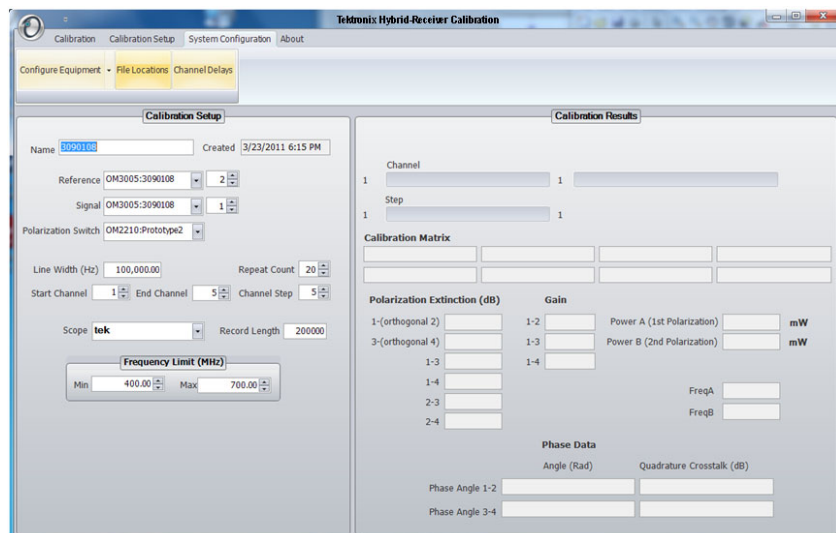
9. Set the following parameters in HRC:

   a. Click on **System Configuration** tab.
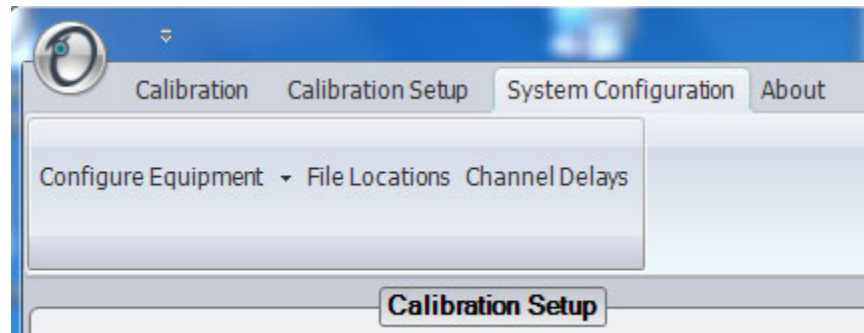
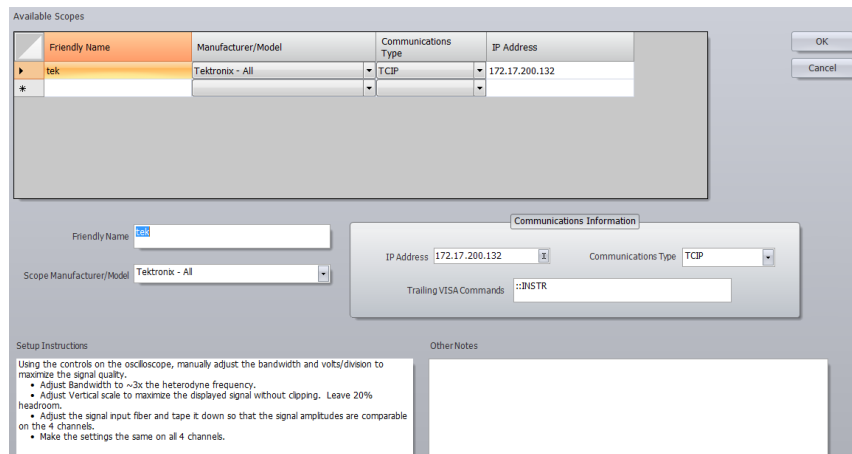b. Click **Configure Equipment > Configure Laser Source**.
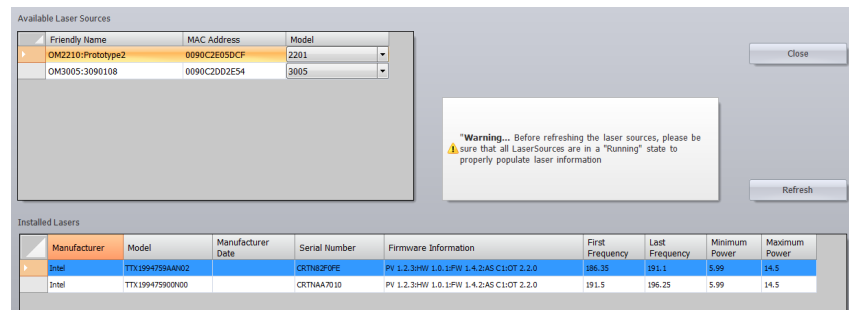
c. Verify that the that LRCP window shows a connection to the Calibration Source (OM2210) and to all of the laser sources to be used in the calibration (such as an OM4106D).

d. Click **Refresh** to pull the information from the LRCP into the HRC. Verify that the list in the HRC shows connections to all laser sources.

e. Click **Close**.

10. Click **Configure Equipment > Configure Oscilloscope** to set the oscilloscope connections. Each oscilloscope setup has a Friendly Name that you can use to label an instrument, which can be used for recalling the settings.

11. Follow the information in the **Setup Instructions** pane to acquire and display a good heterodyne signal on the oscilloscope.

12. Always press the **Single** button on the oscilloscope front panel, after making adjustments on the oscilloscope front panel, to get it ready for external control.

13. **Close** the Configure Oscilloscope window when done.

14. Click **File Locations**:

– The default location for the CoreProcessing Directory is C:\Program Files (x86)\Optametra\OUI4006\. Don't change this unless the OUI installed to a different directory. For example, C:\Program Files\Optametra\OUI4006\.

– Browse to where you would like to save the results files by clicking on the **Folder** icon on the **Results Folder** row. It is best to choose … My Documents\Optametra\Hybrid-Receiver Calibration\ to easily find the files again.

– **Close** the File Locations window when done.

15. Click **Configure Power Meter**:

– Enter the correct serial number to replace the default value. The Power Meter serial number is printed on the body of the Power Meter. The connect string value, USB0::0x1313::0x8072::P2000608::INSTR has the serial number as the last digits (P2000608 in this example).
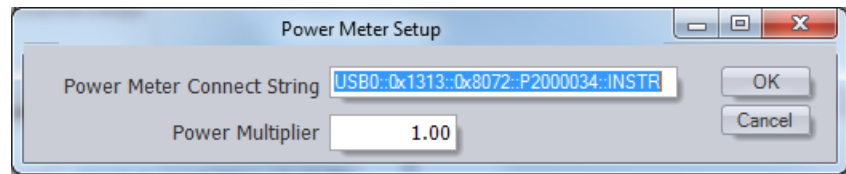
- Select a Power Multiplier of 10 if you are using a 10% coupler to monitor the power.

16. Click the **Calibration Setup** tab.
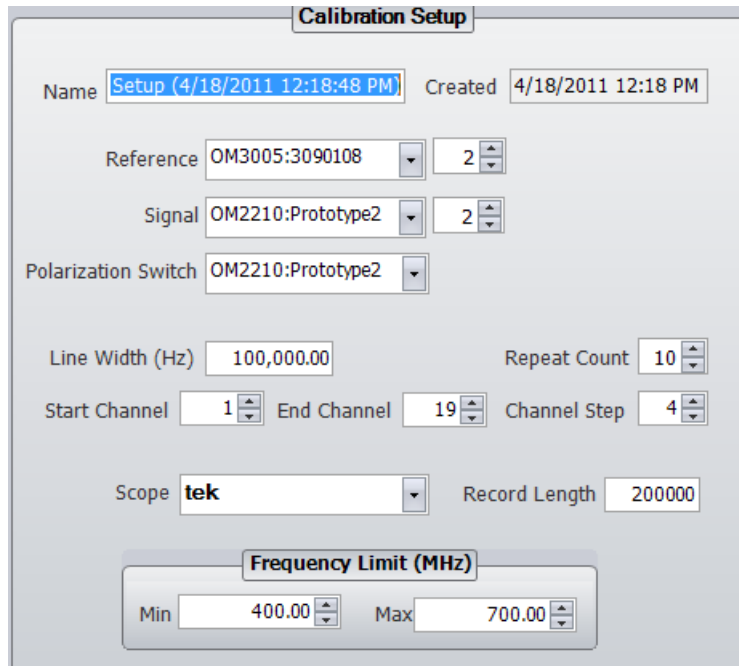
17. Click **New** in the upper left of the Calibration Setup tab to enter the Calibration Setup parameters:

   - Name: this is the base name that will be used with the time and date to form the filename for the results. It will also be used to recall this setup in the future. Use the serial number of the device under test for easiest recall of data.

   - Choose the Reference Laser (LO), Signal Laser (the one connected through the polarization switch), and Polarization Switch using the drop-down menus.

   - Laser Line Width in Hz. This sets the time constant for the phase recovery algorithm. Only an estimate is required. 100,000 is the best choice for OM instrument ECDLs.

   - Start Channel, End Channel, Channel Step define the wavelength channels over which the calibration will be performed. The channel definition is set

by the LRCP. The calibration will be taken a number of times set by the Repeat Count and then averaged for each wavelength.

- The Record Length should be set so that the time window width on the oscilloscope is at least 0.2 / (Line Width) or more. For a 100,000 Hz Line Width, a good choice is a 4 μs window which is 200,000 samples at 20 ps/sample.

- Select the oscilloscope configuration from the drop-down menu.

- Set the frequency limit for the heterodyne frequency during the calibration. Typical values of 400 to 900 MHz work well with ~40-50 Gs/s oscilloscopes. The frequency can be lower for lower sampling rates. The upper frequency should be <1/3 the system bandwidth to minimize phase error. Setting the oscilloscope bandwidth filter to 3 GHz on all four channels will reduce the noise while providing sufficient bandwidth for ~1 GHz heterodyne frequencies.

- Click **Save** to store your settings for future use.

**18.** Click **System Configuration > Channel Delays**:
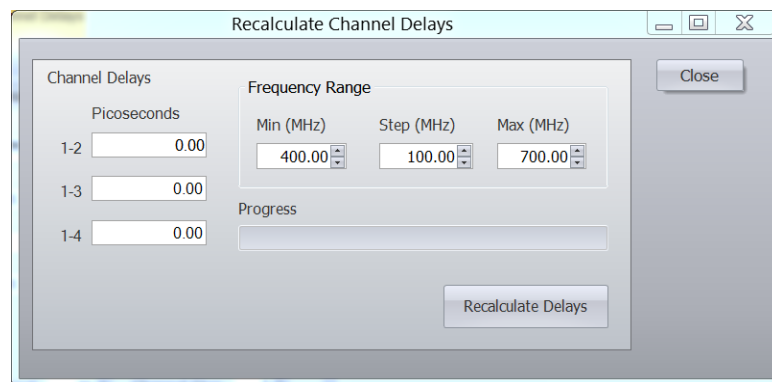
- Enter the relative skew between channels 1 and 2, 1 and 3, and 1 and 4 in the boxes provided if known. To determine the relative channel delays, this utility can measure phase versus frequency over a given range and find the average slope. Enter the min and max frequencies for the utility to use. These should auto-populate to be equal to the range shown on the Calibration Setup window, but you can measure delays over any frequency range less than 10 GHz. The range chosen should also be less than ~1/3 the oscilloscope bandwidth setting. Once the range is set, click Recalculate Delays.

- Once the utility completes a sweep over the desired range at a wavelength in the center of the band to be tested, it will fill in the Channel Delays. Inspect the MATLAB plot to verify that the data was taken over the desired range and is well behaved. You may also type Status in the separate MATLAB program window to see the rms and peak phase error in the measurement. Close the Recalculate Channel Delays utility to use the calculated delays.

19. (FOR ADVANCED USERS) As mentioned above, entering a Frequency Range and clicking on Re-calculate Delays will sweep the heterodyne frequency while measuring the resulting channel-to-channel phase relationship. The slope of the phase versus frequency plot gives the average channel delays.

Alternatively, you can run the FindChannelDelays function from the OUI MATLAB Engine Window. Running the function manually gives you more control over which frequencies are used for the delay calculation. When complete, type Status in the MATLAB Command Window to see the results and error magnitude information.

20. The system configuration is complete. Click on **Calibration > Start Calibration** to start the calibration process.
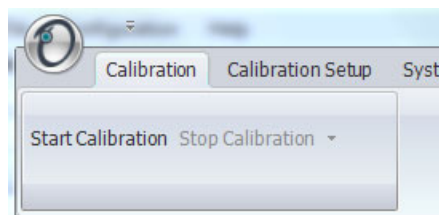
21. The calibration tool opens the Verify Calibration Settings dialog box, where you can review the calibration and equipment settings before starting the calibration.
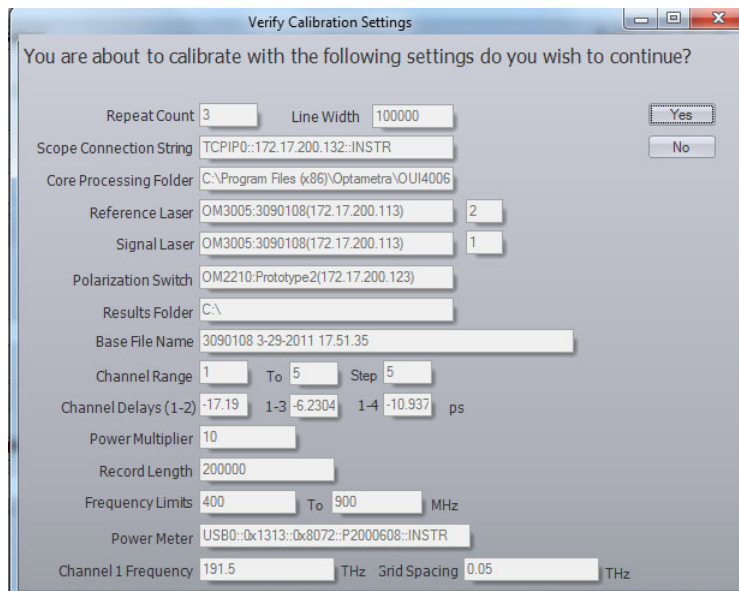
22. Click **Yes** to start the calibration measurement process. Calibration measurements may take approximately 1 hour to finish depending on the number of repeats and the selected wavelengths.

23. As the HRC executes, it shows the results of each step in the "Calibration Results" pane. The pane shows the channel and step status as well as the following:

- Calibration Matrix: The actual values being output to the calibration data file

- Polarization Extinction: A list of calculated crosstalk levels based on the measured calibration matrix

- Gain: the Relative gain between channels

- Power A, B: Power measured for each polarization setting

- Freq A, B: Measured heterodyne frequency at each polarization setting

- Phase Data: Quadrature phase angles and calculated I-Q crosstalk

24. See the Results section for information about measurement results.

Results

As the HRC executes, it shows the following results in the Calibration Results pane, located on the right side of the window:

- Channel and step status

- Calibration Matrix: The actual values being output to the calibration data file

- Polarization Extinction: A list of calculated crosstalk levels based on the measured calibration matrix

- Gain: The Relative gain between channels

- Power A, B: Power measured for each polarization setting

- Freq A, B: Measured heterodyne frequency at each polarization setting

- Phase Data: Quadrature phase angles and calculated I-Q crosstalk

The output of the calibration is both a hybrid-matrix data set and a set of calculated performance metrics. These data are plotted and updated at each wavelength step. Channels 1,2,3,4 are X-I, X-Q, Y-I, Y-Q respectively. Example data is shown in the following plots:
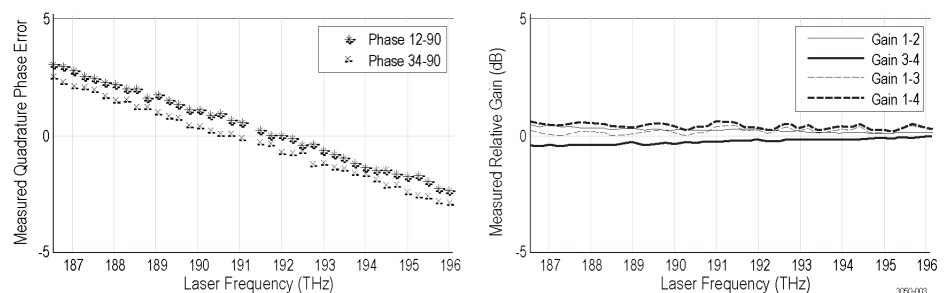
These plots are calculated from the pHybTable variable which is the primary output of the program. The pHybTable has one row for each laser channel tested: a column for each of the 8 entries in the complex pHyb matrix and a first column for the laser channel frequency. This information is stored in the following ways:

1. The pHybCalib.mat file. This file is designed for use with the OUI4006. To do so, move the file from the place designated in the File Locations path to Program Files (x86)\Optametra\ExecFiles. Move and rename the old version in case you need to go back. When using the OUI, you may type pHybInUse in the MATLAB OUI window or separate MATLAB program window to see which file is in use.

2. The data is also stored in .mat, .csv, and .xls files in the directory indicated in the File Locations dialog box.

3. The configuration information is stored in an SQL database called OPTAMETRA in the OPTAMETRACONFIG SQL server. SQL Server Management Studio Express (SSMSE) from Microsoft is a free program that can be used to examine the database.

The Laser Receiver Control Panel (LRCP) user interface

The Laser-Receiver Control Panel application (LRCP) is used to control Integratable Tunable Laser Assembly (ITLA) lasers. The LRCP interface simplifies the control of the lasers, eliminating the need to use low level ITLA commands. The interface automates locating and configuring all OM devices that are present on the local network. It also provides a Windows Communication Foundation (WCF) service interface, allowing Automated Test Equipment (ATE) to interact directly with the controllers and lasers while LRCP is running.
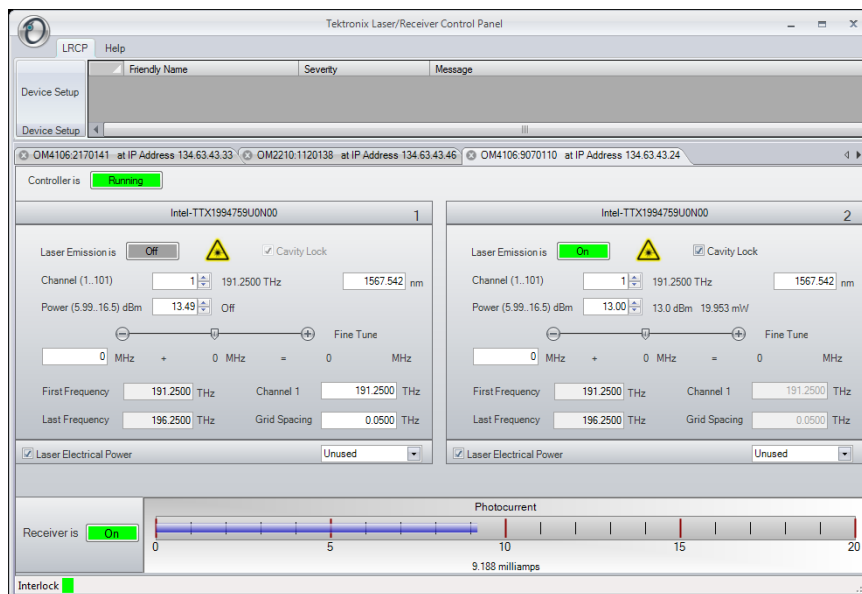
The main components of the LRCP user interface are:

- Menu tabs: Lists available application actions.

- Controller tabs: Each tab represents one physical Laser Control device (for example, an OM4000 or an OM2210) on the network. The tab shows the controls for the one or more lasers that are associated with the device.

- Status bar: provides important information about the overall state of the communications with the controllers. Each controller has a unique status bar.

- Receiver gauge: This gauge displays the total photocurrent output from an instrument. This readout is only functional on devices like the OM4000 instrument that have the appropriate hardware installed.

Device setup and auto configure

Click the Device Setup button to open the Device Setup dialog box. Use this dialog box on initial setup of the controllers and anytime network configuration changes and devices are moved to a new IP address. Click the Auto Configure button to have LRCP search for and list detected OM devices.

An important setting on the Device Setup screen that users will want to adjust is the Friendly Name. Setting this value for each device will aid in the identification of the physical location of the controllers as Friendly Names are retained and are tied to the corresponding MAC Address. Make sure to exit the form by clicking the OK button to save changes.

The Set button is used to modify the addressing as described in the next section. It is not necessary to use the Set button to change the Friendly Name.

Each device must be assigned an IP address in order to communicate with the device. How you manage IP addresses in your network, namely with or without DHCP, will determine the method in which you connect to the devices on your network.

Connecting to your OM devices

Once configured and detected, devices are listed as tabs on the main LRCP screen. They are listed with the friendly name and IP address to allow for easy identification. Up to four lasers are displayed in a 2x2 grid. Lasers are numbered and once the controller is brought online the laser panels will populate with the laser manufacturer and model number.

Once the user presses the button that reads Offline the button will change colors as the control panel attaches to the OM4000 instrument. First, the button will turn yellow and read "Connecting…" indicating that a physical network connection is being established over a socket. Second, the button will turn teal and read "Connected…". This indicates that a session is established between the device and Control Panel. Commands will be sent to initialize the communications with the laser and identify their capabilities. Finally, the button will turn bright green when the controller and lasers are ready for action.

NOTE. The button color scheme of bright green meaning running or active, grey meaning off line or inactive and red indicating a warning or error state is consistent throughout the application.

Once the controller tab is active and the laser panels have populated with the corresponding laser information the user is free to put change the laser settings and/or turn the lasers on. When the controller is first turned on the current state of the hardware is read to pre-populate the laser panel. Any time you exit application, the current state of the lasers is preserved, including the emission state.

If the lasers are used in conjunction with the OM4000 instrument and OUI, the laser usage type needs to be set using the dialog on the lower right corner of each laser panel. The OUI uses the setting to determine from which laser frequency information is retrieved. A usage type can only be selected once between all of the controllers but you can have one usage type on one controller and another usage type on a second controller.

Once laser emission is "On" the channel 1 and grid spacing settings become read only and cavity lock becomes editable. Also the power goes from "off" to the actual power being read from the laser. Readings are taking from the laser once per second.

The receiver gauge (shown at the bottom of the LRCP window) is only active for equipment that have the appropriate hardware present (such as the OM4000 instruments). The receiver gauge, when active, displays the total photocurrent.

Setting laser parameters

NOTE. For all text field entries it is necessary to click away from the field, or press the Tab key, for the value entered to be accepted by the application.

CAUTION. The LRCP saves all laser parameter settings, including the emission output value, when you exit the application, including the emission state. Make sure to verify laser emission parameters before running tests on a new test setup.

- **Channel**: Type a number or use the up/down arrows to choose a channel. The range of channels available will depend on the type of laser, the First Frequency, and the Grid. The finer the Grid, the more channels are available for a given laser. The channel range is indicated next to the word Channel. The laser channel can also be set by entering a wavelength in the text box to the right of the channel entry. The laser will tune to the nearest grid frequency.

- **Cavity Lock**: The Intel/Emcore ITLA laser that is included in the OM4000 instrument has the ability to toggle its channel lock function. Ordinarily, Cavity Lock should be checked so that the laser is able to tune and lock on to its frequency reference. However, once tuning is complete and the laser has stabilized, this box can be unchecked to turn off the frequency dither needed for locking the laser to its reference. The laser can hold its frequency for days without the benefit of the frequency dither. The OM4000 software will work equally well with the Cavity Lock dither on or off.

- **Power**: The allowed power range for the laser. Type or use the up/down arrows to choose the desired laser power level.

- **Fine Tune**: The Intel/Emcore lasers can be tuned off grid up to 12 GHz. This can be done by typing a number in the text box or by dragging the slider. The sum of the text box and slider values will be sent to the laser. Once the laser has accepted the new value it will be displayed after the '=' sign.

- **First Frequency**: Not settable. This is the lowest frequency that can be reached by the laser.

- **Last Frequency**: Not settable. This is the highest frequency that can be reached by the laser.

- **Channel 1**: Settable when emission is off. This is the definition of Channel 1.

- **Grid Spacing**: Settable when emission is off. 0.1, 0.05 or 0.01 THz are typical choices. Use 0.01 THz if tuning to arbitrary (non-ITU-grid) frequencies. Using this grid plus Fine Tune, any frequency in the laser band is accessible.

- **Laser Electrical Power**: This should normally be checked. Unchecking this box turns off electrical power to the laser module. This should only be needed to reset the laser to its power-on state, or to save electrical power if a particular laser is never used.

- **Emission**: Click to turn on or off front panel laser emission.

Channel setting within the ITLA grid gives the corresponding frequency (in THz) and wavelength (in nm). Power is set within the range allowed by the laser. It is best to set the Signal and Reference lasers to within 1 GHz of each other. This is simple if using the internal OM4000 instrument lasers: just type in the same channel number for each.

If using an external transmitter laser, you can type in its wavelength and the controller selects the nearest channel. If this is not close enough, try choosing a finer WDM grid or use the fine tuning feature. If available, fine tuning of the laser is done with the Fine Tune slider bar, and typically works over a range of ±10 GHz from the center frequency of the channel selected.

Certain laser models have a cavity lock feature that increases their frequency accuracy at the expense of dithering the frequency; this feature can be toggled with the Cavity Lock button. Cavity Lock is necessary to tune the laser, but can be unchecked to suppress the dither.

Once the channel and power for each laser is set, turn on laser emission for each laser by clicking on its Laser Emission button; the emission status is indicated both by the orange background of the button and by the corresponding green LED on the OM4000 instrument front panel.

HRC function reference

The functions provided with the HRC program are intended for use with the HRC. However, these functions can be run separately. The function reference provides some guidance on how to use these functions. It is highly recommended to use the HRC first and examine the results before attempting to use the MATLAB functions outside of HRC.

FindChannelDelays

This function plots relative phase versus frequency, then finds the slopes which are the relative channel delays.

Input parameters

FindChannelDelays assumes the following variables are in the workspace:

- **Vblock**, a 4-element array (one for each channel) created by the OUI after a data acquisition from the oscilloscope. Vblock has the following fields:

    - **.dt**, the time spacing between samples.

    - **.t0**, the time of the first sample.

    - **.Values**, a row array of the actual digitized voltages.

- **acq**, initially empty, stores the number of data acquisitions used to make the phase versus frequency diagrams.

NOTE. acq must be reset to empty [] or cleared to start a new ChannelDelay measurement. If acq does not exist, it will be created and set to empty. If acq has a value, FindChannelDelays will build on the existing data in the workspace.

Output variable

- **Status** has fields providing the estimated channel delays as well as a report on the fitting error.

Using this function

FindChannelDelays is intended to be called automatically by the Hybrid-Receiver Calibration program (HRC). However, it can be used as a stand-alone function as follows:

1. Set up the hardware (See page 18, *Equipment setup*.). The signal levels should be approximately the same on the four channels.

2. Launch the OUI and the LRCP programs.

3. Use the LRCP to establish a beat-frequency on the oscilloscope that is equal to the highest beat frequency you would like to use for finding the Channel Delays

4. Set the Record Length to approximately 200,000 points.

5. In the OUI, show the MATLAB Engine Window and type in FindChannelDelays as shown below. Delete anything else from the window. Optionally, put peak-freq(Vblock(1)) also in the window to report the current frequency.

6. Connect to the oscilloscope and click Run on the OUI. This can be done remotely by issuing the Single command in a loop.

7. Once the OUI is running, FindChannelDelays will begin to build the diagrams for finding phase versus frequency. After several acquisitions, a MATLAB plot will appear.

8. Watching either the MATLAB plot, or using the function peakfreq in the Engine Command Window, use the LRCP to decrease the beatnote frequency until you achieve the lowest frequency to be used in the plot. Data will be continuously added to the plot as the laser is tuned.

9. It is important to keep the minimum beat frequency above 200 MHz so that the lasers retain their relative positions. If the laser which was higher in frequency becomes the laser lower in frequency, it is possible there will be some phase discontinuity.

10. Once the plots appear, a Status variable will be updated continuously. The Status variable contains the latest estimate for the Channel Delays as well as a report of how well the data fit a straight line.

peakfreq

function [Fpeak] = peakfreq(V)

This function returns the frequency of a sine wave based on data found in the Vblock variable which is passed as an argument, V.

Input parameters   `Vblock(n)`, where n is the channel number.

Using this function   Place the following command in the OUI Engine Command window to show the frequency of the highest FFT peak, ignoring zero frequency.

`peakfreq(Vblock(1))` % reports the peak frequency on Channel 1. The frequency should be the same on all four channels.

CalHybridTwoSOPs

function pHyb =
CalHybridTwoSOPs(VA,PowA,VB,PowB,ChDelay,Linewidth,BoundValsIn,AlertsIn)

This function creates the pHyb variable which is a model of the hybrid receiver at the particular laser channel. The model is created based on two heterodyne measurements at orthogonal signal polarizations A and B.

Any input polarization state can be used for the calibration with the following constraints:

- The signal level on the oscilloscope should be sufficient to provide good SNR on all channels

- The two polarization states should be orthogonal to > 40 dB

Output variable   **pHyb** has two rows and four columns. It is a transfer function from Electric Field to Voltage representing the Hybrid Receiver function.

- The two rows correspond to Channel 1 + i*Channel 2, and Channel 3 + i*Channel 4.

- The four columns correspond to real(Ex), imag(Ex), real(Ey), imag(Ey).

A perfect hybrid receiver would have a pHyb = [1 i 0 0; 0 0 1 i] where the semicolon indicates the beginning of the next row.

Input parameters
- VA is the Vblock variable acquired when the Hybrid Receiver Signal Input was illuminated with polarization A.

- PowA is the optical power, in Watts, at the Signal Input when the Hybrid Receiver Signal Input was illuminated with polarization A.

- VB is the Vblock variable acquired when the Hybrid Receiver was illuminated with polarization B.

- PowB is the optical power, in Watts, at the Signal Input when the Hybrid Receiver Signal Input was illuminated with polarization B.

- ChDelay is the set of skew values, in seconds, found by FindChannelDelays. It is needed to eliminate skew error from the phase calculation.

- Linewidth is an estimate of laser linewidth, in Hertz, used for the signal estimation algorithm

- BoundValsIn is used by HRC software. Set it to [] empty.

- AlertsIn is used by HRC software. Set it to [] empty.

Using this function   CalHybridTwoSOPs is the function for determining the pHyb matrix to represent the Hybrid Receiver at a particular laser channel using two polarization measurements. It is designed to be used with the OM2210 Calibration Source and the HRC software.

To use this function without the HRC, do the following:

1. Set up the input signal as outlined in the HRC User Guide.

2. Use the OUI to take a single acquisition from the oscilloscope. Store this data as VA. For example, VA = Vblock.

3. Measure the optical power input to the DUT at the same moment that the data for VA is taken. Save this value in the variable PowA.

4. Flip the polarization input to the DUT to a state precisely orthogonal to the state used for measurement A.

5. Use the OUI to take a single acquisition from the oscilloscope. Store this data as VB. For example, VB = Vblock.

6. Measure the optical power input to the DUT at the same moment that the data for VB is taken. Save this value in the variable PowB.

7. Call the CalHybridTwoSOPs function using these values along with the laser Lin-ewidth and ChDelay values.

8. It is a good idea to calculate several pHyb results for each laser channel to reduce random error.

PostProcessFinalData

function pHybTable = PostProcessFinalData(FreqMin, FreqMax, PolExtMin, final_data, final_extra_data)

This function creates the pHybTable based on the parameters passed. After removing invalid rows, the remaining rows are averaged if they are for the same laser channel. The result is a single valid entry for each laser channel.

NOTE. This function is used by HRC which creates the final_data and final_extra_data rows.

Output variable   **pHybTable** is a 2-d array with a row for each laser frequency and a column for each entry in a table which models the DUT function. The table, called the pHyb, has 2 rows and four columns, but is represented here as 8 columns, second row appended to the first, so that there can be a pHyb for each row (laser frequency).

Input parameters   `final_data` is the pHybTable prior to removing the invalid rows and averaging

`final_extra_data` is the corresponding table of hybrid performance metrics and heterodyne frequencies. Each row corresponds to the same row in final_data. final_extra_data has a row for each laser channel tested, with the following columns:

- Column 1: Laser Channel Frequency in Hz

- Column 2: Relative gain of Channel 2 relative to the gain of Channel 1, in linear units.

- Column 3: Relative gain of Channel 3 relative to the gain of Channel 1, in linear units.

- Column 4: Relative gain of Channel 4 relative to the gain of Channel 1, in linear units.

- Column 5: Hybrid phase angle for H-polarization (Channel 2 relative to Channel 1), in radians.

- Column 6: Quadrature crosstalk in dB (Channel 1 and Channel 2)

- Column 7: Hybrid phase angle for V-polarization (Channel 4 relative to Channel 3), in radians.

- Column 8: Quadrature crosstalk in dB (Channel 3 and Channel 4).

- Column 9: Colinearity of Channel 1 and Channel 2 in dB.
  0 dB = orthogonal; –inf = parallel.

- Column 10: Colinearity of Channel 3 and Channel 4 in dB.
  0 dB = orthogonal; –inf = parallel.

- Column 11: Crosstalk of Channels 1 and 3, in dB.

- Column 12: Crosstalk of Channels 1 and 4, in dB.

- Column 13: Crosstalk of Channels 2 and 3, in dB.

- Column 14: Crosstalk of Channels 2 and 4, in dB.

- Column 15: Heterodyne frequency at first measurement for CalHybridTwoSOPs.

- Column 16: Heterodyne frequency at second measurement for CalHybridTwoSOPs.

`FreqMin` is the minimum frequency in Hz. If a row in the final_extra_data file indicates a heterodyne frequency less than FreqMin, the row will not be included in pHybTable.

`FreqMax` is the maximum frequency in Hz. If a row in the final_extra_data file indicates a heterodyne frequency greater than FreqMax, the row will not be included in pHybTable.

PolExtMin is the minimum polarization extinction in dB. If a row in the final_extra_data file indicates that the polarization extinction was worse than the minimum polarization extinction, that row will not be included in pHybTable. Set this to zero normally so that only nonphysical values will be excluded.

Using this function This function can be called any time the input data are available, but is intended to be used at the end of a data acquisition to consolidate and average the data. It creates the pHybTable which the OUI uses to correct for Hybrid Receiver impairments.

CalHybridExtraData

This is a script which calculates DUT metrics based on the pHybTable variable. It assumes that pHybTable is in the workspace. The script also plots the metrics versus laser channel (frequency in Thz). pHybTable is a 2-d array with a row for each laser frequency and a column for each entry in a table which models the DUT function. The table, called the pHyb table has 2 rows and four columns, but is represented here as 8 columns, second row appended to the first, so that there can be a pHyb for each row (laser frequency).

Output variable **pHybTable_extradata** is a table with one row for each row in the pHybTable. The columns are as follows:

Column 1: Laser Channel Frequency in THz

Column 2: Relative gain of Channel 2 relative to the gain of Channel 1, in linear units.

Column 3: Relative gain of Channel 3 relative to the gain of Channel 1, in linear units.

Column 4: Relative gain of Channel 4 relative to the gain of Channel 1, in linear units.

Column 5: Hybrid phase angle for H-polarization (Channel 2 relative to Channel 1), in radians.

Column 6: Hybrid phase angle for V-polarization (Channel 4 relative to Channel3), in radians.

Column 7: Colinearity of Channel 1 and Channel 2 in dB.
0dB = orthogonal; –inf = parallel.

Column 8: Colinearity of Channel 3 and Channel 4 in dB.
0dB = orthogonal; –inf = parallel.

Column 9: Crosstalk of Channels 1 and 3, in dB.

Column 10: Crosstalk of Channels 1 and 4, in dB.

Column 11: Crosstalk of Channels 2 and 3, in dB.

Column 12: Crosstalk of Channels 2 and 4, in dB.

Using this function　This function can be called any time the input data are available. It simply computes the performance metrics and plots them.

Appendix A: Cleaning and maintenance

Cleaning

- To clean the outside of the OM2210 enclosure, use a dry, soft cotton cloth. Do not use any liquid cleaning agents or chemicals that could possibly infiltrate the enclosure, or that could damage markings or labels.

- If the dust filter on the underside of the unit becomes clogged, use a small vacuum or brush to clean the filter.

- From time to time it will be necessary to clean the optical input and output connectors on the front of the unit. Use square-ended swabs made for this purpose to clean each connector.

- Do not attempt to clean the inside of the instrument; cleaning of internal parts is not necessary.

Maintenance

- There are no user-serviceable components or subsystems within the OM2210. Attempting any internal repairs will void your warranty. Never remove the external lid on the unit.

⚠ *WARNING. Removing the external lid and the internal cover on the optics package while the unit is operating will result in exposure to invisible laser radiation. Never view directly with optical instruments.*

- If it becomes necessary to replace the fuse in the power input module in the rear of the unit, use a 5X20 mm "slo-blo" fuse rated at 1 A, 250 VAC. Use a small screwdriver to gently pry open the fuse drawer.

⚠ *WARNING. Disconnect the unit from the power source when changing the fuse to ensure that line voltage is not present during the replacement.*

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