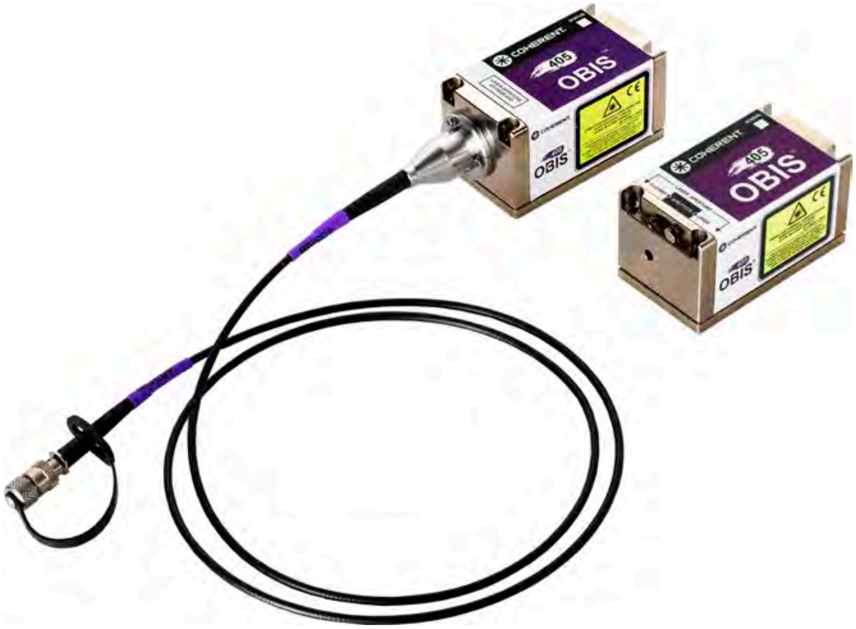
Integrator's Guide
Coherent OBIS™



COHERENT®

Integrator's Guide
Coherent OBIS

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Santa Clara, CA 95054

Patents referenced in this Integrator's guide were active as of the printing date of the manual (see last page for date). The patents referenced herein may have expired. You are advised to check to see if the patents are still active: http://portal.uspto.gov/external/portal/pair.

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Technical Support

In the US:

Should you experience any difficulties with your laser or need any technical information, please visit our website: www.Coherent.com. Additional support can be obtained by contacting our Technical Support Hotline at 1.800.367.7890 (1.408.764.4557 outside the U.S.), or e-mail Product.Support@Coherent.com. Telephone coverage is available around the clock (except U.S. holidays and company shutdowns).

If you call outside our office hours, your call will be taken by our answering system and will be returned when the office reopens.

If there are technical difficulties with your laser that cannot be resolved by support mechanisms outlined above, e-mail, or telephone Coherent Technical Support with a description of the problem and the corrective steps attempted. When communicating with our Technical Support Department via the web or telephone, the Support Engineer responding to your request will require the model and Laser Head serial number of your laser system.

Outside the US:

If you are located outside the U.S., visit our website for technical assistance or contact our local service representative. Representative phone numbers and addresses can be found on the Coherent website: www.Coherent.com.

Coherent provides telephone and web technical assistance as a service to its customers and assumes no liability thereby for any injury or damage that may occur contemporaneous with such services. These support services do not affect, under any circumstances, the terms of any warranty agreement between Coherent and the buyer. Operation of any Coherent laser with any of its interlocks defeated is always at the operator's own risk

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Signal Words and Symbols in this Manual

This documentation may contain sections in which particular hazards are defined or special attention is drawn to particular conditions. These sections are indicated with signal words in accordance with ANSI Z-535.6 and safety symbols (pictorial hazard alerts) in accordance with ANSI Z-535.3 and ISO 7010.

Signal Words

Four signal words are used in this documentation: **DANGER**, **WARNING**, **CAUTION** and ***NOTICE***.

The signal words **DANGER**, **WARNING** and **CAUTION** designate the degree or level of hazard when there is the risk of injury:

DANGER!
Indicates a hazardous situation that, if not avoided, <u>will</u> result in <u>death or serious injury</u>. This signal word is to be limited to the most extreme situations.

WARNING!
Indicates a hazardous situation that, if not avoided, <u>could</u> result in <u>death or serious injury</u>.

CAUTION!
Indicates a hazardous situation that, if not avoided, could result in <u>minor or moderate injury</u>.

The signal word "***NOTICE***" is used when there is the risk of property damage:

NOTICE!
Indicates information considered important, but not hazard-related.

Messages relating to hazards that could result in both personal injury and property damage are considered safety messages and not property damage messages.

Symbols

The signal words **DANGER**, **WARNING**, and **CAUTION** are always emphasized with a safety symbol that indicates a special hazard, regardless of the hazard level:

This symbol is intended to alert the operator to the presence of important operating and maintenance instructions.

This symbol is intended to alert the operator to the danger of exposure to hazardous visible and invisible laser radiation.

This symbol is intended to alert the operator to the presence of dangerous voltages within the product enclosure that may be of sufficient magnitude to constitute a risk of electric shock.

This symbol is intended to alert the operator to the danger of Electro-Static Discharge (ESD) susceptibility.

This symbol is intended to alert the operator to the danger of crushing injury.

This symbol is intended to alert the operator to the danger of a lifting hazard.

Preface

The Coherent OBIS lasers are a group of compact, high-performance, direct diode (“LX”) and OPSL (“LS”) lasers. They have many packaging advantages over older styles of lasers that greatly facilitate their integration into OEM equipment. They may be installed in any orientation and are able to function while being accelerated. These capabilities, combined with their small physical size, allow OBIS lasers to be installed on robot arms or gantries. There are, however, several areas where the integrator must be careful to consider the details of the laser installation so that the system performs reliably. This document highlights these areas, gives examples of good practice and provides tools for the system builder to design a robust product that delivers all of the performance that the OBIS laser can provide.

WARNING!
Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

NOTICE!
Read this guide carefully before operating the laser for the first time. Special attention should be given to the material in “Section One: Laser Safety” (p. 1-1), which describes the safety features built into the laser.
For detailed operating instructions, refer to the *Coherent OBIS Operator’s Manual* (1184163), available in PDF format on the flash drive that shipped with your product.

Export Control Laws Compliance

It is the policy of Coherent to comply strictly with U.S. export control laws.

Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification must be obtained from Coherent or an appropriate U.S. Government agency.

Products manufactured in the European Union, Singapore, Malaysia, Thailand: These commodities, technology, or software are subject to local export regulations and local laws. Diversion contrary to local law is prohibited. The use, sale, re-export, or re-transfer directly or indirectly in any prohibited activities are strictly prohibited.

Section One: Laser Safety

In this section:

Optical Safety

Because of its special properties, laser light poses safety hazards not associated with light from conventional sources. The safe use of lasers requires that all laser users, and everyone near the laser system, are aware of the dangers involved. The safe use of the laser depends upon the user being familiar with the instrument and the properties of coherent, intense beams of light.

DANGER!
Direct eye contact with the output beam from the laser will cause serious damage to the eye and possible blindness.

Table 1-1. Safety Glass OD Table

Wavelength (nm)	Power (mW)	Div (Typ - mrad)	OD	IEC Classification
375	< 20	0.7	> 1.3	3B
405	< 200	0.8	> 2.1	3B
445	< 100	0.8	> 2.0	3B
473	< 80	0.9	> 1.9	3B
488[a]	< 60	0.9	> 1.8	3B
637	< 160	1.0	> 2.5	3B
640	< 150	1.2	> 2.2	3B
647	< 180	0.97	> 2.5	3B
660	< 150	1.2	> 2.2	3B
685	< 100	0.97	> 2.1	3B
730	< 50	0.97	> 1.9	3B
785	< 100	1.4	> 2.3	3B

a. The OBIS 488 LS (=OPSL based) laser may also emit 0.9 to 1 µm wavelength from the aperture in the front of the laser head. Collinear radiation of 0.79 to 0.82 µm may also be present.

Table 1-2. Maximum Emission of OBIS LS Lasers

Wavelength Class	Power Class	Wavelength	Max. Power
488 nm	15, 20 mW	0.45 - 0.50 µm	< 350 mW
		0.90 - 1.00 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
	40 mW . . 200 mW	0.45 - 0.50 µm	< 480 mW
		0.90 - 1.00 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
514 nm	15, 20 mW	0.50 - 0.53 µm	< 350 mW
		1.00 - 1.10 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
	40 mW . . 100 mW	0.50 - 0.53 µm	< 480 mW
		1.00 - 1.10 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
532 nm	15, 20 mW	0.52 - 0.55 µm	< 350 mW
		1.00 - 1.10 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
	40 mW . . 100 mW	0.52 - 0.55 µm	< 480 mW
		1.00 - 1.10 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
552 nm	15, 20 mW	0.53 - 0.57 µm	< 350 mW
		1.00 - 1.20 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
	40 mW . . 100 mW	0.53 - 0.57 µm	< 480 mW
		1.10 - 1.20 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
561 nm	15, 20 mW	0.53 - 0.57 µm	< 350 mW
		1.10 - 1.20 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
	40 mW . . 100 mW	0.53 - 0.57 µm	< 480 mW
		1.10 - 1.20 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
588 nm; 594 nm	15, 20 mW	0.58 - 0.61 µm	< 350 mW
		1.15 - 1.21 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW
	40 mW . . 100 mW	0.58 - 0.61 µm	< 480 mW
		1.15 - 1.21 µm	< 50 mW
		0.79 - 0.82 µm	< 20 mW

Laser beams can ignite volatile substances such as alcohol, gasoline, ether and other solvents, and can damage light-sensitive elements in video cameras, photomultipliers and photodiodes. Reflected beams may also cause damage. For these reasons, and others, the user is advised to follow the precautions below.

1. Observe all safety precautions in the Operator's manual.
2. Extreme caution must be exercised when using solvents in the area of the laser.
3. Limit access to the laser to qualified users who are familiar with laser safety practices and who are aware of the dangers involved.
4. Never look directly into the laser light source or at scattered laser light from any reflective surface. Never sight down the beam into the source.
5. Maintain experimental setups at low heights to prevent inadvertent beam-eye encounter at eye level.

WARNING!
Laser safety glasses can present a hazard as well as a benefit; while they protect the eye from potentially damaging exposure, they block light at the laser wavelengths, which prevents the operator from seeing the beam. Therefore, use extreme caution even when using safety glasses.

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6. As a precaution against accidental exposure to the output beam or its reflection, those using the system must wear laser safety glasses as required by the wavelength being generated.
7. Use the laser in an enclosed room. Laser light will remain collimated over long distances and therefore presents a potential hazard if not confined.
8. Post warning signs in the area of the laser beam to alert those present.
9. Advise everyone using the laser of these precautions. It is good practice to operate the laser in a room with controlled and restricted access.
10. During the laser alignment process, do not wear items with reflective surfaces (for example, a watch or jewelry).

Electrical Safety

The OBIS laser system does not contain hazardous voltages. Do not disassemble the enclosure. There are no user-serviceable components inside. All units are designed to be operated as assembled. Warranty will be voided if the enclosure is disassembled.

NOTICE!
Electrostatic charges as high as 4000V readily accumulate on the human body and equipment and can easily discharge without detection. Although the electronics features have impressive input protection, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation.

The most common ESD damage occurs while handling the device during installation or use. Take the necessary measures to protect the system from ESD.

Dry air and carpet can create an even higher potential for ESD. Precautions or shielding need to be taken for demonstrations or trade show exhibitions.

Laser Safety Features

CDRH/IEC 60825-1 Compliance

When used with the OBIS Remote, the OBIS laser head complies with CDRH (21 CFR 1040.10 and 1040.11, except for deviations pursuant to laser notice no. 50, dated July26, 2001) and IEC 60825-1. To view a list of CDRH accession numbers that were current as of the publication date of this document, open the *141037 rAA - OBIS CDRH Accession Numbers.pdf* file on the OBIS flash drive that shipped with your product. To view the most current list of accession numbers, connect to the following website: http://www.coherent.com/Products/index.cfm?1884/OBIS-Lasers.

In addition to complying with CDRH and IEC 60825-1 requirements, the OBIS family of products has been certified by an outside testing lab to be in compliance with the environmental and safety directives listed below.

EMI Standard for Emissions per:

EN55011:2007
Class A Radiated Emissions

EN55011:2007
Class A Conducted Emissions

EN61000-3-2:2006
Power Line Harmonics

EN61000-3-3:1995:A1:2001:A2:2005
Power Line Voltage Fluctuation and Flicker

EMC Standard for Immunity per:

EN61000-4-2:2003
Electrostatic Discharge – Performance Criteria B

EN61000-4-3:2006
Radiated Immunity – Performance Criteria A

EN61000-4-4:2004
Electrical Fast Transient Immunity – Performance Criteria B

EN61000-4-5:2004
Electrical Slow Transient Immunity – Performance Criteria B

EN61000-4-6:2003
Conducted RF Immunity – Performance Criteria A

EN61000-4-11:2004
Power Line Interruptions, Dips, and Dropouts – Performance Criteria B

Low Voltage Directive 73/23/EEC Tests per:

EN61010-1:2001
Safety Requirements Part 1: General Requirements

MD – Machinery Directive for Laser Devices Tests per:

EN60825-1:2001
Safety of Laser Products – Part 1: Equipment Classification Requirement and User's Guide

EN60825-2:2005
Safety of Laser Products – Part 2: Safety of Optical Fiber Communication Systems

EN60825-12:2004
Safety of Laser Products – Part 12: Safety of Free Space Optical Communication Systems Used for Transmission of Information

21CFR 1040.10

Declaration of Conformity

Declaration of Conformity certificates are available upon request.

Laser Emission and Classification

The OBIS laser system is classified by the United States National Center for Device and Radiological Health (CDRH) as a CLASS IIIb laser product. It may emit VISIBLE or INVISIBLE LASER RADIATION wavelengths of 0.3 to 1.0 µm from the aperture in the front of the laser head.

Protective Housing

The laser radiation is entirely contained within a metal protective housing, except for the laser beam aperture. The protective housing should never be opened.

Remote Interlock

The OBIS Remote and the OBIS 6-Laser Remote are provided with a remote interlock circuit that prevents the generation of laser radiation when open. This interlock circuit is fail-safe or redundant. Figure 1-1 (p. 1-7) shows a diagram of the remote interlock circuit configuration. The interlock is located on the OBIS Remote and the OBIS 6-Laser Remote and is applicable to LS and LX systems.

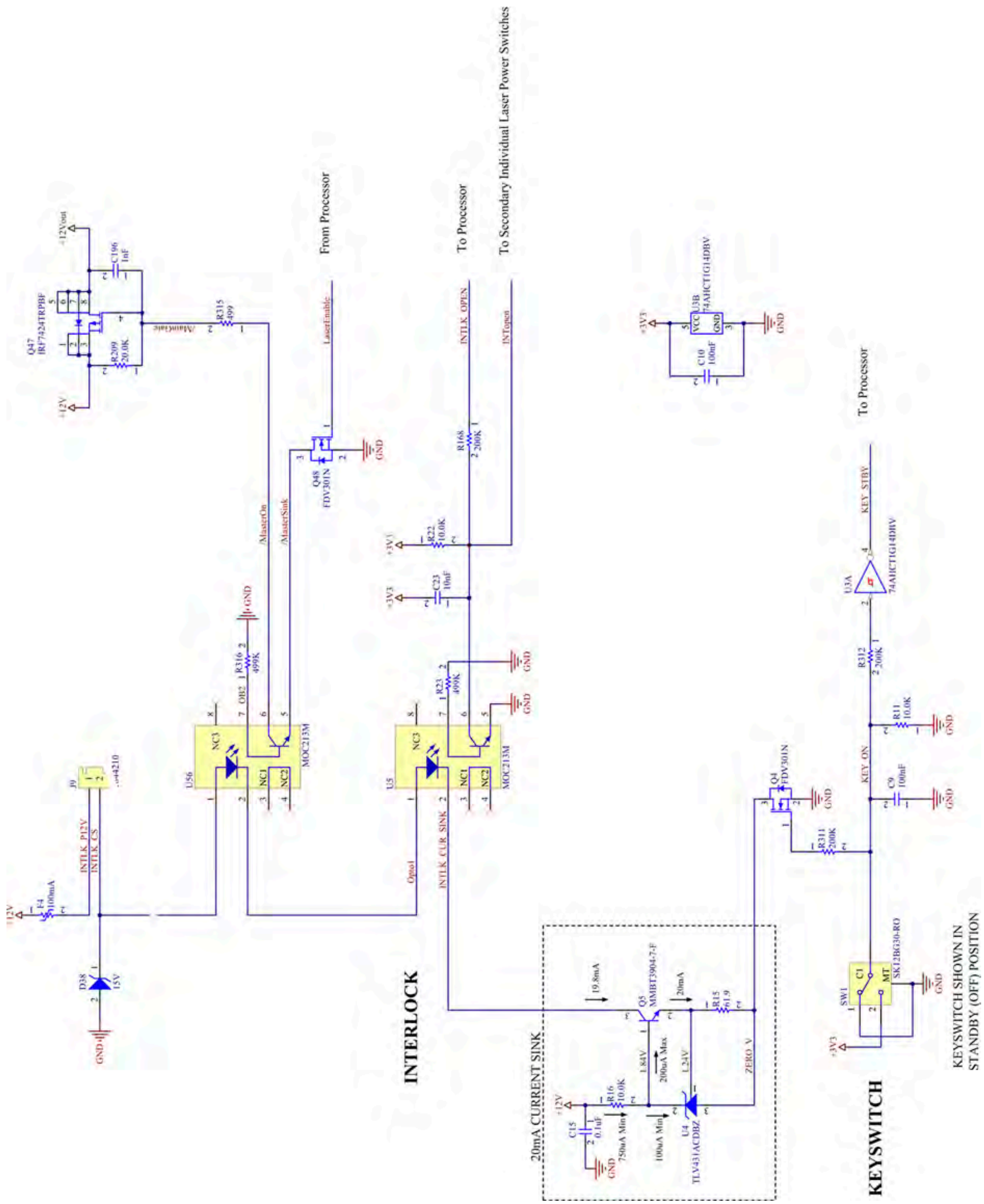

Figure 1-1. Remote Interlock Circuit and Key Switch Diagram

Laser Emission Indicators

The laser system OBIS Remote provides a laser emission indicator, which is located on the front panel. When the white LED emission indicator is not illuminated, laser radiation is not possible. When the indicator is illuminated, the laser should be considered dangerous; a laser beam may be created at any instant (via computer control, for example). After the illumination of the white LED emission indicator, there is a delay until actual laser emission, which allows appropriate action to avoid exposure to the laser beam. The delay is at least five seconds in duration.

The LED indicator on the front panel of the OBIS 6-Laser Remote is NOT a laser emission indicator, but an indicator for the status of the remote.

Radiation Exposure

Use of controls, adjustments, or performance of procedures other than those specified in this manual, may result in hazardous radiation exposure.

Shutter

The laser contains a manually-operated shutter at the beam exit aperture on the front of the laser head. When the shutter is fully closed, there is no laser radiation emitted from the laser.

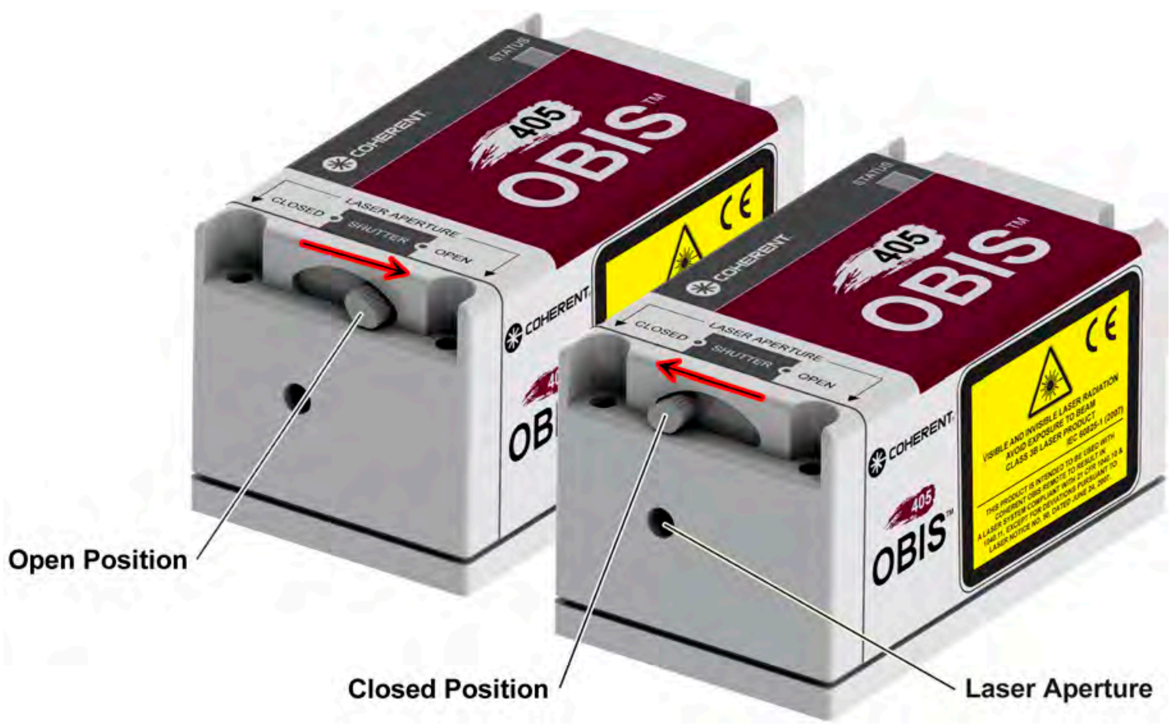

Figure 1-2. Shutter Control: Open and Closed Positions

NOTICE!
OBIS FP: Always use nitrile gloves when handling the fiber output—do <u>not</u> touch the laser fiber output!

NOTICE!
OBIS FP: Open fiber end in an environment that is free of organic material and particulates. The fiber end is susceptible to contamination that can lead to fiber degradation.

Figure 1-3. OBIS FP with and without Fiber Shutter Cap

Waste Electrical and Electronic Equipment (WEEE, 2002)

The European Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) is represented by a crossed-out garbage container label. The purpose of this directive is to minimize the disposal of WEEE as unsorted municipal waste and to facilitate its separate collection. This crossed-out garbage container label is affixed to the cover of the OBIS laser head.

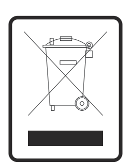

Figure 1-4. Waste Electrical and Electronic Equipment Label

Location of Safety Labels

Refer to the following figure for the location of CDRH compliance labels.

OBIS

OBIS FP

Figure 1-5. Safety Labels (Sheet 1 of 2)

Figure 1-5. Safety Labels (Sheet 2 of 2)

RoHS Compliance

To comply with the China RoHS (Restriction of Hazardous Substances) Directive effective March 1, 2007, a table of hazardous substances is included in this manual showing which of the offending substances is present in the OBIS laser system.

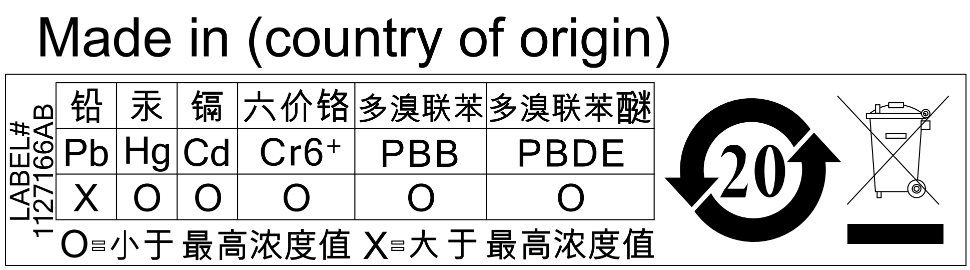

Figure 1-6. China RoHS Table of Restricted Hazardous Substances

The table in Figure 1-6, above, shows that Lead (Pb) is present in the OBIS laser system (due to the use of brass material) and that the environmental-friendly use period is 20 years as indicated by the 20 inside the circle.

Also, the China RoHS directive requires that the date of manufacture (in Chinese characters) for the OBIS laser system be shown on the product. This is accomplished on the conforming/nonconforming label. Refer to the following figure.

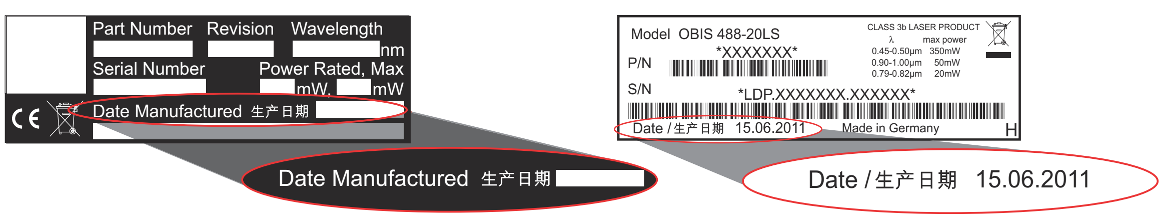

Figure 1-7. China RoHS Date of Manufacture

General Laser Safety Requirements

The information presented in this section is provided to give the System integrator several recommendations on safety requirements when incorporating a laser into an end product. It is by no means a complete list. The System integrator is responsible for insuring that their system meets all of the necessary safety regulations and requirements.

The manufacture of laser products is Federally regulated in the U.S., and the exportation of laser products to Europe also requires conformance to new EC Directives, laws, and standards.

All laser products are subject to regulation under the Radiation Control for Health and Safety Act of 1968 (Public Law 90-602, hereinafter referred to as "the Act"). The Regulations for the Administration and Enforcement of the Act, Title 21 Code of Federal Regulation (21 CFR), require adherence to the Federal Laser Performance Standard contained in 21 CFR §1040, as well as compliance to other reporting, record keeping, and administrative requirements contained in 21 CFR Sub-chapter J.

System Integrators

A laser manufacturer is anyone who supplies (or modifies) a laser product. The definition of a laser product, as presented in 21 CFR, includes any manufactured product or assemblage of components which constitutes, incorporates, or is intended to incorporate, a laser or laser system. This means no matter what relative percentage of your product is laser related, if the product is intended to incorporate a laser, it becomes a laser product.

A manufacturer according to 21 CFR, is any person engaged in the business of manufacturing, assembling, or importing (the subject laser) electronic product. Manufacturers have certain compliance responsibilities before entering commerce. Commerce is defined, for the purpose of the regulation, as any Interstate commerce and includes exchange for value or as a prize or award. Entering commerce may include shipping to a beta test site, a trade show, or even (in some circumstances) transferring the product to another part of the company.

Your Compliance Responsibilities

A purchaser is the end user, or one who receives the product for purposes other than resale. If you have purchased the laser to integrate into a system, it is important to note that a given manufacturer and a given purchaser may be part of the same company. This can occur when the product is subject to interstate commerce, or when it can be shown that one entity has the manufacturer's role and the other the purchaser's role; also, inter-division transfer pricing may be considered for value. It is especially important to note these requirements when dealing with a foreign subsidiary, parent, or division, bringing laser products into the U.S.

The text of the Federal Law is available from the Government printing office as well as directly through the Office of the Center for Devices and Radiological Health. There are also guideline documents and *A Guide To Preparing Product Reports For Lasers And Products Containing Lasers* (dated September 1995). You may request this material from:

U.S. Department of Health and Human Services
Public Health Service, Food and Drug Administration
Center for Devices and Radiological Health
Division of Small Manufacturers Assistance
Rockville, Maryland 20857

Website: www.fda.gov/cdrh

(800) 638-2041

Workplace Safety

As an incorporator of lasers, you not only are a manufacturer of laser products, but a tester and servicer as well. For these reasons you need to become familiar with guidelines for using and working on those products safely (manufacturers are also required by CDRH to provide their customers with safe use information, among other things). Perhaps the most important and widely accepted such standard in the U.S. is the American National Standard Institute (ANSI) Z 136.1-2000 *Standard for Safe Use of Lasers*. This standard is, in fact, the basis for the current *OSHA Guideline on Laser Safety in the Workplace* (OSHA Instruction Publication 8-1.7), and the ANSI model state standard is used as the outline of many existing and proposed state regulations. ANSI Z 136.1 is available through a number of sources, including the Laser Institute of America and the American National Standards Institute.

Laser Institute of America
12424 Research Parkway Suite 125
Orlando FL 32826

Website: www.laserinstitute.org

You may obtain a listing of ANSI standards directly from:

American National Standards Institute
11 West 42nd Street
New York, NY 10036

Website: www.ansi.org

There are also several consulting companies that can assist you, for a fee, in preparing for CDRH, ANSI, and OSHA, and EC laser safety compliance.

SECTION TWO: OBIS DIMENSIONS

Dimensions included in this section:

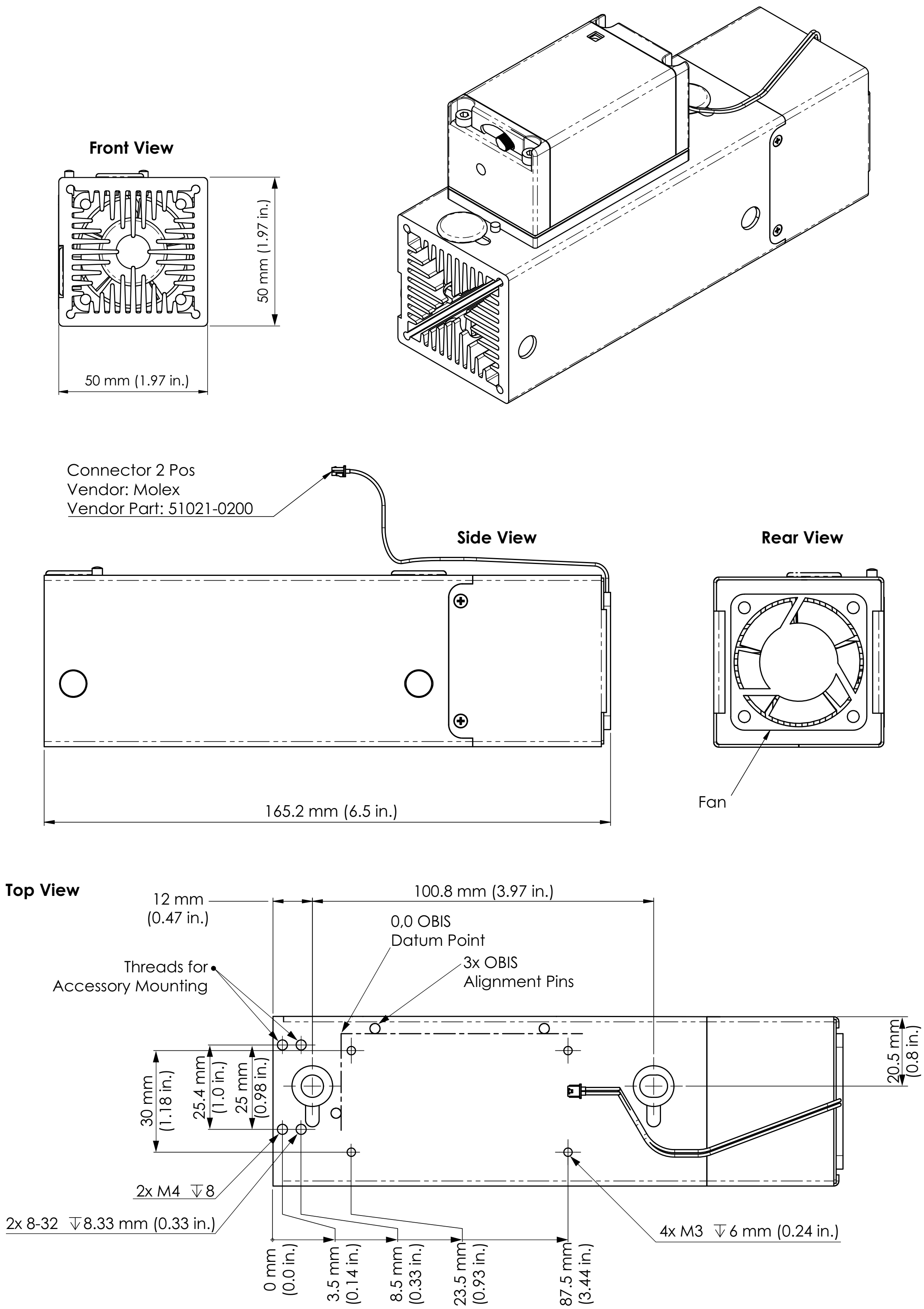

Figure 2-1. Optional Heat Sink Dimensions

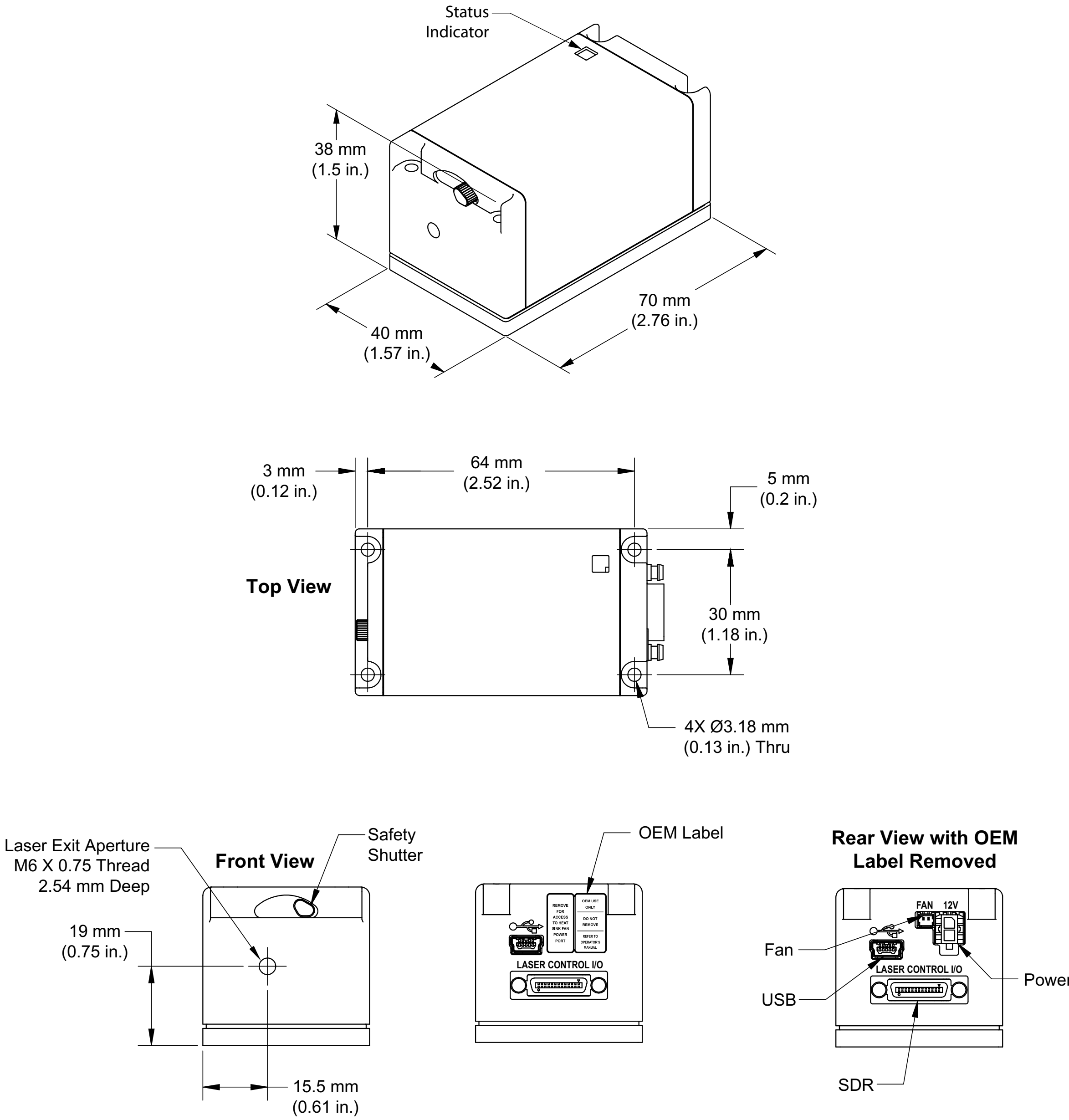

Figure 2-2. OBIS Laser Head Dimensions

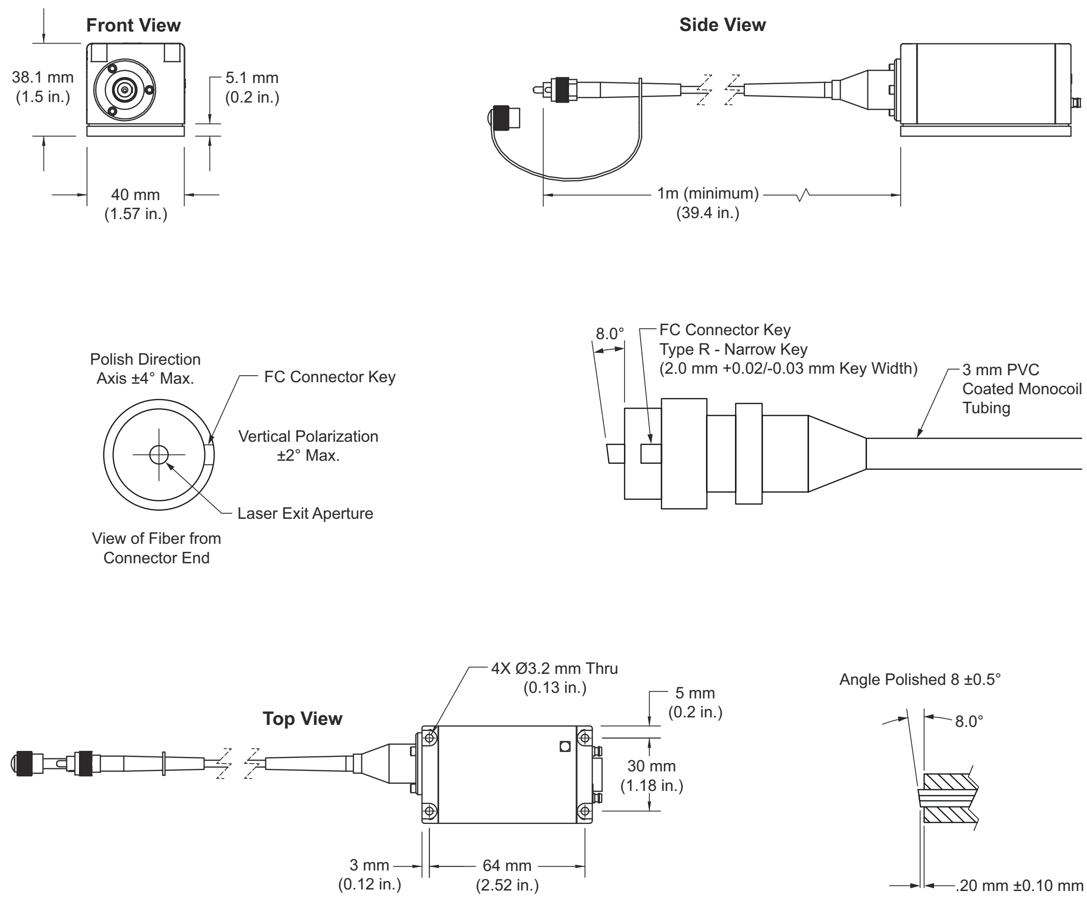

Figure 2-3. OBIS FP Laser Head Dimensions

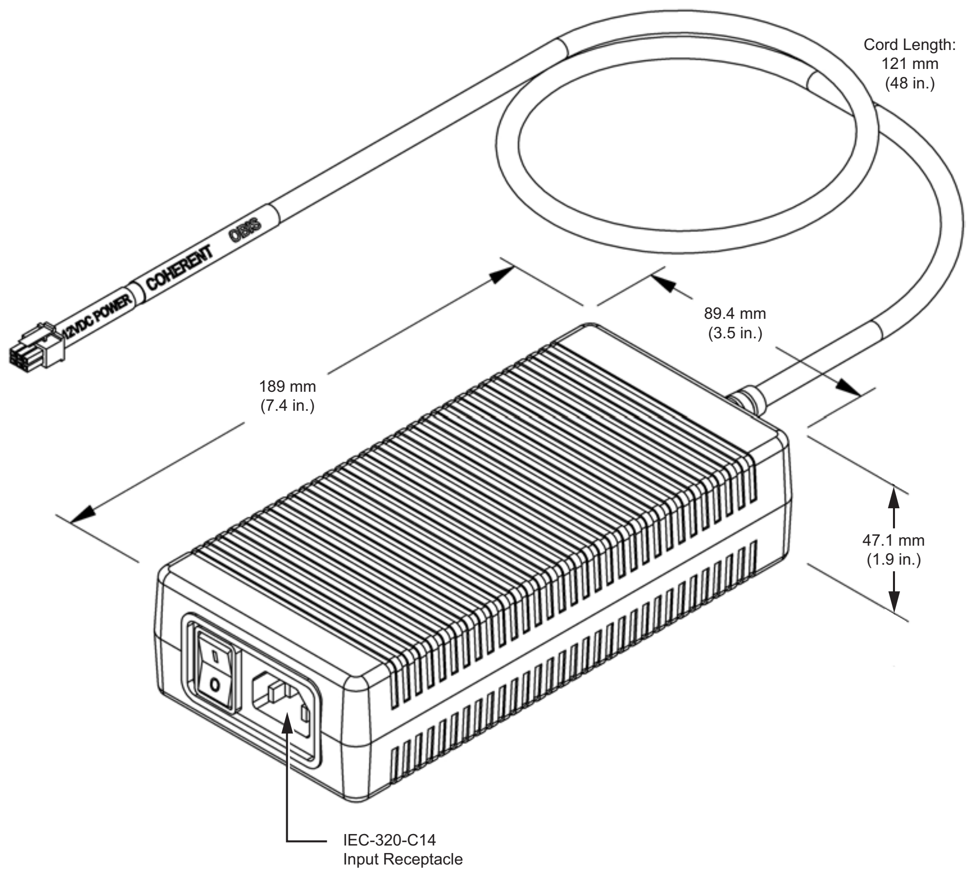

Figure 2-4. OBIS 6-Laser Remote Power Supply Dimensions

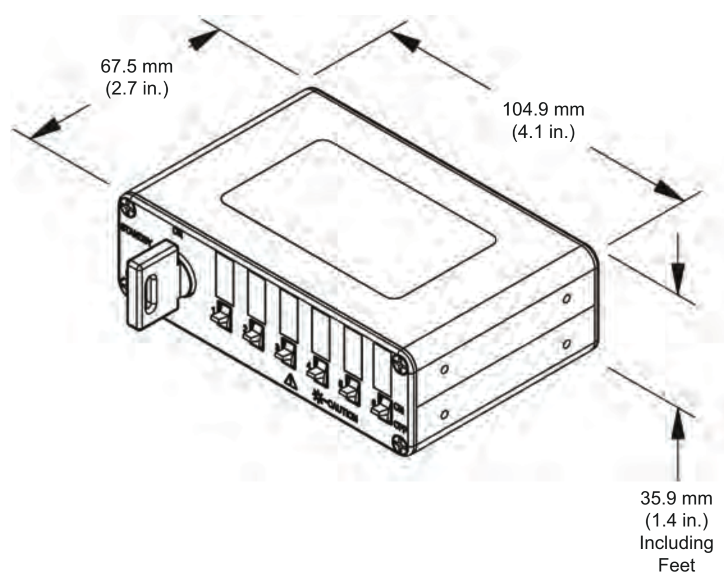

Figure 2-5. OBIS 6-Laser Remote Dimensions

SECTION THREE: INSTALLATION

In this section:

- Overview of the standard installation procedure (this page)
    - Installing the optional heat sink (p. 3-2)
    - Mounting the laser head (p. 3-5)
    - Connecting the SDR cable (p. 3-8)
    - Adding optional fan power (p. 3-8)
- Heat sink requirement (p. 3-9)

Overview of the Standard Installation Procedure

The procedure presented in this section explains how to connect the OBIS laser head and OBIS Remote. For details on installing the laser head *without* the OBIS Remote, refer to the *OBIS Operator's Manual* (1184163).

NOTICE!
Operating the laser head without the OBIS Remote is non-CDRH compliant.

The installation procedure consists of the following steps:

1. Installing the optional heat sink (p. 3-2)
2. Mounting the laser head (p. 3-5)
3. Connecting the SDR cable between the laser head and the OBIS Remote (p. 3-8)
4. Adding optional fan power to the laser head (p. 3-8)

Installing the Optional Heat Sink

The Coherent optional heat sink is the result of significant design research and testing. The mounting of any laser is important to extend the stability of the beam over time and temperature. The heat sink provides proper thermal dissipation and mechanical positioning.

1. Remove the heat sink plugs.

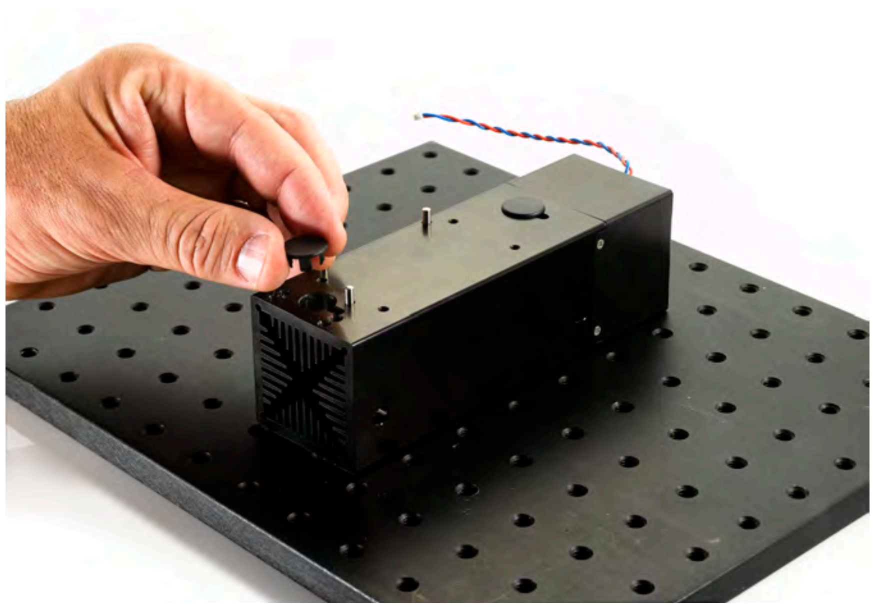

Figure 3-1. Remove the Heat Sink Plugs

Figure 3-2. Heat Sink Plug Locations

2. Bolt the heat sink to the proposed laser location. Ensure the heat sink ends remain unobstructed for proper air flow.

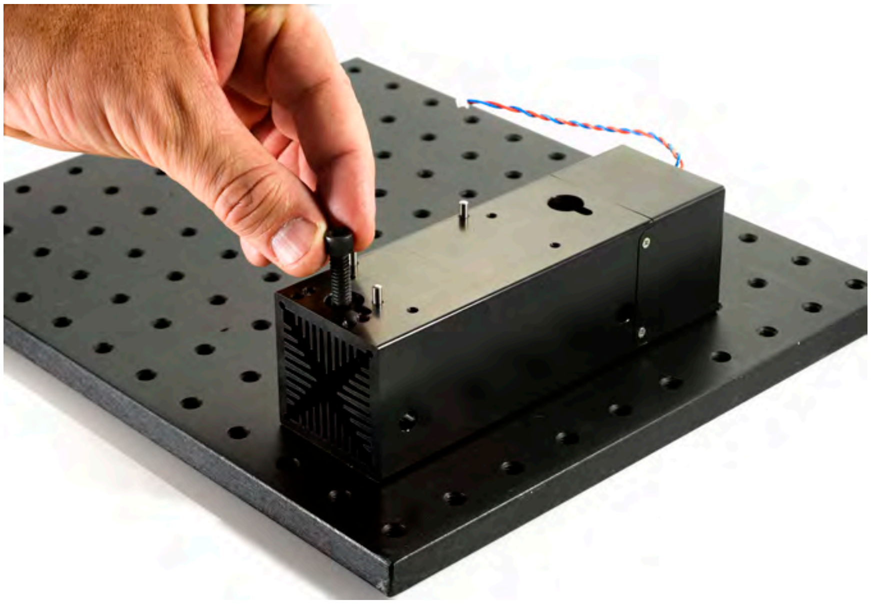

Figure 3-3. Bolt the Heat Sink to the Proposed Laser Location

3. Torque the two M6 mounting screws to 4.5 Nm (635 oz in).

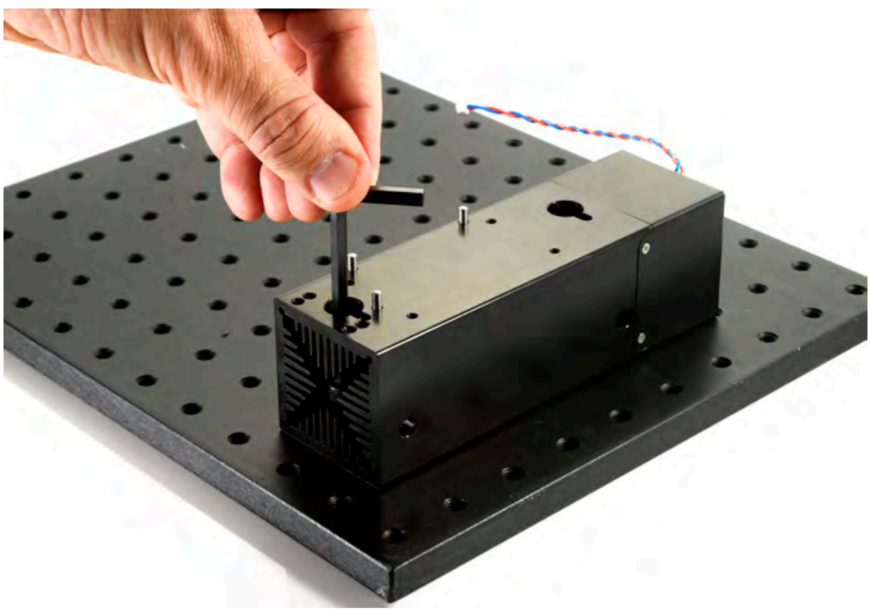

Figure 3-4. Torque the Mounting Screws

4. If fan operation is required, connect the fan to the OBIS power supply with the cable provided with the heat sink. The fan cable will allow power to be supplied to the heat sink fan and to the OBIS, simultaneously.

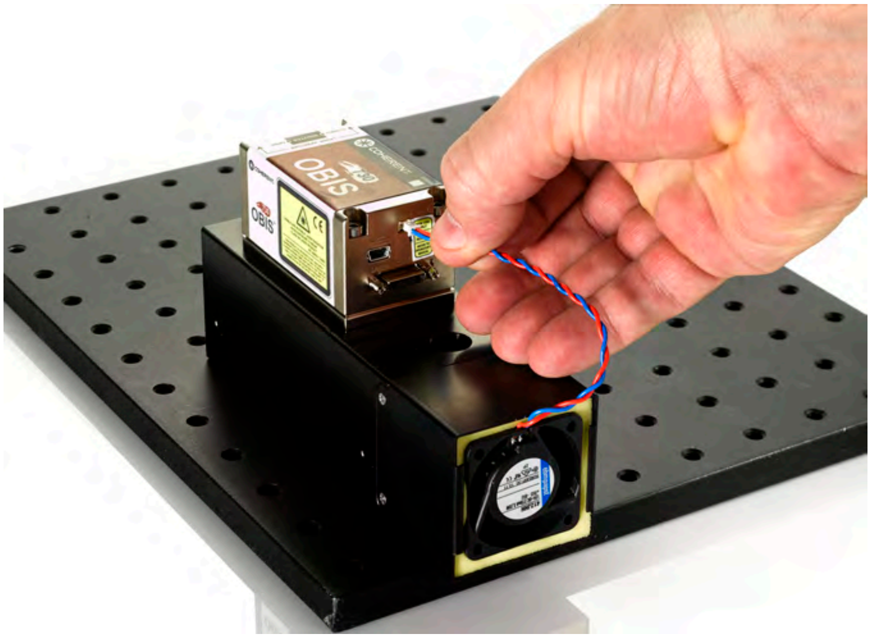

Figure 3-5. Connect the Fan to the OBIS Power Supply

5. Replace the heat sink plugs back to the original position in the heat sink. *This is mandatory to ensure the best cooling efficiency.*

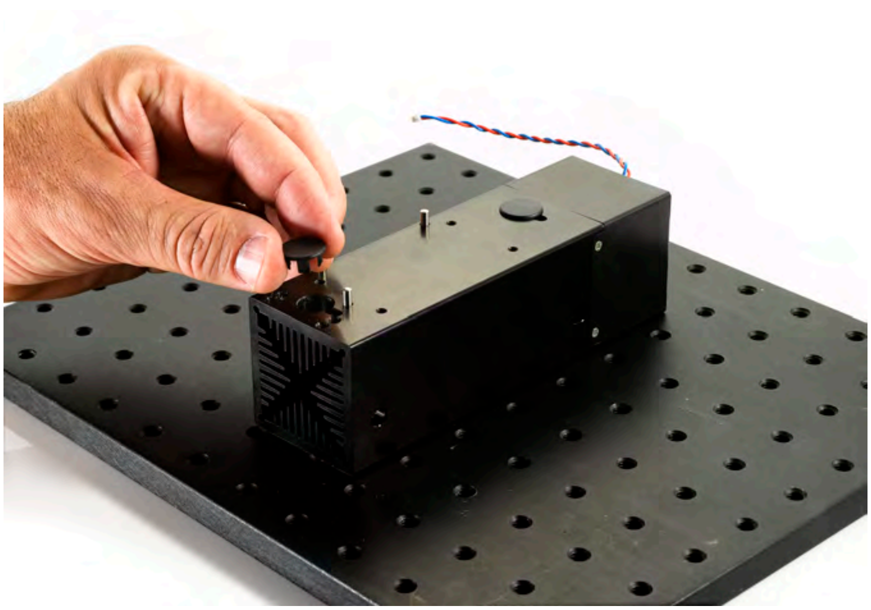

Figure 3-6. Replace the Heat Sink Plugs

Mounting the Laser Head

1. Secure the Coherent heat sink or your own heat sink to the proposed laser location—refer to "Installing the Optional Heat Sink" (p. 3-2). Ensure that the heat sink ends remain unobstructed for proper air flow.
2. Align the laser head with the heat sink and then secure it to the heat sink with the M3 screw kit (provided). Use the washers to spread the tightening force.

Figure 3-7. Provided Mounting Screw Kit for OBIS Laser Head

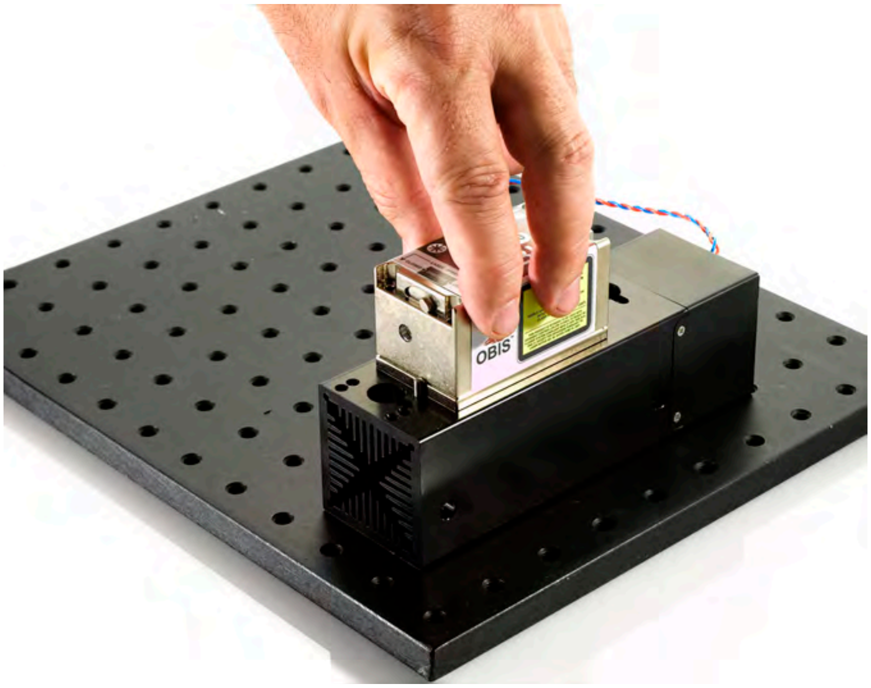

Figure 3-8. Align the Laser Head to the Heat Sink

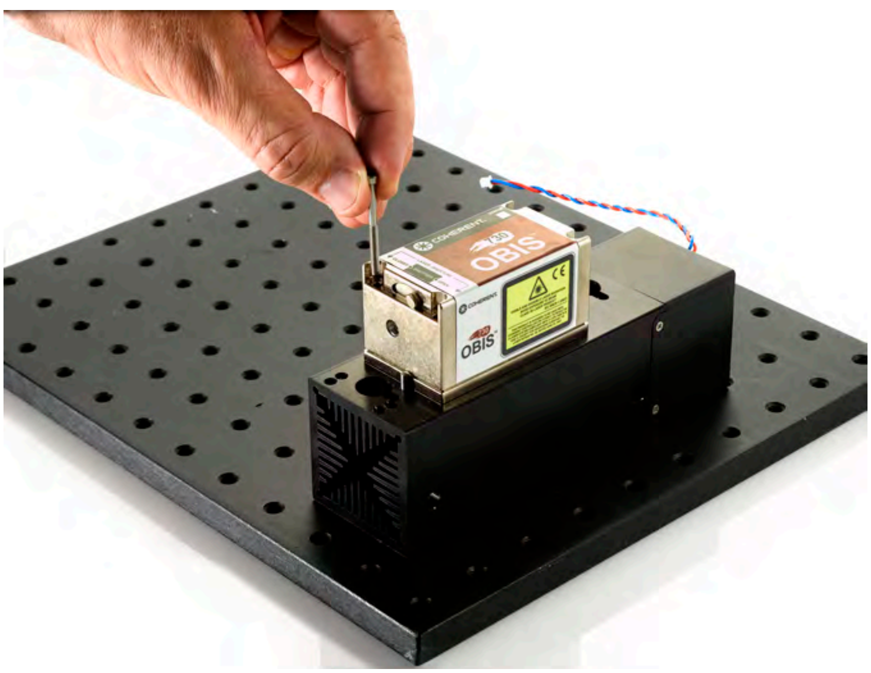

Figure 3-9. Secure the Laser Head to the Heat Sink

3. Tighten screws in a diagonal pattern to ensure optimum pointing stability. Torque the mounting screws to .25 N·m (35.4 oz·in.) in the following sequence: 1-2-3-4. Use the same diagonal pattern for the final torque setting of 1 N·m (141.6 oz·in.).

Figure 3-10. Tightening Pattern for Mounting the OBIS Laser Head

Figure 3-11. Tighten the Mounting Screws

Connecting the SDR Cable

Connect the 26-pin, type: 3M 12226-1150-00FR, SDR connector to the laser head and the OBIS Remote. Refer to the *OBIS Operator's Manual* (1184163) for pin assignment and functions.

Figure 3-12. Connecting the SDR Cable

Adding Optional Fan Power

1. Remove the blue label that covers the FAN connection. *Do not remove the yellow label next to it.*
2. Connect the fan cable to the laser head.

Figure 3-13. Adding Optional Fan Power to the Laser Head

Heat Sink Requirement

It is imperative that the OBIS laser head be adequately heat sinked; otherwise it will overheat and shut down. Figure 3-14 shows the heat dissipation of the OBIS laser head for given baseplate temperatures. The graph shown in Figure 3-15 helps determine the heat sink thermal impedance requirement.

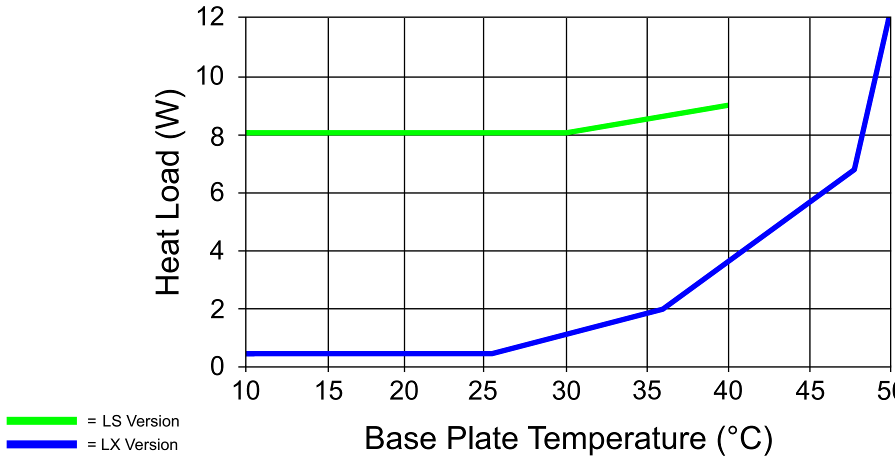

Figure 3-14. Measured Thermal Dissipation Data of the OBIS Laser Head

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NOTICE!
Pyrolytic graphite pads can be used to improve thermal contact between the baseplate and the heat sink. Many extruded heat sinks are warped and the mounting surface should be milled flat (within < 0.05 mm over the mounting surface). Coherent recommends *against* the use of thermal grease.

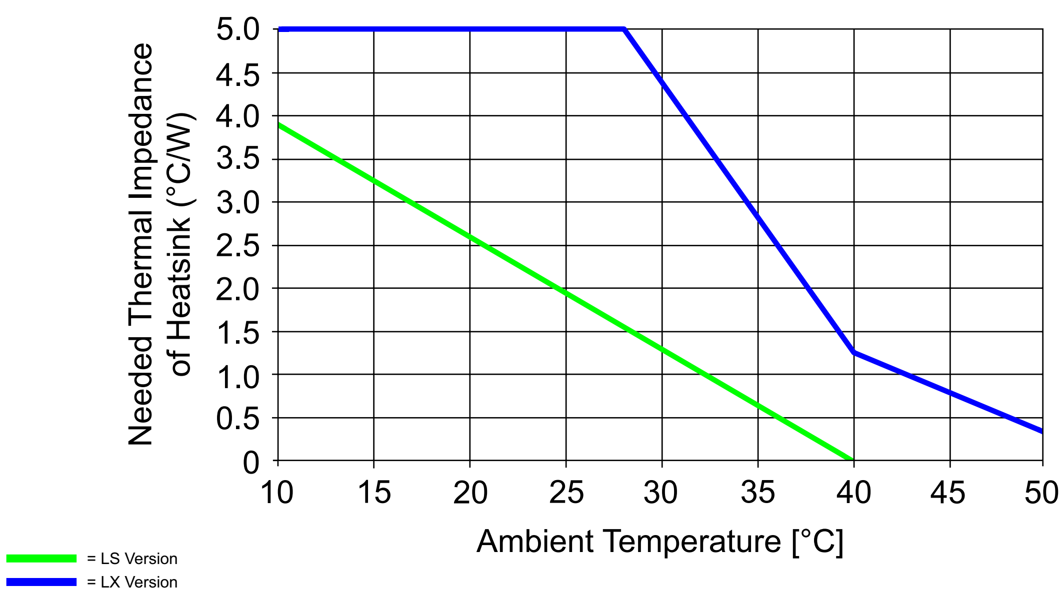


Figure 3-15. Maximum Thermal Impedance of Heat Sink Needed to Cool OBIS Laser

SECTION FOUR: MODULATION

In this section:

Analog Modulation

The OBIS analog input circuits utilize a two-wire differential input circuitry that has a voltage swing of -0.930 to 0.930 VDC and an input resistance of 100 ohms. An advantage to differential signaling is that it offers common mode rejection. The receiver ignores any noise that is coupled equally on to the differential signals and only considers the difference between the two signals.

The following table lists the electrical characteristics of the analog input.

Table 4-1. Analog Input Electrical Characteristics

Parameter	Test Conditions	Min	Typ	Max	Unit
Absolute maximum diff. analog input at SDR connector	[a]			+ 1.00	V
Absolute minimum diff. analog input at SDR connector	[b]	- 1.00			V
Absolute maximum analog input at Remote				5.1	V
Absolute minimum analog input at Remote		- 0.1			V
Maximum laser power	Vdiff = 0.930V or Vanlg = 5.00V[c]	104	110		%
Half power	Vdiff = 0.0V[c]	52	55	58	%
Minimum laser power	Vdiff = - 0.930V or Vanlg = 0.00V[d, c]		0	0	%
Default threshold level			1		%
Common mode analog input at SDR connector	[e]	0		4	V

a. Voltages between 0.930 and 1.00V could generate laser power levels that exceed 110%.
b. Voltages between - 0.930 and - 1.00V will output 0% laser power.
c. Vdiff = differential analog input at the SDR connector of the laser head. Vanlg = analog modulation input of the remote.
d. With blanking enabled.
e. A common mode voltage outside of the recommended range will cause clipping of the differential analog input and the laser may not reach the desired power.

Table 4-2 shows an example of the analog modulation input voltages and the corresponding laser output power for an OBIS 405 nm LX 55 mW with blanking level at 0.3 mW.

Table 4-2. Analog Modulation Input Voltage Levels

Description	Explanation	Voltage at the OBIS Remote SMB Input	LVDS Voltage at OBIS Laser SDR Input	Laser Output Power for a 405 nm LX 55 mW
Analog Modulation Maximum Power	110% of Nominal Power	5.0V	0.930V	60.5 mW
Analog Modulation Nominal Power	100% of Nominal Power	4.55V	0.760V	55 mW
Analog Modulation Threshold	Threshold (Blanking) Level	≤ 0.0248V	≤ -0.922V	≤ 0.3 mW
Analog Modulation Minimum Power	0% Power (minimum)	0.0V	-0.930V	0 mW

The following diagrams illustrate the LVDS signaling of the OBIS laser.

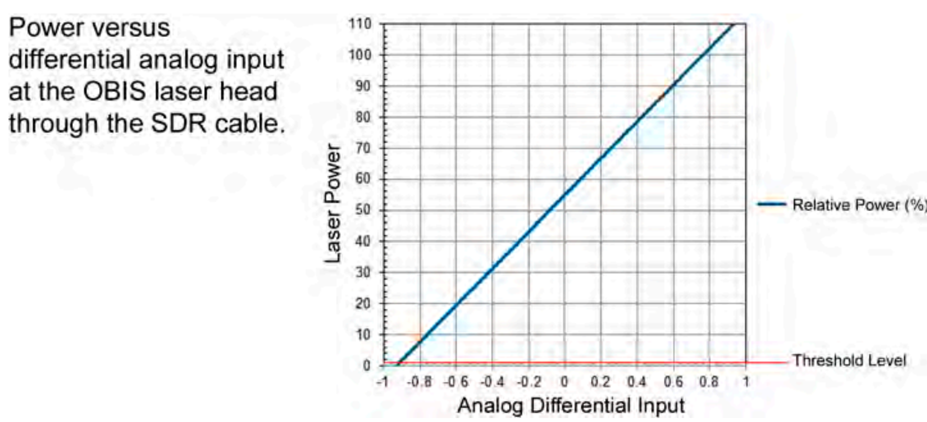


Figure 4-1. Relative Power (%) vs. Differential Analog Input (V)

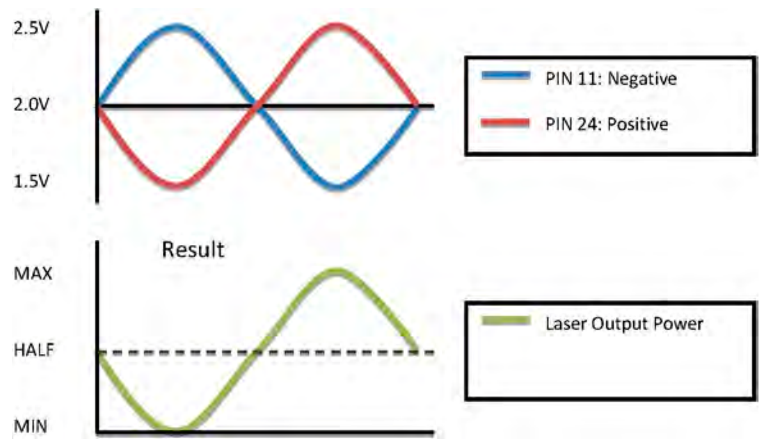


Figure 4-2. Example of Sine Wave Input/Output

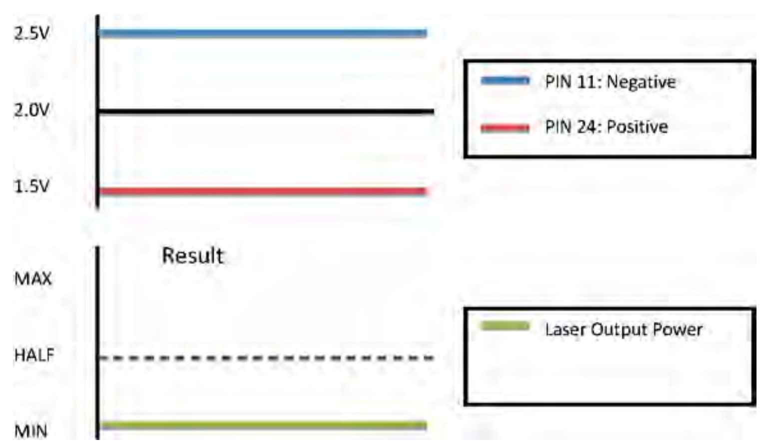


Figure 4-3. Example of Minimum Power

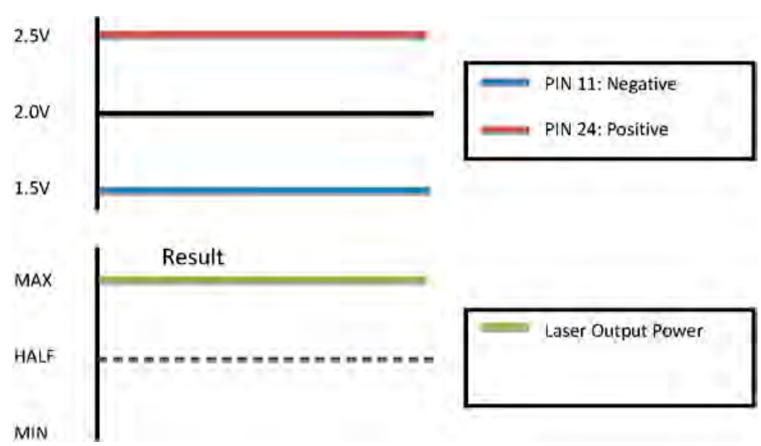


Figure 4-4. Example of Maximum Power

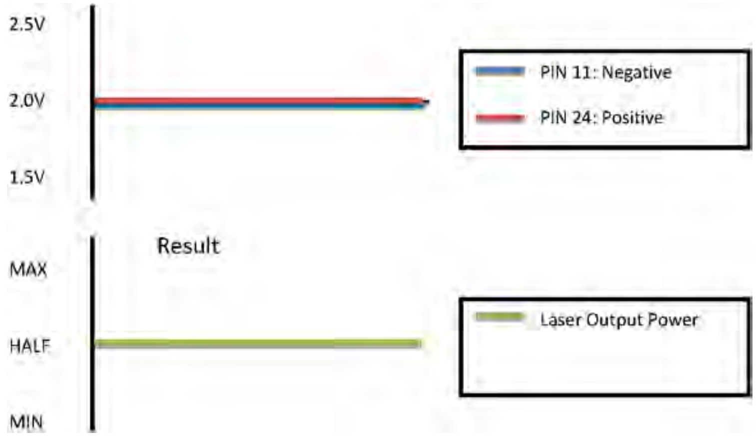


Figure 4-5. Example of Half-Power - Both Pin 11 and Pin 12 at Same Voltage

NOTICE!
Without an input signal on pins 11 and 24, the system will operate at half-power, as this is the common mode function.

Digital Modulation

The OBIS laser family incorporates **L**ow **V**oltage **D**ifferential **S**ignaling (LVDS) technology, which is used for point-to-point cable driving applications. It has a typical voltage swing of 350 mV, with a typical offset voltage of 1.25V above ground.

The following figure shows a typical LVDS circuit.

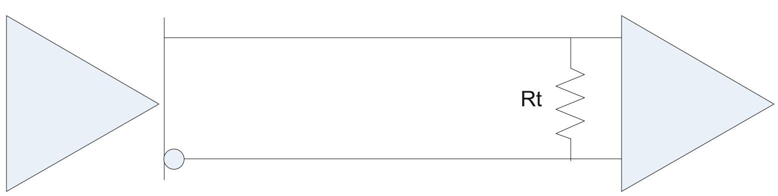


Figure 4-6. LVDS Sample Circuit

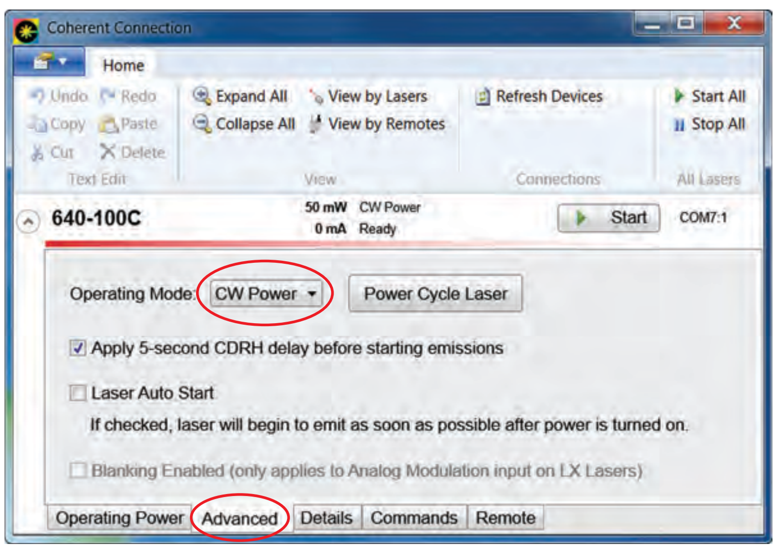
LVDS drivers and receivers perform best when used as point-to-point configured systems. This is how they are used in the OBIS laser. The internal resistance of the digital input to the OBIS is 100 ohms, which is the typical impedance of twisted pair cable. For further discussions on LVDS technology, refer to http://www.ti.com/ww/en/analog/interface/lvds.shtml.

Table 4-3. OBIS LS Modulation Types

Modulation Feature	**OBIS LS versus OBIS Firmware 1.X versus OBIS Firmware 2.X**		
	OBIS LS	**OBIS Firmware 1.X**	**OBIS Firmware 2.X**
Constant power, power control[a]	CW Power	CW Power	CW: Power
Constant Current, current control[b]	CW Current	CW Current	CW: Current
Digital Modulation, current control	Digital Modulation	Digital Modulation	Digital: Current
Digital Modulation, slow, power control	N/A	N/A	Digital: Power
Analog Modulation, power control	Analog Modulation	Analog Modulation	Analog: Power
Mixed Modulation, slow, power control	N/A	N/A	Mixed: Power
Mixed Modulation, current control	Mixed Modulation	Mixed Modulation	Mixed: Current
There is a tradeoff between power and current modes. *Power modes* are more accurate, with small modulation overshoots, but are slower to modulate. *Current modes* have a larger overshoot but allow faster modulation.			

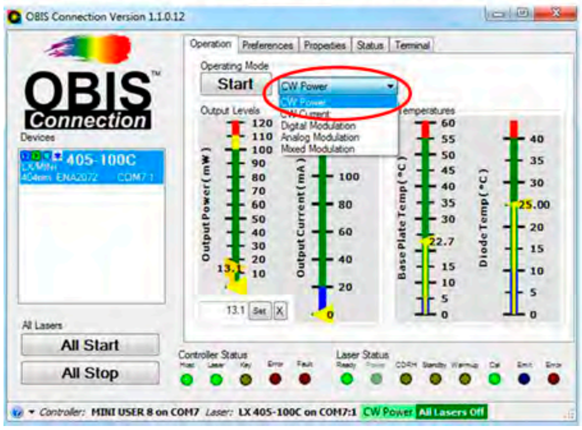
a. Power Control = Light Regulation
b. Current Control = Current Regulation

Modulation operating options are found on the Advanced tab in Coherent Connection.

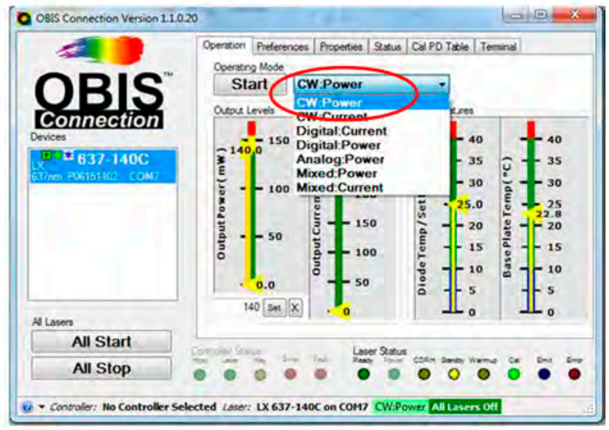


Clicking on the tag will activate the drop-down menu, which lists the different options for modulation.

OBIS LS/OBIS LX Firmware 1.x

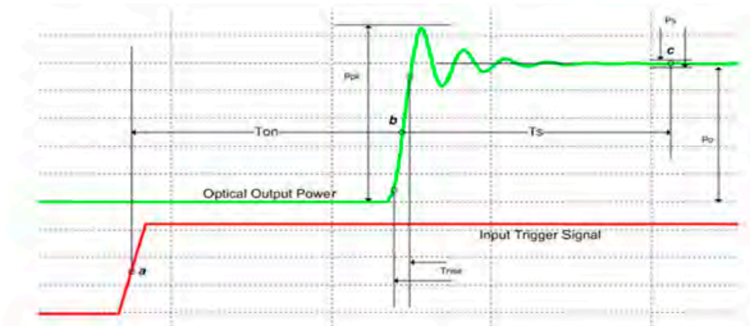


OBIS LX Firmware 2.X

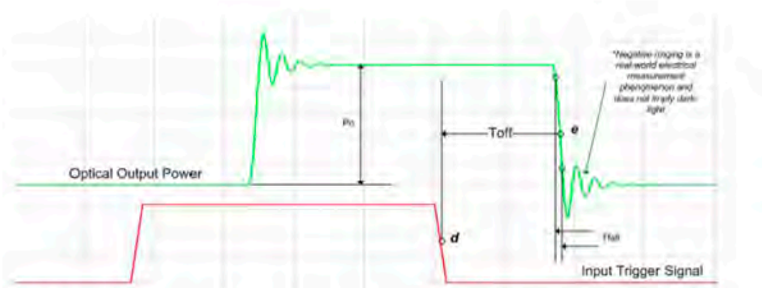


The following three figures show a typical modulation pulse, including the maximum power and the minimum power output pulses.

t on delay = pulse delay time
t rise = pulse rise time
t on = pulse on time
t fall = pulse fall time

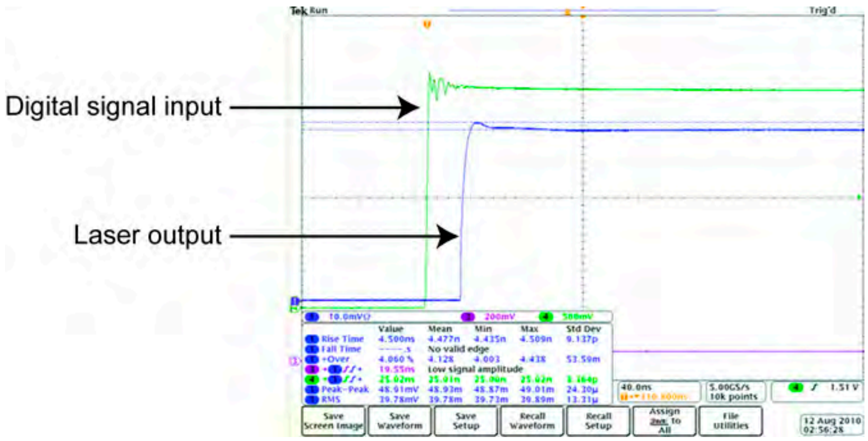


a & d = 50% of input trigger signal
b & e = 50% of Po
Ton = T(b) - T(a)
Toff = T(d) - T(e)
Trise = T(0.1 *Po) - T(0.9 *Po)
Tfall = T(0.9 *Po) - T(0.1 *Po)
Setting time T(s) to 1% = T(c) - T(b) ;***where Ps/Po *100 = 1%***
Overshoot(%) = (Ppk-Po)/Po *100

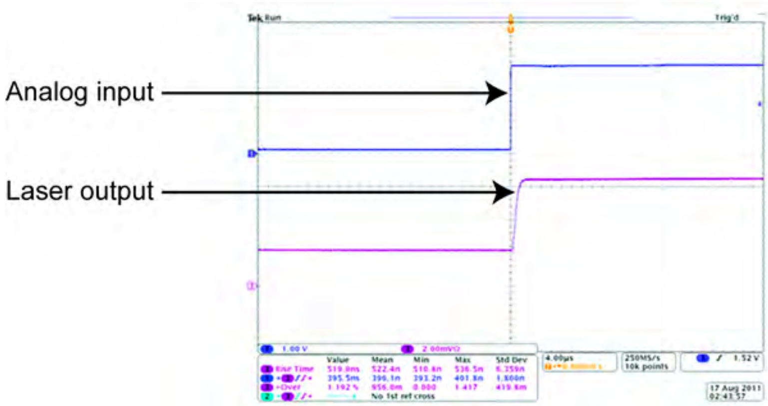


a & d = 50% of input trigger signal
b & e = 50% of Po
Ton = T(b) - T(a)
Toff = T(d) - T(e)
Trise = T(0.1 *Po) - T(0.9 *Po)
Tfall = T(0.9 *Po) - T(0.1 *Po)
Setting time T(s) to 1% = T(c) - T(b) ;***where Ps/Po *100 = 1%***
Overshoot(%) = (Ppk-Po)/Po *100

The OBIS laser can be digitally modulated at up to 150 Mhz in Digital Current Control. Digital modulation turns the laser on/off. Digital Power puts the photo diode in the feedback loop and limits the rise time to ≥ 400 ns.



Analog modulation will vary the output of the OBIS laser. The OBIS LX can be analog modulated at ≤ 500 khz and the OBIS LS as ≤ 100 khz. Analog modulation can be a square wave, sine wave, or triangle wave. The signal must be from 0 to 5V.



Blanking can be enabled/disabled on the Advanced tab in Coherent Connection.

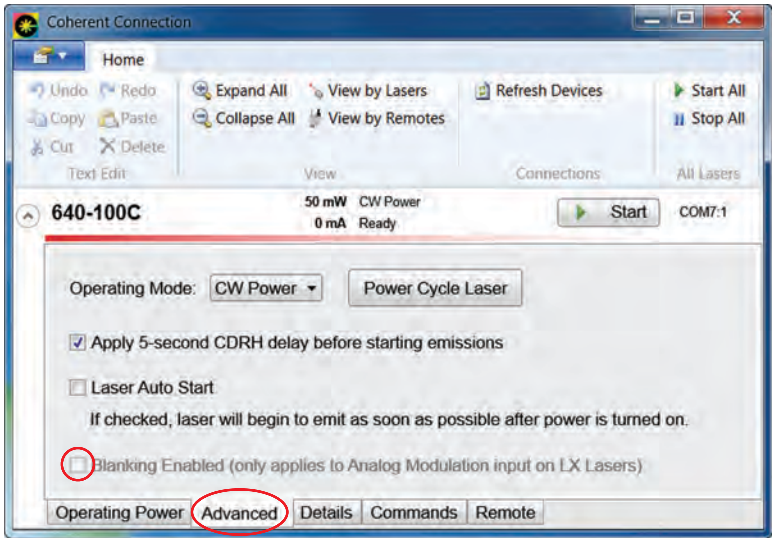


Figure 4-7. Enabling/Disabling Blanking through Coherent Connection

Blanking is used to turn the diode completely off. If not used, the diode will remain on but will be below lasing threshold.

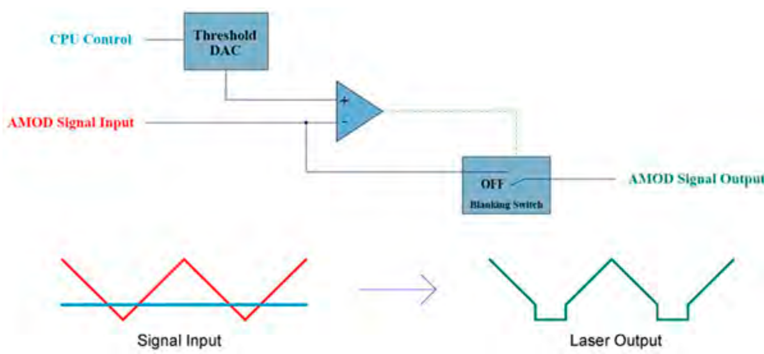


Figure 4-8. OBIS LX Analog Modulation Blanking Circuit Diagram

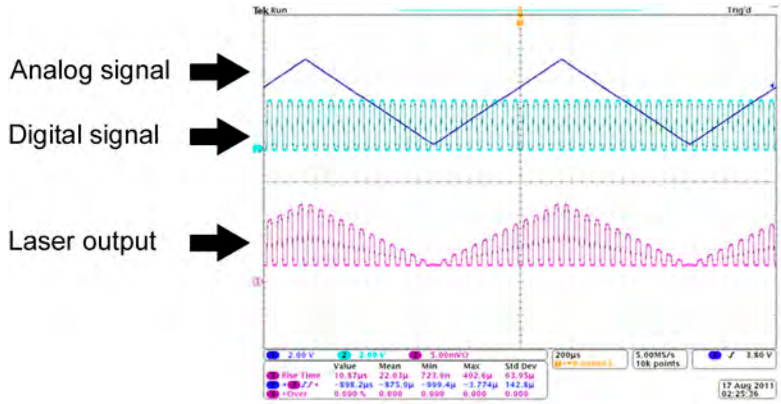


Figure 4-9. Oscilloscope Traces of OBIS Laser Mixed Modulation

The following tables lists typical modulation specifications for OBIS:

Table 4-4. OBIS Typical Modulation Specifications

	Bandwidth	Rise/Fall Time	Modulation Overshoot	Extinction Ratio
Digital: Power	500 KHz	< 700 ns	< 3%	1 000 000:1
Analog: Power	500 KHz	< 700 ns	< 3%	1 000 000:1
Mixed: Power	500 KHz	< 700 ns	< 3%	1 000 000:1
Digital: Current	150 MHz	< 2 ns	< 20%	1 000 000:1 at 0 Hz, 250:1 at 150 MHz
Mixed: Current	150 MHz	< 2 ns	< 20%	1 000 000:1 at 0 Hz, 250:1 at 150 MHz
Note: OBIS modulation specifications for a specific wavelength can be provided upon request.				

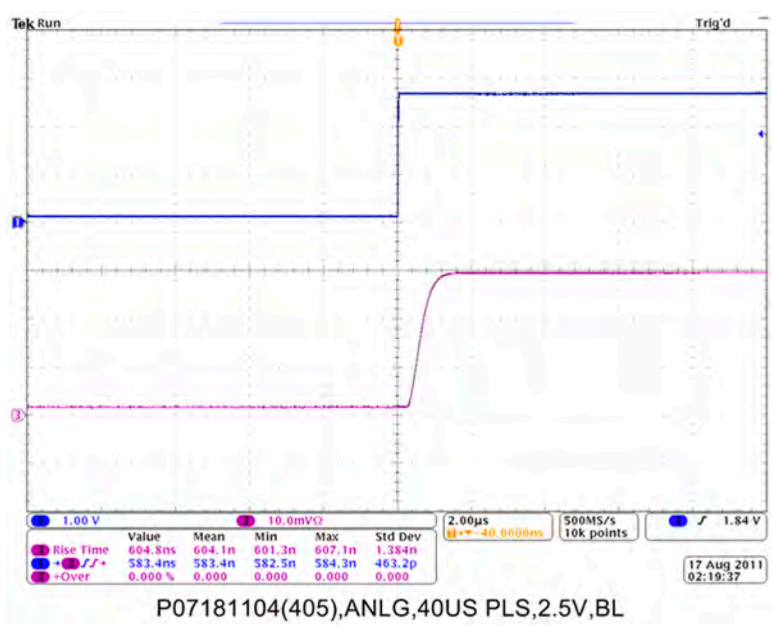


Figure 4-10. Analog Modulation 40 µS Pulse, 405 nm, 2.5V Amplitude

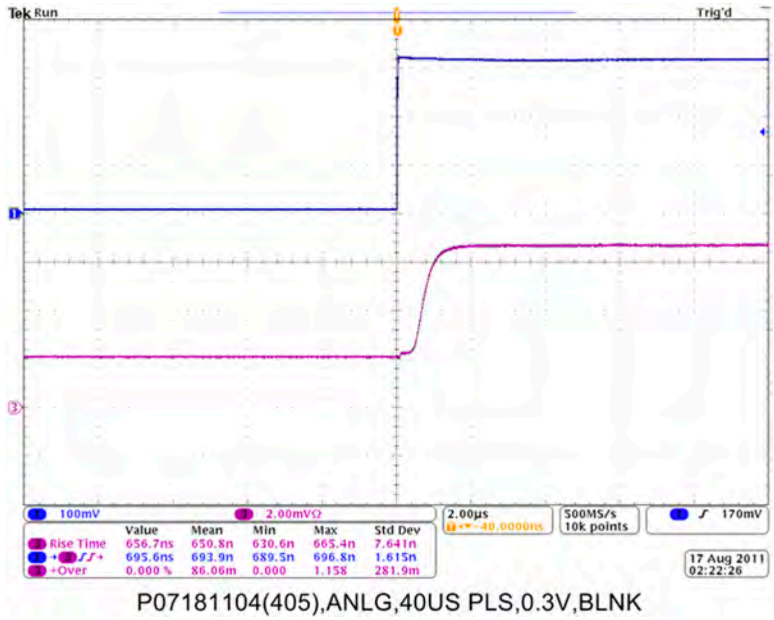


Figure 4-11. Analog Modulation 40 µS Pulse, 405 nm, 0.3V Amplitude

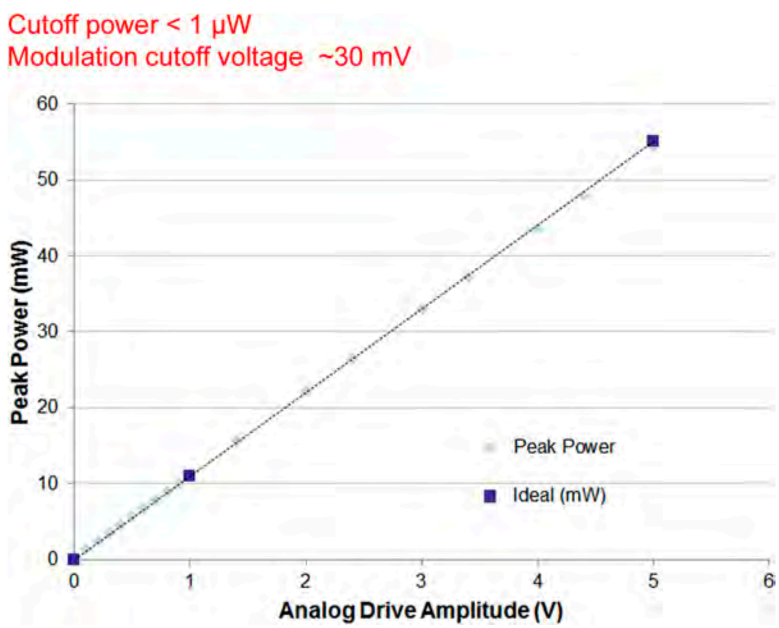


Figure 4-12. Analog Modulation Linearity, 405 nm

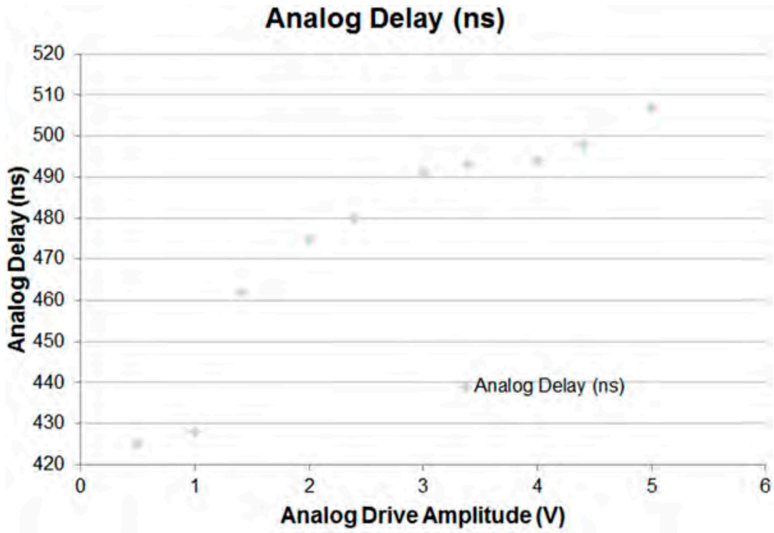


Figure 4-13. Analog Modulation Turn On Delay, 405 nm

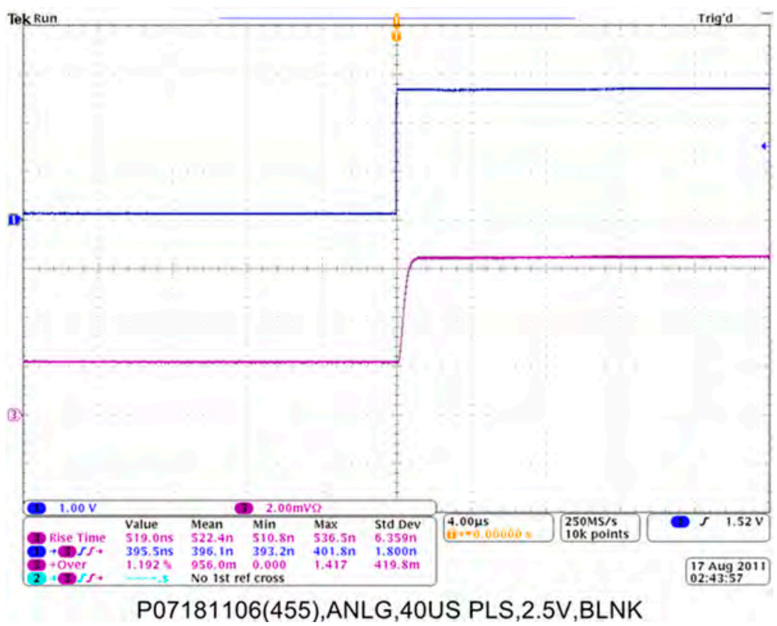


Figure 4-14. Analog Modulation 40 µS Pulse, 445 nm, 2.5V Amplitude

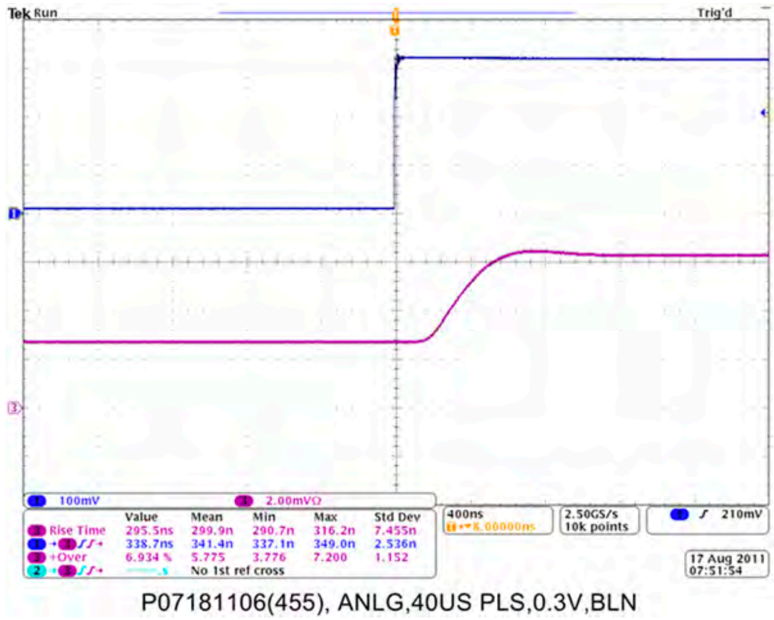


Figure 4-15. Analog Modulation 40 µS Pulse, 445 nm, 0.3V Amplitude

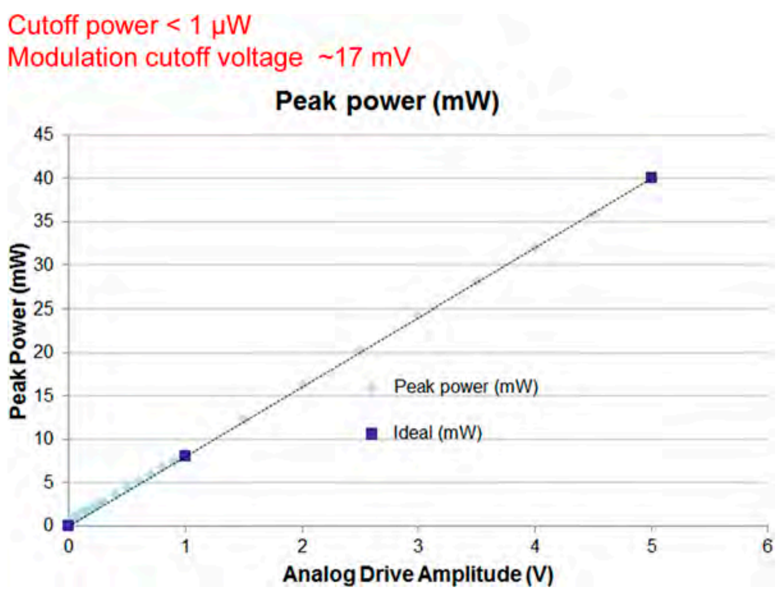


Figure 4-16. Analog Modulation Linearity, 445 nm

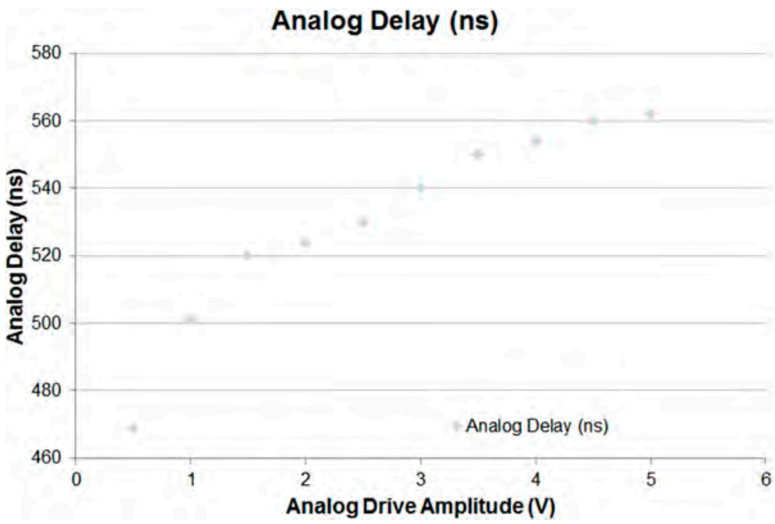


Figure 4-17. Analog Modulation Turn On Delay, 445 nm

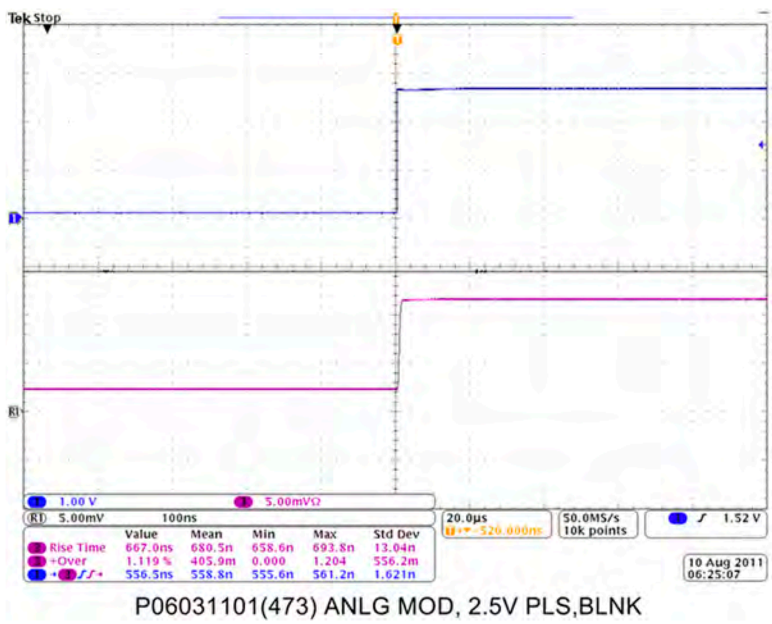


Figure 4-18. Analog Modulation 40 µS Pulse, 473 nm, 2.5V Amplitude

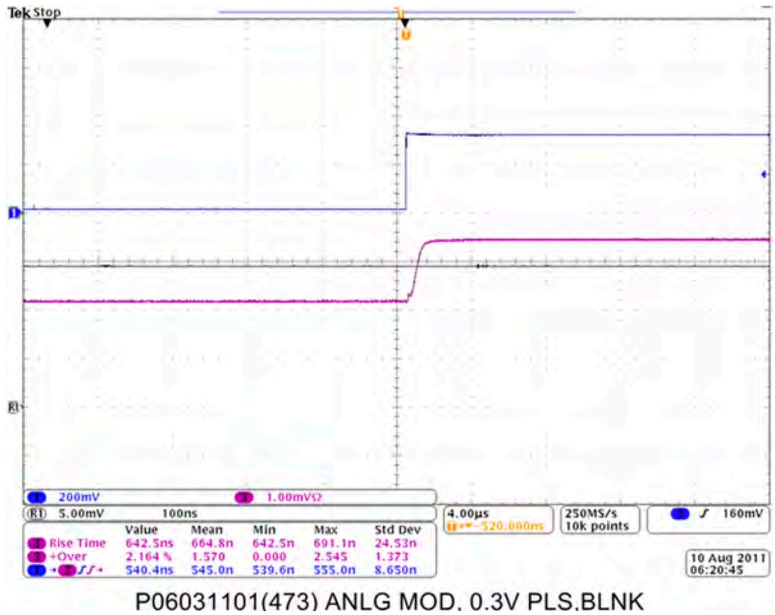


Figure 4-19. Analog Modulation 40 µS Pulse, 473 nm, 0.3V Amplitude

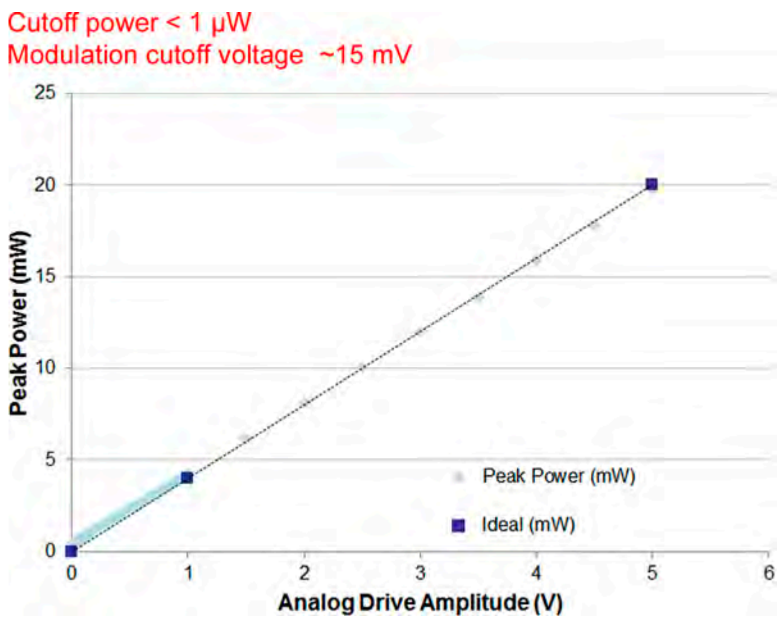


Figure 4-20. Analog Modulation Linearity, 473 nm

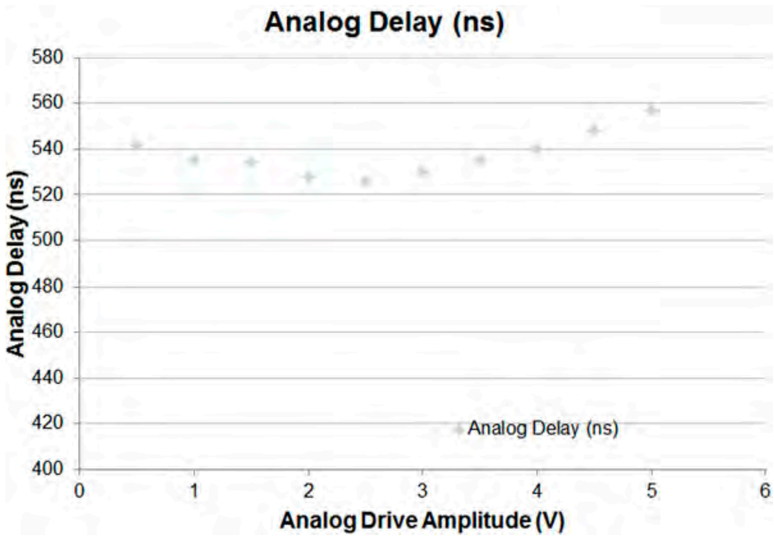


Figure 4-21. Analog Modulation Turn On Delay, 473 nm

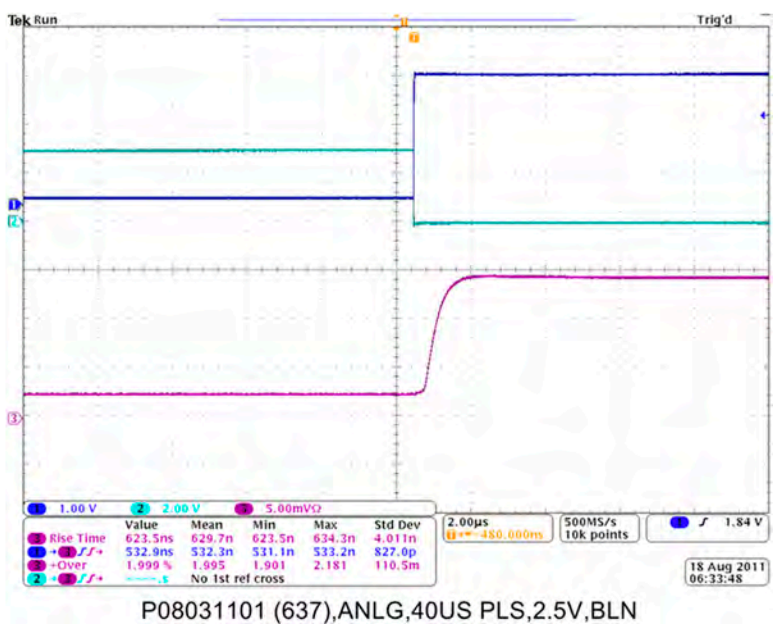


Figure 4-22. Analog Modulation 40 µS Pulse, 637 nm, 2.5V Amplitude

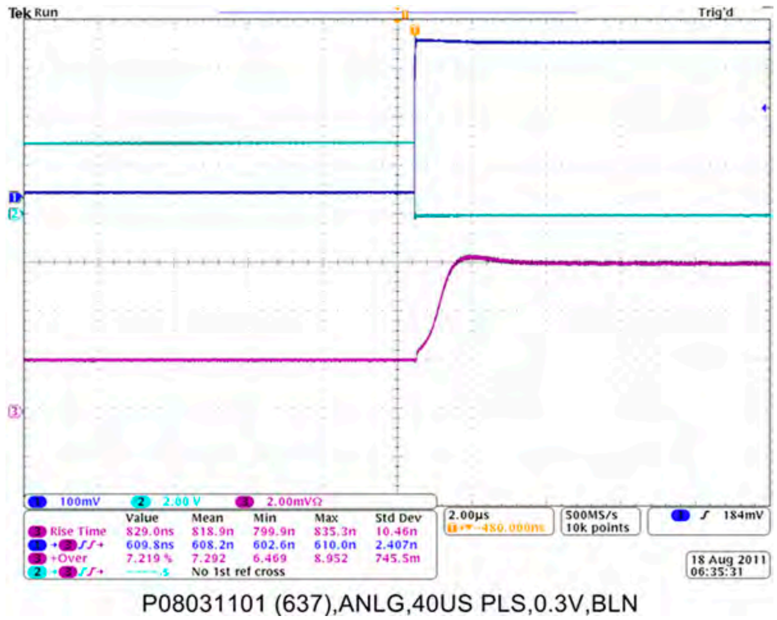


Figure 4-23. Analog Modulation 40 µS Pulse, 637 nm, 0.3V Amplitude

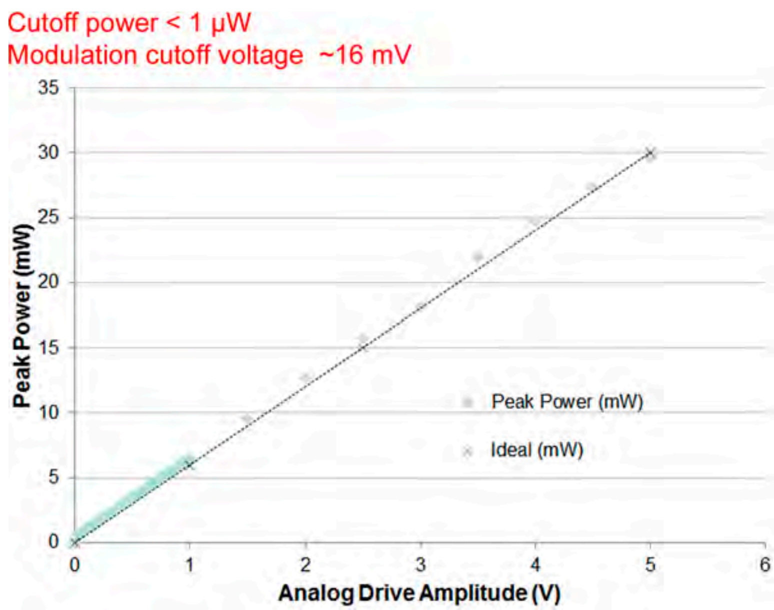


Figure 4-24. Analog Modulation Linearity, 637 nm

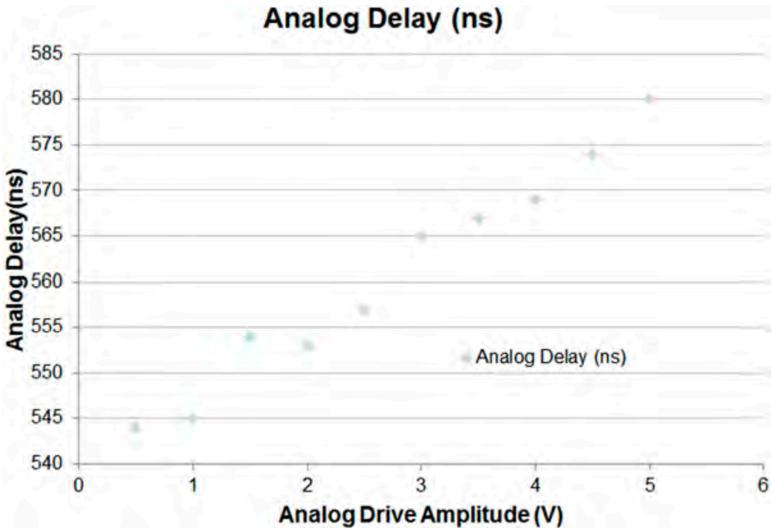
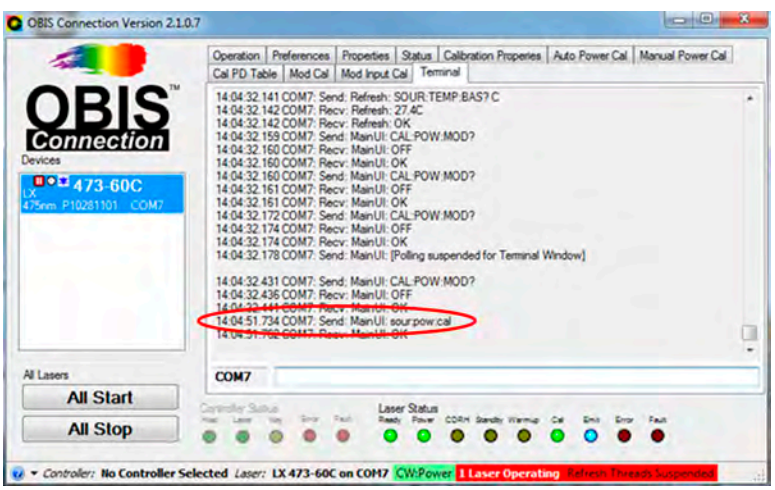


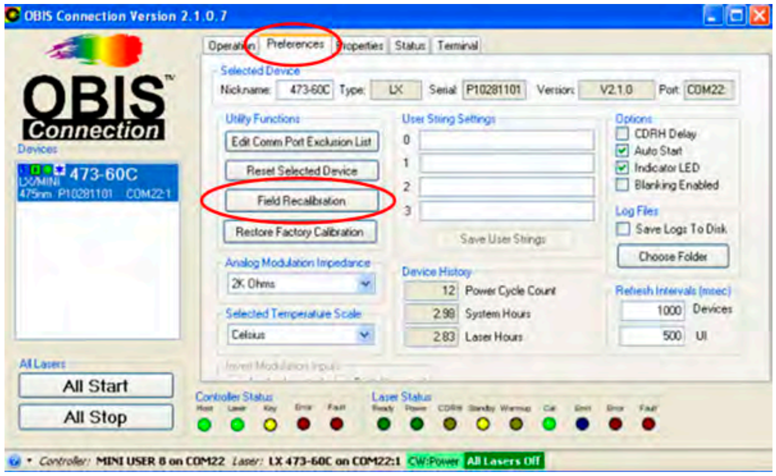
Figure 4-25. Analog Modulation Turn On Delay, 637 nm

OBIS LX Firmware 2.X with OBIS Connection 2.x

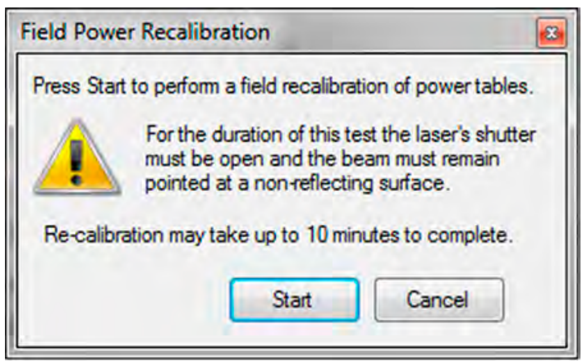
The new OBIS 2.x laser with the OBIS Connection 2.x firmware has a calibration command. The feature needs to be utilized whenever digital modulation is used. Below is the terminal screen with the CAL command implemented. The procedure takes approximately two minutes to complete. The status LED on the OBIS blinks **RED** while calibrating the laser and turns **BLUE** when the process is completed.



The OBIS can also be re-calibrated through the OBIS Connection. Under the Preferences Tab you will find the Field Calibration button. Activating this button will start the recalibration process.

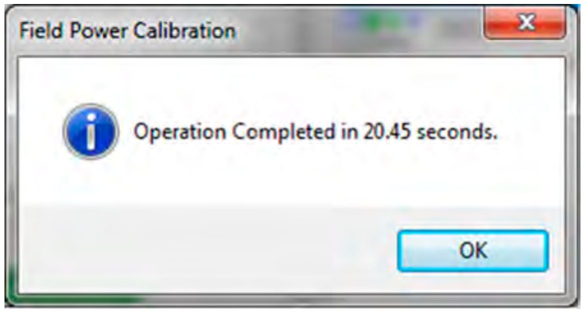


Activating the Field Calibration brings up this dialog box.

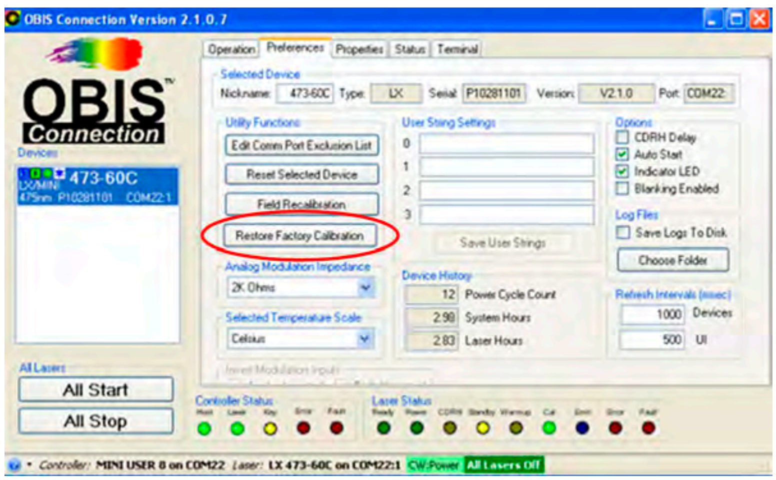


The process takes less than 10 minutes. After pushing the start button, you will see the progress dialog box.

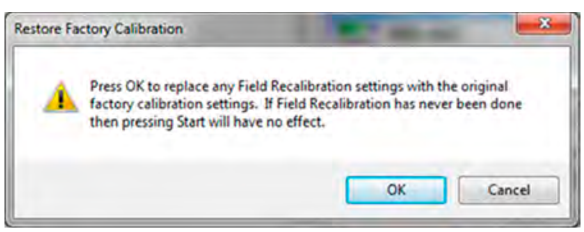
When completed, you see the completed dialog box along with how long it took. This is a typical value.



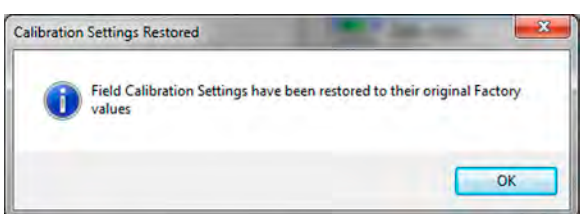
To restore the original factory calibration settings, activate the button in OBIS Connection.



After activating the restore command, the following dialog will appear.



Pressing OK will start the replacement process. When completed, the following dialog box appears and the recalibration is finished.



OBIS SDR Breakout Board

The SDR Breakout Board is designed to speed up the development and bring-up cycles for our customers. The board provides access to all the signals on the OBIS SDR connector and allows the user to connect to the board through either a standard 40-pin ribbon cable connection, or through SMB connections. It also provides a prototyping area for desired custom circuitry.

Features

SDR Breakout Board features include:

- 12 VDC power input using standard OBIS power supply
- Single-ended 50 ohm 0 to 5V analog modulation input through a BNC connector
- Single-ended 50 ohm 0 to 0.3V digital modulation input through a BNC connector
- Adjustable potentiometer for the zero-offset voltage of the analog modulation input
- Adjustable potentiometer for the gain of the analog modulation input
- All SDR cable signals broken out on a 2x20, 40-pin ribbon cable connector
- Additional 40-pin break-out headers for direct and individual signal access
- RS-485 bus converted to 3.3V CMOS logic levels
- 100-mil grid prototyping area for custom circuitry
- Power disconnect jumper to turn off power to OBIS
- Power Indicator LED
- Interlock jumper to control laser emission
- + 3.3V @ 400 mA and - 3V @ 200 mA available for customer use

This board contains all the functional blocks needed to drive an OBIS laser at full analog and digital modulation bandwidth. Customers can very quickly observe their operation and modify or adapt them to their own needs by adding their own circuitry in the 100-mil grid through-hole.

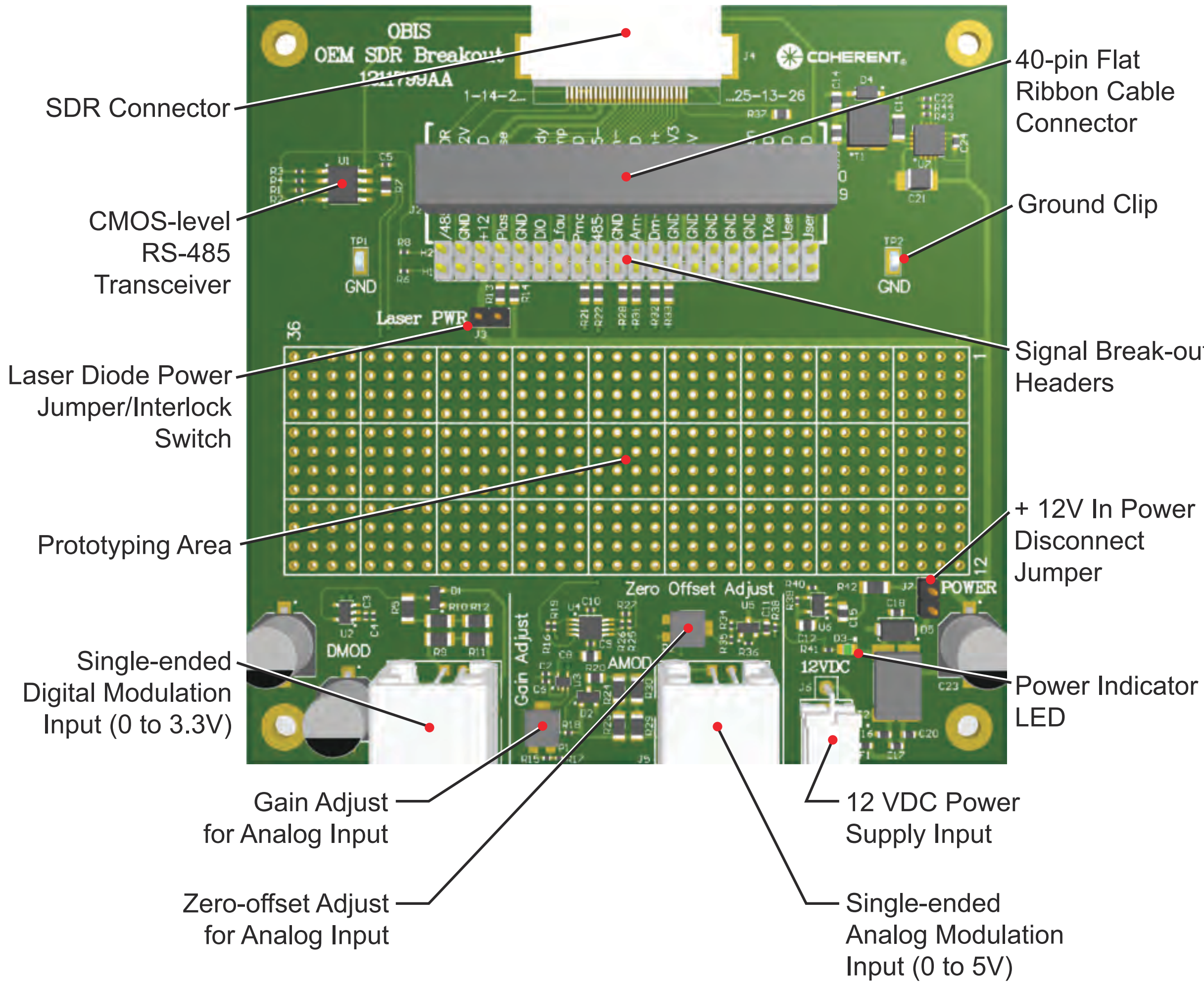


Figure 4-26. OBIS SDR Breakout Board

Functional Guide

Power

Power to the SDR Breakout Board and OBIS laser head is supplied through J6 (12 VDC), and can be controlled with jumper J7. Insertion of the jumper provides power to the Breakout Board and OBIS laser head; extraction of the jumper turns all power off.

Interlock

Jumper J3 provides power to the laser diode in the OBIS laser head and acts as an interlock. Removal of the jumper will turn off laser emission; insertion of the jumper will turn the laser back on.

Digital Modulation

The SDR Breakout Board has a single-ended BNC input (J1) for digital modulation (0 to 3.3V). The circuit on the board converts the signal into the differential LVDS signal used by the OBIS laser head. To disable the single-ended digital modulation input and use the differential LVDS inputs accessible from the flat ribbon cable connector or breakout header, remove R32 and R33 (0 ohm).

Analog Modulation

The SDR Breakout Board has a single-ended BNC input (J5) for analog modulation (0 to 5V). The circuit on the board converts the signal into the differential signal (-0.93V to 0.93V) used by the OBIS laser head. To disable the single-ended analog modulation input and use the differential inputs accessible from the flat ribbon cable connector or breakout header, remove R28 and R31 (0 ohm).

Analog Modulation Zero-Offset Adjustment

The zero-offset voltage of the analog modulation signal can be adjusted by rotating the potentiometer P2 on the board. Adjustment of the zero-offset voltage will increase or decrease the amount of current supplied to the laser diode when the laser is driven with a 0V input. A higher zero-offset voltage will allow for a shorter turn-on delay.

Analog Modulation Gain Adjustment

Similarly, the gain of the analog modulation amplifier can be adjusted by rotating the potentiometer P1 on the board. Adjusting the gain will increase or decrease the maximum laser output power at the maximum analog input voltage (5V).

RS-485 to 3.3V CMOS Converter

The SDR Breakout Board houses a differential RS-485 to single-ended 3.3V CMOS transceiver for development convenience. The CMOS signals can be accessed through the flat ribbon cable connector J2 or through the breakout headers H1 and H2.

3.3V and -3V Supplies

3.3V @ 400 mA and - 3V @ 200mA are available through the flat ribbon cable connector J2 and through the breakout headers H1 and H2.

Prototyping Area

The prototyping area is a 0.1 inch through-hole grid for the user's convenience.

Ribbon Cable Connector and Breakout Header

The ribbon cable breakout headers provide local access to all the SDR signals and some additional signals. The following table describes the pinouts.

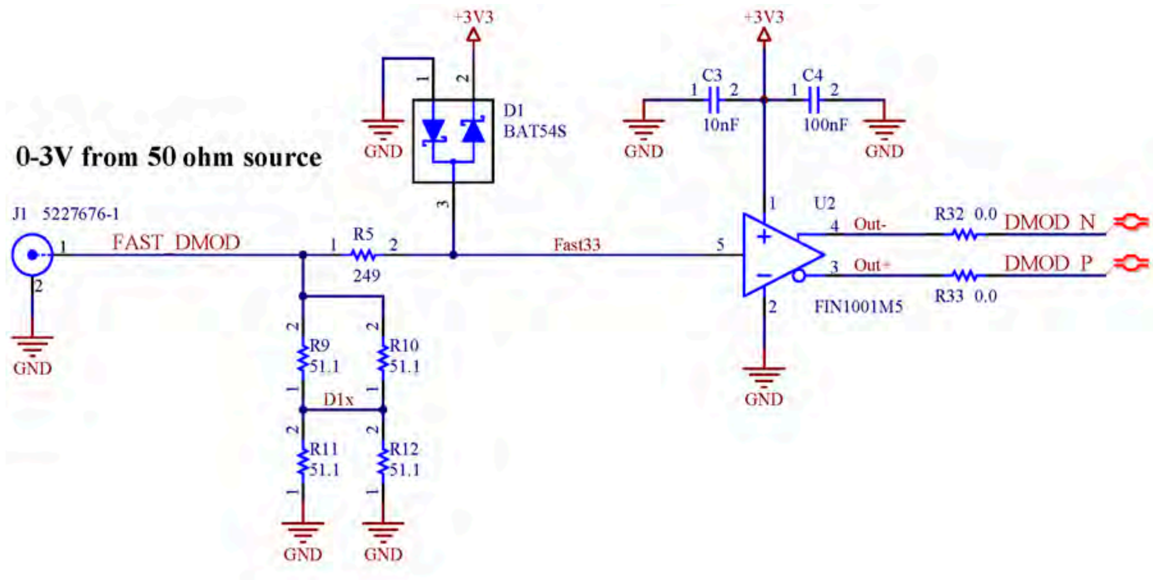
Table 4-5. Ribbon Cable Connector Pinout Description (Sheet 1 of 2)

Pin Number Headers H1, H2	Pin Number Connector J2	Pin Name	Pin Description
H1-1	J2-1	RS485_INHIBIT	Pulled high in laser head. Must be pulled low to enable RS-485 communication. Refer to "OBIS RS-485 Interface" (p. 4-30).
H1-2	J2-2	GND	Ground
H1-3	J2-3	+12 Vin	12 VDC supply to the Breakout Board and to Plaser and Phouse. Can be powered off by removing J7.
H1-4	J2-4	Plaser	12 VDC supply to the laser diode. Also used as interlock. It can be powered down by removing J3 and it can be isolated from + 12 Vin by removing R15.
H1-5	J2-5	GND	Ground
H1-6	J2-6	DIO_CURR	Analog output. 0 to 2V = 0A - maximum allowed diode current.
H1-7	J2-7	LASER_FAULT	< 0.5V: laser OK > 2.5V laser shows error
H1-8	J2-8	PWRMON	Analog output driven by the photodiode amplifier. Scaled to 0 to 2V = 0 to 100% power.
H1-9	J2-9	RS485_P	Differential serial bus high side
H1-10	J2-10	GND	Ground
H1-11	J2-11	AMOD_P	Positive line for analog power modulation. 0 to 4V common mode. - 0.930 to + 0.930V differential scales to 0 to 110% output power.
H1-12	J2-12	DMOD_N	Differential digital modulation input low side. LVDS signal level.
H1-13	J2-13	GND	Ground
H1-14	J2-14	GND	Ground
H1-15	J2-15	GND	Ground
H1-16	J2-16	GND	Ground
H1-17	J2-17	GND	Ground
H1-18	J2-18	TXen	Enables the 3.3V CMOS version of RS-485 transmit signal. Active high to enable.
H1-19	J2-19	User1	Spare signal for the user. Not connected to the SDR connector.
H1-20	J2-20	User2	Spare signal for the user. Not connected to the SDR connector.

Table 4-5. Ribbon Cable Connector Pinout Description (Sheet 2 of 2)

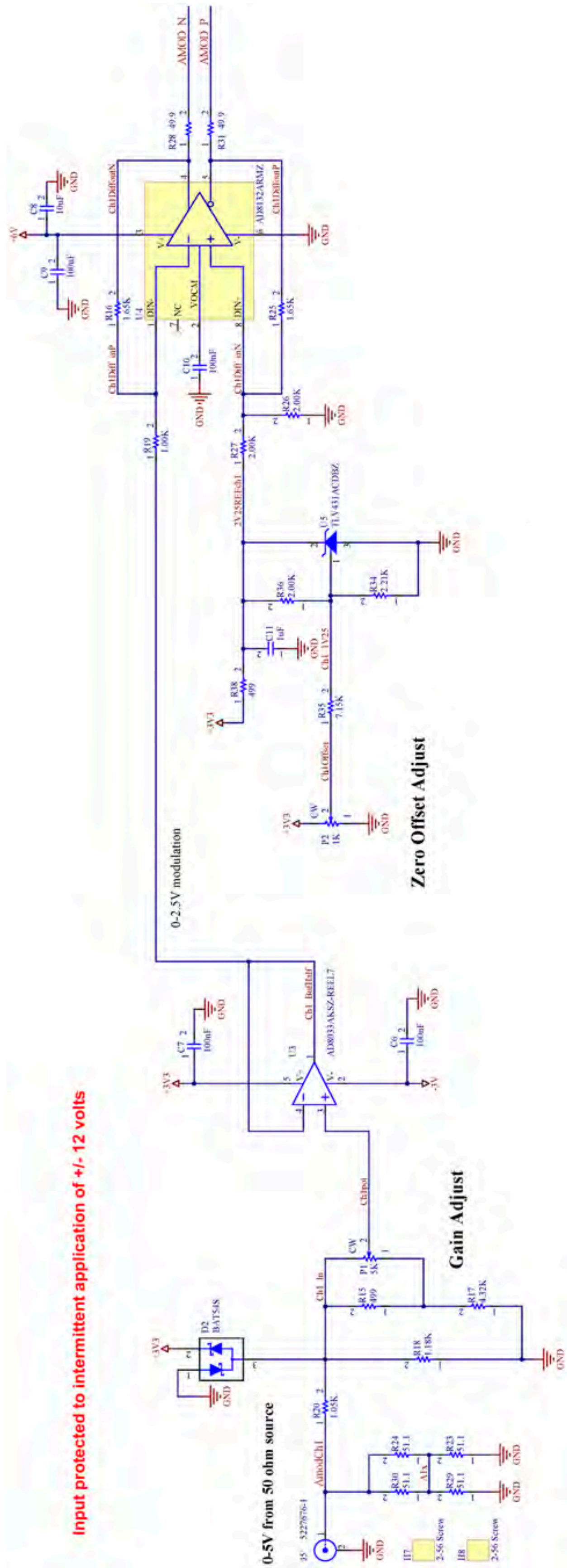
Pin Number Headers H1, H2	Pin Number Connector J2	Pin Name	Pin Description
H2-1	J2-21	SDR_IN_USE#	Pulled high in the laser head. This signal is looped back to pin 13 in the remote so a low on this pin signals to the laser head the presence of a host.
H2-2	J2-22	+ 12 Vin	12 VDC supply to the Breakout Board and to Plaser and Phouse.
H2-3	J2-23	GND	Ground
H2-4	J2-24	Phouse	12 VDC supply to the OBIS laser head. It can be powered down by removing J7 and it can be isolated from + 12 Vin by removing R17.
H2-5	J2-25	NC	No connect
H2-6	J2-26	LASER_READY	> 2.5V when laser output active (only CW mode) and output power is within ± 2% set power; otherwise < 0.5V.
H2-7	J2-27	BP_TEMP	<0.5V: baseplate temp below (upper limit - 10°C). 1.2 to 2V: baseplate between (upper limit - 10°C) and upper limit. > 2.7V: baseplate above upper limit.
H2-8	J2-28	GND	Ground
H2-9	J2-29	RS485_N	Differential serial bus low side.
H2-10	J2-30	AMOD_N	Negative line for analog power modulation. 0 to 4V common mode. - 0.930 to + 0.930V differential scales to 0 to 110% output power.
H2-11	J2-31	GND	Ground
H2-12	J2-32	DMOD_P	Differential digital modulation input high side. LVDS signal level.
H2-13	J2-33	+ 3.3V	+ 3.3V at 400 mA output generated on the Breakout Board to power custom circuitry on the prototyping grid.
H2-14	J2-34	- 3V	- 3V at 200 mA output generated on the Breakout Board to power custom circuitry on the prototyping grid.
H2-15	J2-35	TX	3.3V CMOS version of the RS-485 transmit signal.
H2-16	J2-36	RX	3.3V CMOS version of the RS-485 receive signal.
H2-17	J2-37	RXen#	Enables the 3.3V CMOS version of RS-485 receive signal. Active low to enable.
H2-18	J2-38	GND	Ground
H2-19	J2-39	GND	Ground
H2-20	J2-40	GND	Ground

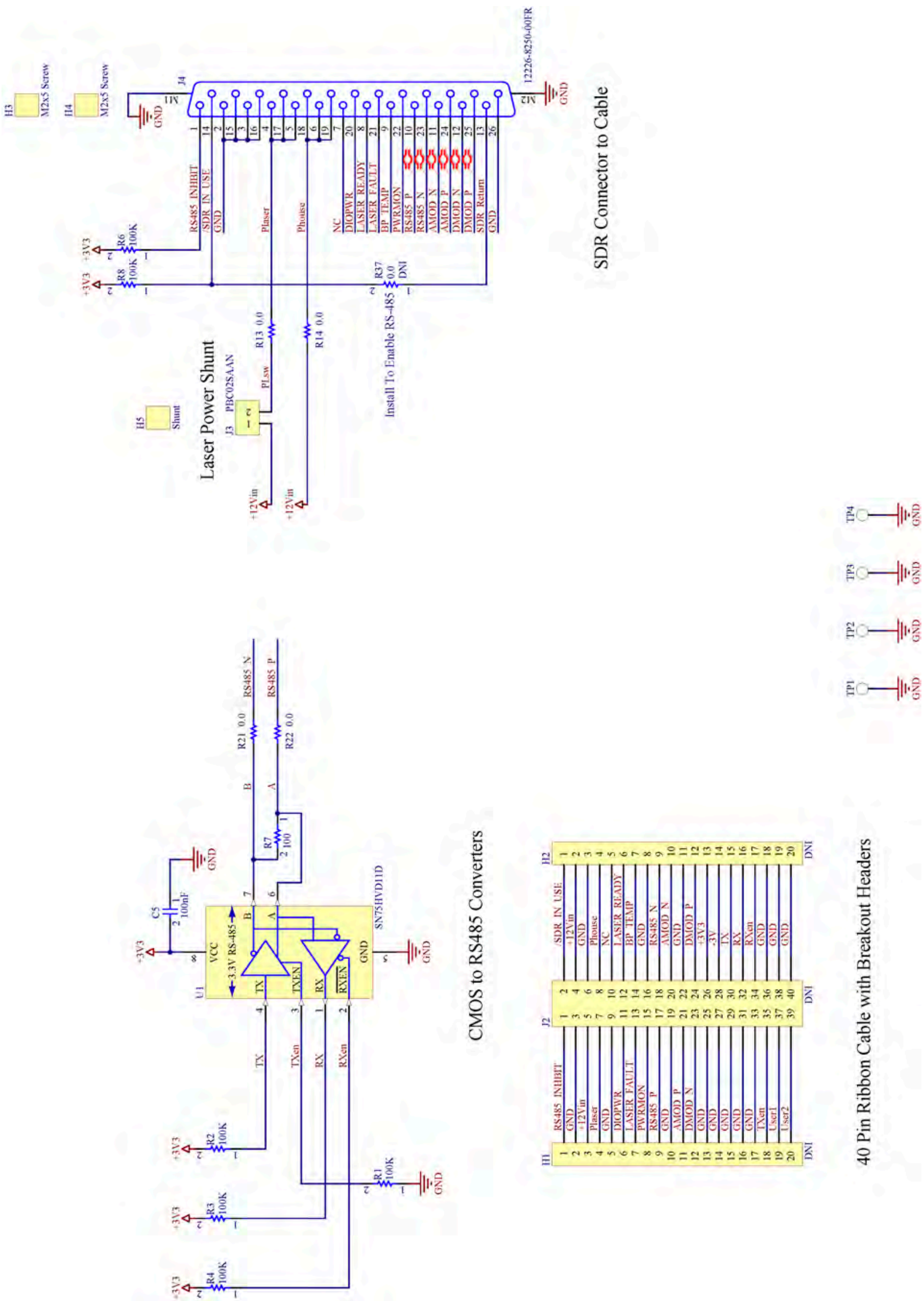
Schematics

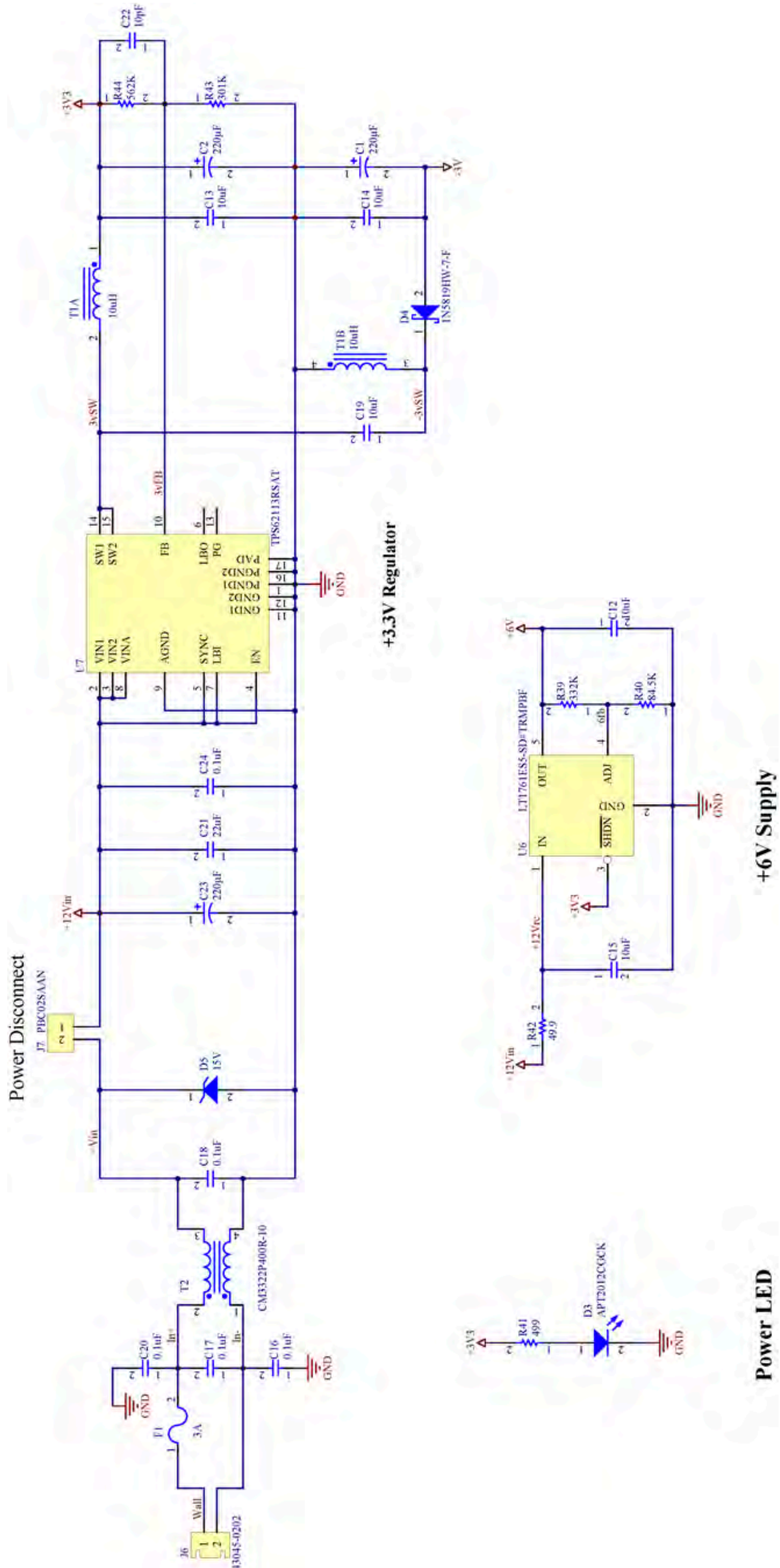


FAST DIGITAL MODULATION

Input protected to intermittent application of +/- 12 volts


Input protected to intermittent application of +/- 12 volts
0-5V from 50 ohm source
Gain Adjust
0-2.5V modulation
Zero Offset Adjust
AD8132ARMZ
AD8033AKSZ-REEL7
TLV431ACDBZ
AMOD N
AMOD P


SDR Connector to Cable
Laser Power Shunt
Install To Enable RS-485
CMOS to RS485 Converters
40 Pin Ribbon Cable with Breakout Headers


Power Disconnect
+3.3V Regulator
+6V Supply
Power LED

Coherent offers two available options that make it easy to connect to the laser SDR:

1. SDR connector (solder cup) (part number 1218636)

2. SDR break-out-PCBA with complete I/O (part number 1211799)

OBIS RS-485 Interface

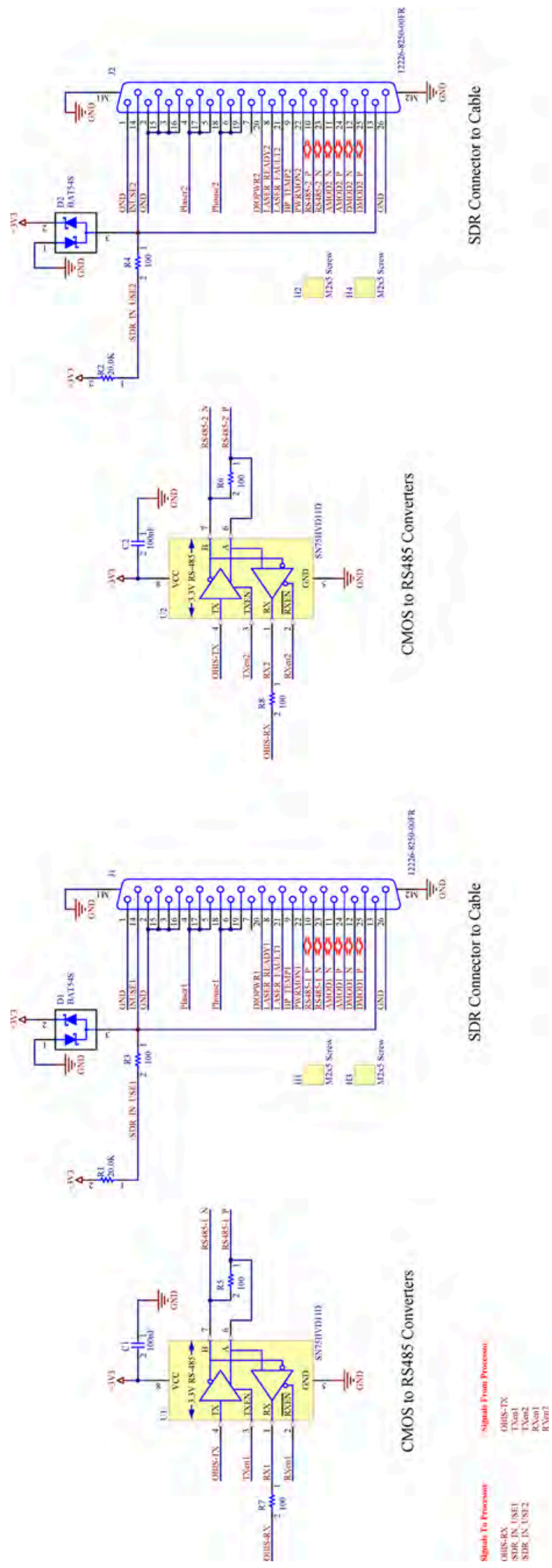
This section describes the recommended RS-485 serial communication interface between a host micro-controller and several OBIS lasers, with the main focus on the hardware configuration. The communication protocol is described in the *OBIS Operator's Manual* (1184163) and is not included in this manual.

Abstract

The communication protocol used by OBIS lasers was designed with reliability and simplicity as the driving factors. While the RS-485 hardware layer supports multi-drop, the communication protocol used by OBIS lasers does not. A host that wants to control more than one laser must either use one UART for each channel or multiplex a single UART. The rest of this section describes a simple implementation of a two-channel multiplexer driven by a single UART port on the host micro-controller. The information only describes the serial interface on the SDR port of the host. For information about all of the other signals on the SDR port, refer to the *OBIS Operator's Manual* (1184163).

Design Description

The schematic on the next page shows the implementation of the required interface to two OBIS lasers. To interface a larger number of lasers, the circuits will need to be replicated. Note that R7 and R8 serve only to guard against bus fighting when more than one TXen line is asserted at the same time.


SDR Connector to Cable
CMOS to RS485 Converters
SDR Connector to Cable
CMOS to RS485 Converters

The required signals between the host and the OBIS laser are shown in the following table.

Table 4-6. OBIS RS-485 Interface Signal Description

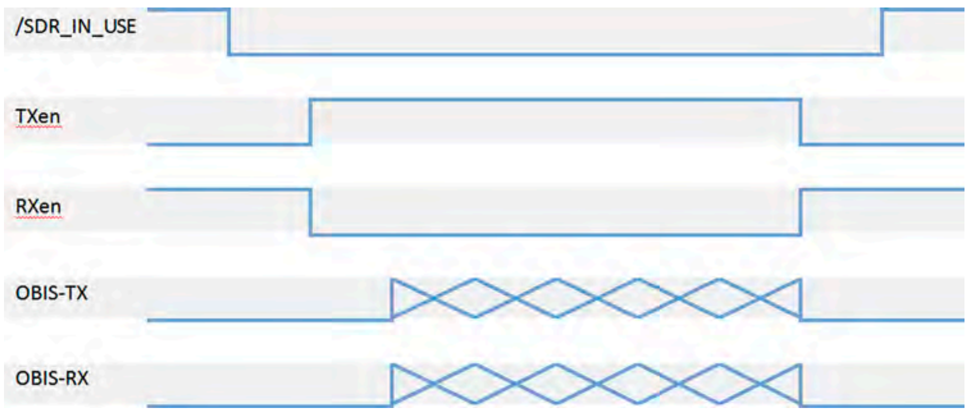
Signal	Input/ Output	Description	Voltage Level
OBIS-RX	Input	Receive data from OBIS Laser	3.3 VCMOS
/SDR_IN_USE1, /SDR_IN_USE2	Input	Pull up to 3.3V. Signal grounded by OBIS laser when plugged into SDR port.	3.3 VCMOS 3.3 VCMOS
OBIS-TX	Output	Transmit Data to OBIS Laser	3.3 VCMOS
TXen1, TXen2	Output	Active High. Signal must go active to address the corresponding OBIS Laser.	3.3 VCMOS
+12V		Power to OBIS Laser	+12V
Ground		Ground	GND

All signals are driven at 3.3 volt CMOS logic levels. This scheme can be expanded to drive as many OBIS lasers as required. The /SDR_IN_USEx lines are pulled up by the host and grounded when an OBIS laser is connected to its SDR cable. The host should use this line to enable or gate +12V power to the corresponding SDR port.

When the RS-485 bus is idle, all TXen lines must be low. To address a laser, the corresponding TXen line needs to be raised (and the RXen line lowered), and data transmission can start. When the last response is received, the host can drop the TXen line.

If a port's SDR_IN_USE line rises while its TXen line is high (indicating that the laser has been unplugged), the host should terminate transmission. Since the OBIS protocol is a strict master-slave, query-response relationship, there is no interrupt line from the laser to the host to initiate communication. The host should regularly round robin poll all SDR ports with a low logic level on their /SDR_IN_USE pin.

The following diagram shows the timing relationship between communication signals.



SECTION FIVE: OBIS INTEGRATION WITH THE SDR CABLE INPUT

In this section:

- RS-485 communication - Coherent Connection bus protocol (p. 5-3)
- Outbound message transmission (p. 5-13)
- Inbound message transmission (p. 5-20)
- Bus management (p. 5-26)

The OBIS laser can be operated for OEM applications by connecting power to the 2-pin Molex connector and using a USB interface. Type: Molex Micro-Fit, part no. 43045-0200. To connect to this connector, use Molex SDA43025-0200 with pins 43031-009.

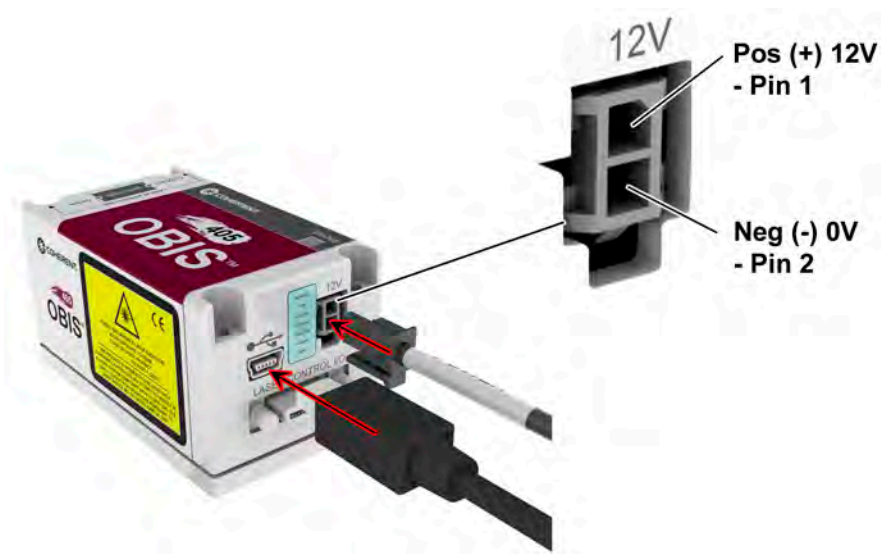


Figure 5-1. Connecting Power and the USB Cable

If the application requires more than CW laser power with USB control, then the SDR connector can be used to interface to the laser and access all functions.

Figure 5-2. Connecting the SDR Cable

The following is a description of the SDR cable signals and an explanation of the RS-485 interface.

Table 5-1. SDR Cable Signals

Signal Name	Pin
System Ground	2, 3, 15, 16
Laser Diode Power (Interlock)	4, 5, 17
+12 VDC System Power	6, 18, 19
No Connect	7
Laser Ready Output Signal	8
Baseplate Temperature Output Signal	9
RS-485 Communications	1, 10, 23
Analog Modulation Input	11, 24
Digital Modulation Input	12, 25
SDR In-Use Logic	13, 14
Diode Current Output Signal	20
Laser Fault Output Signal	21
Power Monitor Output Signal	22, 26

PIN 1, 10, 23: **RS-485**. An addressable RS-232 with differential signals to allow for multiple devices on the same bus with capability to drive long distances. For details on RS-485 standard, see http://en.wikipedia.org/wiki/EIA-485.

Use Coherent OBIS protocol for CCB and enumeration. Half Duplex.

PIN 2, 3, 15, 16: **Power Return**. Same as chassis ground. Chassis ground and system ground are tied at the back SDR connector. (Not the same ground as the Molex connector for Power. The Molex has a common-mode filter for noise suppression.) Do not use the Molex power connection when using the SDR connector.

PIN 4, 5, 17: **Laser Diode Power**. Circuits used for CDRH for just the laser diode power.

PIN 6: **System Power**. Everything except the Laser Diode. Includes computer and TEC (OBIS LX). Recommend applying the System Power before or coincidently with Laser Diode Power.

PIN 7: **No connect**.

PIN 8: **Laser Ready Output Signal**. Circuit contains a 100 Ohm series resistance.

PIN 9: **Baseplate Temperature**. Circuit contains a 100 Ohm series resistance.

PIN 11, 24: **Analog Modulation**. See examples in figures 4-3 through 4-6, starting on p. 4-3.

PIN 12, 25: **Digital Modulation**. LVDS.

Chipsets are readily available to convert a typical signal-generator output to LVDS.

PIN 13, 14: **Connect together to signal OBIS laser that the SDR cable inputs are the master**. Doing so will give communication controls to RS-485 and ignore USB. *This can be overridden with a command to allow both to be connected and give the USB on the laser back panel priority.*

PIN 20: **Diode Current Output Signal**. Circuit contains a 100 Ohm series resistance.

PIN 21: **Laser Fault Output Signal**. Circuit contains a 100 Ohm series resistance.

PIN 22, 26: **Power Monitor Output Signal**. Circuit contains a 100 Ohm series resistance.

RS-485 Communication—Coherent Connection Bus Protocol

The Coherent Connection Bus (CCB) is intended to provide robust communication between a controlling device (master) and one or more controlled devices (slaves). The physical bus is based on the ANSI/TIA/EIA-485-A specification for a two-wire half-duplex multi-drop network that accommodates up to 32 unit loads. Note that each device does not necessarily equate to a single unit load since transceiver impedance and hardware design combine to affect bus loading (refer to the EIA/TIA-485-A spec for more information).

Characteristics of the CCB Protocol include:

- Up to 253 device addresses per bus
- Transparent handling of binary and ASCII data
- Variable length messages to a maximum of 255 bytes

- Collision detection and retry
- Broadcast message support
- Messages are transmitted in LSB order on each byte.
- The SCPI command string portion of the packet must be terminated with a 0x0D 0x0A 0x00, carriage return, line feed, null terminator.
- All data is transmitted with one start bit, eight data bits, one stop bit and no parity

Table 5-2. RS-485 Communication Settings

Baud Rate	921600
Data Bits	8
Stop Bits	1
Parity	None
Flow Control	None

Applicable Documents

- *TIA-485-A Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems (ANSI/TIA/EIA-485-A-98) (R2003)*
- *TSB-89-A: Application Guidelines for TIA/EIA-485-A*
- *Serial Port Complete: COM Ports, USB Virtual COM Ports, and Ports for Embedded Systems, Second Edition (Complete Guides series)* (Paperback) by Jan Axelson
- *RS485 Cables - Why you need 3 wires for 2 (two) wire RS485* (http://www.chipkin.com/articles/rs485-cables-why-you-need-3-wires-for-2-two-wire-rs485)
- *Guidelines for Proper Wiring of an RS-485 (TIA/EIA-485-A) Network* (http://www.maxim-ic.com/appnotes.cfm?appnote_number=763&CMP=WP-1)

Functional Overview

The Coherent Connection Bus is intended to provide message transmission between a single master device and one or more slave devices connected to the bus.

Two general categories of messages are exchanged:

Bus Management Messages are used to manage bus operation, assign addresses, detect device disconnection, and notify client applications of bus events that may affect the client. These messages are sourced by CCB on both master and slave devices.

Standard Messages are sourced by Client Application Software to implement a specific Application Protocol. Typically the client application running on the master device sends standard messages (commands or queries) to slave devices. After receiving a standard message the slave device responds in a manner defined by the received message, which may include replying to the master with another standard message containing query data or an acknowledgement that a command was received and acted upon.

A slave device must respond to a master's standard message request (non-broadcast) within 700 milliseconds before the master will re-send. The master will retry sending up to three times before declaring a device disconnection event. The slave must reply in form of a general acknowledgement or a specific response. This implies all messages have a 'handshake' mechanism. The master won't send another message type to the slave until it responds to the last message sent.

Message flow is always between master and slave devices, slave devices may not communicate with each other on a peer-to-peer basis.

Each device is assigned a unique address on the bus. The master device is always at fixed address 0. When slave devices power-up they utilize defined Bus Management Messages to request an address from the master device. Once an address is acquired the slave will use that address until the master assigns it a new address (usually at the next power cycle).

Master devices may utilize Bus Management Messages to poll (ping) devices on the bus. Polling is generally used to verify the presence of a device when it has not been heard from for awhile (for the purpose of device disconnection notification).

OEM Hardware Design Requirements

The CCB protocol requires one RS-485 serial port for communication with the bus and a timer with sufficient resolution to detect idle line conditions.

The transmission collision detection function of CCB requires hardware that allows the receiver to be enabled while transmitting data. The software must be able to listen to what is being transmitted.

It is important that the bus be designed to prevent reflections that could cause data corruption, which normally is done with terminating resistors at each end of the bus. Under some circumstances an RS-485 bus may operate without termination, which is desirable from the standpoint of simplification and power savings, but elimination of reflections that could corrupt bus data will take precedence. Bus design and termination requirements are beyond the scope of this document but need to be taken into account during the hardware design phase.

Due to the nature of 2-wire half duplex RS-485 it is important that the transmitter be disabled whenever a device is not actually transmitting data. Although a RS-485 bus can tolerate brief periods of time when more than one transmitter is driving the bus it is extremely important that these time periods are kept to a minimum. It is thus important that the length of time a transmitter is enabled be kept to a minimum.

If the hardware supports end of transmission interrupts (an interrupt that occurs after the final message bit has been sent) then it is recommended that the transmitter be enabled at the very start of message transmission and disabled as soon as the end of transmission interrupt is generated.

Not all processors/UARTs provide for an end of transmission interrupt this feature. When this is the case it is acceptable to implement a circuit to perform Automatic Send Data Control (ASDC). This feature automatically enables the transmitter at the beginning of data transmission and disables it immediately after the last stop bit has been sent. The book, *Serial Port Complete*—refer to p. 5-4—describes several simple circuits that may be used to implement this feature.

If ASDC is not implemented then the software requires another method to determine exactly when the last bit of the last message byte has been clocked out of the transmit register so the transmitter can be immediately disabled. This requirement could be met with a UART that can generate an interrupt when the transmitter SHIFT register is empty (a feature that is somewhat rare), or with a high-resolution timer that can provide an interrupt one character transmission time after the last message byte has been shifted into the transmit shift register (at 921.6kbs this could be as short as 11 µsecs), or simply after receiving the last message byte which was transmitted.

However the transmitter is controlled, it is the implementing engineers responsibility to disable the transmitter whenever the device is not actually transmitting. This is necessary to prevent data corruption or seizure of the bus, which would prevent any other device communication.

A software implementation requires access to a timer which has sufficient resolution for detecting idle line conditions and expected event timeouts.

Each device on the bus must have a unique address. Historically assigning RS-485 addresses to devices has been the responsibility of the end user, typically by setting a series of DIP switches or by programming an address into non-volatile storage on the device. Manual address assignment has some undesirable ramifications, including increased hardware costs, customer training and documentation costs, bus operation and troubleshooting problems caused by duplicate addresses, difficulty in swapping out devices, and ill will generated when customers encounter problems due to misunderstandings or errors on their part.

To eliminate manual address assignment the CCB protocol allows for a system of automatic address assignment which relieves the client hardware of any addressing responsibilities.

Message Structure

All messages sent across the CCB will contain a common five-byte header. A message may optionally include up to 255 bytes of data.

The five byte header will be organized as shown in the following table.

Table 5-3. CCB Message Header

Byte	Abbreviated Name	Function
0	Sadd	Source device address
1	Dadd	Destination device address
2	Flags	Message Flags byte
3	Tag	Arbitrary value
4	Len	Data Length

The Flags byte is set by the master device when a command or query transaction is initiated. The responding device will return the Flags byte received in a command or query in any resulting reply message.

The Tag byte is an arbitrary value passed from the original sender through to the destination device. The responding device will return the unmodified Tag byte received in a command or query in any resulting reply message. This byte may be used by the originating node to associate a reply message with the initial command/query message. One possible implementation would be to use an incrementing counter as the tag value for each initiating message sent. This way the sender could easily determine if a reply was dropped between consecutive messages.

When the message contains no additional data, the Len byte will be set to 0. This type of message may be used exclusively by the Bus Management function and will not be used by client applications.

When the message contains additional data, limited to 255 bytes, it will be appended to the four byte header and the header Len byte set to the length of the additional data segment.

Message Framing

Since CCB messages may vary in length it is necessary to indicate the start and end point of each message.

SOM	Sadd	Dadd	Flags	Tag	Len	Data	EOM

Figure 5-3. CCB Message Framing

The CCB protocol prefixes a SOM (Start of Message) indication to the beginning of the message, populates the source address (Sadd field above) with the local device address, sets any flags appropriate to the type of message being sent, and appends an EOM (End of Message) indication to the end of the message.

Both binary and ASCII data may be transmitted. For this reason it is not possible to use a single byte to indicate the start or end of a message, since it would be impossible to determine if the byte value represented a start/end of message handshaking character or a valid message data byte.

Assuming that a message packet begins with a single STX character (value 0x02) and ends with a single ETX character (value 0x03) consider the following binary message packet:

0x02	Sadd	Dadd	Flag	Tag	Len	D_0	D_1	D_2	0x03
	0x00	0x01	0x01	0xnn	0x03	0x02	0x10	0x22	

The intent of this message is to represent a single binary message packet. However, it contains ambiguities. The Len byte of 0x03 may be interpreted as an ETX since it has the same value. Similarly, the D0 value of 0x02 may be interpreted as an STX instead of a data byte as was intended. So instead of a single binary message this packet could be interpreted as two separate messages and there is no unambiguous method that software can use to guarantee correct interpretation.

To resolve this problem the framing logic incorporates an escape feature. During transmission any byte value that is intended to function as a handshake character must be preceded by a DLE character

(Data Link Escape, ASCII value 16 decimal or 0x10 hex). This method also requires that any byte in the transmitted data stream with the same value as DLE be sent as two consecutive DLEs.

Using this method the example above would be framed like this:

		Sadd	Dadd	Flag	Tag	Len	D_0		D_1	D_2		
0x10	0x02	0x00	0x01	0x01	0xnn	0x03	0x02	0x10	0x10	0x22	0x10	0x03

When the leading 0x10 DLE character is read, it “escapes” the very next byte, which is then interpreted unambiguously as an STX byte, so it is easy to identify that sequence as the start of a message. When the Len byte of 0x03 and the D0 byte of 0x02 are read, they are not interpreted as ETX or STX framing characters because they were not immediately preceded by DLE bytes. The D1 value of 0x10, however, is a valid data byte so must be preceded by DLE.

As data is read from the bus, each time the DLE character is encountered the next byte is interpreted as a handshake character. Two consecutive DLE characters will be interpreted as one data byte with value equal to DLE.

In short, a DLE, STX sequence always represents the start of a message (the SOM sequence), a DLE, ETX sequence always represents the end of a message (EOM sequence), and a DLE, DLE sequence always represents a single data byte with value 0x10 as part of the message body.

Table 5-4. CCB Protocol Framing Characters

ASCII Character	Hex Value	Protocol Function
STX	0x02	Start of message data
ETX	0x03	End of message data
DLE	0x10	Data Link Escape

Any DLE escape characters added to the message data are not reflected in the message length field of the message. The message length field is only guaranteed accurate at the application layer. The protocol stack will not use the message length field in determining how many bytes to send or receive. A complete message is framed by SOM/EOM sequences.

The last step of message framing involves computing a checksum and appending it to the message. This is covered in more detail under “Outbound Message Framing Function” (p. 5-14).

Address Allocation

Device addresses are one byte in size allowing a total of 255 possible addresses. Some of these addresses are reserved for specific purposes.

Table 5-5. CCB Address Allocation

Device Address	Function
0	Master device
0x01-0xfd	Unique addresses assigned to slave devices
0xfe	Power up default slave address
0xff	Broadcast address (all slave devices respond to this)

As indicated in the above table, the master device is always at address 0 and should power-up with this address.

Address 0xfe is the power up default address of all slave devices and also the address a slave reverts to following reception of a Bus Reset message. The automatic address assignment function will then assign slave devices a unique address in the 0x01-0xf d range.

Address 0xff is a broadcast address. All slave devices will receive messages sent to the broadcast address.

Message Flags Byte

The Message Flags byte contains bits that are used for various purposes.

Table 5-6. Message Flags Bit Definitions

Bit	Name	Function
0	BUSMGMT	Message is a bus management message
1	SRCCCB	Message originated from CCB stack
2	SRCCONT	Message originated from master device (controller)
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	

The BUSMGMT bit is set on any BUS MANAGEMENT message. When this bit is set on an originating message, the destination protocol stack handles the message response rather than passing it up to the destination application for processing. There is nothing to prevent the application layer on a master device from sending bus management messages but the protocol stack on the destination device will always handle the response. The BUSMGMT flag should be used to do the address assignment, ping, and bus reset commands.

The SRCCCB bit is set on messages that are exchanged between CCB protocol stacks. This bit is used to determine message response routing. If the SRCCCB bit is set on a message then the message will always be handled by the protocol stack.

The SRCCONT bit is set on messages that are sourced by the application layer on a master device (usually a controller). These messages are routed to the application layer on the controller device. *Use the SRCCONT flag to do all the SCPI commands and queries*.

When SRCCCB and SRCCONT are both clear a message is passed on to the host.

LRC Computation

A checksum is computed on each message during framing and sent as the last byte of a message following the two byte EOM sequence.

The CCB checksum algorithm uses a simple Longitudinal Redundancy Check with a seed value of 0xff. The entire message frame, including SOM and EOM sequences, the message body, and all inserted DLE escape characters, are included in the calculation. Pseudo code for the algorithm is:

```
Set LRC = 0xff
For each byte c in the message
do
  Set LRC = LRC XOR c
end do
```

Example of a Framed Command and Response Over RS-485

The following example illustrates a framed command and response over RS-485 for checking laser status with handshaking turned on. Non-ASCII data is represented in hexadecimal format delimited by []. For example, decimal 16 is represented as 0x10 in hex and is shown as [10].

(Master) Command TX:
[10][02][00][DF][04][00][0D]SYST:STAT?[0D][0A][00][10][03][35]

(Slave) Response RX:
[10][02][DF][00][04][00][0F]00000180[0D][0A]OK[0D][0A][00][10][03][27]

For further examples (written in C code), refer to the CCBparser.zip file. This file is available for download on the Software tab of the Coherent OBIS Products Page.

Example of a Complete Query and Answer via RS-485

The following example shows what to send over RS-485 to activate the handshaking in the OBIS.

First, do the address assignment to establish communication:

Binary Data sent over the bus with an OBIS address of 3:

0x10	0x02	0x00	0xFF	0x01	0x00	0x03	0x80	0x03	0x00	0x10	0x03	0x80

Now send the handshaking command/query over the bus:

"SYSTem:COMMunicate:HANDshaking ON\r\n" is 36 characters.

This results in a binary data sent over the bus:

0x10	0x02	0x00	0x03	0x00	0x00	0x24	0x53	0x59	0x53	0x54	0x65	0x6D
0x3A	0x43	0x4F	0x4D	0x4D	0x75	0x6E	0x69	0x63	0x61	0x74	0x65	0x3A
0x48	0x41	0x4E	0x44	0x73	0x68	0x61	0x6B	0x69	0x6E	0x67	0x20	0x4F
0x4E	0x0D	0x0A	0x00	0x10	0x03	0xE5						

The LX will respond with "OK\r\n":

0x10	0x02	0x03	0x00	0x00	0x00	0x05	0x4F	0x4B	0x0D	0x0A	0x00	0x10
0x03	0xFB											

Make sure to use Complete Termination \r\n.

OBIS RS-485 communication enforces use of both the carriage return AND newline characters at the end of the command/query string.

Not including the '\n' causes the CCB stack to return an 'ACK' because the datalink layer saw a valid message, but the application layer didn't understand it. This results in a return of error code "-220" ("Invalid Parameter") when sending the next command or query.

This event only occurs when talking over RS-485.

Outbound Message Transmission

Recommended Outbound Message Functional Flow

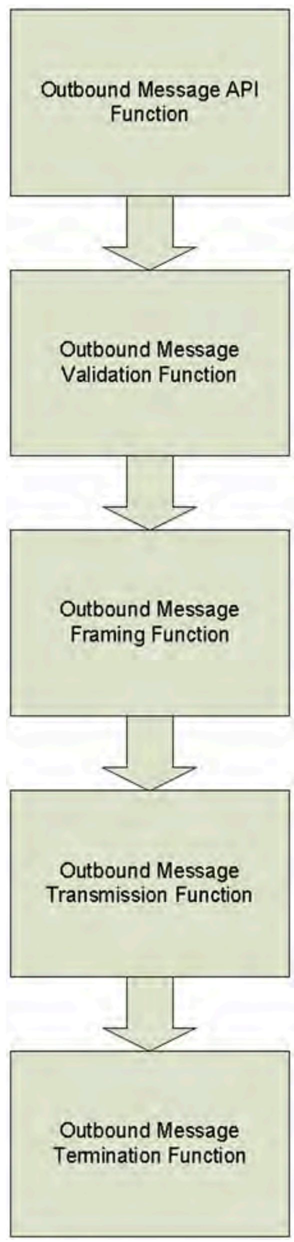


Figure 5-4. Outbound Message Flow

Outbound Message Validation Function

Input Requirements

An outbound message validation function receives fully assembled outbound messages from the outbound message function.

Processing Requirements

The following validations will be performed on outbound messages received from the function.

1. The destination address will be a valid address.
2. The destination address will not equal the local device address (a device cannot send a message to itself).
3. If the message is a broadcast message the local source address must be zero.

Output Requirements

If any of the validation tests fails, the failure event will be passed to the Outbound Message Termination Function for return to the client.

If all validation checks are successful, the message will be passed on to the Outbound Message Framing Function for further processing.

Outbound Message Framing Function

Input Requirements

An outbound message framing function receives validated messages from the outbound message validation function.

Processing Requirements

The Outbound Message Framing Function will construct outbound message packet frames for transmission using the format shown in Figure 5-5 (p. 5-15).

The resulting message packet will be fully framed using the following sequence:

1. The first two bytes of the message will contain the two byte SOM marker (DLE, STX)

2. Each byte of the message, as received from the Outbound Message Validation Function, will be appended to the SOM. As each byte is appended its value will be compared to the DLE value. If the data byte is equal to DLE, then the data byte will be appended to the message as two consecutive DLE bytes. **Note that any DLE expansions in the message body after framing will cause the Message Body Length byte to be invalid during transmission. After the DLEs are stripped by the receiver the Length byte will again be accurate.**
3. Append the two byte EOM sequence (DLE,ETX) to the message modified message data.
4. Compute the LRC for all message bytes and append it to the message.

At this point the assembled packet may be passed to the Outbound Message Transmission Function for further processing.

Figure 5-5, below, shows how a simple message from the master (source address 0) is framed following the framing function. Notice how the D1 byte, with a value of 0x10 that is equal to DLE, is preceded by another DLE byte.

The LRC byte is computed and transmitted by the Outbound Message Transmission Function but the LRC is NOT appended to the message by the framing logic.

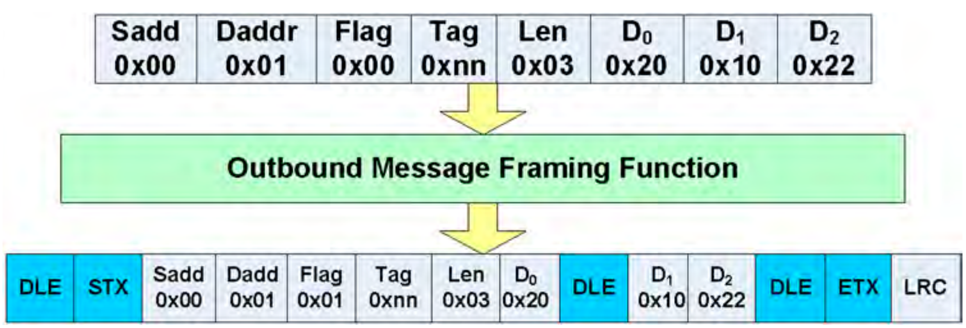


Figure 5-5. Outbound Message Framing

Output Requirements

The fully framed message assembled by the Outbound Message Framing Function is passed to the Outbound Message Transmission Function.

Outbound Message Transmission Function

Input Requirements

The Outbound Message Transmission Function receives a fully assembled and framed message from the Outbound Message Framing Function.

Processing Requirements

The Outbound Message Transmission Function transmits the complete message packet to the destination address and returns the transmission results back to the Outbound Message Termination Function.

Message transmission involves the following steps performed in sequence; however, the task is more complex when error checking and retries are performed.

1. Wait for idle bus condition
2. Transmit the entire message. Each byte transmitted is echoed back and buffered as received.

Devices that use idle frame detection to detect the end of a received message are very sensitive to interbyte timing. For this reason the maximum time between any two message bytes cannot exceed the time it takes to transmit one character frame at the current baud rate. Doing so will cause invalid end of message detection on the receiving device.

---

3. Compare transmitted message and received message byte-by-byte, looking for a mismatch
4. If the received message does not match the transmitted message, perform collision-based retries

The flow chart in Figure 5-6 (p. 5-17) depicts the logical flow of message transmission including collision detection and retries.

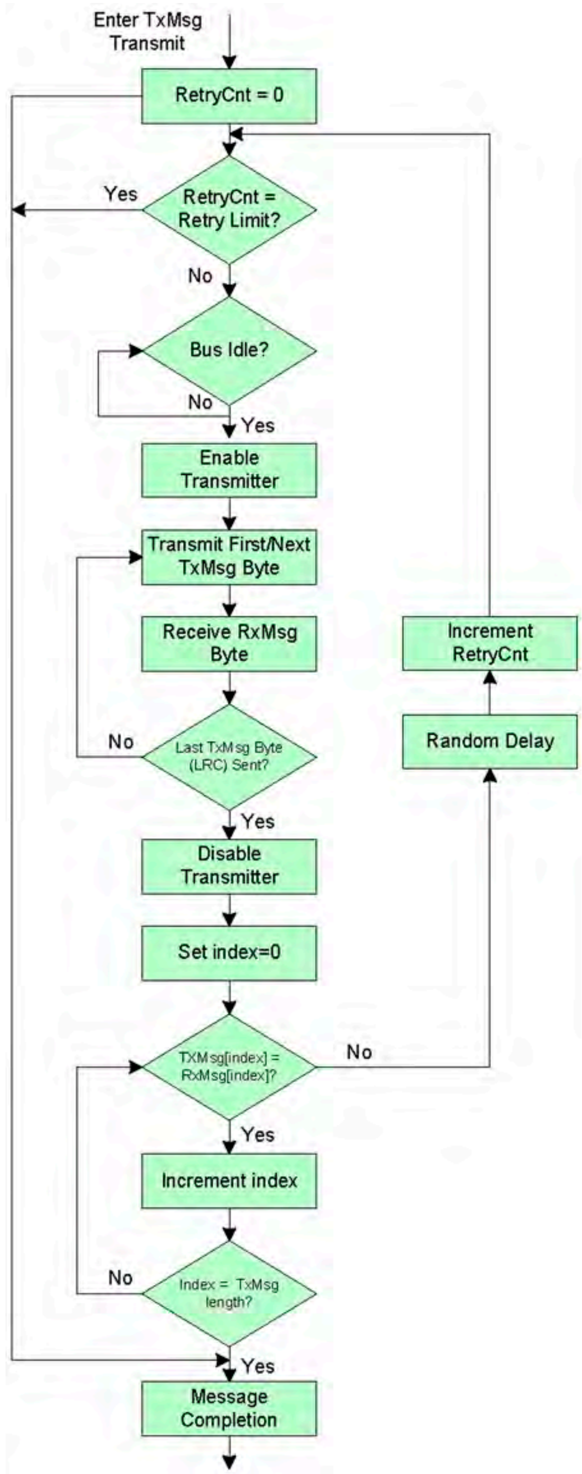


Figure 5-6. Outbound Message Transmission Flow

The following sections describe these operations in more detail.

Transmitter Control

If the hardware supports the recommended Automatic Send Data Control hardware, then enabling/disabling of the transmitter is done in hardware and may be ignored.

However, if ASDC is not available in hardware, the software must ensure that the transmitter is enabled only during message transmission and disabled immediately upon transmission of the last stop bit in the last byte of the message (the LRC byte).

Message Transmission Retries

When message transmission fails due to a bus collision, the transmit function will attempt a maximum of *N* retries (default four). *N* may optionally be made an adjustable parameter.

Idle Bus Detection

Message transmission will not commence until a bus idle condition is detected.

The bus idle condition is defined as the bus being in a spacing state for a period of three character transmission times (30 bit times).

Idle Time = (1/BaudRate)*30

At a baud rate of 921600 bps, the bus spacing state must exist for ~32.5 µs for the bus to be considered idle.

Collision Detection

Collision detection requires that the hardware support enabling of the receiver during data transmission.

During message transmission the receiver circuit will be enabled. This results in a character being received each time a character is transmitted. As the message is transmitted, the resulting received data should be buffered.

After the message and checksum have been transmitted, a byte-by-byte comparison will be performed between the transmitted message and the resultant received message.

If the messages are identical, then no collision occurred.

If, however, the messages differ in any way, a collision or other data corruption event occurred.

In the event of collision or corruption, the Outbound Message Transmission Function will wait for a random delay period to pass and then retry message transmission from the beginning.

Transmission retry attempts will repeat until a complete uninterrupted message has been successfully transmitted without collision, or until all retry attempts have been exhausted.

Random Delay

If a collision or corruption is detected during message transmission, it is important that each device detecting a collision on the bus (that is, each transmitting device involved in the collision) wait a random period of time before attempting transmission.

The algorithm used to determine the back off and retry delay will be a truncated binary exponential back off algorithm. *Truncated* means that after a certain number of increase, the exponentiation stops—that is, the retransmission timeout—reaches a ceiling and thereafter does not increase any further.

After i collisions, a random number of slot times between 0 and 2^i - 1 is chosen. After the first collision, the sender would wait 0 or 1 slot times before retry; after the second collision it would wait 0-3 slot times, etc. After the fourth and subsequent consecutive collisions, the slot time delay will be limited to 0-15 slot times. Note that there is no provision for discarding a message after many collisions; message transmission will retry until it succeeds.

A slot time is defined as the time to transmit 64 characters at the selected baud rate.

The slot time is computed as ceil((1/baudrate)*640).

At 921600 bps the slot time would be (1/921600)*640 = .00069, or 690 microseconds.

Inbound Message Transmission

Inbound Message Functional Diagram

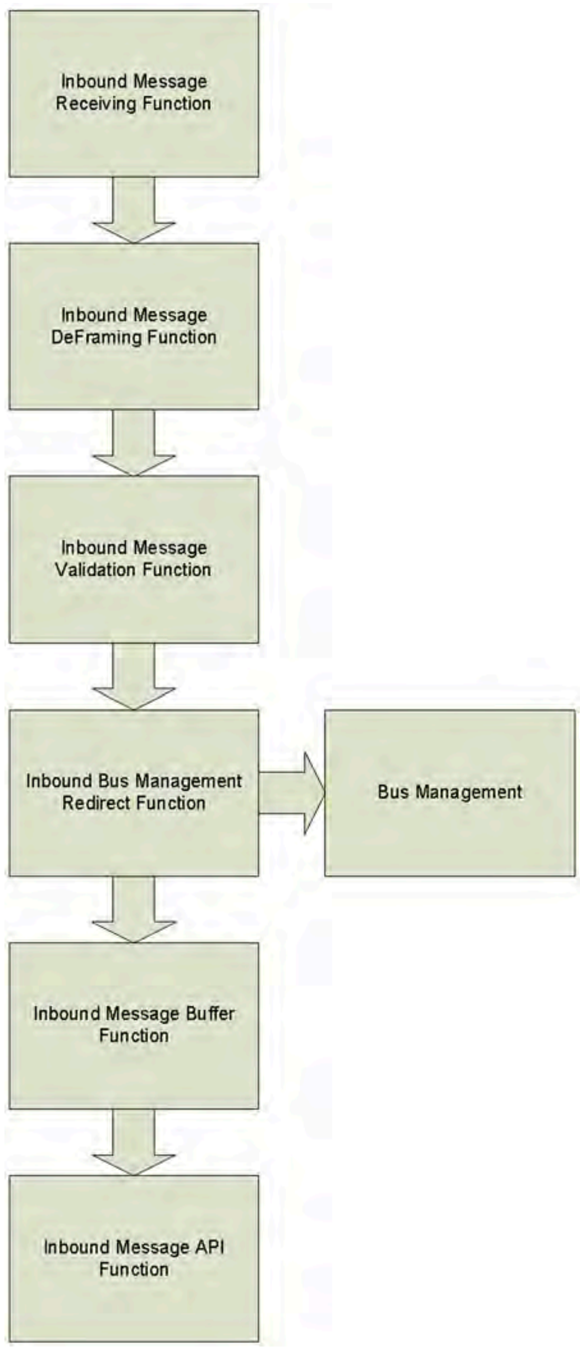


Figure 5-7. Inbound Message Flow

Inbound Message Receiving Function

Input Requirements

The Inbound Message Receiving Function is an event driven function that is kicked off when a data byte is received from the CCB.

Processing Requirements

Data bytes will be read from CCB port and scanned to identify complete messages. A complete message includes the two-byte SOM sequence, all bytes that immediately follow SOM through the two-byte EOM sequence that frames the message, and the LRC byte that immediately follows the EOM sequence.

Conceptually, message reception involves the following steps, performed in sequence (some implementation details left out for clarity):

1. Scan the incoming data stream looking for a SOM sequence.
2. Once SOM is discovered, buffer data, compute LRC and scan for an EOM sequence while limiting any received message to the maximum allowable length.
3. When EOM sequence found, read the LRC checksum byte that follows EOM.
4. Compare the received checksum byte to the computed LRC.
5. If checksum values are equal, a complete message was received.

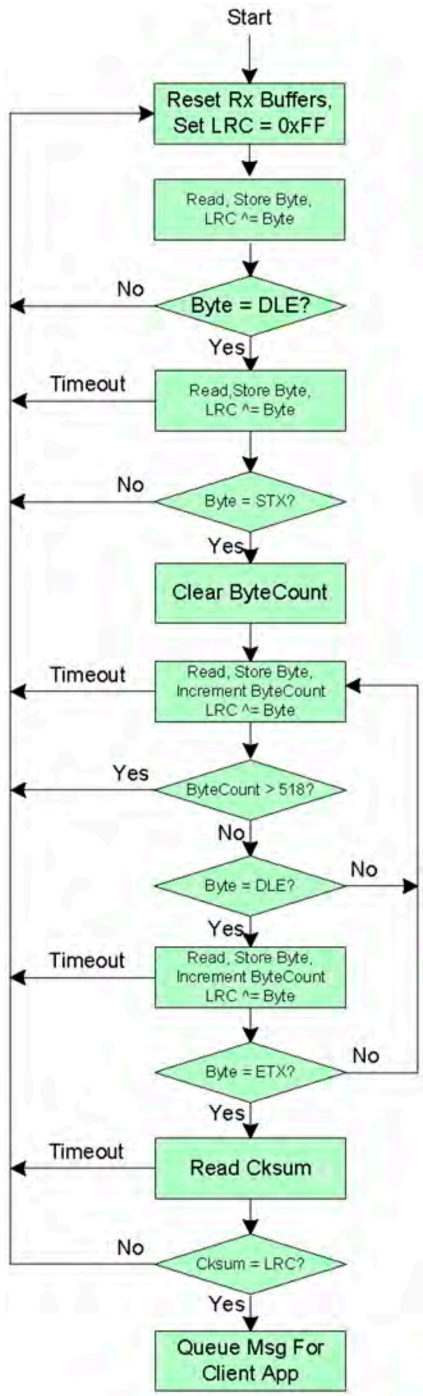


Figure 5-8. Inbound Message Receiving Flow

Output Requirements Complete received messages passing checksum validation are passed to the Inbound Message Deframing Function.

Inbound Message Deframing Function

Input Requirements

The Inbound Message Deframing Function receives complete messages that have passed checksum validation from the Inbound Message Receiving Function.

Processing Requirements

The Inbound Message Deframing Function will remove all framing characters from received messages so subsequent functions can easily validate the message and buffer it for the client.

Framing characters will be removed from inbound messages using the following rules:

1. Strip the two byte SOM sequence from the beginning of the message.
2. Perform a byte-by-byte copy of the received message into a new message buffer. As the copy proceeds each byte is compared to DLE. When a DLE is encountered, it is discarded and the very next byte from the received message is taken literally and placed in the new message buffer without regard to value. Bytes placed in the message buffer are counted to determine the exact message length.
3. When the two byte EOM sequence is encountered the scan terminates. EOM bytes are not stored in the new message buffer or counted.

The following diagram depicts the deframing logic.

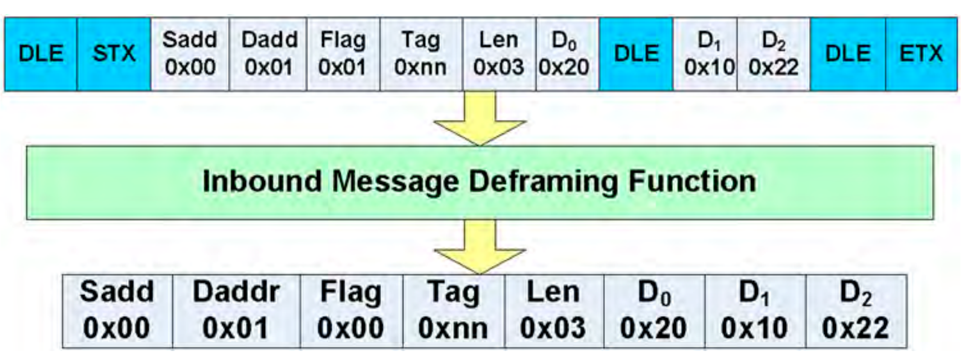


Figure 5-9. Deframing Inbound Messages

Output Requirements

The Inbound Message Deframing Function passes the new message buffer and the size of the new message to the Inbound Message Validation Function.

Inbound Message Validation Function

Input Requirements

The Inbound Message Validation Function receives deframed messages and their associated length from the Inbound Message Deframing Function.

Processing Requirements

Since the CCB is a bus, all messages that are sent on the bus are received by all connected devices. It is necessary to ignore messages that are not intended for the local device.

When a newly deframed message is received, the Inbound Message Validation Function accepts messages according to the following rules:

1. If the local device is a Master device (local address 0), messages are accepted only when the message destination address is 0.
2. If the local device is a Slave device, messages are accepted when either of the following statements is true:
   - The destination address equals the local device address
   - The destination address is 0xff (broadcast message)
3. All other messages are discarded.

Output Requirements

Validated Inbound messages are passed to the Inbound Bus Management Handling Function.

Inbound Bus Management Redirect Function

Input Requirements

The Inbound Bus Management Redirect Function receives validated inbound messages from the Inbound Message Validation Function.

Processing Requirements

The BUSMGMT bit of the Message Flags byte of each inbound message will be examined to determine if the message should be buffered for the client or processed by the Bus Management Function as a bus management message:

- If the BUSMGMT bit of the Message Flags byte is set, the message is a bus management message.
- If the BUSMGMT bit of the Message Flags byte is clear, the message is a client message.

In all cases this function will update an active device list with a timestamp indicating the last time a message was received from the device. The timestamps on the active device list are used by the Bus Management Device Disconnection Detection function to determine when to ping inactive nodes for the purpose of detecting disconnected devices.

Output Requirements

Inbound messages that are bus management messages are passed to the Bus Management Function.

Inbound messages that are not bus management messages are passed to the Inbound Message Buffer Function.

The updated active devices timestamps will be made available to the bus management function as a required part of device disconnect detection logic.

Inbound Message Buffer Function

Input Requirements

The Inbound Message Buffer Function receives validated, non-Bus Management messages from the Inbound Bus Management Function.

Processing Requirements

Received messages and their associated size are buffered for reading by the client application through the API in a first in, first out, fashion.

A maximum number of messages (default six, configurable) will be buffered. Only complete messages are buffered; if there is not enough buffer space remaining for a new message, the message will be discarded.

This function will maintain a count of the number of messages currently buffered.

Output Requirements

The number of buffered messages will be made available to the Inbound Message API Function.

Inbound Message API Function

Input Requirements

Inbound messages are read when a Client Application calls the inbound message API function.

Processing Requirements

The API function will be a blocking call. If no messages are currently buffered, the function will not return until a message arrives to satisfy the read request.

Output Requirements

On success, an N byte message will be stored in the specified client read buffer.

Bus Management

Bus Management Overview

Each device participating on the CCB requires a unique address. Additionally, since the CCB hardware has no way to identify when devices are connected or removed from the bus, it must be done in software. Lastly, since the CCB is a “cloud” rather than a collection of point-to-point connections, it may be necessary to identify which slave device is connected to a each port. To manage these requirements the CCB Bus Management Logic implements for five specific functions:

1. Detection of newly connected slave devices on the bus
2. Assignment of unique addresses to slave devices
3. Associate master device ports to specific slave devices
4. Detection of slave devices that are no longer responding on the bus
5. Apprise client application on master device of bus status

Master and Slave devices are assigned unique bus management roles.

Slave devices will perform the following bus management functions:

- Acquire a unique bus address from the master device
- Conditionally respond to port identification requests
- Respond to ping requests from the master device

The Master device will perform the following bus management functions:

- Issue a Bus Reset command at startup to reset connected slave devices
- Respond to slave address requests with a unique bus address assignment
- Perform port detection logic to associate slave devices to physical ports
- Issue ping requests to devices that have not been active for a period of time
- Maintain a list of all devices on the bus using serial number as unique identifier
- Allow client application to query the list of active slave devices on the bus
- Notify client application as devices are attached and detached from the bus

The bus management command and reply protocol utilizes the same message header used by the application protocol; however, bus management message packets are uniquely identified by the BUSMGMT bit in the message flags byte. When a message is received with the BUSMGMT bit set, it will be passed to the bus management function for handling instead of being passed to the client application.

The following subsections provide overviews of the above functionality.

Bus Management Address Assignment Overview

The Master device will always power up at fixed address 0. At Power-up, the master device will issue a single Bus Reset command to place any configured slave devices into an Address Acquisition mode.

Slave devices will always power up at an initial and temporary address of 0xFE, and will also assume address 0xFE following reception of a Bus Reset command.

The slave will then assemble and transmit an address acquisition request—which includes the unique slave device serial number—to the master device at address 0. Although not enforced by the CCB stack, this is the only unsolicited message that a slave device is allowed to transmit.

When the master device receives a valid address acquisition request, it will assemble an address assignment response packet—which contains the device serial number as received in the Address Request packet and also a unique bus address—and transmit it to the temporary address of 0xFE.

When a slave device receives an address assignment packet containing its unique serial number, it will reset its local address to the new address contained in the message and then will proceed with normal bus operation. NOTE: The slave device will not explicitly acknowledge it received the address assignment packet.

Until a slave address has received an address assignment from the master device, it will ignore all bus commands, except address assignment commands containing its unique serial number, and continue to transmit address acquisition requests using the defined CCB collision detection, back off, and retry method. If the address assignment packet isn't received in a timely manner, the slave device will perform timeout and retries every two seconds until an address is acquired.

The address acquisition requests and reply packets are described under "Bus Management Address Acquisition Protocol" (p. 5-37).

Bus Management Ping Overview

The CCB provides no facility for detection of device disconnection events. The only way to know if a device is connected to the bus is when a message is received from it.

The master will maintain a master list of devices that have been assigned addresses and are connected to the bus.

The CCB stack on the master will perform a background polling loop of connected devices.

If a message has not been received from an assigned address for a period of time (default 10 seconds, configurable), the master CCB stack will send a ping message to the address and wait a period of time (default 2 seconds, configurable) for a response.

When a slave device receives a ping message from the master, it will then assemble and transmit a ping response message. This lets the master know that the slave device is still there.

When a device has not responded to a ping transmission in three consecutive attempts the address will be marked as available and the client application on the master will be informed that the device has been disconnected from the bus.

Bus Management Client Interface Overview

Client applications on the master device typically require the ability to know what devices are on the bus, and also when new devices are connected and old devices disconnected.

The Master device will implement an API function that the client code may call to retrieve a list of all devices that are connected to the bus at the time of the call.

The Master device will also queue a message for the client to read whenever new devices are connected to the bus (when addresses are assigned) or when old devices are disconnected from the bus (when addresses are released).

The Client application on the master would typically retrieve a list of all addresses at startup and then use the queued bus management event messages to keep the list updated from that point on.

Bus Management Port Identification Overview

The Master Controller contains LED indicators to represent the current status of various slave device operational parameters. These LEDs are associated to specific physical ports on the master controller.

However, the CCB is a “cloud” architecture, where the location of specific devices on the bus is not fixed or easily identifiable. Without special logic it is impossible for software to know which physical port a slave device is connected to.

The Bus Management Port Identification logic is thus implemented to identify which physical port a slave device is attached to, so the LED indicators for that port will properly represent the status of the correct device.

The Master Controller has direct control over a signal pin on the connector of each port (herein referred to as the Port Identification Pin, or PIP). For each port, it asserts the PIP and then broadcasts a bus management port identification request. Upon receipt of this message each slave device examines the state of its PIP. If PIP is asserted, the slave device responds with a port identification response. The master controller then knows which slave device is attached to that port. The PIP on the identified port is then de-asserted and this method is repeated for each port on the bus. This logic must be performed at power up and also each time a device is connected to the bus.

Master Device Bus Management Functional Flow

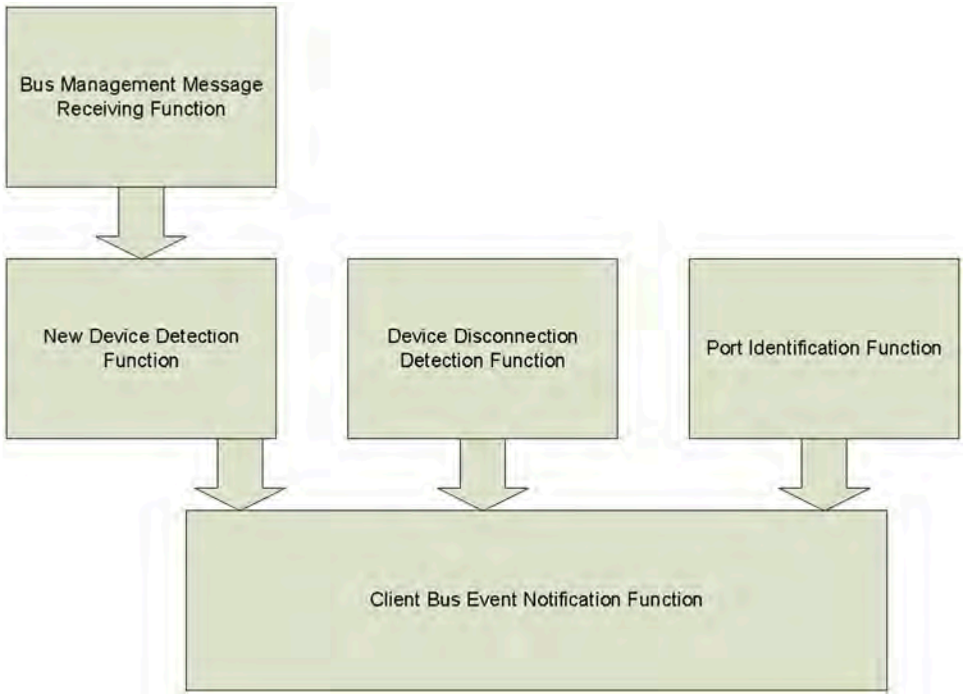


Figure 5-10. Master Device Bus Management Flow Diagram

Bus Management Message Receiving Function

Input Requirements

Bus Management messages are received from the Inbound Bus Management Redirect Function when the BUSMGMT bit in the message flags byte is set in a received message.

Processing Requirements

If the received bus management message is a Ping Response message from a slave device, it will be discarded and not further action taken.

Ping Response messages have served their purpose by causing the device's last received message timestamp to be updated in the Inbound Bus Management Redirect Function.

Output Requirements

All received messages that are not slave device Ping Response messages will be passed to the New Device Detection function.

New Device Detection Function

Input Requirements

The New Device Detection function receives bus management messages from the Bus Management Message Receiving Function.

Processing Requirements

Each received bus management message is examined to see if it is an address acquisition request message from a newly connected slave device.

If the received message is identified as an Address Acquisition Request message, the following processing steps will be performed:

1. A scan of connection devices will be made to remove duplicate serial numbers from list
2. An unused address will be allocated from the address pool and assigned to the device.
3. The device serial number will be stored for the new address
4. The last received message timestamp on the address will be recorded.
5. An Address Assignment message will be assembled as explained under “Master Device Address Assignment Response” (p. 5-37) and then transmitted to the slave device.

Output Requirements

If the results of the New Device Detection Function resulted in assignment of a new device address, the event will be passed to the Client Bus Event Notification Function and no further action on the message will be taken.

If the message does not result in the assignment of a new device address, the message will be discarded and no further action taken.

Device Disconnection Detection Function

Input Requirements

The Device Disconnection Detection Function will be entered on a timed basis once each second.

Processing Requirements

The Device Disconnection Detection Function will scan the active device list to determine the period of time that has elapsed since the last message was received from each active device.

For each active device, if the elapsed time is greater than the maximum dead time limit (default 6000 milliseconds, configurable), the device address will be marked as inactive and a list of all newly inactive devices will be assembled.

For each active device, if the elapsed time is less than the dead time limit, but greater than the minimum dead time limit (default 2000 milliseconds, configurable), a Master Ping Request message will be assembled and transmitted to the device and no further action will be taken.

Output Requirements

If any devices were newly discovered to be disconnected, the list of such devices will be passed to the Client Bus Event Notification Function.

Port Identification Function

Input Requirements

The Port Identification Function will be entered at power up and each time a slave device is connected to the master device.

Processing Requirements

For each physical port on the master device, the Port Identification Function will perform a port identification sequence.

The port identification sequence will be:

1. Assert PIP on one port and de-assert on all other ports
2. Broadcast a Port Identification Request
3. Wait for a response from a slave device for a maximum of 100 ms. If there is no response, one retry will be attempted per port.

Output Requirements

On exit from this function all PIPs will be de-asserted.

The master device will maintain an internal "Port Association List" that associates each physical port to a specific slave device, if any. Slave devices are uniquely identified by a device serial number.

Client Bus Event Notification Function

Input Requirements

The Client Bus Event Notification Function receives input from two sources:

1. New Device Detection Function
2. Device Disconnection Detection Function

The New Device Detection Function will supply the address and serial number of the newly detected device.

The Device Disconnection Detection Function will supply a list of all devices that have been disconnected.

Processing Requirements

For each new device detected, the Client Bus Event Notification Function will assemble a Slave Device Connection Message and queue it for the client.

For each device that has been disconnected, the Client Bus Event Notification Function will assemble a Slave Device Disconnection Message and queue it for the client.

Output Requirements

This function produces no output.

Slave Device Bus Management Functional Flow

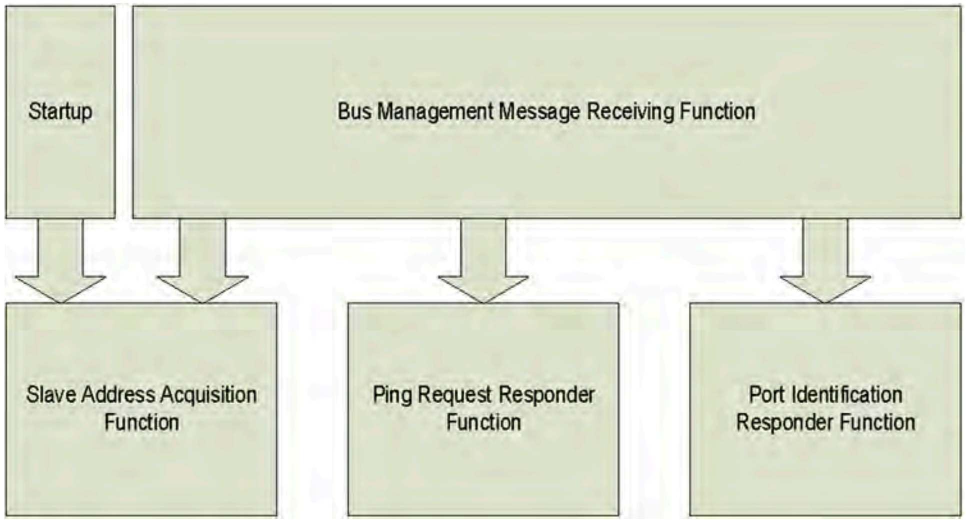


Figure 5-11. Slave Device Bus Management Functional Flow

Slave Address Acquisition Function

Input Requirements

This function will be entered when any of the following conditions occur:

1. Initial power up of the slave device
2. Reception of a Bus Reset message from the master device
3. Timeout while waiting for an Address Assignment message from the master device
4. Arrival of an Address Assignment message from the master device

Processing Requirements

The slave CCB stack will set its local device address to 0xFE at power up and following reception of a Bus Reset command from the master device.

It will then assemble and transmit an Address Request message, including the device serial number string, to the master device at address 0 and set a two second timeout.

Each time an Address Assignment message is received, the serial number on that message will be compared with the local device serial number.

If an Address Assignment message is received with matching serial number, the local device address will be set to the newly assigned address and the timeout canceled.

If the timeout expires before an acceptable Address Assignment message has been received, another Address Request message will be sent, and another two second timeout set.

This cycle will repeat until an Address Assignment message is received with matching device serial number. When an address has been successfully acquired, the Address Acquisition function will be considered complete.

If an Address Assignment message with matching serial number is received subsequent to initial address assignment, the local device address will be reset to the newly assigned address.

Output Requirements

The slave acquisition function will not be considered complete until a unique local address has been acquired and set.

Slave Bus Management Message Receiving Function

Input Requirements

Bus Management messages are received from the Inbound Bus Management Redirect Function when the BUSMGMT bit in the message flags byte is set in a received message.

Processing Requirements

The message will be examined and dispatched to the proper message handling function.

Output Requirements

If the received message represents an Address Assignment Message or a Bus Reset Message, the message will be passed to the Slave Address Acquisition Function.

If the received message represents a Ping Request Message, the message will be passed to the Slave Device Ping Responder Function.

If the received message represents a Port Identification Request Message, the message will be passed to the Slave Device Port Identification Function.

Slave Device Ping Responder Function

Input Requirements

The Slave Device Ping Responder Function receives messages from the Inbound Bus Management Redirect Function when the BUSMGMT bit in the message flag bit is set and the message represents a master Ping Request.

Processing Requirements

The Slave Device Ping Responder function will assemble and transmit a Ping Response message to the master device.

Output Requirements

The Ping Response message will be transmitted to the master device.

Slave Device Port Identification Function

Input Requirements

The Slave Device Port Identification Function receives messages from the Inbound Bus Management Redirect Function when the BUSMGMT bit in the message flag bit is set and the message represents a Port Identification Request Message.

These messages are received at the broadcast address.

Processing Requirements

Upon receipt of a Port Identification Request Message, the function will query the state of the PIP pin on the CCB connector.

Output Requirements

If PIP is asserted, a Port Identification Response Message will be assembled and returned to the master device.

If PIP is de-asserted, no further action will be taken.

Bus Management Protocol Definition

Bus Management Address Acquisition Protocol

The following figure depicts the format for a slave Address Acquisition Request message.

Sadd 0xFE	Dadd 0x00	Flag 0x01	Tag 0xnn	Len N	Cmd 0x00	D_0	D_1	.	.	.	D_N

Figure 5-12. Slave Address Acquisition Request

Since the slave device only needs to acquire an address when using the temporary slave address of 0xFE, the source address is set to that value.

The destination address is always 0 for the master device.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The Length byte includes one byte for the command byte and the length of the device serial number string, including the null string terminator character.

The command byte of 0x00 indicates an Address Acquisition Request.

The slave device serial number, programmed into the device at time of manufacture, is included as data. The serial number will be formatted as a null terminated text string. The serial number string and terminating null character will be appended to the four-byte message header and command byte to form the complete message.

Master Device Address Assignment Response

The following figure depicts the format of an Address Assignment message sent from the master to a specific slave device.

Sadd	Dadd	Flag	Tag	Len	Cmd	New	D_0	D_1	.	.	.	D_N
0x00	0xFE	0x01	0xnn	N	0x80	Addr						

Figure 5-13. Master Address Assignment Response

The source address of 0 represents the fixed address of the master device.

The destination address of 0xFE represents the temporary address of slave devices that have not yet been assigned a unique bus address.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The Len of N includes one byte for the Command byte, one byte for the newly assigned address, the length of the serial number string for the targeted slave device, and the terminating null of the string.

Appended to the four-byte message header is one command byte with value set to 0x80 representing an Address Assignment message, one byte which is the new address assigned to the slave device, the serial number string of the slave device, and the null string terminator.

When a slave receives this message, it will compare the received serial number to its serial number and, if the serial number strings match, it will set its local device address to be equal to the new address sent in the received message packet.

Bus Management Ping Protocol

Master Ping Request

Ping requests sent by the master are formatted as shown in the following figure.

Sadd	Dadd	Flag	Tag	Len	Cmd
0x00	0xN	0x01	0xnn	1	0x81

Figure 5-14. Master Ping Request

Source address of 0x00 represents the fixed master address.

Destination address is set to the unique address that is assigned to the slave device.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of 1 accommodates the single command byte.

The command byte of 0x81 is the ping command.

Slave Ping Response

Ping responses sent by slave devices are formatted as shown in the following figure.

Sadd	Dadd	Flag	Tag	Len	Cmd	D_0	D_1	.	.	.	D_N
0xN	0x00	0x01	0xnn	N	0x01						

Figure 5-15. Slave Ping Request

Source address of 0xN represents the unique assigned address of the slave device.

Destination address is set to the 0x00, the fixed address of the master device.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of N accommodates the single command byte and the length of the device serial number string, including null terminator.

The command byte of 0x01 is the ping response.

The unique device serial number string—including the null string terminator—is appended to the response message.

Bus Management Bus Reset Message

Master Bus Reset

Bus Reset requests sent by the master are formatted as shown in Figure 5-16 (p. 5-39).

Sadd	Dadd	Flag	Tag	Len	Cmd
0x00	0xFF	0x01	0xnn	1	0x84

Figure 5-16. Master Bus Reset

Source address of 0x00 represents the fixed master address.

Destination address is set to the broadcast address of 0xFF for reception by all slave devices.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of 1 accommodates the single command byte.

The command byte of 0x84 is the Bus Reset command.

Bus Management Port Identification Protocol

Master Port Identification Request

Port identification requests sent by the master are formatted as shown in the following figure.

Sadd	Dadd	Flag	Tag	Len	Cmd
0x00	0xFF	0x01	0xnn	1	0x85

Figure 5-17. Master Port Identification Request

Source address of 0x00 represents the fixed master address.

Destination address is set to the broadcast address that will be received by all slave devices.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of 1 accommodates the single command byte.

The command byte of 0x85 is the Port Identification Request.

Slave Port Identification Response

When the port identification pin on the slave device is asserted, the device will assemble and respond with a port identification response as shown in the following figure.

Sadd	Dadd	Flag	Tag	Len	Cmd	D_0	D_1	.	.	.	D_N
0xN	0x00	0x01	0xnn	N	0x02						

Figure 5-18. Slave Port Identification Response

Source address of 0xN represents the unique assigned address of the slave device.

Destination address is set to the 0x00, the fixed address of the master device.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of N accommodates the single command byte and the length of the device serial number string including null terminator.

The command byte of 0x02 is the port identification response.

The unique device serial number string including the null string terminator is appended to the response message.

Bus Management Client Event Messages

Slave Device Connection Message

Each time a slave device is assigned an address the master device will queue a message for its client application to indicate the event. The message will be formatted as shown in the following figure.

Sadd	Dadd	Flag	Tag	Len	Cmd
0xN	0x00	0x01	0xnn	1	0x82

Figure 5-19. Slave Device Connection Message

The source address will be the assigned address of the newly connected slave device.

The destination address will always be zero.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of 1 accommodates the single command byte.

The command byte of 0x82 indicates that this is a connection event.

The message indicates to the client application that slave device 0xN has been newly connected to the bus and is ready for operation.

Slave Device Disconnection Message

Each time the CCB stack on the master determines that a slave device is no longer responding on the bus, master device will queue a message for its client application to indicate the event. The message will be formatted as shown in the following figure.

Sadd	Dadd	Flag	Tag	Len	Cmd
0xN	0x00	0x01	0xnn	1	0x83

Figure 5-20. Slave Device Disconnection Message

The source address will be the address of the now disconnected slave device.

The destination address will always be zero.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of 1 accommodates the single command byte.

The command byte of 0x83 indicates that this is a disconnect event.

The message indicates to the client application that slave device 0xN has been disconnected from the bus.

Slave Device "ACK" Response Message

The slave has the option of sending a general 'ACK' response when it received a message but only when there's no other specific response. The message will be formatted as shown in the following figure.

Sadd	Dadd	Flag	Tag	Len	Cmd
0xN	0x00	0x01	0xnn	1	0x03

Figure 5-21. Slave Device "ACK" Message

The source address will be the assigned address of the slave device.

The destination address will always be zero.

The BUSMGMT bit of the Message Flags byte is set to indicate a bus management message.

The length value of 1 accommodates the single command byte.

The command byte of 0x03 indicates that this is an acknowledgement event.

Bus Management Command Summary

Table 5-7. Bus Management Commands

Command Byte	Source	Function
0x00	Slave	Address Acquisition Request
0x01	Slave	Ping Response
0x02	Slave	Port Identification Response
0x03	Slave	Acknowledgement to message
0x80	Master	Address Assignment Command
0x81	Master	Ping Request
0x82	Master	Slave Connection Message
0x83	Master	Slave Disconnection Message
0x84	Master	Bus Reset Message
0x85	Master	Port Identification Request

SECTION SIX: HOST INTERFACE

In this section:

- Host command quick reference (this page)
- Message considerations (p. 6-4)
- Commands and queries (p. 6-9)
- Controls and queries (p. 6-26)
- OBIS communications through HyperTerminal (p. 6-31)

When a command is sent to the OBIS system, the parameter for the command is stored in internal persistent memory, which has a logic cell life of 1 million cycles for the laser head or 10 thousand cycles for the OBIS Remote. The cell life sets the limits for repetitive commands sent to the OBIS system.

This only applies to commands and not queries.

Host Command Quick Reference

The following table gives a brief description of all host commands and queries. For detailed information about a specific command or query, go to the page referenced in the right-hand column.

Table 6-1. Host Command Quick Reference (Sheet 1 of 3)

Command	Description	Page No.
Mandatory Commands/Queries		
IEEE-488.2		
*IDN?	Gets the laser head's identification string	6-9
*RST	Causes a device to warm boot if implemented	6-10
*TST?	Runs a laser self-test procedure, if implemented	6-10
Session Control		
SYSTem:COMMunicate:HANDshaking	Toggles the system handshaking	6-10
SYSTem:COMMunicate:HANDshaking?	Queries the system handshaking	6-10
SYSTem:COMMunicate:PROMpt	Toggles the system command prompt	6-11
SYSTem:COMMunicate:PROMpt?	Queries the system command prompt	6-11
SYSTem:AUTostart	Enables or disables the laser auto start feature	6-11
SYSTem:AUTostart?	Queries the laser auto start feature	6-11

Table 6-1. Host Command Quick Reference (Sheet 2 of 3)

Command	Description	Page No.
SYSTem:INFormation:AMODulation:TYPe	Sets the analog modulation type	6-11
SYSTem:INFormation:AMODulation:TYPe?	Queries the analog modulation type	6-11
SYSTem:STATus?	Queries the system status	6-11
SYSTem:FAULt?	Queries current system faults	6-13
SYSTem:INDicator:LASer	Turn ON/OFF laser head status indicator(s)	6-14
SYSTem:INDicator:LASer?	Queries laser head status indicator(s)	6-14
SYSTem:ERRor:COUNt?	Queries the number of error records in the error queue	6-15
SYSTem:ERRor:NEXT?	Queries the next error record(s) in the error queue	6-15
SYSTem:ERRor:CLEar	Clears all error records in the error queue	6-15
OBIS Common Commands/Queries		
System Information		
SYSTem:INFormation:MODel?	Retrieves the model name of the laser	6-16
SYSTem:INFormation:MDATe?	Retrieves the manufacture date of the device	6-16
SYSTem:INFormation:CDATe?	Retrieves the calibration date of the device	6-16
SYSTem:INFormation:SNUMber?	Retrieves the serial number of the laser	6-16
SYSTem:INFormation:PNUMber?	Retrieves the manufacturer part number of the laser	6-16
SYSTem:INFormation:FVERsion?	Retrieves the current firmware version	6-16
SYSTem:INFormation:PVERsion?	Retrieves the current OBIS protocol version	6-17
SYSTem:INFormation:WAVelength?	Retrieves the wavelength of the laser	6-17
SYSTem:INFormation:POWer?	Retrieves the power rating of the laser head	6-17
SYSTem:INFormation:TYPe?	Retrieves the device type	6-17
SOURce:POWer:NOMinal?	Returns the nominal CW laser output power	6-17
SOURce:POWer:LIMit:LOW?	Returns the minimum CW laser output power	6-18
SOURce:POWer:LIMit:HIGH?	Returns the maximum CW laser output power	6-18
SYSTem:INFormation:USER	Enters and stores user-defined information	6-18
SYSTem:INFormation:USER?	Queries user-defined information	6-18
SYSTem:INFormation:FCDate	Enters and stores date of last field calibration	6-18
SYSTem:INFormation:FCDate ?	Queries date of last field calibration	6-18
System State		
SYSTem:CYCLes?	Returns the number of ON/OFF power cycles	6-19
SYSTem:HOURs?	Returns the hours the laser head has been powered on	6-19
SYSTem:DIODe:HOURs?	Returns the hours the laser diode has operated	6-19
SOURce:POWer:LEVel?	Returns the present output power of the laser head	6-19
SOURce:POWer:CURRent?	Returns the present output current of the laser head	6-19
SOURce:TEMPerature:BASeplate?	Returns the present laser head base plate temperature	6-19
SYSTem:LOCK?	Returns the status of the system interlock	6-20
Operational		
SOURce:AM:INTernal	Sets the laser operating mode to internal CW	6-20

Table 6-1. Host Command Quick Reference (Sheet 3 of 3)

Command	Description	Page No.
SOURce:AM:EXTernal	Sets the laser operating mode to external modulation	6-21
SOURce:AM:SOURce?	Queries the current operating mode of the laser	6-21
SOURce:POWer:LEVel:IMMediate:AMPLitude	Sets present laser power level	6-21
SOURce:AM:STATe	Turns the laser ON or OFF	6-21
SOURce:AM:STATe?	Queries the current laser emission status	6-21
SYSTem:CDRH	Enables or disables the CDRH laser emission delay	6-21
SYSTem:CDRH?	Queries the status of the CDRH laser emission delay	6-21
OBIS Optional Commands/Queries		
SOURce:TEMPerature:APRobe	Enables/disables temperature control of the laser diode	6-22
SOURce:TEMPerature:APRobe?	Queries temperature control of the laser diode	6-22
DDL-Specific Commands/Queries		
SOURce:POWer:CALibration	Starts a self-laser power calibration	6-22
SOURce:POWer:UNCalibration	Undoes the filed calibration	6-22
SOURce:TEMPerature:PROTection:INTernal:HIGH?	Queries the high internal temperature limit settings	6-22
SOURce:TEMPerature:PROTection:INTernal:LOW?	Queries the low internal temperature limit settings	6-22
SOURce:TEMPerature:DIODe?	Queries the present laser head diode temperature	6-23
SOURce:TEMPerature:DSETpoint?	Queries the diode set point temperature	6-23
SOURce:TEMPerature:INTernal?	Queries the present internal laser temperature	6-23

Figure 6-1, below, shows an example of sending and receiving a host command from an OBIS laser. *Note that whenever you enter a command, the lowercase text of the command is **optional** but the uppercase text is **required**.*

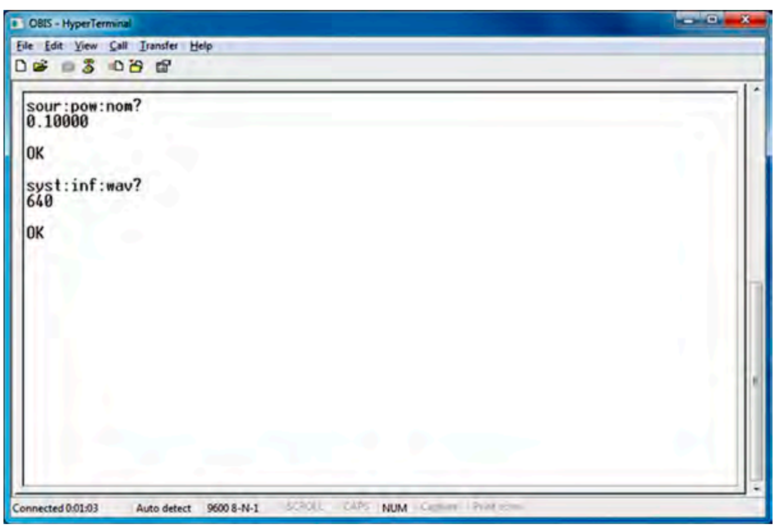


Figure 6-1. Example Host Commands from an OBIS Laser

Message Considerations

Communication Port Selection

The laser head design includes both USB and CCB communication ports.

The communication protocol described within this section works identically on either port; however, the ports are mutually exclusive and cannot be used simultaneously.

When both USB and CCB connections are connected, the laser head gives the CCB port precedence and ignores any input received from the USB port. Note that certain information on the laser head/controller communications—such as one controller talking to multiple laser heads—is part of future expansion protocol and is not applicable to the OBIS Remote.

Message Completion Handshake

SCPI message round trip handshaking is implemented on every message sent by the laser head firmware; however, the handshaking may be disabled using an SCPI command. Change of the setting will be saved in non-volatile memory.

This handshake serves several purposes:

1. It provides an indication to the host/controller that the message was received
2. It provides a synchronization mechanism to the host/controller so it will know when a message has been processed to completion so a new message may be sent
3. It provides the host/controller with an indication of any errors that may have occurred.

The handshake is a short message string that is sent as the last action performed when handling a received message. The handshake string represents either an OK response or an error response if a received message raises an error condition.

Note that quotation marks as depicted here are never included in the handshake string.

The OK response is formatted as "OK\r\n".

Error responses are formatted as "ERR<n>\r\n" where <n> represents the error code number. Negative numbers are permitted in the error string.

When handshaking is enabled, OBIS devices transmit one of the following handshake reply strings in response to each received command or query:

- Valid commands with valid data parameters will reply with “OK\r\n”
- Valid queries with any optional valid data reply as explicitly defined elsewhere in this section, followed by “OK\r\n”. For example, if querying the model name string, the laser will transmit the model name string followed by the “OK\r\n” string.
- Valid commands or queries which result in an error reply with “ERR<n>\r\n”
- Unrecognized or unsupported commands or queries reply with “ERR-100\r\n”

Note that the message completion handshake is not transmitted in response to a command that has been broadcast to all devices.

Message Terminators

Messages between the laser head and the host computer or controller are comprised entirely of ASCII string characters; no binary messages are supported. All message strings passing through the host interface are terminated to signal the end of a message string. The maximum message length supported is 255 bytes, which includes all terminating characters.

Messages Received by the Laser

Messages received by the laser must be terminated by a carriage return (decimal 13) and a line feed (decimal 10) following the carriage return. A command or query is considered incomplete without proper termination.

Messages Sent by the Laser

All messages sent by the laser are terminated by a carriage return (decimal 13) and line feed (decimal 10) pair. The maximum length of any message sent by the laser is limited to 255 bytes, including all terminating characters.

Message Syntax

Syntax specified by the SCPI and IEEE 488.2 Standards is followed unless otherwise specified. Refer to the SCPI and IEEE 488.2 Standards for more information.

Notably, the base-10 numeric data format specification is used heavily in this document and covered in the IEEE 488.2 Standard. Unless otherwise specified, numeric data items referred to as NRf (IEEE flexible numeric representation) are interchangeable and may be represented in any of these formats:

- integer values
- non-scientific notation floating point values
- scientific notation floating point values (uppercase or lowercase E)

For example, the following data values are functionally equivalent:

- 31256
- 31256.0
- 3.1256E4
- 31.256E3
- +3.1256E+4.

Unless otherwise specified, non-numeric data items (typically referred to as strings) are not quoted.

Devices interpret hexadecimal data using the following rules:

- Uppercase and lowercase are accepted ("FE" is the same as "fe")
- Leading zeroes are required and accepted ("0A" is the same as "A")
- The data string may optionally be preceded by a "0x" or "0X" C hexadecimal notation idiom (0xD2C4 is the same as D2C4)
- Following the optional "0x" prefix, the acceptable characters are from the list: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f, A, B, C, D, E, and F

Enumerated values must match exactly, using the long form/short form comparison rules defined under the SCPI Standard.

Dates (manufacturing date, calibration date, etc.) will use the YYYYMMDD format. Using this format, dates may be stored as ASCII strings or as numeric long integers and converted easily from one format to the other.

Device Selection Syntax

Many common commands are supported by all OBIS devices. When such a command is transmitted by a host computer to a system of devices (a controller and one or more laser heads), an ambiguity exists where the exact destination device is not clear.

The SCPI protocol provides a method to communicate with multiple virtual devices within an instrument. Since a complete OBIS system could be considered an “instrument” (controller) with multiple “virtual devices” (laser heads) this mechanism is used to disambiguate the destination of a command.

A SCPI command consists of one or more words separated by delimiters. The first word in a command string is called the base word.

SCPI channel selection is performed by appending a numeric suffix to the base word in any command string. When the numeric suffix is left off or has a value of zero, the command refers to the first connected device.

For example, “*idn?* and “*idn0?” query strings both refer to the first connected device. If a host computer is connected to a controller and this query is issued, it will be responded to by the controller. If the host is connected directly to a laser head, without going through a controller, the first connected device is the laser head and it should respond.

Consider the scenario where the host computer is connected to a mini controller, which, in turn, is connected to a laser head.

If the host issues the “*idn?” query, the OBIS Remote should respond. If, however, the host appends a numeric suffix to the base word of the query, then the suffix specifies the device which should respond. In this scenario “*idn?” and “*idn0?” would be responded to by the OBIS Remote, “*idn1?” would be responded to by the laser head, and “*idn2?” would receive no response since device number 2 does not exist.

If the host is connected to a master controller with four connected laser heads, then a missing or zero suffix would apply to the master controller and suffixes 1..4 would refer to laser heads 1..4.

The numeric suffix mechanism may be applied to the base word of any command or query.

As an implementation detail, laser heads should always respond to commands with either no suffix or suffixes of 0 or 255 to accommodate connections to a bus and also directly to a host computer.

When host commands are routed through an OBIS controller, the numeric suffix will be stripped off before the command is transmitted to a laser head. In this instance, the laser head won't have to deal with the numeric suffix at all and can behave as if it were connected directly to a host.

However, when a laser head is connected directly to a host, then it is valid for the host to append a 0 to the command base word to refer to the first connected device. Since that device could be a laser head, the laser will support a numeric suffix of 0.

The numeric suffix of 255 refers to a command (not query) that is broadcast to all devices on the bus. Queries cannot be broadcast since a stream of query results won't make any sense to the host. Therefore, the command "SYSTem255:PROMpt ON" enables the system prompt for all devices while "SYSTem0:PROMpt ON" enables the prompt for the first connected device.

Command Prompt

Each device implements the ability to output a command prompt to support interactive operation by an operator typing commands in a terminal program. A command has been specified to describe the command prompt behavior.

Note that the command prompt will not be transmitted in response to a command that has been broadcast to all devices.

Broadcast Commands

It is possible that a host message could be broadcast to all attached devices. Generally the broadcast capability is best used when a command is needed to synchronize the action of a group of devices (such as turning all connected lasers on or off simultaneously). The ability to broadcast device queries is prohibited.

Laser heads silently ignore any query that is broadcast and will act upon a broadcast command, if possible, without transmitting anything in response (including error, handshake, or command prompt strings).

Controllers respond to queries that are broadcast by returning error 103 along with optional handshake and command prompt strings.

Controllers respond to commands that are broadcast by rebroadcasting them to all devices on the bus, performing the broadcast action locally if appropriate for the command, and then returning any optional handshake and command prompt strings to the host.

This method allows the host to receive a single handshake and/or command prompt when a command is broadcast to several devices.

Commands and Queries

The OBIS Laser Head Protocol supports three types of laser devices:

- OBIS LX - Direct Diode Lasers (DDL)
- OBIS LS - Optically Pumped Semiconductor Lasers (OPSL)
- Other similar accessories

Each of these laser types support the common command sets and zero or more of the extension command sets, as shown in the following table.

Table 6-2. Supported Commands by Laser Type

Command Set	OBIS LX (DDL)	OBIS LS (OPSL)	Other
SCPI Common Command Set	X	X	X
OBIS Common Command Set	X	X	X
OBIS LX Extension Command Set	X		
OBIS LS Extension Command Set		X	

Mandatory Commands and Queries

IEEE-488.2 Mandated Commands/Queries

The SCPI Standard specifies a mandatory set of IEEE-488.2 common commands. All of these commands and queries start with an asterisk. Refer to the IEEE-488.2 specification for more detailed information concerning these commands.

Identification Query - *IDN?

Gets the laser head's identification string, such as model name, firmware version, and firmware date.

Query: *IDN?
Reply: “Coherent, Inc” + “-” + <model name> + “-” + <firmware version> + “- ” + <firmware date>

The dash sign separates all fields within the reply string. The first field will always be “Coherent, Inc”. The second field is the model name, which varies based on the laser head. The third field is the firmware version number, having the format “V<major>.<minor><optional qualifier characters>”. The fourth field is the firmware date, having the form YYYYMMDD. The reply string will not be quoted.

For example, a typical identification string might look like:

"Coherent, Inc - OBIS 405nm 50mW C - V1.3 - 20090630" *Note: the quotes are not transmitted*.

Reset Command - *RST

Causes a device to warm boot if implemented. Note that the message handshake is transmitted immediately prior to execution of the reset. If the command is not implemented, then no error is returned and no response is necessary.

Command: *RST

Query: None

Self-test Query - *TST?

Runs a laser self-test procedure, if implemented. Any detected faults are set in the laser fault code.

Query: *TST?
Reply: <System Fault Code>

The returned system fault code is formatted as a 32-bit hex value. A value of 0 indicates no fault conditions. If the self-test is not implemented, a value of 0xffffffff is returned.

OBIS Mandatory Commands/Queries

The OBIS Mandatory Command set is implemented by all OBIS compatible devices.

Session Control Commands

Handshaking

Toggles the system handshaking on and off. Setting is saved in persistent memory. Factory default is ON.

Command: SYSTem:COMMunicate:HANDshaking {ON|OFF}

Query: SYSTem:COMMunicate:HANDshaking?
Reply: ON|OFF

When enabled, the device transmits, in response to each received command or query, one of the handshaking strings described under "Message Completion Handshake" (p. 6-4).

Note that the handshaking reply is not transmitted in response to a command that has been broadcast to all devices, except by a controller device.

Command Prompt

Toggles the system command prompt on and off. Setting is saved in persistent memory. Factory default is OFF.

Command: SYSTem:COMMunicate:PROMpt {ON|OFF}

Query: SYSTem:COMMunicate:PROMpt?
Reply: ON|OFF

When enabled the device outputs a command prompt after each reply string. The command prompt is preceded by a carriage return and line feed, and consists of a '>' character and a space character.

Note that the command prompt is not transmitted in response to a command that has been broadcast to all devices, except by a controller device.

Laser Auto Start

Enables or disables the laser auto start feature. Setting is saved in persistent memory. Factory default is OFF.

Command: SYSTem:AUTostart {ON|OFF}

Query: SYSTem:AUTostart?
Reply: ON|OFF

If auto start is enabled, the device, when powered up, will automatically start emission at a previously-set level.

The auto start setting is saved in the non-volatile memory of the laser head. If the laser head is connected to a OBIS Remote through a SDR cable, this setting is overridden by the hardware switch of the min-controller; however, the ON/OFF position of the switch will not overwrite the setting in the laser head memory.

Analog Modulation Type

Sets the analog modulation type that provides unique electrical impedance on the analog interface of the OBIS Remote. Factory default is 50Ω.

Command: SYSTem:INFormation:AMODulation:TYPe {1 | 2}

Query: SYSTem:INFormation:AMODulation:TYPe?
Reply: 1 | 2

The input impedance is 50Ω and 2 kΩ for type 1 and 2, respectively.

System Status Query

Gets the system status code. The status code is returned in a string expressed in uppercase hexadecimal integer form. The 32-bit word represents a bit-mapped status indicator.

The MSB of the code is used to indicate if the code represents the status of a controller or a laser head. If the MSB is set, the code represents controller status. This is important since the meaning of some bits is subtly different for a controller. Refer to Table 6-3, below, for differences.

The following table describes status code bit mapping. The "Controller" column specifies the meaning of each bit when the status word is read from the controller and the "Laser Head" column specifies the bit meaning when the status word is read from a laser. The status word MSB indicates whether a status word is from a laser head or from a controller.

Table 6-3. Status Code Bit Definitions

Bit	Mask	Bit Label	Controller	Laser Head
0	00000001	Laser Fault	Logical OR from all lasers	Laser head faults—that is, fault words shown in Table 6-4 (p. 6-13)
1	00000002	Laser Emission	Logical OR from all lasers	Laser emission status
2	00000004	Laser Ready	Logical OR from all lasers	Laser ready status
3	00000008	Laser Standby	Logical OR from all lasers	Laser standby status
4	00000010	CDRH Delay	Logical OR from all lasers	Laser CDRH delay status
5	00000020	Laser Hardware Fault	Logical OR from all lasers	Hardware related faults in Table 6-4 (p. 6-13)
6	00000040	Laser Error	Logical OR from all lasers	Laser error is queued
7	00000080	Laser Power Calibration	Logical OR from all lasers	Laser power is within factory calibration specification
8	00000100	Laser Warm Up	Logical OR from all lasers	Laser warm-up status
9	00000200	Laser Head Noise	Logical OR from all lasers	Noise level is over 30
10	00000400	External Operating Mode	Logical OR from all lasers	External operating mode is selected
11	00000800	Field Calibration	Logical OR from all lasers	Field calibration is in progress when set
12	00001000	Laser Power Voltage	Logical OR from all lasers	12V laser power voltage is present when set
...	…	…		
25	02000000	Controller Standby	Key switch is in "STANDBY" position	Always 0
26	04000000	Controller Interlock	"INTERLOCK" is open.	Always 0
27	08000000	Controller Enumeration	One or more laser heads have bee enumerated	Always 0
28	10000000	Controller Error	Controller error flag	Always 0
29	20000000	Controller Fault	Controller fault status	Always 0
30	40000000	Remote Active	Host is connected	Always 0
31	80000000	Controller Indicator	Status word is from controller.	Always 0

Unspecified bits are reserved and are zero.

Command: None

Query: SYSTem:STATus?
Reply: <status word>

As an example, if the laser is turned on, but is being delayed by the CDRH required delay, the system status query returns:

00000012 (*Laser emission enabled but delayed by CDRH*)

System Fault Query

Gets the system fault code. The fault code is returned in a string expressed in uppercase hexadecimal integer form. The 32-bit word represents a bit-mapped fault indicator.

The MSB of the code is used to indicate if the code represents the status of a controller or a laser head. If the MSB is set, the code represents controller fault status. This is important since the meaning of some bits is subtly different for a controller. Refer to the following table for differences.

The following table describes fault code bit mapping.

Table 6-4. Fault Code Bit Definitions (Sheet 1 of 2)

Bit[a]	Mask	Bit Label	Controller	Laser Head
0	00000001	Base Plate Temp. Fault	Logical OR from all lasers	Base plate temperature out of range
1	00000002	Diode Temp. Fault	Logical OR from all lasers	Diode temperature out of range
2	00000004	Internal Temp. Fault	Logical OR from all lasers	Internal temperature out of range
3	00000008	Laser Power Supply Fault	Logical OR from all lasers	No electrical power to laser diode
4	00000010	I2C Error	Logical OR from all lasers	I2C bus error
5	00000020	Over Current	Logical OR from all lasers	Diode over current
6	00000040	Laser Checksum Error	Logical OR from all lasers	EEPROM checksum error in at least one section
7	00000080	Checksum Recovery	Logical OR from all lasers	EEPROM was restored to default settings
8	00000100	Buffer Overflow	Logical OR from all lasers	Bus message buffer overflow
9	00000200	Warm-up limit fault	Logical OR from all lasers	Warm-up time limit exceeded
10	00000400	TEC Driver Error	Logical OR from all lasers	TE controller driver failure
11	00000800	CCB Error	Logical OR from all lasers	RS-485 bus error
12	00001000	Diode Temp Limit Error	Logical OR from all lasers	Diode temperature off by > 3°C from set point
13	00002000	Laser Ready Fault	Logical OR from all lasers	Fail to emit at set power level
14	00004000	Photodiode Fault	Logical OR from all lasers	Negative photodiode readout
15	00008000	Fatal Fault	Logical OR from all lasers	Irrecoverable system failure

Table 6-4. Fault Code Bit Definitions (Sheet 2 of 2)

Bit[a]	Mask	Bit Label	Controller	Laser Head
16	00010000	Startup Fault	Logical OR from all lasers	Errors encountered during firmware startup
17	00020000	Watchdog Timer Reset	Logical OR from all lasers	Firmware resumed from watchdog reset
18	00040000	Field Calibration	Logical OR from all lasers	Errors encountered during field calibration
...	...	...		
30	40000000	Controller Checksum	Controller checksum error	Always 0
31	80000000	Controller Status	Fault word is from controller	Always 0

a. Unspecified bits are reserved and will be zero.

Command: None

Query: SYSTem:FAULt?
Reply: <fault word>

As an example, if the base plate and laser diode temperature limits are both exceeded, the system fault query will return:

00000003 *(Base Plate & Laser Diode Temp. Limits Exceeded*)

Turn On/Off Laser Status Indicator

Turns on (or turns off) the status indicator(s) associated with the laser head. Setting is saved in persistent memory. Factory default is ON.

Command: SYSTem:INDicator:LASer {ON|OFF}

Query: SYSTem:INDicator:LASer?
Reply: ON|OFF

This command is used to turn on (or turn off) the LED status indicator(s) that is visible to the user. The status bits returned by "SYSTem:STATus?", however, are not affected by this command.

Error Record Reporting

Programming and system errors will occasionally occur while testing or debugging remote programs and during measurement. Error strings follow the SCPI Standard for error record definition:

<error code>,<quoted error string><CR><LF>

The host queries for errors in two steps.

1. First, the host queries for the number of error records available (N).

2. Secondly, the host queries N times for the error records.

Errors are stacked up to 20 deep. In the case of error overflow, the last error in the error list is an indication of error overflow.

Note that the error records defined in this section are the errors generated in response to external commands or queries. Any errors generated from the internal operation of the laser head or controller will be reflected in the fault code displayed in Table 6-4 (p. 6-13).

Error Count Query

Gets the number of error records in the error queue at the time of the query.

Command: none

Query: SYSTem:ERRor:COUNt?
Reply: <integer count of error records stored>

Error Query

Gets the next error record(s) in the error queue. More than one error record may be queried using the optional <error record count> parameter, which must be an integer value. A single error record is returned if <error record count> is not specified. No reply is transmitted if there are no available error records.

As the device transmits each error record:

- The error record is permanently removed from the error queue
- The queued error record count is decremented by one

Command: none

Query: SYSTem:ERRor:NEXT?
Reply: <next available error record>

All Error Clear

Clears all error records in the error queue.

Command: SYSTem:ERRor:CLEar

Query: none

OBIS Common Commands and Queries

OBIS Common Commands and Queries is implemented by all OBIS devices that support the features contained in this section. If a device does not support a given feature, the command may be ignored.

System Information Queries

The System Information commands allow a host to retrieve static information describing the characteristics of the laser.

System Model Name Query

Retrieves the model name of the laser.

Query: SYSTem:INFormation:MODel?
Reply: <model name>

System Manufacture Date Query

Retrieves the manufacture date of the device.

Command: SYSTem:INFormation:MDATe?
Reply: <manufacture date>

System Calibration Date Query

Retrieves the calibration date of the device.

Command: SYSTem:INFormation:CDATe?
Reply: <calibration date>

System Serial Number Query

Retrieves the serial number of the laser.

Query: SYSTem:INFormation:SNUMber?
Reply: <serial number>

System Part Number Query

Retrieves the manufacturer part number of the laser.

Query: SYSTem:INFormation:PNUMber?
Reply: <manufacturer part number>

System Firmware Version Query

Retrieves the current firmware version from the laser firmware. The format of the returned firmware version number string is identical to that described in the *IDN? Query.

Query: SYSTem:INFormation:FVERsion?
Reply: <current firmware version>

System Protocol Version Query

Retrieves the current OBIS protocol version from the laser firmware. The format of the returned firmware version number string is: “P<major>.<minor><optional qualifier characters>”.

Query: SYSTem:INFormation:PVERsion?
Reply: <current protocol version>

The firmware version is the format: “P<major>.<minor><optional qualifier characters>”. For example, P1.0a is a valid firmware version format.

System Wavelength Query

Retrieves the actual wavelength (in nanometers) of the laser.

Query: SYSTem:INFormation:WAVelength?
Reply: <wavelength>

System Power Rating Query

Retrieves the power rating (in watts) of the laser head.

Query: SYSTem:INFormation:POWer?
Reply: <power>

The power rating is minimum output power under a given set of operating conditions during the laser life. It is generally the same as nominal power

Device Type Query

Retrieves the device type. The device includes laser head and controller. At this time, the types of lasers supported by this protocol are OBIS LX (Direct Diode Lasers (DDL)), OBIS LS (Optically Pumped Semiconductor Lasers (OPSL)) and OTHER. The set of extended laser-specific commands is determined by the response to this query. The type of the controller is hard coded in the controller.

Query: SYSTem:INFormation:TYPe?
Reply: DDL|OPSL|MINI|MASTER|OTHER

CW Nominal Power Query

Returns the nominal CW laser output power in watts.

Query: SOURce:POWer:NOMinal?
Reply: <x.xxxxx>

The reply string represents the nominal power value in watts.

CW Minimum Power Query

Returns the minimum CW laser output power in watts.

Query: SOURce:POWer:LIMit:LOW?
Reply: <x.xxxxx>

The reply string represents the minimum power in watts.

CW Maximum Power Query

Returns the maximum CW laser output power in watts.

Query: SOURce:POWer:LIMit:HIGH?
Reply: <x.xxxxx>

The reply string represents the maximum power value in watts.

Set/Query User-Defined ID

Enters and stores user-defined identification or any other information the user desires to store. The information entered is stored in nonvolatile memory. The user can enter up to four items, with each comprised of up to 31 characters.

Command: SYSTem:INFormation:USER <item number> , <item>

Query: SYSTem:INFormation:USER? <item number>
Reply: Item stored at the location pointed to by <item number>

Note: The item number starts at zero.

Set/Query Field Calibration Date

Enters and stores the date on which the last field calibration was performed. This is normally done by the user or Coherent field service personnel.

Command: SYSTem:INFormation:FCDate <alphanumeric string>

Query: SYSTem:INFormation:FCDate?
Reply: <alphanumeric string >

Note: The number of alphanumeric character is limited to 31 maximum.

System State Commands/Queries

System State commands allow a host to retrieve dynamic information describing the current operational state of the laser.

System Power Cycle Query

Returns the number of ON/OFF power cycles the laser has endured.

Query: SYSTem:CYCLes?
Reply: <integer cycle count>

System Power Hour Query

Returns the number of hours the laser head has been powered on.

Query: SYSTem:HOURs?
Reply: <value in x.xx format>

Diode Hour Query

Returns the number of hours the laser diode has operated. This is defined as the accumulation of time while the “Laser Enable” pin is asserted.

Query: SYSTem:DIODe:HOURs?
Reply: <value in x.xx format>

System Output Power Level Query

Returns the present output power of the laser head measured in watts.

Query: SOURce:POWer:LEVel?
Reply: <x.xxxxx>

The reply string is an NRf value representing the present laser output power measured in watts.

System Output Current Query

Returns the present output current of the laser head measured in amps.

Query: SOURce:POWer:CURRent?
Reply: <x.xxxxx>

The reply string is an NRf value representing the present laser output current measured in amps.

Base Plate Temperature Query

Returns the present laser head base plate temperature. An optional unit indicator may be specified. If the 'C' unit indicator is specified, or if the unit indicator is left off, the returned value represents the laser base plate temperature in degrees C. If the 'F' unit indicator is specified, the returned value represents the laser base temperature in degrees F.

Query: SOURce:TEMPerature:BASeplate? {C|F}
Reply: <x.xU where U is the unit indicator 'C' or 'F'>

The reply string represents the base temperature in NRf format, with a unit indicator of 'C' or 'F' appended.

System Interlock Query

Returns the status of the system interlock. The method of determining interlock status is device dependent. This feature may not apply to the laser head itself.

Query: SYSTem:LOCK?
Reply: ON|OFF

Query returns the interlock state in string format.

Operational Commands/Queries

Operational commands and queries are used to configure and operate the laser from a Host or Controller. These commands and queries are for use by user level applications as well.

Laser Operating Mode Selection

Five mutually exclusive operating modes are available:

- CWP (continuous wave, constant power)
- CWC (continuous wave, constant current)
- DIGITAL (CW with external digital modulation)
- ANALOG (CW with external analog modulation)
- MIXED (CW with external digital + analog modulation)

The exact meaning of the selected mode is device-dependent.

<u>Select CW Mode</u>

Sets the laser operating mode to internal CW and deselects external modulation. The setting is saved in non-volatile memory.

The default setting is CW with constant power or CWP.

Command: SOURce:AM:INTernal CWP|CWC

Select Modulation Mode

Sets the laser operating mode to CW constant current modulated by one or more external sources. MIXED source combines both external digital and external analog modulation. The setting is saved in non-volatile memory.

Command: SOURce:AM:EXTernal DIGital|ANALog|MIXed

Laser Operating Mode Query

Queries the current operating mode of the laser.

Query: SOURce:AM:SOURce?
Reply: CWP|CWC|DIGITAL|ANALOG|MIXED

The reply string represents the present laser operating mode, where CWP and CWC are not modulated externally and the other modes imply external modulation.

Set/Query Laser Power Level

Sets present laser power level in watts. Setting power level does not turn the laser on.

Command: SOURce:POWer:LEVel:IMMediate:AMPLitude <value>

Query: SOURce:POWer:LEVel:IMMediate:AMPLitude?
Reply: <x.xxxxx>

The reply string represents the present laser power level setting as an NRf value in watts.

Set/Query Laser Enable

Turns the laser ON or OFF. When turning the laser ON, actual laser emission may be delayed due to internal circuit stabilization logic and/or CDRH delays.

Command: SOURce:AM:STATe ON|OFF

Query: SOURce:AM:STATe?
Reply: ON|OFF

Query returns the present laser ON/OFF state in string format.

Set/Query CDRH Delay

NOTICE!
Disabling the CDRH delay will render the OBIS system non-CDRH compliant.

Enables or disables the CDRH five-second laser emission delay.

Command: SYSTem:CDRH ON|OFF

Query: SYSTem:CDRH?
Reply: ON|OFF

Query returns the present CDRH setting in string format.

OBIS Optional Commands

Set/Query TEC Enable

Enables or disables temperature control of the laser diode via the TEC circuit.

Command: SOURce:TEMPerature:APRobe ON|OFF

Query: SOURce:TEMPerature:APRobe?
Reply: ON|OFF

Query returns the present ON/OFF TEC control state in string format.

DDL-Specific Commands

The commands in this section pertain to DDL lasers only.

Enable/Undo Laser Power Field Calibration

Starts a self laser power calibration using an internal reference. It is used to re-calibrate the laser power in the field against possible degradation of both laser diode and internal reference during its lifetime. You may undo the field calibration if need be.

Command: SOURce:POWer:CALibration

Command: SOURce:POWer:UNCalibration

The calibration process involved in this command may take a few minutes to finish. Do not disrupt the power supply until the process is complete. Status bit 11 is set up as a handshaking mechanism for the host program for the progress of calibration process.

Internal Temperature Limit Queries

These queries return the present internal temperature limit settings. An optional unit indicator may be specified. If the 'C' unit indicator is specified, or if the unit indicator is left off, the returned value represents the internal temperature high or low limit in degrees C. If the 'F' unit indicator is specified, the returned value represents the internal temperature limit in degrees F. The internal temperature represents the temperature taken from a built-in temperature sensor of the microprocessor.

The reply string represents the limit value in NRf format with a unit indicator of 'C' or 'F' appended.

Internal Temperature High Limit Query

Query: SOURce:TEMPerature:PROTection:INTernal:HIGH?
Reply: <x.xU where U is the unit indicator 'C' or 'F'>

Internal Temperature Low Limit Query

Query: SOURce:TEMPerature:PROTection:INTernal:LOW?
Reply: <x.xU where U is the unit indicator 'C' or 'F'>

Diode Temperature Query

Returns the present laser head diode temperature. An optional unit indicator may be specified. If the 'C' unit indicator is specified, or if the unit indicator is left off, the returned value represents the laser diode temperature in degrees C. If the 'F' unit indicator is specified, the returned value represents the laser diode temperature in degrees F.

Query: SOURce:TEMPerature:DIODe? {C|F}
Reply: <x.xU where U is the unit indicator 'C' or 'F'>

The reply string represents the diode temperature in NRf format with a unit indicator of 'C' or 'F' appended.

Diode Set Point Temperature Query

Returns the diode set point temperature that the TEC controller manages to maintain. An optional unit indicator may be specified. If the 'C' unit indicator is specified, or if the unit indicator is left off, the returned value represents the laser diode temperature in degrees C. If the 'F' unit indicator is specified the returned value represents the laser diode temperature in degrees F.

Query: SOURce:TEMPerature:DSETpoint? {C|F}
Reply: <x.xU where U is the unit indicator 'C' or 'F'>

The reply string represents the target temperature in NRf format with a unit indicator of 'C' or 'F' appended.

Internal Temperature Query

Returns the present internal laser temperature. An optional unit indicator may be specified. If the 'C' unit indicator is specified, or if the unit indicator is left off, the returned value represents the internal laser temperature in degrees C. If the 'F' unit indicator is specified the returned value represents the laser base temperature in degrees F.

Query: SOURce:TEMPerature:INTernal? {C|F}
Reply: <x.xU where U is the unit indicator 'C' or 'F'>

The reply string represents the internal laser temperature in NRf format with a unit indicator of 'C' or 'F' appended.

Table 6-5. Fault Codes—OBIS Remote (Mini) and Laser Head (LH) (Sheet 1 of 3)

Note: A warm or cold device reboot is required to clear an OBIS Remote or laser head fault.

Code Bit	Error Value	Mini	LH	Error Description	Cause and Possible Solution
0	00000001		X	Baseplate temperature fault	**Cause**: Baseplate temperatures is greater than 40°C or lower than 10°C. **Solution**: Improve heat sink to reduce baseplate temperature or adjust the ambient temperature where the laser operates.
1	00000002		X	Diode temperature fault	**Cause**: Diode temperature is greater than 40°C or lower than 10°C. **Solution**: Make sure the TE cooler is on and/or adjust the ambient temperature where the laser operates.
2	00000004		X	Internal temperature fault	**Cause**: Microprocessor temperature exceeds factory set limit. **Solution**: Make sure the TE cooler is on and the ambient temperature is within the specified range.
3	00000008		X	Laser power supply fault	**Cause**: There is no electrical power to the laser diode. **Solution**: Make sure the SDR cable is plugged in and secured properly on both ends.
4	00000010		X	Device internal I2C bus error	**Cause**: An error was encountered in internal I2C bus communications. **Solution**: Perform a warm or cold reboot of the laser system. If the problem persists, contact Coherent technical support.
5	00000020		X	Laser diode over-current error	**Cause**: Laser diode current exceeds the specified upper limit. **Solution**: Turn off laser emission and reboot the device. If the problem persists, contact Coherent technical support.
6	00000040		X	Laser checksum error	**Cause**: An error occurred that is associated with persistent memory where critical data is stored. **Solution**: Reboot the laser system. If the problem persists, contact Coherent technical support.
7	00000080		X	Checksum recovery error	**Cause**: An error occurred when trying to recover from checksum error via host command. **Solution**: Contact Coherent technical support.

Table 6-5. Fault Codes—OBIS Remote (Mini) and Laser Head (LH) (Sheet 2 of 3)

Note: A warm or cold device reboot is required to clear an OBIS Remote or laser head fault.

Code Bit	Error Value	Mini	LH	Error Description	Cause and Possible Solution
8	00000100		X	Message buffer overflow	**Cause**: An overflow error associated with message buffer was encountered in the firmware. **Solution**: Perform a warm or cold reboot of the laser system. If the problem persists, contact Coherent technical support.
9	00000200		X	Warm-up limit fault	**Cause**: The 5-minute warm-up limit was exceeded. **Solution**: Make sure the TE cooler is enabled. If the laser was started in a very low temperature environment, keep the laser powered for 10-15 minutes, then reboot the device.
10	00000400		X	TEC control error	**Cause**: An error associated with the TEC operation was encountered. It can be caused by insufficient heat sink. **Solution**: Make sure heat sink is sufficient, then perform a device reboot. If the problem persists, contact Coherent technical support.
11	00000800		X	Coherent connection bus error	**Cause**: An error associated with RS-485 bus communications between the laser and OBIS Remote was encountered. **Solution**: Make sure the SDR cable is plugged in and secured properly on both ends.
12	00001000		X	Diode temperature limit error	**Cause**: Laser diode temperature deviates from the temperature set point by more than 3°C. **Solution**: Make sure the TE cooler is turned on. If the laser warm-up process is disabled, keep the laser running for 10-15 minutes, then perform a device reboot.
13	00002000		X	Laser ready fault	**Cause**: Laser fails to emit within ± 2% of the requested power. **Solution**: If the problem persists, contact Coherent technical support for a system recalibration.
14	00004000		X	Photodiode fault	**Cause**: Readings from the internal photodiode for power control were negative. **Solution**: Reboot the laser head. If the problem persists, Contact Coherent technical support.
15	00008000		X	Device fatal error	**Cause**: An irrecoverable system failure was encountered. **Solution**: Contact Coherent technical support.
16	00010000		X	Startup error	**Cause**: Errors were encountered during firmware startup. **Solution**: Perform a cold or warm device reboot.

Table 6-5. Fault Codes—OBIS Remote (Mini) and Laser Head (LH) (Sheet 3 of 3)

Note: A warm or cold device reboot is required to clear an OBIS Remote or laser head fault.

Code Bit	Error Value	Mini	LH	Error Description	Cause and Possible Solution
17	00020000		X	Watchdog timer reset	**Cause**: Firmware was resumed from a processor watchdog reset. **Solution**: Contact Coherent technical support.
18	00040000		X	Field calibration error	**Cause**: Errors were encountered while running power field calibration. **Solution**: Re-run field calibration. If the problem persists, contact Coherent technical support.
...	...	...	...	...	
30	40000000	X		Min-controller checksum error	**Cause**: An error associated with persistent memory was encountered. **Solution**: Reboot the OBIS Remote. If the problem persists, contact Coherent technical support.
31	80000000	X		Fault status from OBIS Remote	**Cause**: A firmware or hardware fault was encountered in the OBIS Remote. **Solution**: Reboot the OBIS Remote. If the problem persists, contact Coherent technical support.

Controls and Queries

The OBIS control and query command set confirms to the Standard Commands for Programmable Instruments (SCPI) and IEEE 488.2 standards. In short, a SCPI control command consists of a header built with keyword(s) plus one or more optional parameters. The header and the parameter(s) are separated by a space. A query command is formed by directly appending a question mark to the end of the header. For more detailed information on SCPI commands and syntax, refer to the SCPI standard documentation.

Here's a brief description of the notation conventions for the OBIS commands:

- Parameter(s) following a control command is required.
- Item(s) within the angle brackets following a control or query command is required.
- Item(s) within the curly brackets following a control or query command is optional.
- Acceptable parameters or items required for a control or query command are separated by the OR symbol "|".
- The upper and lower bounds of the range for a parameter or item are given in parentheses.

Table 6-6 and Table 6-7 contain a complete list of OBIS SCPI control and query commands for the OBIS Remote (MINI), the OBIS LX direct diode laser (DDL), and the OBIS LS optically-pumped semiconductor laser (OPSL).

Table 6-6. OBIS Control Commands (Sheet 1 of 2)

Command	Remote	OBIS LX (DDL)	OBIS LS (OPSL)	Description
*RST	X	X	X	Performs a firmware warm reset. Message handshaking, if enabled, is transmitted prior to the execution of reset. This command may be used to clear a fault condition.
SYSTem:COMMunicate:HANDshaking ON|OFF	X	X	X	Enables | Disables host/controller communication handshaking. This setting is stored in persistent memory so that it remains unchanged after a power ON/OFF cycle.
SYSTem:COMMunicate:PROMpt ON|OFF	X	X	X	Enables | Disables command/query prompt (>). This setting is stored in persistent memory.
SYSTem:AUTostart ON|OFF		X	X	Enables | Disables laser power automatic emission. Note: This setting will be overridden by interlock switch, key switch, or other hardware mechanisms in the OBIS Remote. This setting is stored in persistent memory.
SYSTem:CDRH ON|OFF		X	X	Enables | Disables CDRH delay. This setting is stored in persistent memory.
SYSTem:DIODe:WARMup ON|OFF		X	X	Enables | Disables laser diode warm-up process. If this process is disabled, the laser is capable of starting emission as soon as the electronics is up and running. If this process is enabled, the laser will not emit until after the warm-up process is complete, even if the laser-on command is issued or the auto start is enabled. This setting is stored in persistent memory.
SYSTem:RECovery		X	X	Recovers device from checksum failure. This command may also be used to restore device to factory default settings. The laser head status LED illumination, if enabled, will be steady green while the device is recovering.
SYSTem:INFormation:AMODulation:TYPe 1|2	X			Selects electrical input impedance for the analog modulation channel of the OBIS Remote. Parameter 1 selects 50Ω while parameter 2 selects 2 kΩ. This setting is stored in persistent memory.
SYSTem:INDicator:LASer ON|OFF		X	X	Enables | Disables illumination of LED status indicator. This setting does not affect the state of device status bits or fault bits. This setting is stored in persistent memory.
SYSTem:ERRor:CLEar	X	X	X	Clears host/controller communication error records.

Table 6-6. OBIS Control Commands (Sheet 2 of 2)

Command	Remote	OBIS LX (DDL)	OBIS LS (OPSL)	Description
SYSTem:INFormation:USER <index>, <item>	X	X	X	Enters and stores user-defined identification or other information. <index> = (0, 3). <item> = (0, 31 characters).
SOURce:AM:INTernal CWP|CWC		X	X	Sets laser internal operating mode. Note: The laser internal and external operating modes are mutually exclusive. CWC = CW constant power; CWC = CW constant current.
SOURce:AM:EXTernal DIGital|ANALog|MIXed		X	X	Sets laser external operating mode. Note: The laser internal and external operating modes are mutually exclusive and the laser head is required to connect to a OBIS Remote to use these modes. DIGital = digital modulation; ANALog = analog modulation; MIXed = digital + analog modulation.
SOURce:POWer:LEVel:IMMediate:AMPLitude <laser_power>		X	X	Sets laser output power level in watts. <laser_power> = (0, 110% nominal power). This command itself will not enable laser emission. If laser emission has been enabled, this command will change the laser output power and the new setting is saved in persistent memory. Note: Setting power level to zero watts does not turn off the electrical power to the laser diode.
SOURce:AM:STATe ON|OFF		X	X	Turns On | Turns Off laser emission. Actual laser emission may be delayed due to internal electronic circuit stabilization and/or CDRH delay.
SOURce:TEMPerature:APRobe ON|OFF		X		Enables | Disables thermoelectric cooler for DDL laser head.
SOURce:POWer:CALibration		X		Performs field calibration for analog modulation. This command will result in a match of 5V analog input to 100% nominal power.

Table 6-7. OBIS Query Commands (Sheet 1 of 3)

Command	Mini	DDL	OPSL	Description
*IDN?	X	X	X	Returns device identification string that includes information about manufacturer name, product name, nominal wavelength, power rating, firmware version, and firmware release date in the format shown in this example: "Coherent, Inc - OBIS 405nm 50mW C - V1.0.1 - Dec 14 2010".
*TST?	X	X	X	Returns 0xFFFFFFFF for DDL.
SYSTem:COMMunicate:HANDshaking?	X	X	X	Returns communication handshake setting. Replay = ON|OFF.
SYSTem:COMMunicate:PROMpt?	X	X	X	Returns command prompt setting. Replay = ON|OFF.

Table 6-7. OBIS Query Commands (Sheet 2 of 3)

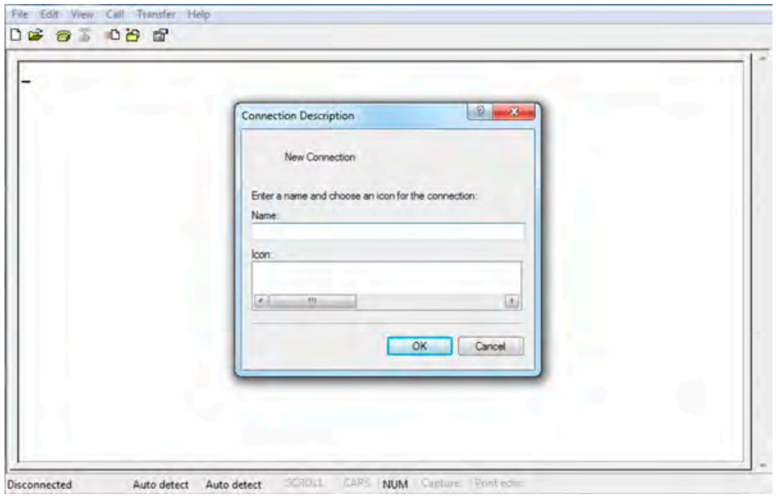
Command	Mini	DDL	OPSL	Description
SYSTem:AUTostart?		X	X	Returns laser auto emission setting. Replay = ON|OFF.
SYSTem:CDRH?		X	X	Returns CDRH delay setting. Replay = ON|OFF.
SYSTem:FAULt?	X	X	X	Returns device fault bits in 32-bit hexadecimal format. Refer to Table 6-4 (p. 6-13) for definitions of device fault bits.
SYSTem:CYCLes?		X	X	Returns number of device power-on cycles.
SYSTem:DIODe:HOUR?		X		Returns accumulated laser emission hours. The returned value has a resolution of two digits after decimal point.
SYSTem:DIODe:WARMup?		X		Returns diode warm-up setting. Replay = ON|OFF.
SYSTem:HOUR?		X	X	Returns accumulated device operating hours. The returned value has a resolution of two digits after decimal point.
SYSTem:LOCK?	X			Returns OBIS Remote interlock status. Replay = ON|OFF, with ON = Close and OFF = Open.
SYSTem:INFormation:AMODulation:TYPe?	X			Returns input impedance type for OBIS Remote analog modulation channel. Replay = 1|2, with 1 = 50Ω and 2 = 2kΩ.
SYSTem:NOISe?		X		Returns noise level of laser power. The returned integer is a relative measure of laser power stability. It applies to constant power mode only. A level above 30 is considered noisy. It is normal to see a relatively high noise level when the laser is warming up or when the laser power is changed.
SYSTem:INDicator:LASer?		X	X	Returns LED status indicator setting. Replay = ON|OFF.
SYSTem:ERRor:COUNt?	X	X	X	Returns host/controller communication error count.
SYSTem:ERRor:NEXT?	X	X	X	Returns host/controller communication error record.
SYSTem:INFormation:MODel?	X	X	X	Returns device modal.
SYSTem:INFormation:MDATe?	X	X	X	Returns device manufacture date.
SYSTem:INFormation:CDATe?	X	X	X	Returns device calibration date.
SYSTem:INFormation:SNUMber?	X	X	X	Returns device serial number.
SYSTem:INFormation:PNUMber?	X	X	X	Returns device manufacturer part number.
SYSTem:INFormation:FVERsion?	X	X	X	Returns device firmware version.
SYSTem:INFormation:WAVelength?		X	X	Returns laser nominal wavelength in nanometers based on a diode operating temperature of 25 degrees Celsius.
SYSTem:INFormation:POWer?		X	X	Returns laser power rating in watts.
SYSTem:INFormation:TYPe?	X	X	X	Returns device type. Replay = MINI|DDL|OPSL.

Table 6-7. OBIS Query Commands (Sheet 3 of 3)

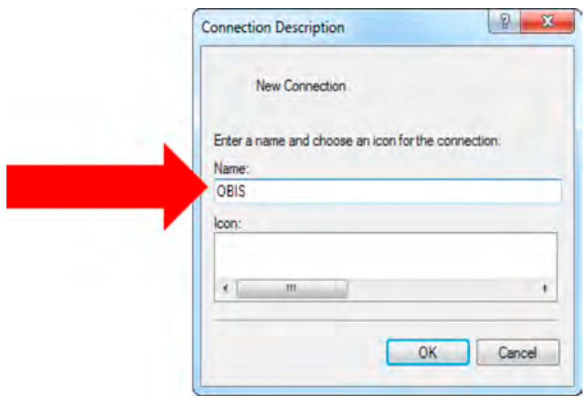
<table>
<tr><th>Command</th><th>Mini</th><th>DDL</th><th>OPSL</th><th>Description</th></tr>
<tr><td>SOURce:POWer:LIMit:LOW?</td><td></td><td>X</td><td>X</td><td>Returns minimum laser power output in watts available in CW constant current or CW constant power mode.</td></tr>
<tr><td>SOURce:POWer:LIMit:HIGH?</td><td></td><td>X</td><td>X</td><td>Returns maximum laser power output in watts available in CW constant current or CW constant power mode.</td></tr>
<tr><td>SYSTem:INFormation:USER? <index></td><td>X</td><td>X</td><td>X</td><td>Returns user defined identification. <index> = (0,3).</td></tr>
<tr><td>SOURce:POWer:LEVel?</td><td></td><td>X</td><td>X</td><td>Returns present laser output power in watts.</td></tr>
<tr><td>SOURce:POWer:CURRent?</td><td></td><td>X</td><td>X</td><td>Returns present laser output current in amperes.</td></tr>
<tr><td>SOURce:TEMPerature:BASeplate? {C|F}</td><td></td><td>X</td><td>X</td><td>Returns present baseplate temperature.</td></tr>
<tr><td>SOURce:AM:SOURce?</td><td></td><td>X</td><td>X</td><td>Returns present laser operating mode. Replay = CWP|CWC |DIG|ANAL|MIX.</td></tr>
<tr><td>SOURce:POWer:LEVel:IMMe-diate:AMPLitude?</td><td></td><td>X</td><td>X</td><td>Returns laser output power set level in watts.</td></tr>
<tr><td>SOURce:AM:STATe?</td><td></td><td>X</td><td>X</td><td>Returns laser emission status. Replay = ON|OFF.</td></tr>
<tr><td>SOURce:TEMPerature:PROTec-tion:BASeplate:HIGH? {C|F}</td><td></td><td>X</td><td>X</td><td>Returns maximum laser baseplate temperature without triggering a fault condition.</td></tr>
<tr><td>SOURce:TEMPerature:PROTec-tion:BASeplate:LOW? {C|F}</td><td></td><td>X</td><td>X</td><td>Returns minimum laser baseplate temperature without triggering a fault condition.</td></tr>
<tr><td>SOURce:TEMPerature:PROTec-tion:DIODe:HIGH? {C|F}</td><td></td><td>X</td><td></td><td>Returns maximum laser diode temperature without triggering a fault condition.</td></tr>
<tr><td>SOURce:TEMPerature:PROTec-tion:DIODe:LOW? {C|F}</td><td></td><td>X</td><td></td><td>Returns minimum laser diode temperature without triggering a fault condition.</td></tr>
<tr><td>SOURce:TEMPerature:DIODe? {C|F}</td><td></td><td>X</td><td></td><td>Returns present laser diode temperature.</td></tr>
<tr><td>SOURce:TEMPerature:DIODe:DSET-point? {C|F}</td><td></td><td>X</td><td></td><td>Returns TEC temperature set point for the laser diode.</td></tr>
<tr><td>SOURce:TEMPerature:APRobe?</td><td></td><td>X</td><td></td><td>Returns thermoelectric cooler (TEC) status. Replay = ON|OFF.</td></tr>
<tr><td>SOURCE:CURRent:LIMit:LOW?</td><td></td><td>X</td><td></td><td>Returns laser diode threshold current in amperes.</td></tr>
</table>

OBIS Communications through HyperTerminal

1. Open HyperTerminal and display the Connection Description screen.

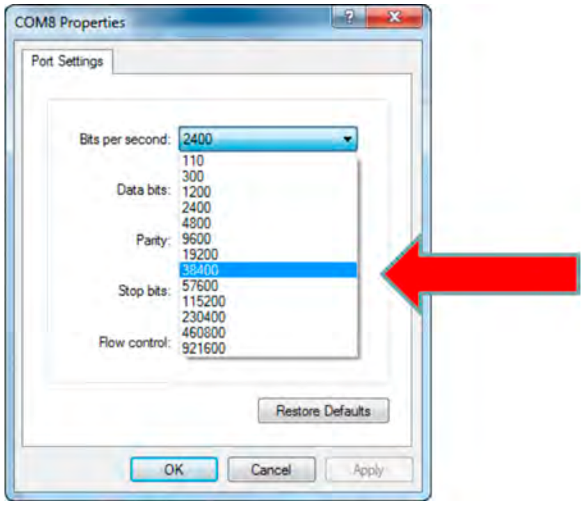


2. Enter a name for the new connection and click the OK button.

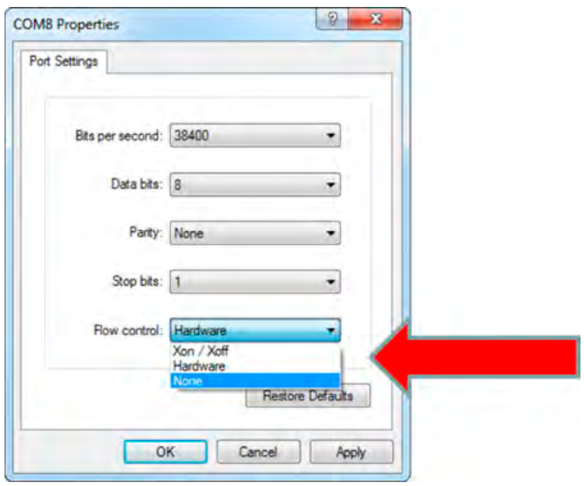


3. Select the COM port from the dropdown menu and click OK.

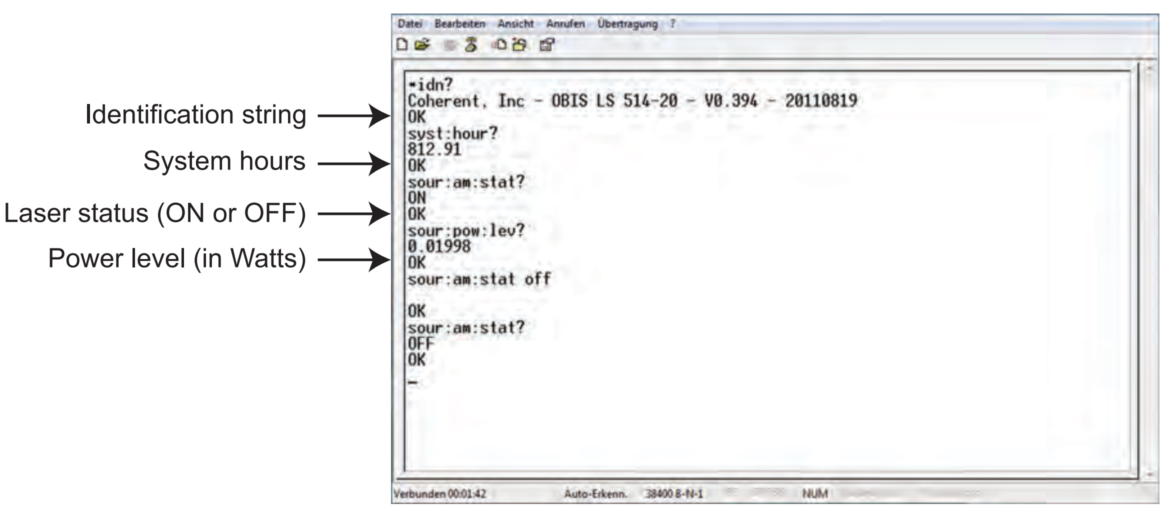
4. Select the baud rate from the dropdown menu.



5. Set flow control to *None* and click the OK button.



Here's an example of an output screen:



SECTION SEVEN: BEAM PROPAGATION

In this section:

It is not the intent here to have an exhaustive discussion of optics theory and beam propagation—that information is readily available in optics and laser text books. The following basic optics information will be helpful when designing a beam delivery system.

WARNING!
It is very important to always wear laser safety glasses when aligning the OBIS laser to an optical assembly.

NOTICE!
It is important to avoid back reflections when aligning the OBIS. As little as 5% back reflection can damage the diode.

Beam Diameter

The typical Coherent OBIS laser beam is very close to an ideal Gaussian beam profile, where the peak intensity of the beam is at the center. In Figure 7-1 (p. 7-2), the intensity profile cutting through a laser beam is shown for the ideal case. For these beams, the beam diameter is defined as the width of the beam, where the intensity is 13.5% of the peak intensity. Based on the mathematical description of the beam profile, this is a good first approximation of beam diameter. The practical information here is selecting the clear aperture of optics that the laser beam must go through. To allow at least 99% of the laser beam though an aperture, it should be at least 1.5 times the beam diameter at that point. In actual practice, the clear aperture should be selected to be several millimeters larger so it is easy to align the beam through the optic. The laser beam information provided in the data sheets is based on measurements using specific instruments designed to measure beam diameters.

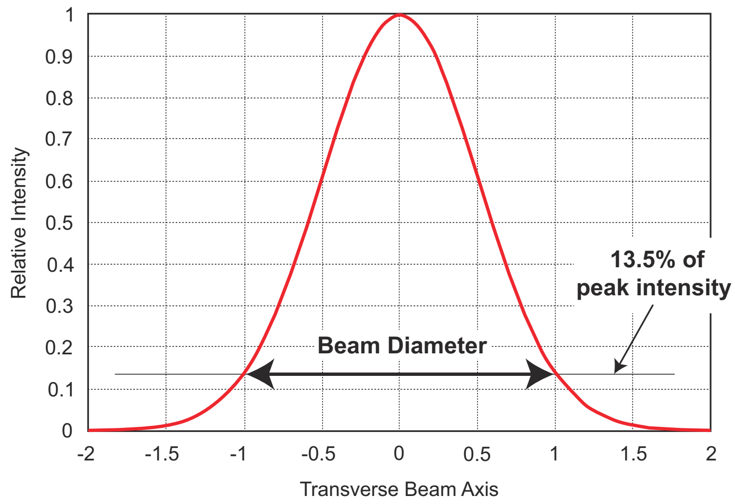


Figure 7-1. Gaussian Beam Profile

M^2 (M Squared) Factor

The actual laser beams differ somewhat from the ideal Gaussian profile shown in Figure 7-1, above. To handle the handle the deviation from the ideal case, the factor M^2 or K has been developed and is often quoted in laser specifications. For the ideal beam, the M^2 factor is 1 and the factor increases as the beam deviates more from ideal behavior. For a beam with an M^2 factor of 1.2, the beam is actually $\sqrt{1.2} = 1.1$ larger than an ideal Gaussian beam. It basically relates to the factor by which the beam diameter is different from ideal. As will be shown in later examples, it has practical use to determine the beam size at various locations in a beam delivery system. Note that the $M^2 = 1/K$ and is also in common use.

Beam Propagation

As a laser beam propagates away from it narrowest point or beam waist, it will increase in size in a very predictable fashion. To calculate the beam size at a specific location, one must know the size of the beam waist and its location. Thus the beam diameter, *D*, at a distance *Z* away from the beam waist with a beam diameter of D_0 follows the equation:

$$D = \sqrt{D_o^2 + \Theta^2 Z^2}$$

The factor Θ is the beam divergence. The beam divergence depends on some basic properties of the beam including the wavelength, and the beam waist size D_0. The relationship for the beam divergence at full angle, then is:

$$\Theta = \frac{4\lambda M^2}{\pi D_o}$$

Often the beam divergence is a value included in the specifications of a laser. If a calculation is being made of the divergence, the units of the wavelength and the beam waist diameter must be the same. As an example a laser operating at a wavelength of 10.6 µ, a 7 mm beam waist diameter, and an M^2 of 1.2 the calculated divergence is as follows:

$$\Theta = 4 \text{ x } 0.0106 \text{ mm x } 1.2 / (3.14 \text{ x } 7) = 0.0023 \text{ rad} = 2.3 \text{ mrad}$$

Now calculating the beam diameter for the same laser as above at 2 meters from the beam waist:

$$D = \sqrt{}(49 \text{ mm}^2 + 0.0023^2 \text{ x } 2000 \text{ mm}^2)$$

$$D = \sqrt{}(49 \text{ mm}^2 + 5.29 \text{ x } 10^{-6} \text{ x } 4 \text{ x } 10^6 \text{ mm}^2) = 8.4 \text{ mm}$$

Focusing a Beam

Most laser processing applications call for focusing the laser beam to a small spot so that the high power density can accomplish the desired work. This is true for applications involving cutting, drilling, scribing, welding, and others on a wide range of material. The typical question is what is the spot size that will be achieved for this application. To achieve the smallest spot size, the beam must be focused with a lens that transmits the laser wavelength. To achieve the desired spot size, one must size the clear aperture for the diameter of the beam at that point using the guidelines covered in the section on beam diameters. The approximate spot size of the focused laser beam using a lens with focal length *f* is:

$$D_f = \frac{4f\lambda M^2}{\pi D_e}$$

Where D_e is the beam diameter at the focusing lens and D_f is the focused beam diameter. Calculating for the same beam in the beam propagation example with a 5 inch (127 mm) focal length lens for a beam at 2 meters from the beam waist:

$$D_f = (4 \text{ x } 127 \text{ mm x } 0.0106 \text{ mm x } 1.2) / (3.14 \text{ x } 8.4 \text{ mm})$$

$$D_f = 0.245 \text{ mm} = 245\ \mu$$

Rayleigh Range and Depth of Focus

When processing material it is important to have knowledge of the work range where the process will function properly. The major issue is the acceptable range in the distance between a focusing lens and the work surface. A convenient model for this is to calculate the Rayleigh range for the focused beam as an initial evaluation of the optical design. The Rayleigh range is the difference in distance between the beam waist location and the point at which the beam is 1.4 times larger.

$$Z_r = \frac{\pi D_o^2}{4\lambda M^2}$$

The beam waist diameter can be for a focused beam in this issue but it could also be any other beam waist and the equation is still applicable. For the same focused beam in the previous example, the Rayleigh range or depth of focus is:

$$Z_r = (3.14 \text{ x}(0.245 \text{ mm})^2) / (4 \text{ x } 0.0106 \text{ mm x } 1.2)$$

$$Z_r = (0.188 \text{ mm}^2) / (0.051 \text{ mm}) = 3.7 \text{ mm}$$

It should be noted that reducing the spot size will reduce the depth of focus more rapidly than the spot size is reduced. Thus when reducing spot size the process can become much more intolerant to variability in the distance between the focusing lens and the work piece. The Rayleigh range provides a guide to the range of acceptable working distances but the actual value will depend on the process, the equipment, and dynamics between the two factors.

Beam Expansion

As noted above, an increase in the beam diameter on a focusing lens can produce smaller focused spot size. The other issue that beam expansion addresses is variation in the focused spot size on a gantry-based system. In these later systems, the beam size on the focusing lens will vary as the distance between the laser and the focusing lens is moved which in turn causes the focused spot size to change as well as the distance to the beam waist. Beam expansion will reduce the change in the focused spot size and changes in focal point. The simplest beam expanders use two lenses with different focal lengths—see Figure 7-2 (p. 7-5). The ratio of the focal lengths gives the magnification of the beam. Galilean beam expanders use a negative lens followed by a positive lens for expansion.

Using the simple beam expander as an example, the combination of a 2.5-inch and 5-inch lenses will magnify the beam by a factor of two. The proper separation of the two lenses is the sum of their focal lengths. Small adjustment of the separation is required to correct for the effect of the distance from the first lens to the beam waist. As a general guide line for design keep the ratio of the focal length divided by the beam diameter for each lens greater than 10 to minimize effects of aberration. Also the same guidelines on acceptable clear apertures and beam diameters given above are still applicable.

On gantry-based systems, the beam expander can be used to adjust focus at the work surface. This is accomplished by setting the final objective lens to exactly its back focal length (BFL) from the work surface (along the middle of the optical axis). The BFL is specified by the lens manufacturer. Focusing is then done by adjusting the spacing of the lenses in the beam expander.

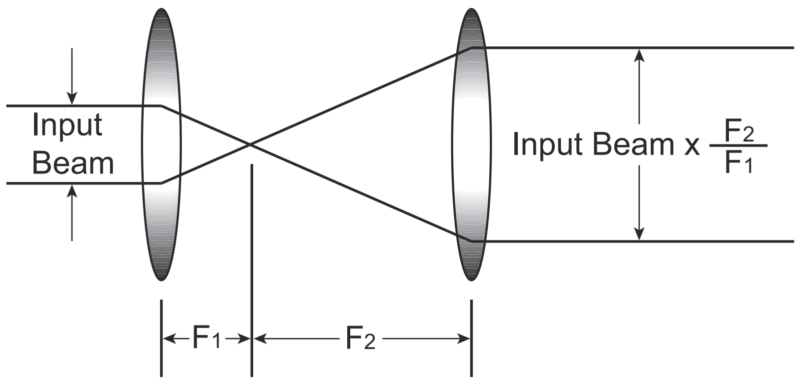


Figure 7-2. Simple Beam Expander

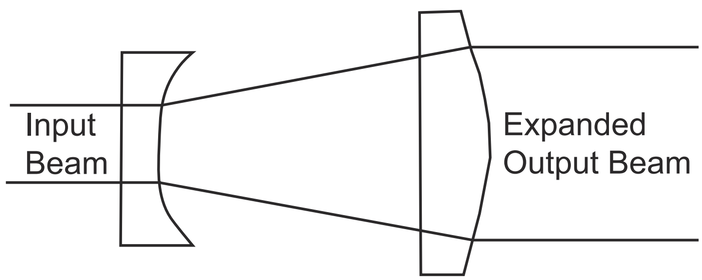


Figure 7-3. Galilean Beam Expander

GLOSSARY

Master Controlling device which manages bus direction, assigns device addresses, and generally the source for all application protocol command initiation

Slave Device which receives and interprets messages and responds as required

SOM A two byte sequence indicating the start of a message packet

EOM A two byte sequence indicating the end of a message packet

Address A unique one byte identifier assigned to each device on the bus

Source Address
Address of the device transmitting a message

Destination Address
Address of the recipient device for a message

CCB Abbreviation for Coherent Connection Bus

Broadcast Message
Message sent by a master device and received by all connected slave devices

Standard Message
Message sent from the master device to a specific slave device address

System Protocol
A set of predefined bus management commands and responses used by CCB protocol stacks for setup and management of the bus

Application Protocol
A set of application defined commands and replies used to implement a system of cooperative devices

Automatic Send Data Control
An optional hardware feature that is useful to control enable/disable of transmit enable line of RS-485 transceiver

PIP Port Identification Pin, a signal pin located on the cable connecting the slave device to the CCB

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