# *Excelsior*

## Diode-Pumped, Visible CW Lasers

### *User's Manual*

This laser product is intended to be sold to a manufacturer of OEM products for use as a component (or replacement thereof) in those products. As such, this product is exempt from performance standards of *United States Code of Federal Regulations*, Title 21, Chapter 1 – Food and Drug Administration, Department of Health and Human Services, Subchapter J – Parts 1040.10 (a), (1) or (2).

Spectra-Physics
A Division of Newport Corporation

1335 Terra Bella Avenue
Mountain View, CA 94043

Part Number 0000-347A, Rev. A
September 2005

# Preface

This manual contains information you need in order to safely install, operate and service your *Excelsior* diode-pumped, visible CW laser. An *Excelsior* system consists of one of seven different models of laser head that produce either green or blue laser light, together with the *Excelsior* controller.

The controller is a small stand-alone unit that provides basic control and monitoring functions for the laser. All of the different models of the *Excelsior* make use of the same controller, without modification.

*Excelsior* is designed to be an OEM product, and all power and command signals are intended to be provided by a master system to the laser through the controller.

Chapter 1, "Introduction," contains a brief description of this laser system, its components and patent information.

Chapter 2, "Laser Safety," is required reading before the system is installed and operated. The *Excelsior* lasers are Class IIIb devices and, as such, emit laser radiation that can cause permanent eye damage. Chapter 2 contains descriptions of these hazards and information on how to safeguard against them, as well as descriptions of the laser labels and safety devices. To minimize the risk of injury or expensive repairs, be sure to read this chapter and carefully follow its instructions.

Chapter 3, "Laser Description," contains a short section on laser theory regarding the principals used in the *Excelsior* laser. The theory section is followed by a more detailed description of the *Excelsior* laser that concludes with the specifications for the various *Excelsior* models.

Chapter 4, "Installation and Operation," describes the procedures and requirements for first installing and then operating the laser.

Chapter 5, "Troubleshooting and Service," will help guide you to the source of any problems with the laser. *Do not attempt repairs yourself while the unit is still under warranty*; instead, report all problems to Spectra-Physics for warranty repair.

"Customer Service" in this chapter gives information on service calls and warranty issues. Should you experience any problems with the your *Excelsior* laser, or if you are in need of technical information or support on any issues related to its use, refer to the list of world-wide Spectra-Physics service centers in this chapter.

Every effort has been made to ensure that the information in this manual is accurate. All information in this document is subject to change without notice. Spectra-Physics makes no representation or warranty, either express or implied, with respect to this document. In no event will Spectra-Physics be liable for any direct, indirect, special, incidental or consequential damages resulting from any defects in this documentation.

Finally, if you encounter any difficulty with the content or style of this manual, or encounter problems with the laser itself, please let us know. At the end of this manual is a form to aid in bringing such problems to our attention.

Thank you for your purchase of Spectra-Physics instruments.

# CE Environmental Specifications

## CE Electrical Equipment Requirements

For information regarding the equipment needed to provide the electrical service requirements listed in Table 3-4 on page 3-12, please refer to specification EN-309, "Plug, Outlet and Socket Couplers for Industrial Uses," listed in the official *Journal of the European Communities.*

## Environmental Specifications

The environmental conditions under which the laser system will function are listed below:

**Indoor use**

| | |
|---|---|
| Vibration: | < 1.5 m/sec$^2$ (0.15 G), 15 Hz−200 Hz |
| Laser Head | |
| Temperature: | 10°C to 40°C |
| Maximum relative humidity: | < 80% non-condensing over allowed temperature range |
| Controller | |
| Temperature: | 10°C to 45°C |
| Maximum relative humidity: | < 90% non-condensing over allowed temperature range |
| Insulation category: | II |
| Pollution degree: | 2 |

# Table of Contents

**Preface** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **iii**

**CE Environmental Specifications.** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **v**

CE Electrical Equipment Requirements . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . v
Environmental Specifications . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . v

**Warning Conventions** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **xi**

**Standard Units** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **xiii**

**Unpacking and Inspection** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **xv**

Unpacking Your Laser . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . xv
System Components . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . xv
Accessories . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . xv

**Chapter 1: Introduction** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **1-1**

Patents . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1-2

**Chapter 2: Laser Safety** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **2-1**

Precautions For The Safe Operation Of Class IIIb High Power Lasers . . . . . . . . . . . . . . . . . . . . . . . . 2-1
Safety Devices . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-3
Laser Power On Control . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-3
Internal/External Control Switch . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-4
Laser Emission Indicator . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-4
Safety Interlocks . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-4
Maximum Emission Levels . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-4
Requirements for Safely Operating the Excelsior Laser
System with a User-provided Control Device . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-5
Schedule of Maintenance in Accordance with Center for Devices
and Radiological Health (CDRH) Regulations . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-5
Radiation Safety Control Drawings . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-6
Warning Labels . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-7
Label Translations . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-8
Waste Electrical and Electronic Equipment Recycling Label . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-9
CE Declaration of Conformity . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-10
Sources for Additional Information . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-11
Laser Safety Standards . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-11
Equipment and Training . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-12

**Chapter 3: System Description . . . . . . . . . . 3-1**

A Brief Review of Laser Theory . . . . . . . . . . 3-1
Emission and Absorption of Light . . . . . . . . . . 3-1
Population Inversion . . . . . . . . . . 3-2
Resonant Optical Cavity and Cavity Modes . . . . . . . . . . 3-3
Single Longitudinal Mode Operation . . . . . . . . . . 3-4
$Nd^{3+}$ as a Laser Medium . . . . . . . . . . 3-4
Diode-Pumped Laser Design . . . . . . . . . . 3-5
Frequency Doubling . . . . . . . . . . 3-7
The Excelsior Lasers . . . . . . . . . . 3-8
The Excelsior Laser Head . . . . . . . . . . 3-8
The Excelsior Controller . . . . . . . . . . 3-9
Power Supply Requirements . . . . . . . . . . 3-9
Specifications . . . . . . . . . . 3-10

**Chapter 4: Installation and Operation . . . . . . . . . . 4-1**

Installation . . . . . . . . . . 4-1
Power Supply Requirements . . . . . . . . . . 4-1
Thermal Management . . . . . . . . . . 4-1
Installing the Hardware . . . . . . . . . . 4-3
Controls and Connections . . . . . . . . . . 4-5
Operation . . . . . . . . . . 4-7
Turning the Laser On and Off . . . . . . . . . . 4-7
Using the Emission Indicator . . . . . . . . . . 4-8
Using the Diode Laser Alarm . . . . . . . . . . 4-8
Changing the Laser Output Power . . . . . . . . . . 4-9
Interlock Jumper Plug . . . . . . . . . . 4-9

**Chapter 5: Troubleshooting and Service . . . . . . . . . . 5-1**

Maintenance . . . . . . . . . . 5-1
Service Training Programs . . . . . . . . . . 5-1
Troubleshooting . . . . . . . . . . 5-2
Replacement Parts . . . . . . . . . . 5-4
Customer Service . . . . . . . . . . 5-5
Warranty . . . . . . . . . . 5-5
Returning the Instrument for Repair . . . . . . . . . . 5-5
Service Centers . . . . . . . . . . 5-6

**Notes**

**Report Form for Problems and Solutions**

## List of Figures

Figure 1-1: The Excelsior Laser . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1-1
Figure 2-1: These standard safety warning labels are appropriate for use as entry warning signs (EN 60825-1, ANSI Z136.1 Section 4.7). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-2
Figure 2-2: Folded Metal Beam Target . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-2
Figure 2-3: Safety Devices on the Excelsior Controller . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-3
Figure 2-4: Interlock Jumper Plug . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-3
Figure 2-5: Excelsior Radiation Control Drawings . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-6
Figure 2-6: Warning Labels . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-7
Figure 3-1: A Typical Four-level Transition Scheme . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-2
Figure 3-2: Frequency Distribution of Longitudinal Modes . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-3
Figure 3-3: Energy Level Scheme for the Nd Ion in YAG . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-4
Figure 3-4: $Nd^{3+}$ absorption spectra compared to emission spectra of a Black Body Source (a) and a Diode Laser (b). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-6
Figure 3-5: Mode Matching . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-6
Figure 3-6: Interlock Jumper Plug . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-9
Figure 4-1: Heat Dissipation of the Laser Head . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-2
Figure 4-2: Laser Head Heatsink Thermal Impedance for 50°C Baseplate Temperature . . . . . . . . . . 4-2
Figure 4-3: Excelsior Laser Head Outline Drawing . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-3
Figure 4-4: Excelsior Controller Outline Drawing . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-4
Figure 4-5: Excelsior Controller Connections . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-5
Figure 4-6: External Control Connector Pin Numbering . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-6
Figure 4-7: Laser On/Off Control Example . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-7
Figure 4-8: Laser Emission Indicator Example . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-8
Figure 4-9: Diode Laser Alarm Example . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-8
Figure 4-10: Interlock Jumper Plug . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-9

## List of Tables

Table 1-1: Green Excelsior Lasers . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1-2
Table 1-2: Blue Excelsior Lasers . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1-2
Table 2-1: Maximum Emission Levels . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-4
Table 2-2 : Label Translations . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2-8
Table 3-1 : Excelsior Green Laser Output Specifications . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-10
Table 3-2 : Excelsior Blue Laser Output Specifications . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-11
Table 3-3: Environmental Specifications . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-12
Table 3-4: Electrical/Mechanical Specifications . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3-12
Table 4-1 : External Control Connector Pin Functions . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4-6
Table 5-1: Replacement Parts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5-4

# Warning Conventions

The following warnings are used throughout this manual to draw your attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances. All messages are set apart by a thin line above and below the text as shown here.

| | |
|---|---|
| Danger! Laser Radiation | Laser radiation is present. |
| Danger! | Condition or action may present a hazard to personal safety. |
| Danger! | Condition or action may present an electrical hazard to personal safety. |
| Warning! | Condition or action may cause damage to equipment. |
| Warning! ESD | Action may cause electrostatic discharge and cause damage to equipment. |
| Caution! | Condition or action may cause poor performance or error. |
| Note | Text describes exceptional circumstances or makes a special reference. |
| Don't Touch! | Do not touch. |
| Eyewear Required | Appropriate laser safety eyewear should be worn during this operation. |
| | Refer to the manual before operating or using this device. |

# Standard Units

The following units, abbreviations, and prefixes are used in this Spectra-Physics manual:

| Quantity | Unit | Abbreviation |
|---|---|---|
| mass | kilogram | kg |
| length | meter | m |
| time | second | s |
| frequency | hertz | Hz |
| force | newton | N |
| energy | joule | J |
| power | watt | W |
| electric current | ampere | A |
| electric charge | coulomb | C |
| electric potential | volt | V |
| resistance | ohm | Ω |
| inductance | henry | H |
| magnetic flux | weber | Wb |
| magnetic flux density | tesla | T |
| luminous intensity | candela | cd |
| temperature | celcius | C |
| pressure | pascal | Pa |
| capacitance | farad | F |
| angle | radian | rad |

| Prefixes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| tera | ($10^{12}$) | T | deci | ($10^{-1}$) | d | nano | ($10^{-9}$) | n |
| giga | ($10^{9}$) | G | centi | ($10^{-2}$) | c | pico | ($10^{-12}$) | p |
| mega | ($10^{6}$) | M | mill | ($10^{-3}$) | m | femto | ($10^{-15}$) | f |
| kilo | ($10^{3}$) | k | micro | ($10^{-6}$) | μ | atto | ($10^{-18}$) | a |

# Unpacking and Inspection

## Unpacking Your Laser

Your *Excelsior* laser was packed with great care, and its container was inspected prior to shipment—it left Spectra-Physics in good condition. Upon receiving your system, immediately inspect the outside of the shipping container. If there is any major damage (holes in the container, crushing, etc.), insist that a representative of the carrier be present when you unpack the contents.

Carefully inspect your laser system as you unpack it. If any damage is evident, such as dents or scratches on the covers, etc., immediately notify the carrier and your Spectra-Physics sales representative.

**Keep the shipping container.** If you file a damage claim, you may need it to demonstrate that the damage occurred as a result of shipping. If you need to return the system for service at a later date, the specially designed container assures adequate protection.

## System Components

Two components comprise an *Excelsior* laser system:

- *Excelsior* laser head (one of seven models)
- *Excelsior* controller

The controller weighs about 0.3 kg (0.7 lb). The laser head weighs about 0.25 kg (0.6 lb). Both can be handled easily by one person.

Verify that both components are present. The laser head and controller are shipped in one container.

## Accessories

Included with the laser is this manual, a packing slip listing all the parts shipped, and an accessory kit. The following accessories are shipped standard with the system:

- 1 LASER HEAD cable (1 m)
- 1 INTERLOCK jumper plug

# Chapter 1 Introduction


**Figure 1-1: The *Excelsior* Laser**

Spectra-Physics *Excelsior* lasers produce a green or blue continuous laser beam from an exceptionally compact package. These small, rugged diode-pumped solid-state lasers are especially well suited for applications requiring a low-noise, high-quality, CW visible beam. *Excelsior* lasers are intended for OEM integration into master systems.

There are seven lasers in the *Excelsior* family—five green lasers with an output between 10 mW and 150 mW at 532 nm, and two blue lasers with outputs of 5 mW or 10 mW at 473 nm. All are designed to operate at constant output power. The three higher power green lasers allow the operator to vary laser power via the controller interface. The different models are summarized in Table 1-1 and Table 1-2 on page 1-2.

These lasers deliver efficient, stable light with excellent spatial mode that is critical for applications in graphics, photo finishing and flow cytometry. Individual *Excelsior* models operate in either single or multiple longitudinal mode. Again, refer to Table 1-1 and Table 1-2.

The *Excelsior* laser heads come in two sizes that are approximately 8.5 and 9.5 cm in length. The heads are designed for precision mounting and alignment of the beam, which, together with the specified boresight of the output, simplifies the task of designing the master optical train, or replacing a laser head in the master system. All of the optical components, including the diode pump source, are contained in the laser head itself.

The lasers are controlled by the master system by means of analog signals provided through the connector on the small controller. All *Excelsior* models use the same controller.

**Note**

Since all *Excelsior* lasers use the same controller, the laser heads are completely interchangeable. In case the laser head or the controller needs to be exchanged, the new unit is simply fastened in place and the cabling connected. No adjustment or calibration is needed.

The laser head is specifically designed to facilitate heat removal. Electrical power is supplied by the master system; only a few Amps at 5 V are required.

**Table 1-1: Green Excelsior Lasers[1]**

| Excelsior Model | Power @532 nm | Longitudinal Mode | Head Length |
|---|---|---|---|
| Excelsior-532-150 | 150 mW | single | 9.5 cm |
| Excelsior-532-100 | 100 mW | single | 9.5 cm |
| Excelsior-532-50 | 50 mW | single | 9.5 cm |
| Excelsior-532-20[2] | 20 mW | multi | 8.5 cm |
| Excelsior-532-10[2] | 10 mW | multi | 8.5 cm |

[1]*Values are for illustration only; refer to Chapter 3 for specified values.*
[2]*Available in collimated and uncollimated versions; refer to Chapter 3 for specifications.*

**Table 1-2: Blue Excelsior Lasers[1]**

| Excelsior Model | Power @473 nm | Longitudinal Mode | Head Length |
|---|---|---|---|
| Excelsior-473-10 | 10 mW | single | 8.5 cm |
| Excelsior-473-05 | 5 mW | single | 8.5 cm |

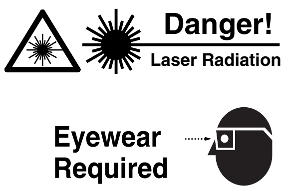
[1]*Values are for illustration only; refer to Chapter 3 for specified values.*

## Patents

*Excelsior* lasers are manufactured under one or more of the following United States patents:

| | |
|---|---|
| 4,756,003 | |
| 4,872,177 | |
| 5,870,415 | |
| 3,046,562 | (Japanese patent) |

# Chapter 2 Laser Safety




The Spectra-Physics *Excelsior* lasers are *Class IIIb—High Power Lasers* whose beams are, by definition, a safety and fire hazard. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye damage.

Refer to the product serial label for wavelength (nm) and laser power.

**Note**

This product is an OEM laser system. As such, it does not conform to the safety specifications and performance standards required of a Class IV laser as defined by the Center for Devices and Radiological Health (CDRH), 21 CFR 1040.

## Precautions For The Safe Operation Of Class IIIb High Power Lasers

- Wear protective eyewear at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use, and the visual function required. Protective eyewear is available from suppliers listed in the *Laser Focus World*, *Lasers and Optronics*, and *Photonics Spectra* buyer's guides. Consult the ANSI and ACGIH standards listed at the end of this section for guidance.
- Maintain a high ambient light level in the laser operation area so the eye's pupil remains constricted, reducing the possibility of damage.
- Avoid looking at the output beam; diffuse reflections are hazardous.
- Establish a controlled access area for laser operation. Limit access to those trained in the principles of laser safety.
- Enclose beam paths wherever possible.
- Post prominent warning signs near the laser operating area (Figure 2-1).
- Install the laser so that the beam is either above or below eye level.
- Set up shields to prevent any unnecessary specular reflections or beams from escaping the laser operation area.
- Set up a beam dump to capture the laser beam and prevent accidental exposure (Figure 2-2).

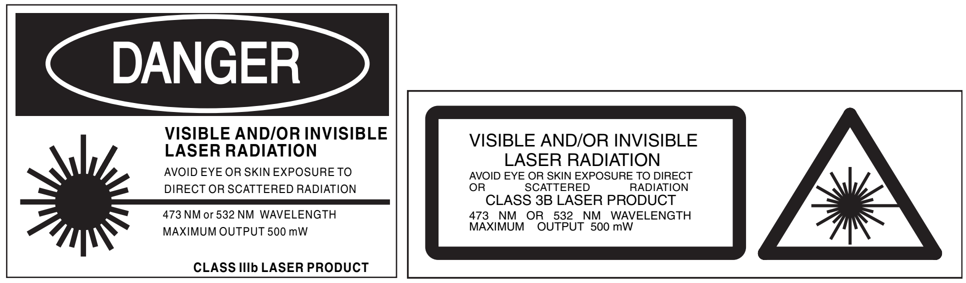



**Figure 2-1: These standard safety warning labels are appropriate for use as entry warning signs (EN 60825-1, ANSI Z136.1 Section 4.7).**

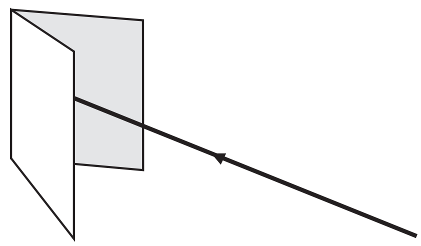


**Figure 2-2: Folded Metal Beam Target**


Use of controls or adjustments, or performing the procedures described in this manual in a manner other than specified may result in hazardous radiation exposure.

**Danger!**

Operating this laser without due regard for these precautions or in a manner that does not comply with recommended procedures may be dangerous. At all times during installation, maintenance or service of your laser, avoid unnecessary exposure to laser or collateral radiation* that exceeds the accessible emission limits listed in "Performance Standards for Laser Products," *United States Code of Federal Regulations*, 21CFR1040.10(d).

Follow the instructions contained in this manual to ensure proper installation and safe operation of your laser.

* *Any electronic product radiation, except laser radiation, emitted by a laser product as a result of or necessary for the operation of a laser incorporated into that product.*

## Safety Devices

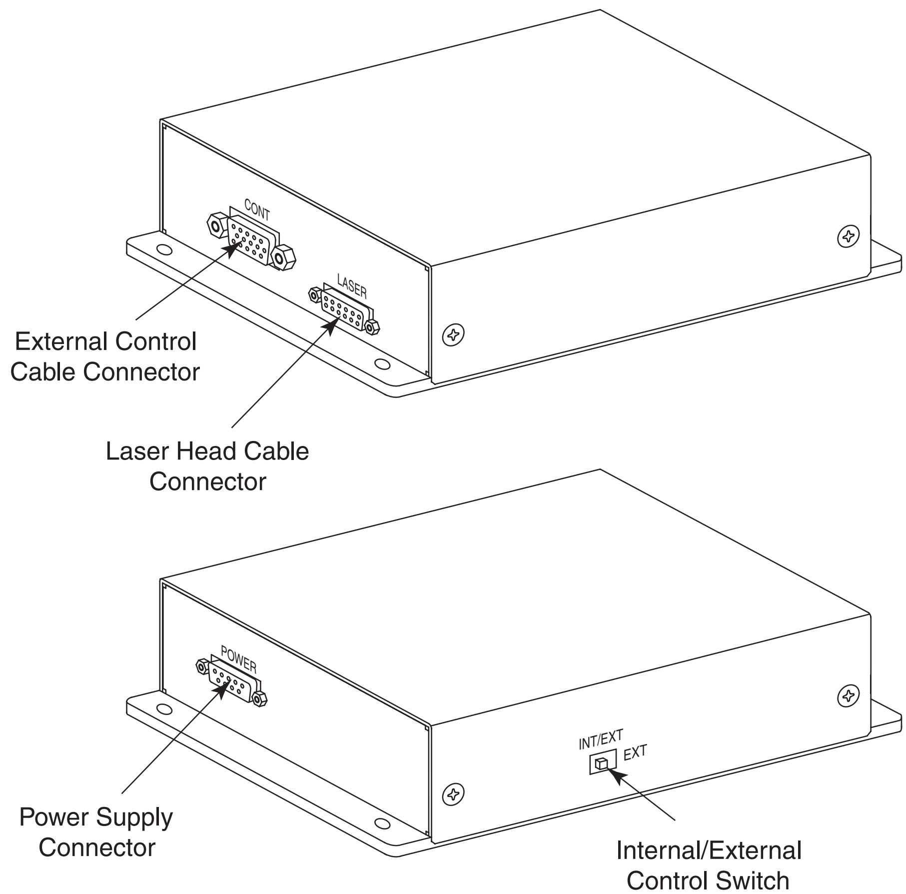



**Figure 2-3: Safety Devices on the Excelsior Controller**

There are no safety devices—no indicators, shutter, or power controls—on the laser head itself. All control and monitoring of laser functions is through the EXTERNAL CONTROL connector on the controller.

### *Laser Power On Control*

The *Excelsior* laser turns on when current is available to the diode laser in the laser head and a suitable control signal is applied to Pin 2 of the EXTERNAL CONTROL cable connector on the controller. Laser output begins immediately when these conditions are met.

A interlock jumper plug is provided with the system to allow operation without an external control cable.

**Figure 2-4: Interlock Jumper Plug**

### *Internal/External Control Switch*

This switch provides the option to control the level of the laser output of the *Excelsior-532-50,* the *Excelsior-532-100* and the *Excelsior-532-150*. Control is by means of an analog signal applied to Pin 8 on the EXTERNAL CONTROL connector (see Chapter 4 for details on how to use this option). All other models of the *Excelsior* laser are pre-set at the factory to their maximum specified output power.

### *Laser Emission Indicator*

Pin 1 of the EXTERNAL CONTROL connector can be used to control an external laser emission indicator. See Chapter 4 for an example of a circuit used for this purpose.

### *Safety Interlocks*

#### Safety Interlock

Pin 2 of the EXTERNAL CONTROL connector can be used as a safety interlock. The function of Pin 2 is to provide an on/off signal to the laser. See Chapter 4 for an example of a circuit used to turn the laser emission on or off. By connecting a safety switch in series with such a circuit, the laser can be made to turn off when the safety switch is opened. The switch can be attached to a laboratory door or similar critical access point to limit access to the laser system or master system.

#### Cover Safety Interlocks

The *Excelsior* lasers are OEM systems that are designed to be integrated into a master system that itself complies with regulatory requirements. As such, the individual components of the laser system—the laser head and controller—do not have cover safety interlocks. The laser head and controller covers are not to be opened by the user. When the diode pump laser in the *Excelsior* laser requires replacement, the entire laser head must be replaced as a unit. Before starting the replacement procedure, the controller must be disconnected from the AC electrical service. The *Excelsior* laser is not intended to be operated with the cover removed.

## Maximum Emission Levels

The following are the maximum emission levels possible for the different *Excelsior* laser systems. Use this information for selecting appropriate laser safety eyewear and implementing appropriate safety procedures. These values do not imply actual system specifications.

**Table 2-1: Maximum Emission Levels**

| Emission Wavelength | Maximum CW Output Power |
|---|---|
| Diode Laser Emission: 808 nm | 2 W |
| Laser Head Emission: 1064 nm | 1.5 W |
| Laser Head Emission: 532 nm | 0.5 W |
| Laser Head Emission: 473 nm | 0.1 W |

## Requirements for Safely Operating the Excelsior Laser System with a User-provided Control Device

When the *Excelsior* laser system is controlled by a device provided by the user or software written by the user, the following must be provided:

- **A key switch**—that limits access to the laser and prevents it from being turned on. It can be a real key lock, a removable computer disk, a password that limits access to computer control software, or a similar "key" implementation. The laser must only operate when the "key" is present and in the "on" position.
- **An emission indicator**—that indicates laser energy is present or can be accessed. It can be a "power-on" lamp, a computer display that flashes a statement to this effect, or an indicator on the control equipment for this purpose. It need not be marked as an emission indicator so long as its function is obvious. Its presence is required on any control panel that affects laser output.

## Schedule of Maintenance in Accordance with Center for Devices and Radiological Health (CDRH) Regulations

This laser product is intended for OEM use. Therefore, an application has not been submitted with the Center for Devices and Radiological Health (CDRH) for compliance review. However it is recommended that the same schedule of maintenance be followed as that for systems that comply with these regulations. Once a year, or whenever the product has been subjected to adverse environmental conditions (e.g., fire, flood, mechanical shock, spilled solvent, etc.), check to see that all features of the product identified on the Radiation Control Drawing on page 2-6 function properly. Also, make sure that all warning labels remain firmly attached.

1. Verify that opening any safety interlock switch used with the system prevents laser operation.
2. Verify the laser can only be turned on when the master system key-switch is in the on position, and that the key can only be removed when the switch is in the off position.
3. Verify the user-supplied emission indicator provides a visible signal when the laser emits accessible laser radiation that exceeds the accessible master system emission limits for Class I.*
4. Verify the time delay between turn-on of the user-supplied emission indicator and the start of laser emission; it must give enough warning to allow action to avoid exposure to laser radiation.
5. Verify that when the interlock loop is opened the master system shutter closes and actually blocks laser radiation emission.

If any of the above items fail to operate as noted and you cannot correct the error, please call your Spectra-Physics service representative for assistance.

**0.39 µW for continuous-wave operation where output is limited from 400 nm to 1400 nm.*

## Radiation Safety Control Drawings

**Refer to the warning labels on page 2-10.**

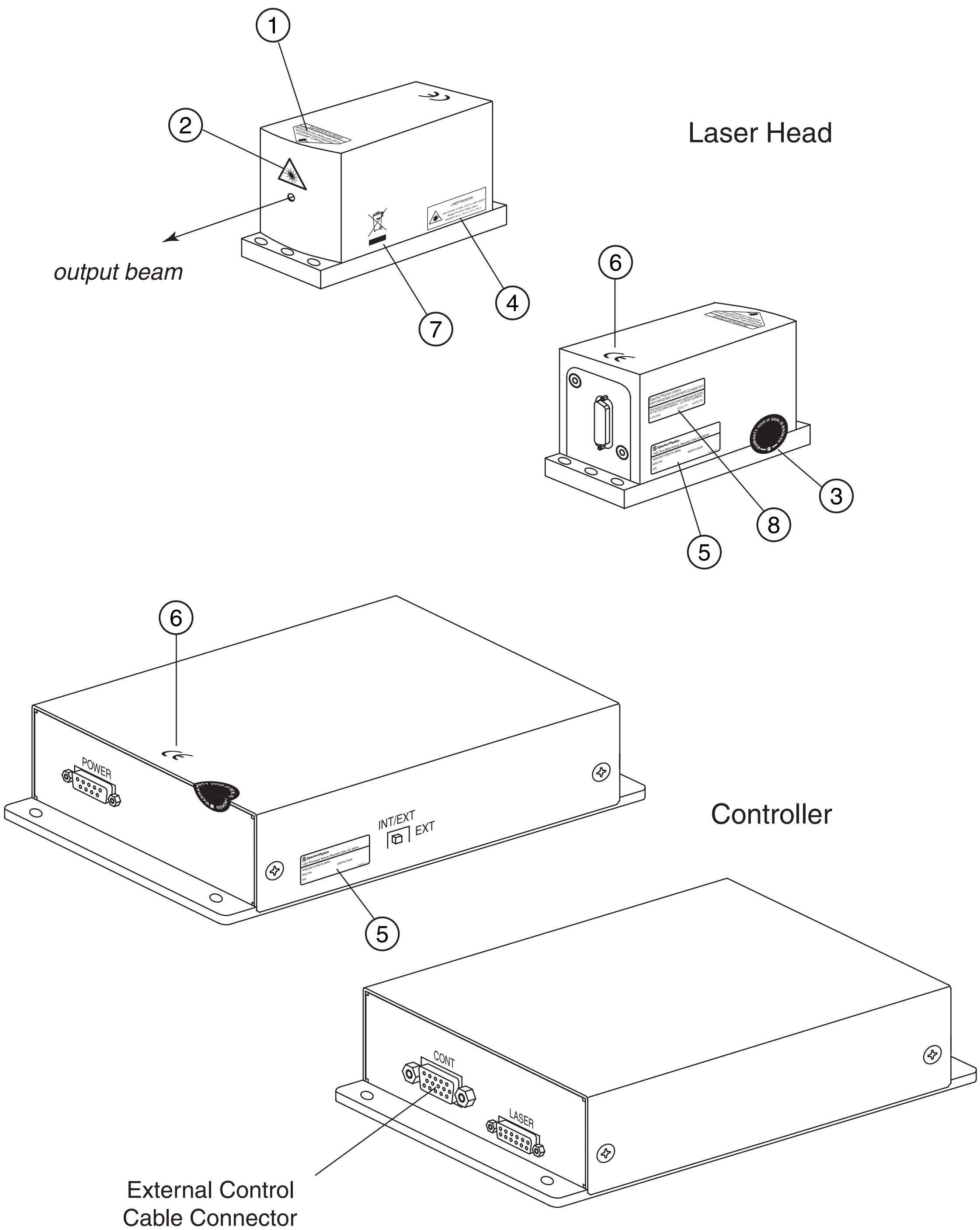
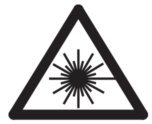



**Figure 2-5:** ***Excelsior*** **Radiation Control Drawings**

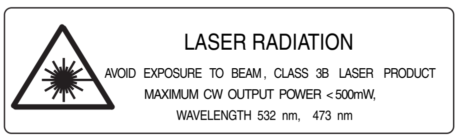
## Warning Labels


Aperture Label,
Laser Head (1)

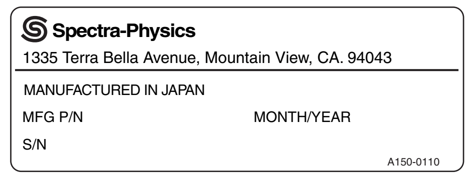


CE Aperture
Label (2)


Warranty
Seal (3)

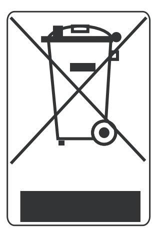



OEM Danger
Label (4)

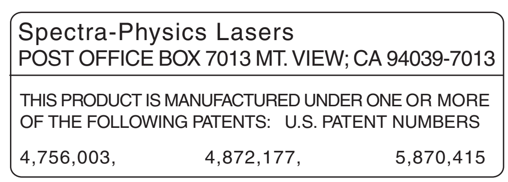



OEM Serial Number
Label (5)

CE Certification
Label (6)



WEEE
Label (7)




Patent
Label (8)

**Figure 2-6: Warning Labels**

## *Label Translations*

For safety, the following translations are provided for non-English speaking personnel. The number in parenthesis in the first column corresponds to the label number listed on the previous page.

**Table 2-2: Label Translations**

| Label No. | French | German | Spanish | Dutch |
|---|---|---|---|---|
| Aperture Label (1) | Ouverture Laser - Exposition Dangereuse - Un rayonnement laser visible et/ ou invisible est émis par cette ouverture. | Austritt von sichtbarer und unsichtbarer Laserstrahlung! Bestrahlung vermeiden! | Por esta abertura se emite radiación láser visible e invisible; evite la exposición. | Vanuit dit apertuur wordt zichtbare en onzichtbare laserstraling geemitteerd! Vermijd blootstelling! |
| OEM Danger Label (4) | Rayonnement laser Exposition Dangereuse, Appareil a laser de Classe 3b. Puissance maximum < 500 mW, Longueur d'onde 532 nm, 473 nm | Laserstrahlung Bestrahlung vermeiden. Laser Klasse 3b. Maximale Ausgangsleistung < 500 mW Wellenlänge 532 nm, 473 nm | Radiación láser Evite la exposición, Producto láser Clase 3b. Potencia máxima < 500 mW Longitud de onda: 532 nm, 473 nm | Laser-straling Vermijd blootstelling! Klasse 3b laser produkt. Max. output vermogen < 500 mW, Golflengtebereik 532 nm, 473 nm |
| Patent Label (7) | Ce produit est fabriqué sous l'un ou plusieurs des brevets suivants des Etats Unis: | Dieses Produkt wurde unter Verwendung einer oder mehrerer der folgenden US-Patente hergestellt: | Este producto esta fabricado con una o más de las siguientes patentes de los Estados Unidos: | Dit product is gefabriceerd met een of meer van de volgende USA patenten: |

## Waste Electrical and Electronic Equipment Recycling Label

To Our Customers in the European Union:

As the volume of electronics goods placed into commerce continues to grow, the European Union is taking measures to regulate the disposal of waste from electrical and electronic equipment. Toward that end, the European Parliament has issued a directive instructing European Union member states to adopt legislation concerning the reduction, recovery, re-use and recycling of waste electrical and electronic equipment (WEEE).

In accordance with this directive, the accompanying product has been marked with the WEEE symbol. See label 7 on page 2-7.

The main purpose of the symbol is to designate that at the end of its useful life, the accompanying product should not be disposed of as normal municipal waste, but should instead be transported to a collection facility that will ensure the proper recovery and recycling of the product's components. The symbol also signifies that this product was placed on the market after 13 August, 2005. At this time, regulations for the disposal of waste electrical and electronic equipment vary within the member states of the European Union. Please contact a Newport / Spectra-Physics representative for information concerning the proper disposal of this product.

## CE Declaration of Conformity

We,

Spectra-Physics
1335 Terra Bella Avenue
Mountain View, CA. 94043
United States of America

declare under our sole responsibility that the following products:

**Excelsior Low Power CW DPSS Laser**

manufactured after August 31, 2005,
meet the intent of "EMC Directive 89/336/EEC (2004/C 98/05) for Electromagnetic Compatibility" and "Directive 73/23/EEC (1973), the Low Voltage Directive." Compliance was demonstrated to the following Specifications as listed in the official *Journal of the European Communities*:

**89/336/EEC: 2004/C 98/05, EMC Directive**

**EN 55011: 1998+A1:1999+A2:2002:** Industrial, scientific and medical (ISM) radio-frequency equipment radio disturbance characteristics

**EN 61000-4-2: 1995+A1:1998+A2:2001:** Electromagnetic Compatibility (EMC); Part 4: Testing and measurement techniques—Electrostatic discharge immunity test

**EN 61000-4-3: 2002+A1:2002:** Electromagnetic Compatibility (EMC)—Basic Immunity Standard—Radiated, radio frequency, electromagnetic field immunity test

**EN 61000-4-4: 1995+A1:2001+A2:2002:** Electromagnetic Compatibility (EMC); Part 4:Testing and measurement techniques—Electrical fast transient/burst immunity test

**EN 61000-4-5: 1995+A1:2001:** Electromagnetic Compatibility (EMC)—Basic Immunity Standard—Surge immunity test

**EN 61000-4-6: 1996+A1:2001:** Electromagnetic Compatibility (EMC)—Basic Immunity Standard—Immunity to conducted disturbances induced by radio frequency fields

**EN 61000-4-8: 1993+A1:2001:** Electromagnetic Compatibility (EMC)—Testing and measurement techniques—Power, frequency, magnetic field immunity test

**EN 61000-4-11: 1994+A1:2001:** Electromagnetic Compatibility (EMC); Part 4—Testing and measurement techniques—Voltage dips, short interruptions and voltage variations immunity tests

**EN 61000-6-2: 2001:** Electromagnetic Compatibility (EMC)—Immunity for industrial environments

**EN 61000-6-4: 2001:** Electromagnetic Compatibility (EMC)—Emission standard for industrial environments

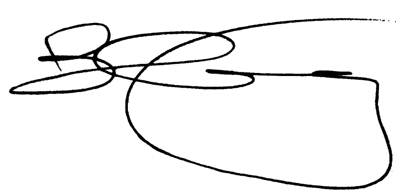
**73/23/EEC: 1973, Low Voltage Directive**

**EN60825-1: 1994+A1:2002+A2:2001+Cor.2004:** Safety of laser products—Equipment classification, requirements, and users guide

**EN60950: 2001+A11+Cor.:** Safety of Information Technology Equipment, including electrical business equipment

**EN 61010-1: 2001+Cor.1+2:** General requirements—Safety requirements for electrical equipment for measurement

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.



Bruce Craig
Vice President
Spectra-Physics / Newport
September 6, 2005

## Sources for Additional Information

### *Laser Safety Standards*

*Safe Use of Lasers* (Z136.1)
American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
Tel: (212) 642-4900

Occupational Safety and Health Administration (Publication 8.1-7)
U. S. Department of Labor
200 Constitution Avenue N. W., Room N3647
Washington, DC 20210
Tel: (202) 693-1999
Internet: http://www.osha.gov

*A Guide for Control of Laser Hazards,* 4th Edition, Publication #0165
American Conference of Governmental and
Industrial Hygienists (ACGIH)
1330 Kemper Meadow Drive
Cincinnati, OH 45240
Tel: (513) 742-2020
Internet: http://www.acgih.org/home.htm

Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
Tel: (800) 345-2737
Internet: http://www.laserinstitute.org

Compliance Engineering
Canon Communications LLC
11444 W. Olympic Boulevard
Los Angeles, CA 90064
Tel: (310) 445-4200

International Electrotechnical Commission
*Journal of the European Communities*
EN 60825-1 Safety of Laser Products — Part 1: Equipment classification, requirements and user's guide
Tel: +41 22-919-0211   Fax: +41 22-919-0300
Internet: http://www.iec.ch

Cenelec
35, Rue de Stassartstraat
B-1050 Brussels, Belgium
Tel: +32 2 519 68 71
Internet: http://www.cenelec.org

Document Center, Inc.
111 Industrial Road, Suite 9
Belmont, CA 94002
Tel: (650) 591-7600
Internet: http://www.document-center.com

### *Equipment and Training*

*Laser Safety Guide*
Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
Tel: (800) 34LASER
Internet: http://www.laserinstitute.org

*Laser Focus World Buyer's Guide*
Laser Focus World
Pennwell Publishing
98 Spit Rock Road
Nashua, NH 03062
Tel: (603) 891-0123
Internet: http://lfw.pennnet.com/home.cfm

*Photonics Spectra Buyer's Guide*
Photonics Spectra
Laurin Publications
Berkshire Common
PO Box 4949
Pittsfield, MA 01202-4949
Tel: (413) 499-0514
Internet: http://www.photonics.com

# Chapter 3 System Description

## A Brief Review of Laser Theory

### *Emission and Absorption of Light*[1]

*Laser* is an acronym derived from Light Amplification by Stimulated Emission of Radiation. Because the laser is an oscillating amplifier of light, and because its output comprises photons that are identical in phase and direction, it is unique among light sources. Its output beam is singularly directional, monochromatic, and coherent.

Radiant emission and absorption take place within the arrangement of the electrons in atoms or molecules. Each electron occupies a distinct orbital that represents the probability of finding the electron at a given position relative to the nucleus. The energy of an electron is determined by the orbital that it occupies, and the over-all energy of an atom—its energy level—depends on the distribution of its electrons throughout the available orbitals.

Each atom has an array of energy levels: the level with the lowest possible energy is called the ground state, and higher energy levels are called excited states. If an atom is in its ground state, it will stay there until it is excited by external forces.

Movement of an electron from one energy level to another—a transition—happens when the atom either absorbs or emits energy. Transitions in both directions can occur as a result of interaction with a photon of light. Consider a transition from a lower level whose energy content is $E_1$ to a higher one with energy $E_2$. It will only occur if the energy of the incident photon matches the energy difference between levels, i.e.,

$$h\nu = E_2 - E_1 \qquad [1]$$

where $h$ is Planck's constant and $\nu$ is the frequency of the photon.

Likewise, when an atom excited to $E_2$ decays to $E_1$, it loses energy equal to $E_2 - E_1$. The atom may decay spontaneously, emitting a photon with energy $h\nu$ and frequency

$$\nu = \frac{E_2 - E_1}{h} \qquad [2]$$

[1] *"Light" will be used to describe the portion of the electromagnetic spectrum from the infrared to the ultraviolet.*

Spontaneous decay can also occur without emission of a photon. An atom excited to $E_2$ can also be stimulated to decay to $E_1$ by absorbing a photon of frequency $\nu$, then emitting a pair of photons that are identical to the incident one in phase, frequency, and direction. This is known as stimulated emission. By contrast, spontaneous emission produces photons that have no directional or phase relationship with one another.

A laser is designed to take advantage of both stimulated and spontaneous emission and absorption as well, using them to create conditions favorable for light amplification. The following paragraphs describe these conditions.

### *Population Inversion*

A material in thermal equilibrium has most of its atoms or molecules in their ground state. As a result, the rate of absorption of incident light at all frequencies exceeds that of emission.

If enough light at the correct frequency $\nu$ is supplied, electrons in a lower energy level will absorb light energy and shift to an upper level until the populations of two levels are equal, $N_1 = N_2$. For transition between two levels, $N_2$ can never exceed $N_1$ because every upward transition is matched by one in the opposite direction. However, if three or more energy levels are involved in the transition, a population inversion can occur where $N_2 > N_1$.

A model four-level laser transition scheme is depicted in Figure 3-1. A photon of frequency $\nu_1$ excites—or "pumps"—an atom from $E_1$ to $E_4$. If the $E_4$ to $E_3$ transition probability is greater than that of $E_4$ to $E_1$, and if the lifetime of an atom at $E_4$ is short, the atom will decay almost immediately to $E_3$. If $E_3$ is metastable, i.e., electrons occupy it for a relatively long time, the population will grow rapidly as excited electrons cascade from above.

The $E_3$ electron will eventually decay to $E_2$, emitting a photon of frequency $\nu_2$. Finally, if $E_2$ is unstable, its electrons will rapidly return to the ground state, $E_1$, keeping the population of $E_2$ small and reducing the rate of absorption of $\nu_2$. In this way the population of $E_3$ is kept large and that of $E_2$ remains low, thus establishing a population inversion between $E_3$ and $E_2$. Under these conditions, light is amplified as it passes through the material, which is now a gain medium.

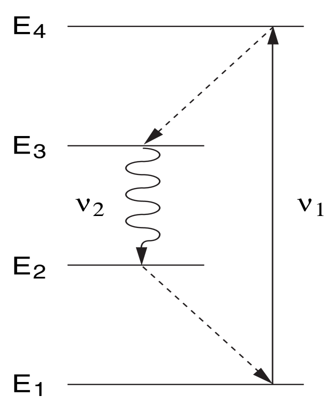



**Figure 3-1: A Typical Four-level Transition Scheme**

## *Resonant Optical Cavity and Cavity Modes*

Most laser materials must be placed in a resonant optical cavity to achieve useful levels of amplified light. This cavity is typically two mirrors placed facing each other to form a resonator that reflects light back and forth through the gain material that is placed between them. Both resonator mirrors are coated to reflect the laser wavelength (thus containing it within the cavity) while transmitting all others (and thus removing them from the cavity).

As the reflected light passes through the gain material, stimulated emission produces two photons. The two photons are trapped in the resonator and are reflected through the gain to become four, four become eight, and the numbers continue to increase geometrically until an equilibrium is reached where the excitation rate and emission rate of the gain medium are equal.

The light in the resonator forms standing waves with frequencies that depend on the resonator design. Standing wave frequencies that are amplified in the gain material form the circulating light in the cavity. This is the energy that is transmitted through the output coupler as the laser beam.

There is one standing wave pattern, or cavity mode, that has the simplest possible form, termed $TEM_{00}$. $TEM_{00}$ operation results from choosing the mirror curvatures and the shape and pumping geometry of the laser material so that gain is confined along the central axis of the material (this is further discussed in the section "Diode-Pumped Laser Design" below).

The $TEM_{00}$ mode appears brightest in the center and attenuates smoothly toward the edges of the beam. The spectral content of the light in this mode arises from the standing waves formed along the axis of the cavity, with frequencies determined by the separation between the resonator mirrors. The difference in frequency between any two of these "longitudinal modes" is given by

$$\Delta f = \frac{c}{2nl} \qquad [3]$$

where $c$ is the speed of light, $n$ is the refractive index, and $l$ is the distance between the cavity mirrors. The number of such longitudinal modes in the laser output is determined by the number of such modes that fall under the bandwidth of the gain material as shown in Figure 3-2.

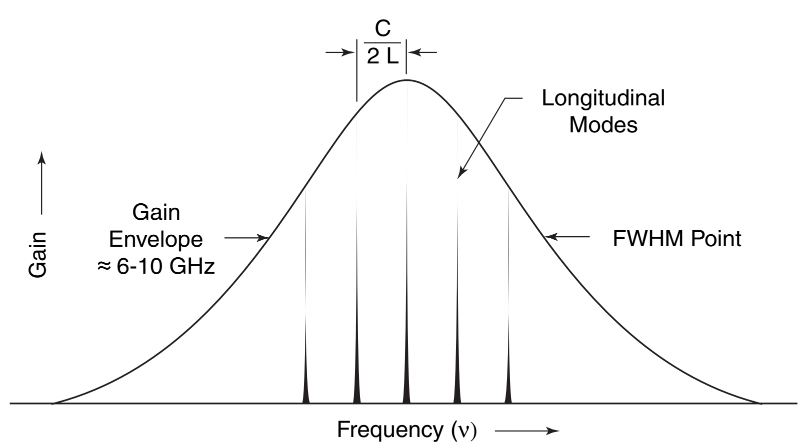



**Figure 3-2: Frequency Distribution of Longitudinal Modes**

### Single Longitudinal Mode Operation

Some laser applications benefit from a beam with only a single longitudinal mode. From equation [3] it can be seen that reducing the separation between the resonator mirrors will increase the frequency spacing of the longitudinal modes and sometimes enable only a single mode to remain within the gain bandwidth of the laser material. Often however the gain bandwidth is so large that the mirror separation would have to be impractically short to result in only a single mode remaining. Although the *Excelsior* lasers are very small, they still produce numerous longitudinal modes due to the broad gain bandwidth of the neodymium-based crystals.

A variety of means exist to eliminate all but one longitudinal mode in such a case, including the insertion of an etalon into the resonant cavity. An etalon is type of resonator and, in its simplest form, is just a thin, flat piece of glass resembling a microscope slide. Placed intracavity, the mode separation of this thin element will limit the modes allowed to resonate.

### $Nd^{3+}$ as a Laser Medium

The output of one laser can be used to excite or "pump" the gain medium of another laser, e.g., a diode laser can be used to pump a solid-state laser. The *Excelsior* lasers use a diode laser to pump $Nd^{3+}$ ions added to either a crystal of yttrium vanadate (Nd:$YVO_4$) or yttrium aluminum garnet (Nd:YAG).

The properties of neodymium-doped crystals are the most widely studied and best understood of all solid-state laser media. The four-level Nd:YAG ion scheme is shown in Figure 3-3. The active medium is ionized neodymium, which has principle absorption bands in the red and near infrared.

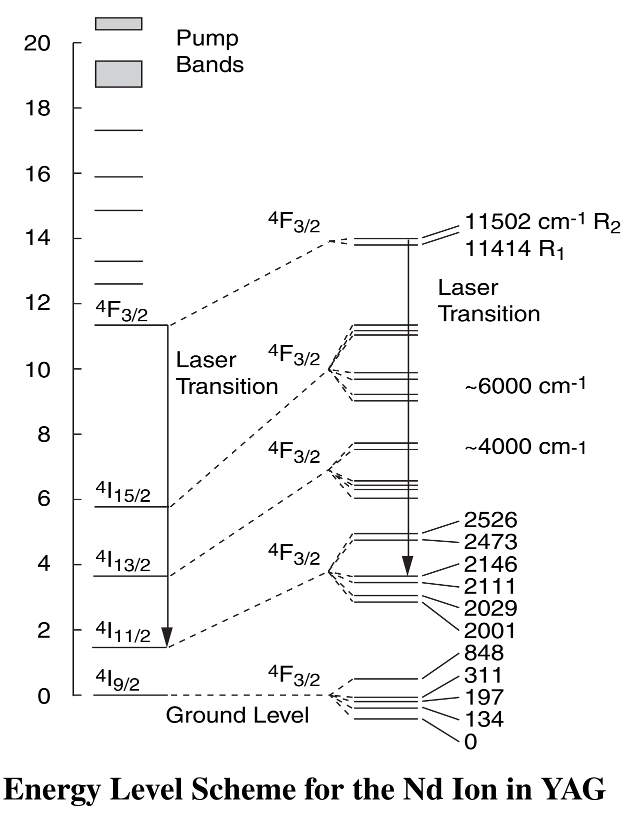



**Figure 3-3: Energy Level Scheme for the Nd Ion in YAG**

The electrons in the neodymium ions are very efficient at absorbing the diode laser light that excites them to the “pump bands” shown in the figure. The excited electrons quickly drop to the $^4F_{3/2}$ level, the upper level of the lasing transition, where they remain for a relatively long time.

The most probable laser transition is to the $^4I_{1/2}$ state, which emits photons at 1064 nm. Because electrons in that state quickly relax to the ground state, the population of this state remains low. Hence it is easy to build a population inversion where the number of electrons in the higher energy level exceeds the number in the lower level.

There are several different laser transitions in neodymium that start from the same upper state. These transitions compete for the same population of electrons, and, left to themselves, the 1064 nm transition will dominate. The blue *Excelsior* lasers employ vanadate ($Nd:YVO_4$) crystals to produce the 1064 nm wavelength for doubling to 532 nm. Vanadate is a popular solid-state laser material for small- to medium-power solid-state lasers due to its low threshold for lasing, along with its large cross section for stimulated emission.

Neodymium can be made to lase at other wavelengths, at 946 nm in particular. This 946 nm transition has a lower gain and a higher threshold than the 1064 nm transition. When lasing at this wavelength is desired, it can be achieved by choosing the proper wavelength-selective coatings for the resonator mirrors. Such coatings transmit a high percentage of any 1064 nm light that might be present, thus decreasing the rate of stimulated emission for this wavelength and allowing the 946 nm transition to lase.

The 946 nm transition is referred to as “quasi three level” because the lower laser level lies so close to the $^4I_{9/2}$ ground state. Despite this small difference in energy, the lower laser level still empties quickly enough to allow CW operation for this wavelength. However, the small difference in energy from the ground state does mean that the material will “self-absorb” at the lasing wavelength.

Self-absorption is a parasitic effect where the laser light is absorbed by the laser crystal itself. The lower laser level for the quasi three level transition in vanadate is significantly populated by electrons thermally excited from the ground state, resulting in absorption of the 946 nm light as the electrons then make the reverse transition to the upper laser level. Nd:YAG exhibits the same effect, but thermal population of the lower laser level is less, so the blue *Excelsior* lasers employ YAG crystals to produce the 946 nm wavelength for doubling to 473 nm. Self-absorption can also be reduced somewhat by carefully engineering the diode-pump design.

### *Diode-Pumped Laser Design*

Diode lasers combine very high brightness, high efficiency, monochromaticity and compact size in a near-ideal source for pumping solid-state lasers. Figure 3-4 shows the emission spectra of a diode laser compared to a black body source. The near-perfect overlap of the diode laser output with the $Nd^{3+}$ absorption band ensures that the pump light is efficiently coupled into the laser medium. Any pump light *not* coupled into the medium must ultimately be removed as heat.

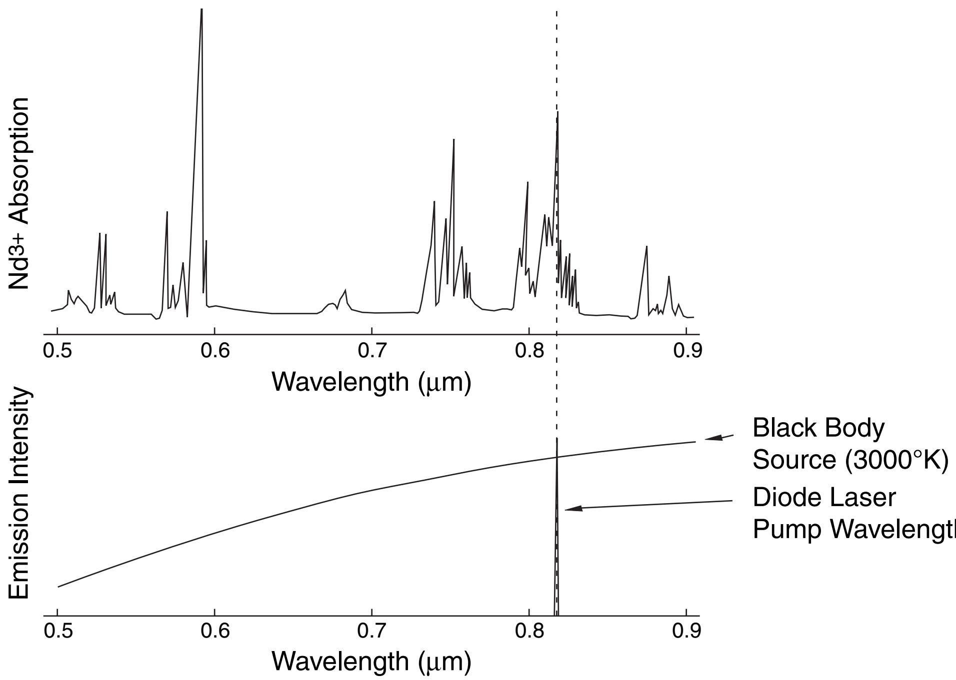



**Figure 3-4: $Nd^{3+}$ absorption spectra compared to emission spectra of a Black Body Source (a) and a Diode Laser (b).**

One of the key elements in optimizing the efficiency of a solid-state laser is maximizing the overlap of the regions of the active medium excited by the pumping source and the active medium occupied by the laser mode. The maximization of this overlap is often called mode matching, and in most applications, $TEM_{00}$ is the laser mode that is most desired. A longitudinal pumping geometry provides this sort of optimal mode-match.

Longitudinal pumping allows the diode laser output to be focused on a volume in the active medium that best matches the radius of the $TEM_{00}$ mode. In general, the $TEM_{00}$ mode radius is chosen to be as small as possible to minimize the solid-state laser threshold. Figure 3-5 shows a schematic of a mode-matching design of this type.

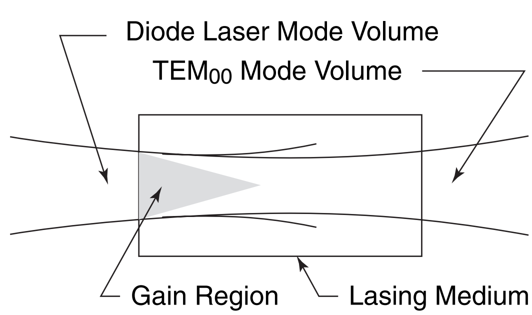



**Figure 3-5: Mode Matching**

## *Frequency Doubling*

In the *Excelsior*, the infrared output a neodymium-based laser crystal is converted to visible light through frequency doubling (also called “second harmonic generation”) in a nonlinear crystal. Frequency doubling occurs when an intense laser beam enters a nonlinear crystal and generates a second beam at half the incident wavelength. The blue *Excelsior* lasers use a lithium triborate (LBO) crystal as the doubling medium; the green lasers use a potassium titanyl phosphate (KTP) crystal.

Phase matching is a requirement of nonlinear optics to achieve an efficient conversion of the fundamental incident light to a new wavelength. To produce any significant output at the new wavelength, the fundamental light wave and the converted light wave must stay in phase over a sufficient length in the nonlinear material to allow the conversion to take place.

In most nonlinear materials, however, the indices of refraction at the two wavelengths will be significantly different, causing the two waves to become rapidly out of phase unless special techniques are employed. One such technique takes advantage of the birefringence of nonlinear crystals.

The indexes of refraction of the two light waves can be made to match exactly if the direction of propagation and the polarization orientation of the beams within the crystal are carefully controlled. This technique is referred to as “critical phase matching.” LBO and KTP are nonlinear crystals that lend themselves well to this technique.

The high nonlinear coefficient of KTP has made it historically a very popular material for conversion of lower-power 1064 nm infrared lasers to green wavelengths. KTP can be fabricated in a specialized structure that keeps the infrared and green beams in an approximate phase-matched condition over a longer distance than in a typical bulk crystal.

Although LBO has a comparatively smaller nonlinear coefficient, it produces no spatial “walk-off” of the fundamental and second harmonic beams. This favors a long interaction length for higher gain. Consequently LBO has subtle advantages that provide superior conversion efficiency of CW infrared laser light to blue wavelengths.

The second harmonic power ($P_{2\omega}$) produced by frequency doubling is given by:

$$P_{2\omega} \propto \frac{d_{eff}^2 P_\omega^2 l^2 [\phi]}{A} \qquad [4]$$

where $d_{eff}$ is the effective nonlinear coefficient, $P_\omega$ is the fundamental input power, $l$ is the effective crystal length, $[\phi]$ is a phase-matching factor, and $A$ is the cross-sectional area of the beam in the crystal.

The important point to note from equation [4] is that the second harmonic output is dependent upon the square of the fundamental peak power. High conversion efficiencies can therefore be achieved by placing the doubling crystal within the laser resonator itself (called “intracavity frequency doubling”) to take advantage of the high circulating intensity. This is the optical design used in the *Excelsior*.

# The Excelsior Lasers

An *Excelsior* system comprises one of seven models of the laser head, together with the controller interface that routes electrical power, control and monitoring signals between the OEM laser head and the master system. All of the *Excelsior* lasers operate at constant power; in addition, the three high power green models allow the option of varying the output power using an external control signal.

## *The Excelsior Laser Head*

The *Excelsior* laser head provides maximum reliability with minimum complexity and size. The inherent operation is so stable and the output so quiet that no adjustments are needed in normal operation.

### Laser Cavity Design

The *Excelsior* uses a compact linear cavity for convenient end-pumping of the laser crystal.

**Note** The diode pump laser in the *Excelsior* laser head is sometimes referred to simply as the "diode" in this manual, e.g., when we refer to the "diode current."

The infrared light generated by the laser crystal is intracavity frequency doubled to produce either green or blue output; that is, the output of a vanadate crystal at 1064 nm is doubled to 532 nm in the green lasers, and the output of a YAG crystal at 946 nm is doubled to 473 nm in the blue lasers. A dichroic output coupler transmits a fraction of the doubled light out of the resonator while confining virtually all of the infrared beam inside the laser head.

The infrared pump power of the diode laser is mode-matched in the laser crystal which, together with the design of the resonator optics, results in $TEM_{00}$ output. The lasers also operate in single longitudinal mode, except for the two lower power green models, which have multiple longitudinal mode output. Refer to the tables of specifications at the end of this chapter.

Single longitudinal mode operation is achieved by inserting an etalon in the intracavity space to broaden the spacing of the longitudinal modes beyond the bandwidth of the laser gain so that only one mode at a time fits within the gain spectrum.

The higher power models of the green laser include an output telescope assembly that expands and collimates the beam before it exits the laser head. Collimation is offered as an option for the lower power green lasers as well, which are otherwise uncollimated. The output of the blue lasers is uncollimated. Again, refer to the tables of specifications for exact details.

All models of the *Excelsior* include an internal detector to measure output power. The detector is part of a servo-loop that maintains constant laser output power over the lifetime of the device by adjusting the current of the diode pump.

### Mechanical and Thermal Design

The laser resonator is machined from a solid piece of brass for exceptional thermal and mechanical stability. The waste heat produced by the diode pump laser (typically less than 2 W) is removed from the laser head by thermal conduction through the baseplate. The laser crystal is set to a stable operating temperature of about 45°C by a thermal-electric cooler (TEC) that is located in the head beneath the laser cavity.

The mechanical design of the miniature laser heads allows for mounting the lasers using precision alignment pins. Together with the excellent stability and boresight specifications of the *Excelsior*, this facilitates both the design of the master optical train as well as the replacement of the laser head when the diode pump laser eventually reaches its end-of-life condition.

## *The Excelsior Controller*

Power for the laser, as well as monitoring and control, are provided to the laser head through the small, separate controller unit.

**Note**

The same controller is used on all models of the *Excelsior* without modification.

The *Excelsior* system produces output signals proportional to the laser power and the diode pump current, as well as an alarm for the diode lifetime and a status signal that can be used to control a laser emission indicator. These features are all available through the *Excelsior* controller.

An interlock jumper plug (Figure 3-6) is provided with the system to allow operation without an external control cable during test and installation.

**Danger!**
Laser Radiation

Note that when power is supplied to the laser, the laser will come on immediately when either the ON signal is present or the jumper plug is inserted into the EXTERNAL CONTROL connector of the controller.

**Figure 3-6: Interlock Jumper Plug**

## *Power Supply Requirements*

The *Excelsior* requires up to 6 Amps of regulated +5 Vdc power to drive the diode pump laser. See the installation section in Chapter 4 for more information.

# Specifications

### Table 3-1: Excelsior Green Laser Output Specifications[1]

| | 10 and 20 mW *Excelsior* | 50, 100 and 150 mW *Excelsior* |
|---|---|---|
| **Power** | | |
| Excelsior-532-10[2] | 10 ±0.2 mW | |
| Excelsior-532-20[2] | 20 ±0.5 mW | |
| Excelsior-532-50[3] | | 50 ±0.5 mW |
| Excelsior-532-100[3] | | 100 ±1.0 mW |
| Excelsior-532-150[3] | | 150 ±1.0 mW |
| **General Characteristics** | | |
| Wavelength | 532 nm | 532.3 ±0.3 nm |
| Longitudinal Mode | multi | single |
| Spectral Linewidth | < 0.5 nm | < 10 MHz (< 0.01 pm) |
| IR Power | ≤ 5 μW | ≤ 10 μW |
| **Beam Characteristics** | | |
| Spatial Mode | $TEM_{00}$ | $TEM_{00}$ |
| Beam Quality | $M^2 < 1.1$ | $M^2 < 1.1$ |
| Polarization[4] | > 100:1 | > 100:1 |
| Beam diameter ($1/e^2$ points) | 0.11 ±0.01 mm (optional 0.32 mm) | 0.32 ±0.02 mm |
| Beam divergence, full angle | < 7.4 mrad (optional < 2.5 mrad | < 2.5 mrad |
| Beam Ellipticity ($\theta_V/\theta_H$) | 1.0 ±0.1 | 1.0 ±0.1 |
| **Stability** | | |
| Power Stability[5] | < ±2% | < ±2% |
| Warm-up Time | 5 minutes | 5 minutes |
| Optical Noise | < 0.5% rms (10 Hz−20 MHz) | < 0.2% rms (10 Hz−100 MHz) |
| Beam Pointing Stability[6] | ≤ 20 μrad/°C | ≤ 6 μrad/°C |
| Frequency Drift | n/a | ≤ 50 MHz/°C |
| Boresight Tolerance | | |
| Near field | < ±0.1 mm | < ±0.1 mm |
| Far field | < ±0.5 mrad | < ±0.5 mrad |

[1] *Specifications are subject to change without notice.*
[2] *Available in uncollimated and collimated versions; see beam diameter and divergence specs.*
[3] *The output power of the Excelsior-532-50, Excelsior-532-100 and Excelsior-532-150 can be varied using external control; all other models operate at constant power.*
[4] *Vertical polarization*
[5] *Measured over an 8-hour period after warm-up.*
[6] *Measured as far-field x and y positions, after a 5-minute warm-up.*

**Table 3-2: Excelsior Blue Laser Output Specifications[1]**

| | **10 mW *Excelsior*** | **5 mW *Excelsior*** |
|---|---|---|
| **General Characteristics** | | |
| Power | 10.0 ±0.2 mW | 5.0 ±0.1 mW |
| Wavelength | 473 nm | |
| Longitudinal Mode | single | single |
| Spectral Linewidth | < 10 MHz | < 10 MHz |
| IR Power | ≤ 1 µW | |
| **Beam Characteristics** | | |
| Spatial Mode | $TEM_{00}$ | |
| Beam Quality | $M^2 < 1.1$ | |
| Polarization[2] | > 100:1 | |
| Beam diameter ($1/e^2$ points) | 0.10 ±0.01 mm | |
| Beam divergence, full angle | < 7.4 mrad | |
| Beam Ellipticity ($\theta_V/\theta_H$) | 1.0 ±0.15 | 1.0 ±0.15 |
| **Stability** | | |
| Power Stability[3] | < ±2% | |
| Warm-up Time | < 5 minutes | |
| Optical Noise[4] | < ±0.5% rms | |
| Beam Pointing Stability[5] | ≤ 20 µrad/°C | |
| Frequency Drift | ≤ 50 MHz/°C | |
| Boresight Tolerance | | |
| Near field | < ±0.5 mm | |
| Far field | < ±5.0 mrad | |

[1] *Specifications are subject to change without notice*
[2] *Vertical polarization*
[3] *Measured over an 8-hour period after warm-up*
[4] *Measured over a 10 Hz to 100 MHz bandwidth*
[5] *Measured as far-field x and y positions, after a 5-minute warm-up*

**Table 3-3: Environmental Specifications**

| | Operating Conditions |
|---|---|
| **Temperature range** | |
| Laser Head | 10°C to 40°C |
| Controller | 10°C to 45°C |
| **Humidity** | < 80%, non-condensing, for temperatures within range |
| **Vibration** | < 1.5 m/sec$^2$ (0.15 G), 15–200 Hz |
| | **Non-Operating Conditions** |
| **Temperature range** | –20°C to 60°C |
| **Humidity** | < 90%, non-condensing, for temperatures within range |
| **Vibration** | < 20 m/sec$^2$ (2 G), 15–200 Hz |
| **Shock** | < 300 m/sec$^2$ (30 G), 11 msec |

**Table 3-4: Electrical/Mechanical Specifications**

| | |
|---|---|
| **Electrical Requirements** | 5 Vdc (±10%), 6 A |
| **Power Consumption** | < 30 W |
| **Cooling** | Air-cooled |
| **Beam Height** | 19 mm (0.75 in.) |
| **Weight**[1] | |
| all Laser Heads | 0.3 kg (0.7 lb) |
| Controller | 0.25 kg (0.6 lb) |
| **Size (l x h x w)**[2] | |
| Laser Head | |
| 50, 100, & 150 mW Green | 9.50 x 3.65 x 2.8 cm (3.74 x 1.44 x 1.10 in.) |
| 10, 20 mW Green and 5, 10 mW Blue | 8.45 x 3.65 x 2.8 cm (3.33 x 1.44 x 1.10 in.) |
| Controller | 13.8 x 3.35 x 9.94 cm (5.30 x 1.32 x 3.91 in.) |
| **Laser Head Cable Length**[3] | 1 m (3 ft) |

[1] *Weights are approximate*
[2] *Refer to outline drawings for exact dimensions*
[3] *Cable length is approximate*

# Chapter 4 Installation and Operation

Read this chapter in its entirety before attempting to install and operate the laser.

## Installation

*Excelsior* lasers are OEM devices designed to be integrated into a master system that provides all of the necessary electrical power, control signals and regulatory safety features. System connections are described below in “Controls and Connections.”

An *Excelsior* laser head is connected to the controller by a one meter long cable that provides on/off control of the laser, as well as diagnostic information. The cable connects to the 15-pin EXT analog port.

Electrical power for the laser is provided to the controller through the 9-pin POWER connector. To provide a margin of safety, select a cable capable of carrying at least a 10 Amp current to connect to the controller.

**Warning!** Because of the high initial current draw, make sure that the load is shared between the pins on this connector. Refer to “Controls and Connections” below.

Thermal management of the heat load produced by the laser is important to maintaining its specified output. Refer to “Thermal Management” below for details.

### *Power Supply Requirements*

The laser is powered by a low-noise (150 mV ripple peak-to-peak), 5 Vdc power source connected to the controller. The source must be capable of providing 30 Watts (6 A maximum current).

### *Thermal Management*

#### Laser Head

The laser head must be mounted on a heatsink capable of maintaining its baseplate temperature below 50°C and greater than 10°C. The diode pump laser in the laser head will produce several Watts of waste heat that must be removed through the baseplate by the heatsink (see Figure 4-1).

Cooler ambient temperatures for the environment of the laser will make the job of dissipating waste heat through the baseplate easier (see Figure 4-2).

The heatsink surface must be flat to 0.050  mm or better.

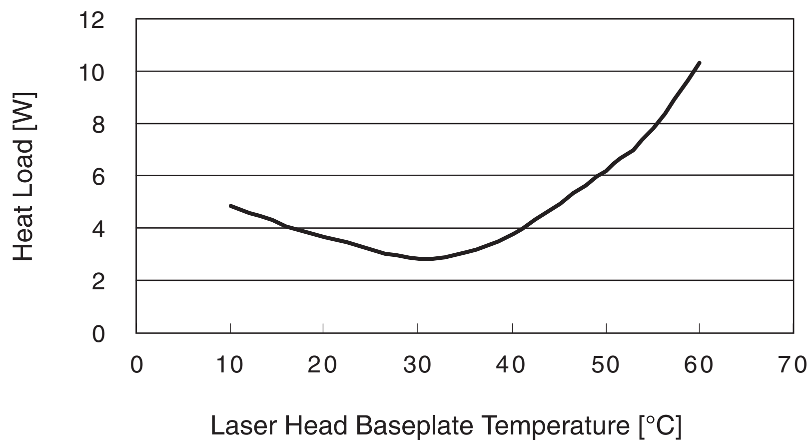



**Figure 4-1: Heat Dissipation of the Laser Head**

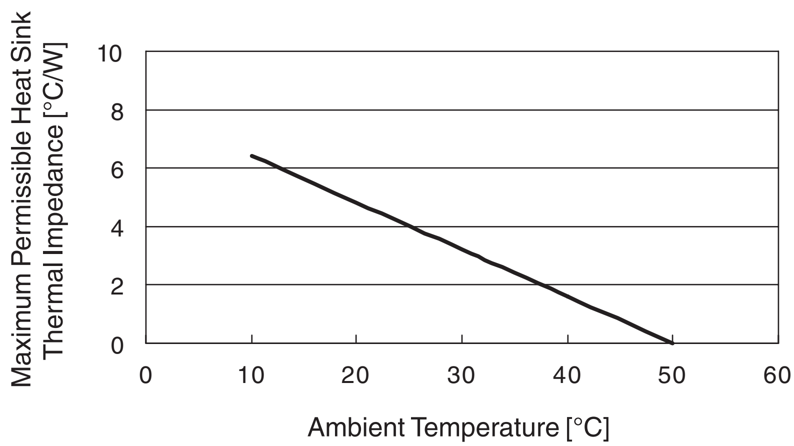



**Figure 4-2: Laser Head Heatsink Thermal Impedance for 50°C Baseplate Temperature**

### Controller

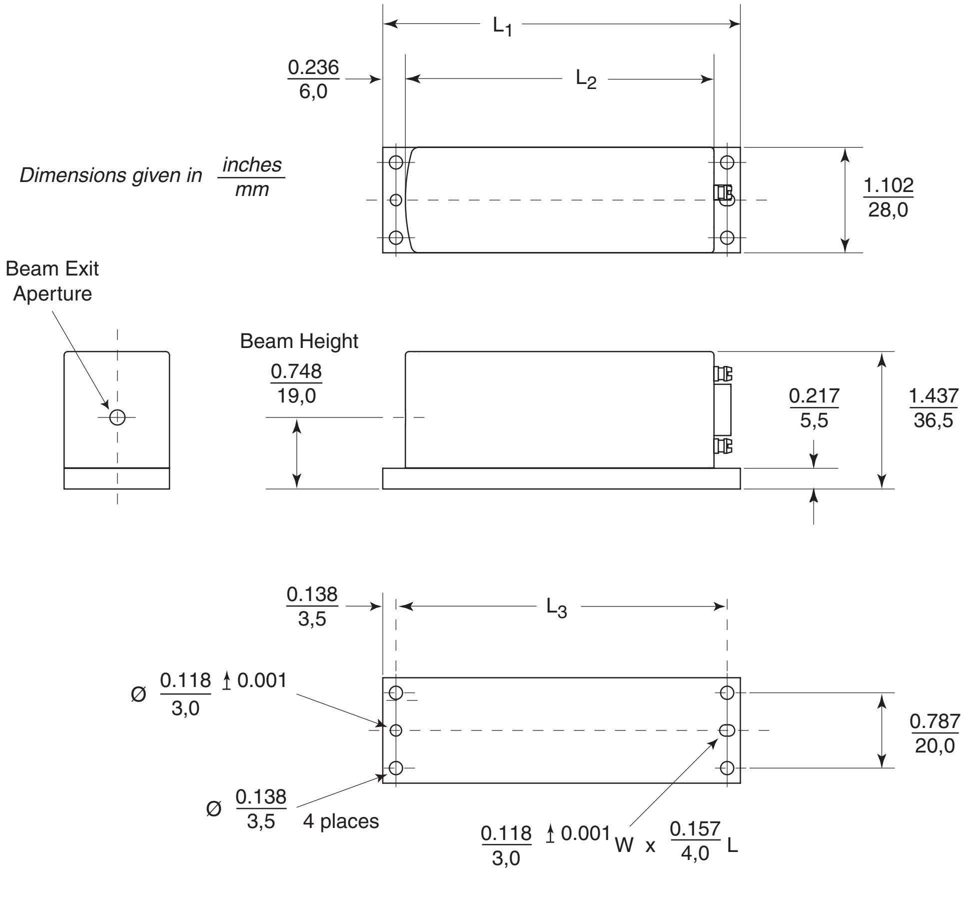
The *Excelsior* controller transfers a significant current load in a relatively small package to the laser head to power the diode pump laser. Consequently, a reliable means must be provided to remove waste heat from the controller in addition to the laser head.

Follow standard practice to mount the controller on a heatsink with a thermal impedance of no greater than 2°C/W.

## Installing the Hardware

### Mount the Laser Head

Follow standard practice to mount the laser head on a suitable heatsink as described in the preceding section. Use four M3 or 4-40 screws and washers to mount the laser head using the mounting holes shown in Figure 4-3.




| *Excelsior Model* | $L_1$ | $L_2$ | $L_3$ |
|---|---|---|---|
| 532-150, 532-100, 532-50 | 3.74 in. (95.0 mm) | 3.23 in. (82.0 mm) | 3.47 in. (88.0 mm) |
| 532-20, 532-10, 473-5, 473-2 | 3.33 in. (84.5 mm) | 2.83 in. (71.5 mm) | 3.05 in. (77.5 mm) |

(Length)

**Figure 4-3: *Excelsior* Laser Head Outline Drawing**

Note the location of the precision alignment holes in the laser head baseplate. The boresight specifications are with respect to the axis of these holes. Note that the beam height is located 19 mm (about ¾ in.) above the baseplate mounting surface.

The heatsink surface for the laser head must be flat to 0.050 mm or better.

### Mount the Controller

Follow standard practice to mount the controller on a suitable heatsink as described in the preceding section. Use four M3 or 4-40 screws and washers to mount the controller using the mounting holes shown in Figure 4-4.

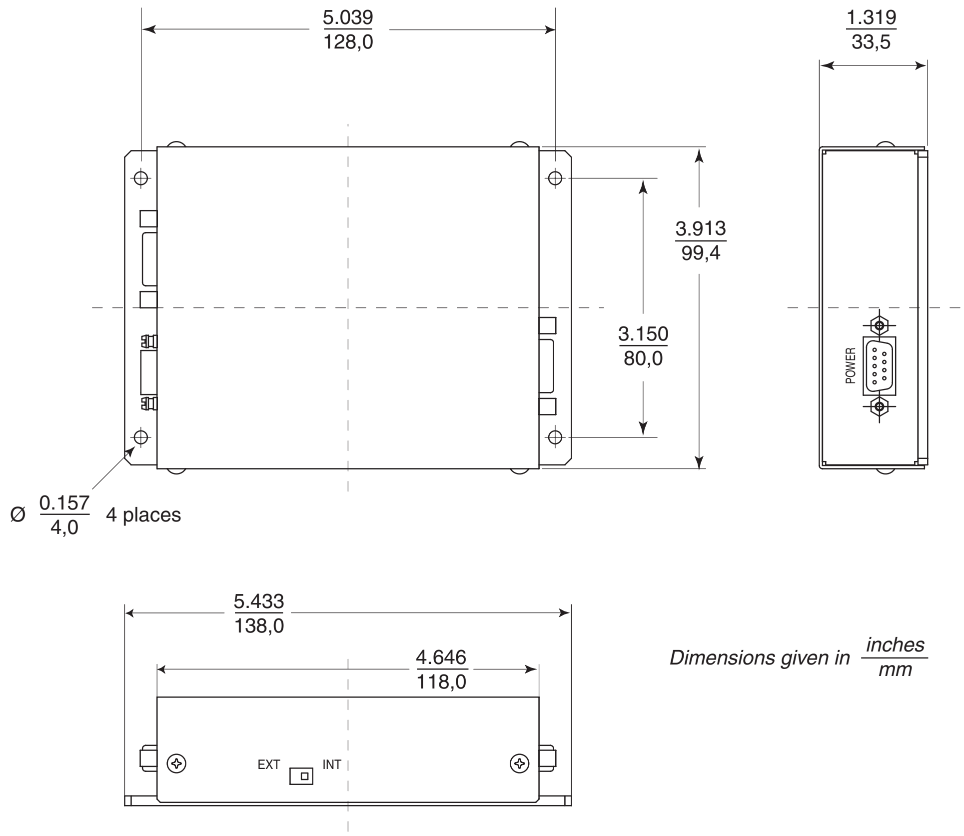



**Figure 4-4: *Excelsior* Controller Outline Drawing**

The laser head and controller can withstand a small amount of vibration and still perform to specification. Refer to the specifications listed at the end of Chapter 3 for more information.

## Controls and Connections

1. Connect the one meter long laser head cable to the connector on the *Excelsior* laser head. Refer toFigure 4-5.

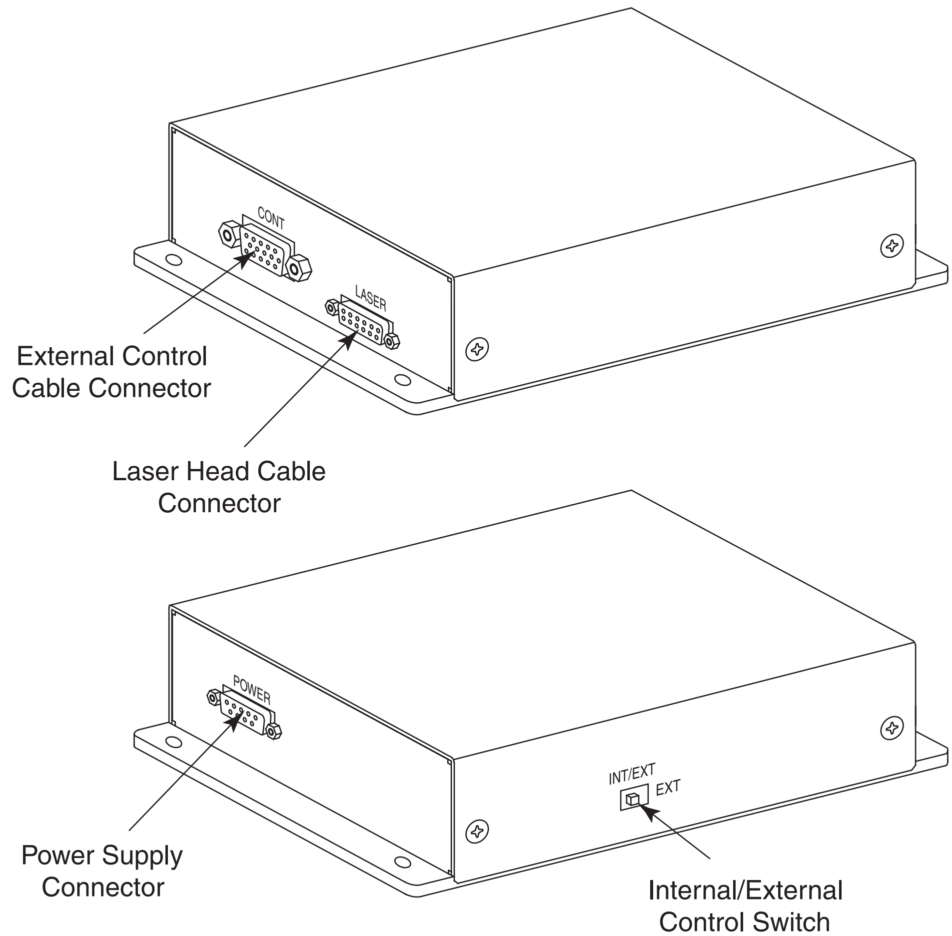



**Figure 4-5: Excelsior Controller Connections**

2. Connect the cable carrying the +5 Vdc power to the 9-pin POWER SUPPLY D-sub connector on the controller. The high current level should be shared by the connector pins. Verify the cable is securely fastened to the controller.

| | |
|---|---|
| +5 VDC in | Pins 1, 2, 6, *and* 7 |
| Ground (return) | Pins 4, 5, 8, *and* 9 |

3. Next, connect a cable with a 15-pin D-sub connector to the EXTERNAL CONTROL connector on the controller. The sequence for the pin numbering is shown in Figure 4-6 (looking at the controller connector). Pin numbers proceed from right to left.

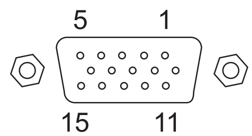



**Figure 4-6: External Control Connector Pin Numbering**

The function of each of these pins is listed below.

**Table 4-1: External Control Connector Pin Functions**

| Pin | Type | Description | Function |
|---|---|---|---|
| 1 | Output | Laser OK | This pin is internally shorted to ground when the laser is in stable operation, i.e., laser output power is at the specified level and the laser head temperature is within the proper operating range.<br>Pin 1 can be used as a switch for a laser emission indicator as shown in Figure 4-8. |
| 2 | Input | Laser ON/OFF | When this pin is shorted to ground, the laser will turn on immediately (if +5 Vdc power is available to the laser head through the controller).<br>Refer to “Turning the Laser On and Off” on page 4-7 for instructions on using this input. |
| 3 | N/A | Reserved | Must be open |
| 4 | Output | Current Monitor | Pin 4 provides an output signal proportional to the current of the diode pump laser. The scale is 100 mV/Amp, the maximum signal is 160 mV (corresponding to 1.6 A). |
| 5 | Output | Laser Power Monitor | Pin 5 provides an output signal that is approximately proportional to the power output of the laser. At full output power, the signal is 95–100 mV.<br>Example: a Pin 5 signal of 50 mV for the *Excelsior-473-10* indicates that laser power has fallen to about 5 mW. |
| 6 | Ground | | |
| 7 | Ground | | |
| 8 | Input | External Power Control | This pin is used to vary the output power of the *Excelsior-532-100* and the *Excelsior-532-150*. This pin works only for these two models.<br>Refer to “Changing the Laser Output Power” on page 4-9 for directions on using this input. |
| 9 | N/A | Reserved | Must be open. |
| 10 | Output | Diode Laser Alarm | Indicates the diode pump laser in the laser head is nearing its end of life. To employ this “open collector” alarm, refer to Figure 4-9 for an example of this circuit. |
| 11 | Ground | | |
| 12 | Ground | | |
| 13 | N/A | Reserved | Must be open. |
| 14 | N/A | Reserved | Must be open. |
| 15 | N/A | Reserved | Must be open. |

## Operation

Please read this entire chapter and Chapter 2, "Laser Safety," before turning on the *Excelsior* laser for the first time.

**Danger!**
Laser Radiation

The Spectra-Physics *Excelsior* laser is a *Class IIIb—High Power Laser* whose beam is, by definition, a safety hazard. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye damage.

### *Turning the Laser On and Off*

Starting and stopping the laser is straightforward: once +5 Vdc power is connected to the laser head, use a switching circuit similar to that shown in Figure 4-7 below to turn the laser on or off. The laser will be ready to perform according to specifications after a 5-minute warm-up.

**Danger!**
Laser Radiation

Note that the *Excelsior* emits laser radiation immediately after Pin 2 of the EXTERNAL CONTROL connector receives the ON signal. Take care to protect against unexpected exposure.

A simple circuit to turn the laser on and off is shown below. If a suitable drive current is supplied from a +5 Vdc source to Pin 2 of the EXTERNAL CONTROL connector, the diode pump laser will turn on and the *Excelsior* will emit laser light.

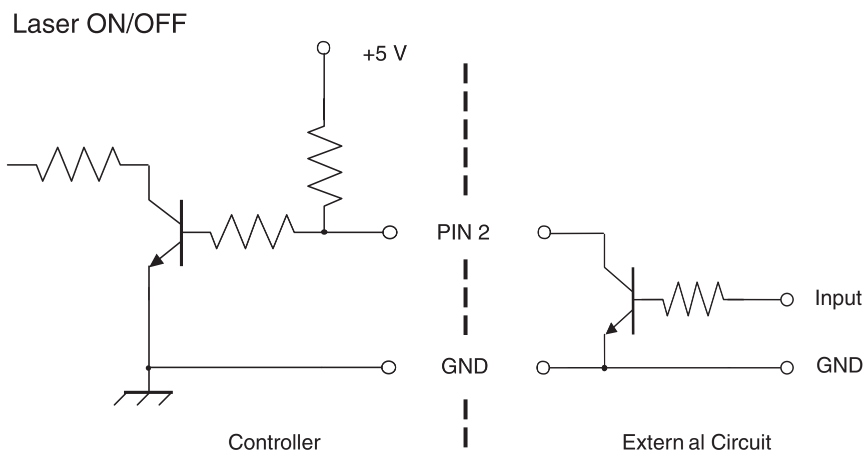



**Figure 4-7: Laser On/Off Control Example**

Note that the ground pins of the EXTERNAL CONTROL connector are Pins 6 and 7, and Pins 10 and 11.

## Using the Emission Indicator

An example of a simple circuit used to turn an emission indicator on and off is shown in Figure 4-8 below.

When the laser output is at its specified level and the laser head temperature is within operating range, the internal transistor connected to Pin 1 in the circuit shown in Figure 4-8 will turn on. The LED shown in the figure will then turn on, indicating that the laser is emitting laser light.

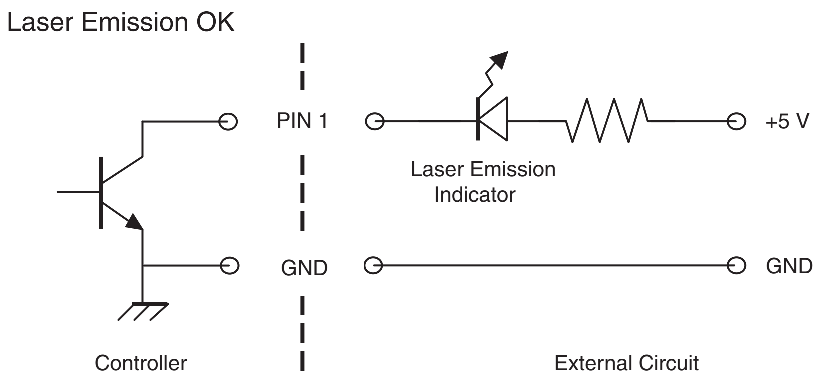



**Figure 4-8: Laser Emission Indicator Example**

Note that the ground pins of the EXTERNAL CONTROL connector are Pins 6 and 7, and Pins 10 and 11.

## Using the Diode Laser Alarm

A circuit to monitor the diode laser alarm is shown in Figure 4-9 below. The diode laser alarm is activated on Pin 10 when the drive current reaches 95% of the factory-set maximum limit. Note that the Pin 10 signal is disabled for the first 5 minutes after the diode pump laser is turned on while the diode current stabilizes.

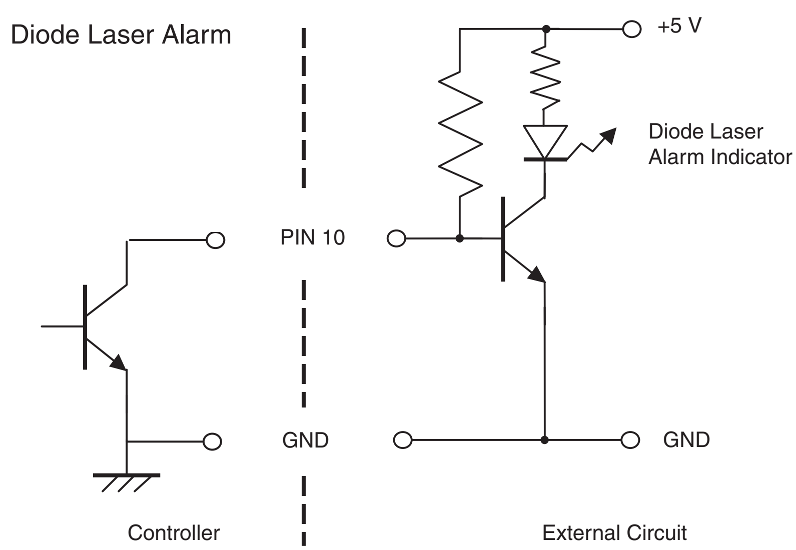



**Figure 4-9: Diode Laser Alarm Example**

### *Changing the Laser Output Power*

The output power of the *Excelsior-532-50, Excelsior-532-100* and the *Excelsior-532-150* can be varied by external control. All other *Excelsior* models produce constant output power.

To change the power of the *Excelsior-532-50, Excelsior-532-100* or the *Excelsior-532-150*, connect a voltage to Pin 8 that can be varied from 50 mV to 100 mV. Use one of the ground pins of the EXTERNAL CONTROL connector for reference (see Table 4-1). Set the EXTERNAL/INTERNAL CONTROL switch on the side of the controller to EXT.

**Caution!**

Be certain that the EXTERNAL/INTERNAL CONTROL switch is set to INT for all other *Excelsior* models, or when the three high-power green lasers are meant to operate at full and constant power. The lasers will not operate if this switch is mistakenly set to EXT.

The power level can be changed between 50% and full power by changing the voltage on Pin 8 between 50 mV and 100 mV. For the *Excelsior-532-50*, output varies from 25 mW to 50 mW; for the *Excelsior-532-100*, from 50 mW to 100 mW; for the *Excelsior-532-150* from 75 mW to 150 mW.

**Note**

Operating the laser below 50% of its rated power is not recommended. The full set of *Excelsior* specifications are guaranteed only at the 100% power level.

As is the case with the other *Excelsior* models, these three high-power green *Excelsior* lasers will operate at constant power when the EXTERNAL/INTERNAL CONTROL switch is set to INT.

### *Interlock Jumper Plug*

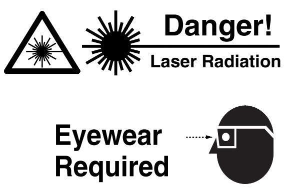
A interlock jumper plug (Figure 4-10) is provided with the system to allow operation without an external control cable.

**Danger!** Laser Radiation

Note that when power is supplied to the laser, the laser will come on immediately when the jumper plug is inserted into the External Control connector of the controller.

**Figure 4-10: Interlock Jumper Plug**

# Chapter 5 Troubleshooting and Service




The Spectra-Physics *Excelsior* lasers are *Class IIIb—High Power Lasers* whose beams are, by definition, a safety hazard. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye damage. Always wear proper eye protection when working on the laser and follow the safety precautions in Chapter 2, "Laser Safety."

## Maintenance

The *Excelsior* laser head requires no routine maintenance. *Do not remove the outer cover; there are no user-serviceable parts inside the laser head.* This cover should only be removed by an authorized service engineer.

To retain a clean intracavity environment, all components are cleaned to stringent standards prior to assembly and alignment at the factory. The cover of the laser module inside the laser head is secured and sealed and should never be opened. *Removing the module cover will compromise the cleanliness of the intracavity space, degrade laser performance and void the warranty.*

Replacing the diode pump laser can only be performed at a Spectra-Physics facility by someone trained and authorized by Spectra-Physics. Call your Spectra-Physics service representative when you suspect that the diode pump laser is at its end of life.

All parts that normally come in contact with laboratory or industrial environments retain surface contamination that can be transferred to optical components during handling. Skin oils can be very damaging to optical surfaces and coatings and can lead to serious degradation problems under intense laser illumination. It is therefore essential that only clean items come into contact with optical components and to the mechanical parts immediately surrounding them.

## Service Training Programs

*Excelsior* lasers are designed for hands-off operation. This product does not require alignment nor routine cleaning of cavity optics. Service is generally limited to replacing the entire laser head. Spectra-Physics offers service training programs to train personnel in the diagnosis of problems.

# Troubleshooting

This troubleshooting guide is intended to assist you in isolating some of the problems that might arise while using the system. For information concerning the repair of this unit, please call your Spectra-Physics representative. A list of world-wide service sites is included at the end of this chapter.

### Symptom: No laser beam

| Possible Causes | Corrective Action |
|---|---|
| No *On* signal applied to the controller | Pin 2 of the EXTERNAL CONTROL connector must be pulled to ground to turn on the laser.<br>If the laser power is controlled externally, set the INTERNAL/EXTERNAL switch to EXT and provide a stable, low-noise, 5 V signal to Pin 8 of the EXTERNAL CONTROL connector. |
| Improper power supply voltage | Verify the DC power supply voltage is between 4.5 V and 5.5 V, and that the power supply is capable of supplying at least 30 W. |
| Loose cable connector | Check that all cables are securely connected. |
| Improper settings for the INTERNAL/EXTERNAL switch | Verify the controller INTERNAL/EXTERNAL switch is set to INT.<br>If laser power is controlled externally, set the INTERNAL/EXTERNAL switch to EXT and provide a stable, low-noise, 5 V signal to Pin 8 of the EXTERNAL CONTROL connector. |

### Symptom: Low power

| Possible Causes | Corrective Action |
|---|---|
| Improper power supply voltage | Verify the DC power supply voltage is between 4.5 V and 5.5 V, and that the power supply is capable of supplying at least 30 W. |
| Loose cable connector | Verify all cables are securely connected. |
| Improper settings for the INTERNAL/EXTERNAL switch | Verify the Controller INTERNAL/EXTERNAL switch is set to INT.<br>If laser power is controlled externally, set the INTERNAL/EXTERNAL switch to EXT and provide a stable, low-noise, 5 V signal to Pin 8 of the EXTERNAL CONTROL connector. |
| Incorrect power measurement | Ensure that output power is measured as it leaves the laser head before the output beam enters any external optical elements. |
| Laser is not warmed up | Allow the laser to warm up for at least 5 minutes. |
| Dirty output window | Clean the laser head output window. |
| Laser head temperature outside operating range | Measure the temperature of the baseplate. If it is below 10°C or exceeds 50°C, verify the ambient temperature is within the allowable operating range and correct if necessary.<br>Verify the laser head baseplate is properly heat-sinked. |
| Reflected laser light is destabilizing the laser | Ensure that light reflected from any external optical elements does not reflect back through the window of the laser head. |
| Diode pump laser has reached its end of life | Contact your Spectra-Physics service representative about replacing the laser head. |

**Symptom: High optical noise**

| Possible Causes | Corrective Action |
|---|---|
| Improper power supply voltage | Verify the DC power supply voltage is between 4.5 V and 5.5 V, and that the power supply is capable of supplying at least 30 W. |
| Loose cable connector | Verify all cables are securely connected. |
| Improper settings for the INTERNAL/EXTERNAL switch | Verify the controller INTERNAL/EXTERNAL switch is set to INT.<br>If the laser power is controlled externally, set the INTERNAL/EXTERNAL switch to EXT and provide a stable, low-noise, 5 V signal to Pin 8 of the EXTERNAL CONTROL connector. |
| Laser is not warmed up | Allow the laser to warm up for at least 5 minutes. |
| Laser head temperature is outside operating range | Measure the temperature of the baseplate. If it is below 10°C or exceeds 50°C, verify the ambient temperature is within the allowable operating range and correct if necessary.<br>Verify the laser head baseplate is properly heat-sinked. |
| Reflected laser light is destabilizing the laser | Ensure that light reflected from any external optical elements does not reflect back through the window of the laser head. |
| Improper ground | Check the grounding of the laser head and the controller. |
| Vibration outside of operating limits | Ensure that any vibration experienced by the laser head is within operating limits. |
| Power supply ripple | Verify the power supply ripple is below 150 mV peak-to-peak. |
| External noise source | Check that there are no strong electromagnetic noise sources near the system. If the output power is controlled externally, verify the voltage signal applied to Pin 8 of the EXTERNAL CONTROL connector is low noise. |

**Symptom: Bad transverse mode**

| Possible Causes | Corrective Action |
|---|---|
| Improper power supply voltage | Verify the DC power supply voltage is between 4.5 V and 5.5 V, and that the power supply is capable of supplying at least 30 W. |
| Improper settings for the INTERNAL/EXTERNAL switch | Verify the controller INTERNAL/EXTERNAL switch is set to INT.<br>If laser power is controlled externally, set the INTERNAL/EXTERNAL switch to EXT and provide a stable, low-noise, 5 V signal to Pin 8 of the EXTERNAL CONTROL connector. |
| Laser is not warmed up | Allow the laser to warm up for at least 5 minutes. |
| Dirty output window | Clean the laser head output window. |
| Laser head temperature outside operating range | Measure the temperature of the baseplate. If it is below 10°C or exceeds 50°C, verify the ambient temperature is within the allowable operating range and correct if necessary.<br>Verify the laser head baseplate is properly heat-sinked. |
| Reflected laser light is destabilizing the laser | Ensure that light reflected from any external optical elements does not reflect back through the window of the laser head. |

**Symptom: Output power is unstable**

| Possible Causes | Corrective Action |
|---|---|
| Improper power supply voltage | Verify the DC power supply voltage is between 4.5 V and 5.5 V, and that the power supply is capable of supplying at least 30 W. |
| Loose cable connector | Verify all cables are securely connected. |
| Improper settings for the INTERNAL/EXTERNAL switch | Verify the controller INTERNAL/EXTERNAL switch is set to INT.<br>If laser power is controlled externally, set the INTERNAL/EXTERNAL switch to EXT and provide a stable, low-noise, 5 V signal to Pin 8 of the EXTERNAL CONTROL connector. |
| Laser is not warmed up | Allow the laser to warm up for at least 5 minutes. |
| Laser head temperature outside operating range | Measure the temperature of the baseplate. If it is below 10°C or exceeds 50°C, verify the ambient temperature is within the allowable operating range and correct if necessary.<br>Verify the laser head baseplate is properly heat-sinked. |
| Reflected laser light destabilizing the laser | Ensure that light reflected from any external optical elements does not reflect back through the window of the laser head. |

## Replacement Parts

The following is a list of parts that may be purchased to replace broken, worn-out or misplaced components.

**Table 5-1: Replacement Parts**

| Description | Part Number |
|---|---|
| *Excelsior* green 10 mW laser head | Excelsior-532-10 |
| *Excelsior* green 10 mW laser head, collimated output | Excelsior--532-10-C |
| *Excelsior* green 20 mW laser head | Excelsior--532-20 |
| *Excelsior* green 20 mW laser head, collimated output | Excelsior-532-20-C |
| *Excelsior* green 50 mW laser head | Excelsior-532-50 |
| *Excelsior* green 100 mW laser head | Excelsior-532-100 |
| *Excelsior* green 100 mW laser head | Excelsior-532-150 |
| *Excelsior* blue 5 mW laser head | Excelsior-473-5 |
| *Excelsior* blue 10 mW laser head | Excelsior-473-10 |
| *Excelsior* Controller | Excelsior-PS |

## Customer Service

At Spectra-Physics, we take great pride in the reliability of our products. Considerable emphasis has been placed on controlled manufacturing methods and quality control throughout the manufacturing process. Nevertheless, even the finest precision instruments will need occasional service. Our instruments have excellent service records compared to competitive products, and we strive to provide excellent service to our customers in two ways: by providing the best equipment for the price, and by servicing your instruments as quickly as possible.

When calling for service inside the United States, dial our toll free number: **1 (800) 456-2552**. To phone for service in other countries, refer to "Service Centers" on page 5-6.

Order replacement parts directly from Spectra-Physics. For assistance of any kind, contact your sales office or service center. You will need your model and serial numbers available when you call. To order optional items or other system components, or for general sales assistance, dial **1 (800) SPL-LASER** in the United States, or **1 (650) 961-2550** from anywhere else.

### *Warranty*

All parts and assemblies manufactured by Spectra-Physics are unconditionally warranted to be free of defects in workmanship and materials for the period of time listed in the sales contract following delivery of the equipment to the F.O.B. point.

Liability under this warranty is limited to repairing, replacing, or giving credit for the purchase price of any equipment that proves defective during the warranty period, provided prior authorization for such return has been given by an authorized representative of Spectra-Physics. Spectra-Physics will provide at its expense all parts and labor and one-way return shipping of the defective part or instrument (if required). In-warranty repaired or replaced equipment is warranted only for the remaining portion of the original warranty period applicable to the repaired or replaced equipment.

This warranty also does not apply to equipment or components that, upon inspection by Spectra-Physics, is found to be defective or unworkable due to abuse, mishandling, misuse, alteration, negligence, improper installation, unauthorized modification, damage in transit, or other causes beyond the control of Spectra-Physics.

This warranty is in lieu of all other warranties, expressed or implied, and does not cover incidental or consequential loss.

### *Returning the Instrument for Repair*

Contact your nearest Spectra-Physics field sales office, service center, or local distributor for shipping instructions. You are responsible for one-way shipment of the defective part to Spectra-Physics. Instruments can be returned only in Spectra-Physics containers. We encourage you to use the original packing boxes to secure instruments during shipment. If shipping boxes have been lost or destroyed, we recommend ordering new ones.

## Service Centers

**Belgium**

Telephone: (32) 0800 1 12 57

**France**

Telephone: (33) 0810 00 76 15

**Germany and Export Countries***

Spectra-Physics GmbH
Guerickeweg 7
D-64291 Darmstadt
Telephone: (49) 06151 708-0
Fax: (49) 06151 79102

**Japan (East)**

Spectra-Physics KK
East Regional Office
Daiwa-Nakameguro Building
4-6-1 Nakameguro
Meguro-ku, Tokyo 153-0061
Telephone: (81) 3-3794-5511
Fax: (81) 3-3794-5510

**Japan (West)**

Spectra-Physics KK
West Regional Office
Nishi-honmachi Solar Building
3-1-43 Nishi-honmachi
Nishi-ku, Osaka 550-0005
Telephone: (81) 6-4390-6770
Fax: (81) 6-4390-2760

**The Netherlands**

Telephone: (31) 0900 5 55 56 78

**United Kingdom**

Telephone: (44) 1442-258100

**United States and Export Countries****

Spectra-Physics
1330 Terra Bella Avenue
Mountain View, CA 94043
Telephone: (800) 456-2552 (Service) or
(800) SPL-LASER (Sales) or
(800) 775-5273 (Sales) or
(650) 961-2550 (Operator)
Fax: (650) 964-3584
e-mail: service@spectra-physics.com
sales@spectra-physics.com
Internet: www.spectra-physics.com

**And all European and Middle Eastern countries not included on this list.*
***And all non-European or Middle Eastern countries not included on this list.*

# Notes

# Report Form for Problems and Solutions

We have provided this form to encourage you to tell us about any difficulties you have experienced in using your Spectra-Physics instrument or its manual—problems that did not require a formal call or letter to our service department, but that you feel should be remedied. We are always interested in improving our products and manuals, and we appreciate all suggestions.

Thank you.

**From:**

Name ____________________________________________

Company or Institution ____________________________________________

Department ____________________________________________

Address ____________________________________________

____________________________________________

Instrument Model Number ____________________ Serial Number ____________________

**Problem:** ____________________________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

**Suggested Solution(s):** ____________________________________________

____________________________________________

____________________________________________

**Mail To:**

Spectra-Physics, Inc.
Quality Manager
1335 Terra Bella Avenue, M/S 15-50
Post Office Box 7013
Mountain View, CA 94039-7013
U.S.A.

E-mail: sales@spectra-physics.com
www.spectra-physics.com

**FAX to:**

Attention: Quality Manager
(650) 961-7101