KEITHLEY

Model 2500INT Integrating Sphere
Quick Start Guide

A GREATER MEASURE OF CONFIDENCE

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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4/02

Model 2500INT Integrating Sphere
Quick Start Guide

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 2500INT-903-01).....October 2001

KEITHLEY

Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting ca-

bles or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If  or  is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

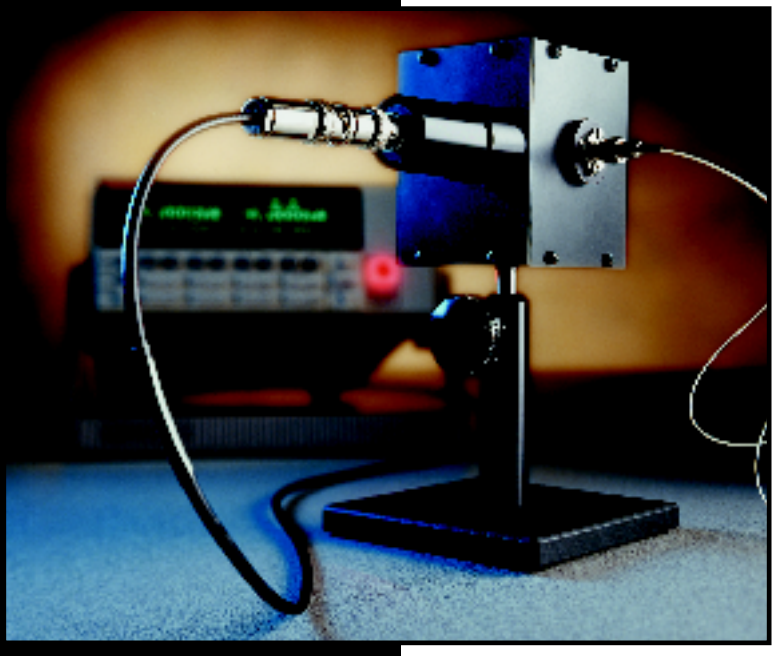
Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

2500INT

Integrating Sphere



- Choose from silicon, germanium, or cooled indium gallium arsenide detectors
- Spectralon® sphere interior ensures high reflectivity
- Part of Keithley's high throughput system for production testing laser diodes and LEDs

Ordering Information

2500INT-2-Si
Integrating Sphere with Silicon Detector

2500INT-2-Ge
Integrating Sphere with Germanium Detector

2500INT-2-IGAC
Integrating Sphere with Cooled Indium Gallium Arsenide Detector

This product is available with an Extended Warranty.

Accessories Supplied

Quick Start Guide, Calibration Chart for each sphere, TEC Controller (included with 2500INT-2-IGAC)

The Model 2500INT Integrating Sphere is the latest addition to Keithley's growing line of solutions for L-I-V (light-current-voltage) testing. When connected via a low-noise triax cable to the Model 2500 Dual Photodiode Meter included in Keithley's L-I-V Test System, the integrating sphere allows the system to make direct measurements of optical power, with results expressed in watts. The integrating sphere simplifies production testing of laser diodes (LDs), light emitting diodes (LEDs), and other optical components by eliminating common optical power measurement problems related to detector alignment, beam profile, polarization, and back reflection.

Choice of Three Detector Types

The Model 2500INT is available with a silicon (2500INT-2-Si), germanium (2500INT-2-Ge), or cooled indium gallium arsenide detector (2500INT-2-IGAC), each calibrated with the sphere. Spheres equipped with cooled indium gallium arsenide detectors include a controller to regulate the detector's temperature.

Unaffected by DUT Beam Profile

Laser diodes can produce non-gaussian beam profiles, which can lead to inaccurate optical power measurements due to underfill or overfill of the detector. While a number of methods are available to correct for underfill and overfill, these methods can add to the overall inaccuracy of the measurement.

In contrast, an integrating sphere is inherently insensitive to beam profiles. The interior of the Model 2500INT integrating sphere has a highly reflective Spectralon® surface, which scatters, reflects, and diffuses the source beam produced by the device under test (DUT). This spreads the light from the DUT uniformly over the interior surface of the sphere with minimal absorption loss. A detector can be placed on the interior surface of the sphere, then the sphere/detector combination can be calibrated. The amount of optical radiation striking the detector is the same as any other point on the sphere interior due to the multiple diffuse reflections within the sphere. Therefore, the calibration and resulting measurement accuracy are independent of beam profile.

The Model 2500INT's Spectralon surface offers a variety of other advantages. It is a nearly perfect diffuse reflector, exhibiting Lambertian reflectance properties, so it reflects equally in all directions, regardless of viewing angle. This eliminates the inaccuracies associated with less diffuse materials by distributing the optical radiation more evenly over the interior of the sphere. In addition, a Spectralon surface offers high reflectance for wavelengths from 250-2500nm, which makes it ideal for laser diode measurement applications. It is also chemically inert, which helps ensure stable measurements in harsh environments.

Eases Beam Alignment

If an integrating sphere is not used in laser diode testing, the entire beam from the laser must shine directly onto the detector in order to measure optical power accurately. However, it is difficult to align a laser and detector with the high degree of precision required, particularly when the laser is operating outside of the visible spectrum. With the use of an integrating sphere, beam alignment is trivial because any light that enters the sphere will be spread evenly across its interior surface. Simply stated, it is easier to direct a laser into a ½-inch port than it is to direct a laser onto a 5mm detector. The sphere is insensitive to input beam alignment up to 40° off normal or divergences up to 40° half-angle.

APPLICATIONS

Production testing of:

- Laser diode modules
- Chip on submount laser diodes
- Laser diode bars
- LEDs
- Passive optical components

Enables direct optical power measurement in watts with the Model 2500

OPTOELECTRONIC TEST SOLUTIONS

1.888.KEITHLEY (U.S. only)

www.keithley.com

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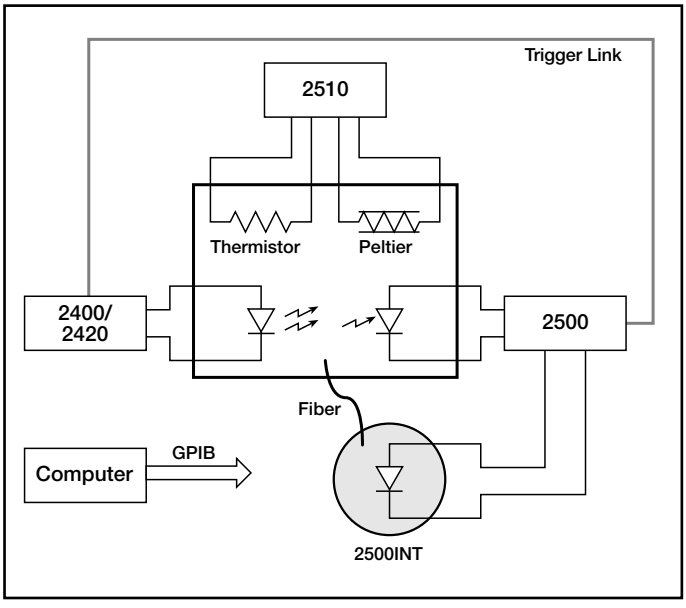
2500INT Integrating Sphere



The Model 2500INT allows the L-I-V Test System to measure optical inputs directly and to display power measurements in watts. Other instruments in the L-I-V Test System include the Model 2500 Dual Photodiode Meter, the Model 2510 TEC SourceMeter®, and either the Model 2400 or 2420 SourceMeter. Each integrating sphere is characterized at the factory and provided with a calibration constant for every 25 nanometers in the detector's range. Prior to testing, the user simply enters the constant in the Model 2500 Dual Photodiode Meter to ensure accurate measurements of optical power for that wavelength.

Minimizes Polarization Concerns

The randomizing effects of multiple reflections within Keithley's integrating sphere minimize beam polarization problems that can affect optical measurement accuracy when measuring polarized sources. Beam polarization is of particular concern for manufacturers of distributed feedback lasers (DFBs) and Vertical Cavity Surface Emitting Lasers (VCSELs).

Eliminates Back Reflection

The stability of a laser diode is significantly affected by back reflections from objects in the optical path. The geometric nature of the integrating sphere and the diffusing properties of the sphere's reflective material help prevent back reflection and ensure greater device stability during testing.

Attenuates High-power Laser Diode Outputs

Detectors have specified maximum power capability, which is typically just a few milliwatts. By spreading the output power evenly over its interior surface, an integrating sphere automatically attenuates the power from the source; therefore, the power level at any point on the sphere surface is far less than that of a beam that falls directly on the detector. The Model 2500INT sphere is particularly useful for testing high-power laser diodes because it provides calibrated attenuation of the laser diode output, which prevents damage to the detector due to the high density of the output or other problems associated with saturation of the detector.

Designed Specifically for Laser Diode Testing

The design of the Model 2500INT Integrating Sphere is optimized for measuring the optical power of laser diodes. Each sphere is two inches in diameter with a ½-inch input port suitable for fiber or direct light (as in chip on submount applications). The port and detector are positioned so there is no need to use a baffle to prevent the input from shining directly onto the detector. These design characteristics ensure that the proper diameter/source and surface to port area ratios are maintained.

	Silicon Detector	Germanium Detector	Cooled InGaAs Detector
Wavelength range	190–1100nm	800–1800nm	900–1670nm
Peak wavelength (λ_p)	960nm	1550nm	1550nm
Sensitivity at peak wavelength	Excellent at 960nm	Good at 1550nm	Excellent at 1550nm
Sensitivity at certain wavelengths			
visible	***	N/A	N/A
980nm	***	**	**
1310nm	N/A	**	***
1550nm	N/A	**	***
>1550nm	N/A	**	***
Speed	***	*	**
Calibration Accuracy/ Stability	Spectral response changes rapidly with temperature at wavelengths >1000nm.	Spectral response changes rapidly with temperature and λ above λ_p.	Extremely stable (Spectral response is stable because λ calibration is fixed at constant operating temperatures, i.e., –10°C.)
Cost	$	$$	$$$

* = Good ** = Better *** = Best N/A = not applicable

Detector Selection Criteria

When choosing the most appropriate detector for a specific application, consider the following selection criteria:

- Wavelengths of maximum interest
- Sensitivity at wavelength of interest
- Speed
- Cost
- Calibration accuracy/stability

2500INT Integrating Sphere

SPECIFICATIONS

TYPICAL REFLECTANCE DATA FOR SPECTRALON® MATERIAL

Wavelength (nm)	Spectralon
500	.991
600	.992
700	.992
800	.991
900	.992
1000	.993
1100	.992
1200	.992
1300	.992
1400	.991
1500	.990
1600	.989
1700	.986
1800	.987

PHYSICAL, THERMO-OPTICAL, AND ELECTRONIC PROPERTIES OF SPECTRALON® MATERIAL

Property	ASTM Test	Value
Density:	N/A	1.25–1.5g/cm^3
Water Permeability	D-570	<0.001% (hydrophobic)
Hardness	D-785	20–30 Shore D
Thermal Stability	N/A	Decomposes at >400°C
Coefficient of Linear Expansion	D-696	5.5–6.5 × 10^{-5} in/in –°F; 10^{-4} °C^{-1}
Vacuum Stability	N/A	No outgassing except for entrained air
Flammability	N/A	Non-flammable (UL rating V-O) Incompatible with non-polar solvents and greases
Yield Stress	D-638	208psi
Ultimate Stress	D-638	891psi
Young's Modulus	N/A	35774psi
Elongation in 2 in.	D-638	42.8%
Elongation at Failure	E-132	91.3%
Poisson's Ratio	D-621	0.296
Deformation under Load	D-621	13.3% @ 250 lbs. 22.6% @ 500 lbs.
Absorbance (ax)	N/A	0.07
Emittance (e)	N/A	0.88
Volume Resistivity	N/A	>10^{18}Ω/cm
Dielectric Strength	D-149	18V/μm
Refractive Index	D-542	1.35
Flammability Rating	UL-94	V-O

PHOTODIODE SPECIFICATIONS

	Silicon	Germanium	Cooled InGaAs
Wavelength range	190–1100nm	800–1800nm	900–1670nm
Peak Sensitivity Wavelength	960nm	1550nm	1550nm
Operating Temperature	–20° to +60°C	–55° to +60°C	–40° to +70°C
Storage Temperature	–55° to +80°C	–55° to +80°C	–55° to +85°C
Active Area	2.4mm × 2.4mm	5.0mm (diameter)	3.0mm (diameter)
Measurement Temperature	—	—	–10°C
Thermistor Allowable Dissipation	—	—	0.2mW
Peltier Element	—	—	1.5A
Allowable Current	*	*	1.0A

ACCESSORIES AVAILABLE

(Appropriate cables and connectors are required to operate the Model 2500INT Integrating Sphere and must be ordered separately. They are not included with the instrument.)

7078-TRX-1	Low-Noise Triax Cable 0.3m (1 ft)
7078-TRX-3	Low-Noise Triax Cable 0.9m (3 ft)
7078-TRX-5	Low-Noise Triax Cable 1.5m (5 ft)
7078-TRX-10	Low-Noise Triax Cable 3.0m (10 ft)
7078-TRX-12	Low-Noise Triax Cable 3.5m (12 ft)
7078-TRX-20	Low-Noise Triax Cable 6.0m (20 ft)
2500INT-FC/APC	FC/APC Connector for 2500INT
2500INT-FC/PC	FC/PC Connector for 2500INT
2500INT-SMA	SMA Connector for 2500INT
6172	2-Slot Male to 3-Lug Female Triax Adapter

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1
General Overview

General Information

Warranty information

Warranty information is lcoated at the front of this guide. Should your Model 2500INT require warranty service, contact te Keithley representative or authorized repair facility in your area for further information. when returning the unit for repair, be sure to fill out and include the service form at the back of this guide to provide the repair facility with the necessary information.

Contact information

Worldwide phone numbers are listed at the back of this guide. if you have any questions, lease contact your local Keithley representative or call one of our application Engineers at 1-800-348-3735 U.S. and Canada only). Additional information may be obtained at www.keithley.com.

Manual addenda

Any improvements or changes concerning the instrument or guide will be explained in an addendum included with the guide. be sure to note these changes and incorporate them into the guide.

Specifications

Model 2500INT specifications shown in this guide were current at the time of printing but they are subject to change without notice. For the most recent specifications, refer to the web site at www.keithley.com.

Safety symbols and terms

The following symbols and terms may be found on an instrument or used in this guide.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the guide.

The  symbol on the instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this guide explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this guide explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Laser safety precautions

WARNING **While the Model 2500INT does not incorporate a laser, it is designed to be used with laser diode devices. The following safety practices must be used to protect operators and other users of this product from potential exposure to laser radiation:**

- **Operators must be protected from radiation and electrical hazards at all times.**
- **The installer must comply with all applicable laws and regulation on laser safety. This requirement includes warning signs and operator training.**
- **An interlock is required for safe operation. The test fixtures must ensure that the interlock circuit is disabled (source outputs inhibited) so that an operator is not exposed to any radiation. The test fixture interlock must not be defeated.**
- **When servicing the test system, any required personnel protection equipment (e.g. laser safety goggles) must be provided by the customer's responsible body.**
- **The customer's laser safety officer (LSO) must review and approve all installations before being put into operation. Any safety concerns must be immediately reported to the customer's LSO.**
- **When making connections, do not leave any exposed connections. Be sure that all external circuits are properly insulated.**

Inspection

The Model 2500INT was carefully inspected before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. The following items are included with every Model 2500INT order:

- Model 2500INT Integrating Sphere.
- Quick Start Guide.
- Addenda, containing any improvements or changes.

If an additional quick start guide is required, order the appropriate manual package (for example, 2500INT-903-00). The packages include a quick start guide and any pertinent addenda.

Optional accessories

The following accessories are available to make connections to the Model 2500INT.

Triax cable and adapter

The following cable and adapter are required to connect the Model 2500INT detector output to the input of the Model 2500 Dual Photodiode Meter:

- Model 7078-TRX Series Cable: Low-noise triax cable to connect the Model 2500INT to the Model 2500 Dual Photodiode Meter via the Model 6172-triax adapter.
- Model 6172 Adapter: The Model 6172 is a two-slot male to three-lug female adapter to connect the 7078-TRX series low noise triax cable to the Model 2500INT.

Optical port adapters

The following optical adapters are available to make fiber-optic cable connections to the Model 2500INT optical entrance port.

- 2500INT-FC/PC for use with FC/PC or FC/SPC terminated fibers.
- 2500INT-FC/APC for use with FC/APC terminated fibers.
- 2500INT-SMA for use with SMA terminated fibers.

Product overview

The 2500INT series are integrating sphere-based detectors specifically designed to provide highly accurate light intensity measurements. The integrating sphere simplifies production testing of optical components by eliminating common measurement problems related to detector alignment, beam profile, polarization, and back reflection.

Available models

As summarized in Table 1-1, there are three different available models, dependent on detector type. See the Model 2500INT specifications for key characteristics of each model.

Table 1-1
Model 2500INT versions

Model	Detector Type
2500INT-2-Si	Silicon
2500INT-2-Ge	Germanium
2500INT-2-IGAC	Cooled indium gallium arsenide

Configuration

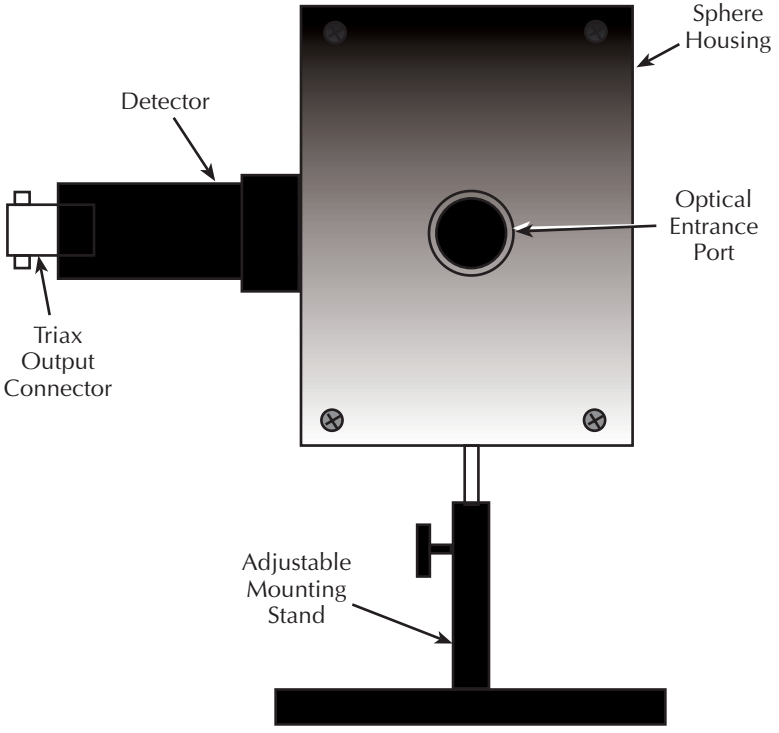
As shown in Figure 1-1, the 2500INT consists of a sphere housing (aluminum rectangular enclosure), detector, mounting stand, and temperature controller (for 2500INT-IGAC).

Key components include:

- Detector output: 2-lug female triax connector to connect the unit to the Model 2500 Dual Photodiode Meter.
- Optical input port: 1/2 inch port connects either via fiber or directly to LED or laser diode module under test.
- Adjustable stand: allows positioning the unit at a convenient height.
- Temperature controller (not shown; Model 2500INT-IGAC only): integral TEC and thermistor sensor to maintain detector at desired temperature.

NOTE *Specifications are subject to change without notice.*

Figure 1-1
Model 2500INT configuration



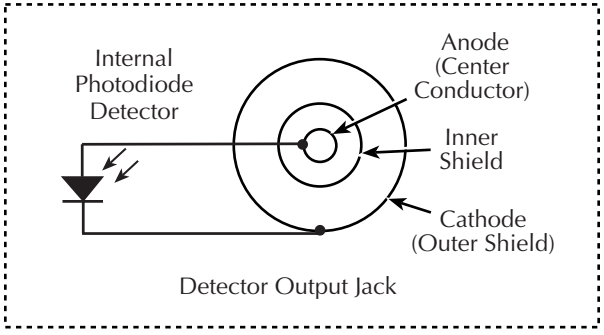
2
Getting Started

Electrical connections

Detector output terminals

Figure 2-1 shows the configuration of the detector output terminals. Note that center conductor is the anode, while the outer shield is connected to the cathode.

Figure 2-1
Detector terminals



Model 2500INT

Connections to Model 2500

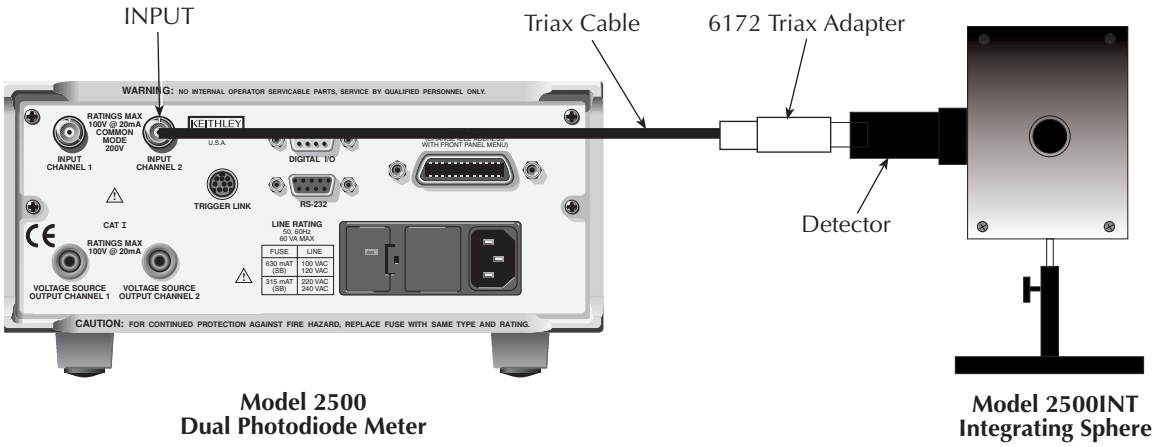
Using Figure 2-2 as a guide, make electrical connections to the desired Model 2500 Dual Photodiode Meter channel as follows:

1. Install the Model 6172 two-slot male to three-lug female adapter on the Model 2500INT detector output connector.
2. Connect one end of the Model 7078-TRX triax cable to the Model 6172 triax adapter.
3. Connect the other end of the Model 7078-TRX triax cable to the desired Model 2500 INPUT jack.

CAUTION **Do not attempt to connect BNC connectors to the Model 2500INT triax detector output jack. Attempting to do so may damage the connector, voiding the warranty.**

NOTE *The ground connect mode must be disabled to use the connections shown in Figure 2-2. See Section 2 of the Model 2500 User's Manual for connection details.*

Figure 2-2
Electrical connections



Connections to DUT

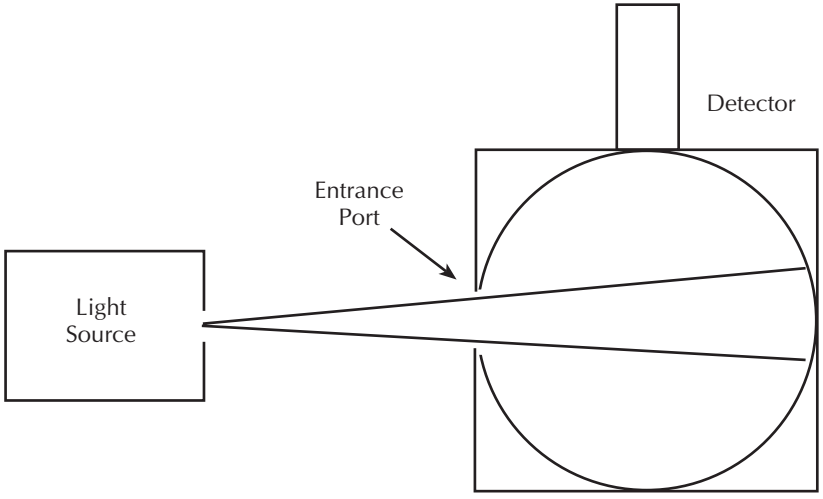
Free space operation and alignment considerations

For free space operation, remove the entrance port cover then position the Model 2500INT as close as possible to the DUT. Proper alignment of the Model 2500INT to the light source under test is important for optimum optical power measurement. Key considerations include divergent beams, collimated beams, and full beam collection.

Divergent beams

Devices such as diode chips and bars have divergent beams. As shown in Figure 2-3, the beam diameter increases as distance from the source increases. If improperly placed, the port could block some of the entrance beam and lead to inaccurate power measurement.

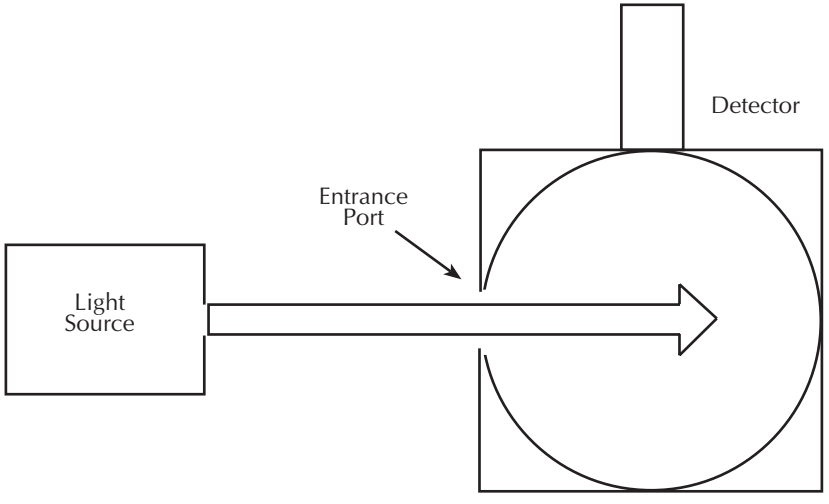
Figure 2-3
Divergent beams



Collimated beams

Collimated beams differ from divergent beams in that the edges of the beam are parallel. As shown in Figure 2-4, the beam diameter stays constant even as the distance from the source increases.

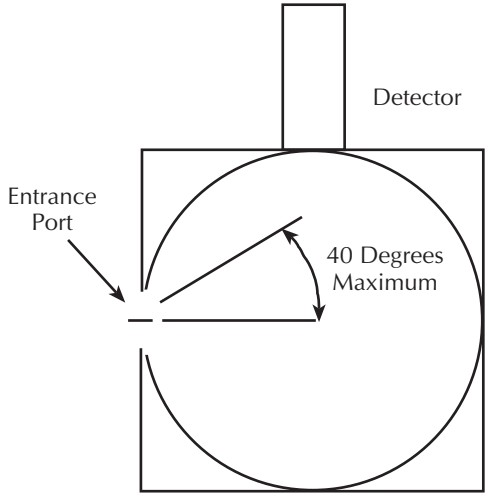
Figure 2-4
Collimated beams



Full beam collection

Full beam collection is important for optimum optical power measurement (Figure 2-5). The maximum acceptance angle of the sphere is 40° half angle (divergence) from the entrance port. For optimum operation, keep the light source angle to a minimum.

Figure 2-5
Acceptance angle



Fiber-coupled connections

Port adapters

One of the following optional port adapters are required to connect a fiber-optic cable to the Model 2500INT.

- 2500INT-FC/PC for use with FC/PC or FC/SPC terminated fibers
- 2500INT-FC/APC for use with FC/APC terminated fibers
- 2500INT-SMA for use with SMA terminated fibers

Using fiber port adapters

1. Attach the fiber port adapter by loosening two hex mounting screws on the adapter with the provided tool (0.035 in./0.9mm hex wrench), placing the port adapter over the sphere optical entrance port, and gently tightening the hex mounting screws.
2. Clean the tip of the fiber-optic cable with gentle swipes from a cotton swab lightly dipped in isopropyl alcohol or a mechanical reel style fiber optic cleaner.
3. Attach the proper fiber-optic cable connector to the adapter and gently tighten.

WARNING **The following safety practices must be used to protect operators and other users of this product from potential exposure to laser radiation:**

- **Operators must be protected from radiation and electrical hazards at all times.**
- **An interlock is required for safe operation. The test fixtures must ensure that the interlock circuit is disabled (source outputs inhibited) so that an operator is not exposed to any radiation. The test fixture interlock must not be defeated.**
- **The customer's Laser Safety Officer (LSO) must review and approve all installations before being put into operation. Any safety concerns must be immediately reported to the customer's LSO.**

Mating optical connectors

Observe the following precautions when mating optical connectors:

- Clean both connectors prior to mating. Any small particles trapped during the mating process can permanently damage the connector.
- Insert the appropriate connector ferrule into the adapter smoothly. Do not allow the fiber tip to contact any surface. If the tip accidentally contacts a surface before mating, do not make the connection. Reclean the connector and try again.
- Tighten the connector until it is finger tight or to the torque specified by the connector manufacturer. Do not overtighten the connector as this can lead to optical loss and connector damage.
- Check the optical insertion loss. If the loss is unacceptable remove the connector, reclean both ends of the mate, and reconnect. You may have to repeat this process several times before a low-loss connection is made.
- After you make the connection, monitor the stability of the optical throughput for a few minutes. Optical power trending (slowly increasing or decreasing) is caused by the slow evaporation of alcohol trapped in the connection. Continue to monitor optical power until it stabilizes. (Optical power trending can also be a natural effect of the laser source as it warms up.) If the loss is unacceptable, reclean the connectors and start again.

Handling fiber-optic cables

Treat fiber-optic cables with care to avoid cable damage and minimize optical loss. The minimum bend radius for most optical cables is 35mm. Never bend an optical cable more sharply than this specification. Optical performance will degrade and the cable may break.

General handling precautions include:

- Avoid bending the optical cable near a cable strain relief boot or switch housing. Bending an optical cable near a strain relief boot or switch housing is one of the easiest ways to permanently damage the optical fiber.
- Avoid bending the optical cable over a sharp edge.
- Avoid using cable tie wraps to hold optical cable. Tie wraps can create micro-bends or break an optical cable when tightened. Micro bends can cause a dramatic reduction in optical performance.
- Do not pull on the bare fiber. Doing so can break the fiber inside the component.
- Avoid using soldering irons near optical cable. Accidental damage can easily occur when a soldering iron is used near an optical cable. In addition, solder splatter can contaminate and permanently damage optical fiber connectors.
- In order to obtain the most stable, repeatable optical performance, immobilize optical cables using wide pieces of tape or some form of mechanical cushion after the optical cables have been connected.

Instrument setup

The Model 2500 Dual Photodiode Meter must be properly set up to measure and display optical power using the supplied Model 2500INT calibration constants and measured dark current as outlined below.

NOTE *The procedures outlined below provide only an overview for optical power measurements. For complete details on setting up the Model 2500, see Section 4 of the Model 2500 User's Manual.*

Model 2500INT calibration constants

Each Model 2500INT is supplied with calibration constants that are necessary to properly setup the Model 2500 to measure optical power. The key constants for the procedures below are responsivity, which is given in amps/watt.

Model 2500 firmware revision

Model 2500 units with Rev. A02.1 or later firmware have built-in optical power measurement capabilities. For Model 2500 units with firmware from A01 to A02.1, use the MX+B math function to calculate optical power as described in the Model 2500 User's Manual.

You can determine the firmware revision level as follows:

- From the front panel, use the MENU/GENERAL/SERIAL # selection.
- Use the *IDN? query via remote.

Detector dark current measurements

Description

The dark current is a current offset produced by the detector in the absence of light. Its value is based on many factors including the reverse bias voltage on the detector, temperature, semiconductor architecture, and even the quality of the semiconductor material itself. Proper measurement of and compensation for the dark current will ensure accurate absolute optical power measurements.

Typical responsivity values are summarized in Table 2-1.

Table 2-1
Typical responsivity values

Detector	Typical Responsivity (mA/W)
Silicon (2500INT-Si)	0.1 @ 960nm
Germanium (2500INT-Ge)	0.6 @ 1550nm
Indium Gallium Arsenide (2500INT-IGAC)	0.07 @ 1550nm

Detector voltage bias

Detector dark current is measured with 0V bias values. It is recommended that you also make your normal optical power measurements with 0V detector bias values, or optical power measurement accuracy will be affected by changes in dark current and responsivity.

Measuring dark current

1. Connect the Model 2500INT to the desired Model 2500 input channel.
2. Cover the optical input port of the Model 2500INT with a dust-free, lightproof cover. Light leakage will result in erroneous dark current measurements and will effect the overall accuracy of absolute power measurements.
3. From the Model 2500 front panel, press the CHANNEL SELECT key until the channel to which the Model 2500INT is connected is displayed.
4. Press the STORE key, and enter the number of readings to store. 3000 is the maximum number of stored points allowed and will give you better statistical data in calculating the average dark current.
5. Press ENTER. The Model 2500 will begin acquiring data at a rate determined by the NPLC setting. Data storage is indicated by a star (asterisk) annunciator on the front panel. When finished, the asterisk will turn off.
6. When the Model 2500 is finished acquiring data, press the RECALL key to access the data storage buffer.
7. Press the TOGGLE key until the average value of the current measurement is displayed. This value is the average dark current for the detector. Use this value when setting up the optical power measurement.

Optical power measurements

Optical power calculation

Optical power is calculated as follows:

Optical power = $(I_{measured} - I_{dark\ current})$/Responsivity

Where: $I_{measured}$ = measured photodiode current (amps)

$I_{dark\ current}$ = photodiode dark current in amps (see above)

Responsivity = amps/watt (see supplied Model 2500INT calibration constants)

Configuring optical power measurements

1. Press CONFIG then MSR1 or MSR2 to select channel 1 or channel 2 as required.
2. Select P→, then press ENTER.
3. At the prompt, enter the detector responsivity (R) value from the supplied Model 2500INT calibration constants, then press ENTER.
4. At the prompt, enter the detector dark current (D), as determined from the above procedure, then press ENTER.
5. If you are using the connections shown in Figure 2-2, disable the ground connect mode as follows:
   a. Press CONFIG then SRC1 or SCR2 as required.

b. Select GND-CONNECT then press ENTER.
c. Select DISABLE, then press ENTER.

6. Press the MSR1 or MSR2 key as required to select the desired channel.
7. The Model 2500 will then display optical power on the selected channel using the measured photodiode current and the programmed responsivity and dark current values.

Remote instrument setup

Basic optical power commands

Model 2500 units with Rev. A02.1 or later firmware can be set up for remote optical power measurements by using the commands summarized in Table 2-3. See Sections 4 and 17 of the Model 2500 User's Manual for details on using these and other commands necessary for complete measurements.

Table 2-2
Remote optical power commands

Command	Description
:CALC1:FORM OP1	Select channel 1 optical power math function.
:CALC1:KMAT:DC <dark_current>	Set channel 1 dark current (amps).
:CALC1:KMAT:RESP <responsivity>	Set channel 1 responsivity (amps/watt).
:CALC1:STAT ON	Enable channel 1 math.
:CALC1:DATA?	Query channel 1 math data.
:CALC2:FORM OP2	Select channel 2 optical power math function.
:CALC2:KMAT:DC <dark_current>	Set channel 2 dark current (amps).
:CALC2:KMAT:RESP <responsivity>	Set channel 2 responsivity (amps/watt).
:CALC2:STAT ON	Enable channel 2 math.
:CALC2:DATA?	Query channel 2 math data.

Programming example

Table 2-3 summarizes the basic command sequence for optical power measurements on channel 1. These commands set up the Model 2500 as follows:

- Measurement range: auto
- Math function: optical power
- Responsivity: 0.6mA/W
- Dark current: 1µA
- Ground connect mode: Disabled
- Bias voltage: 0V

Table 2-3
Optical power programming example

Command*	Description
*RST	Restore GPIB defaults.
:SENS1:CURR:RANG:AUTO ON	Enable channel 1 current measure auto range.
:CALC1:FORM OP1	Select channel 1 optical power measurement.
:CALC1:KMAT:RESP 6e-4	Responsivity = 0.6mA/W.
:CALC1:KMAT:DC 1E-6	Dark current = 1µA.
:CALC1:STAT ON	Enable channel 1 math.
:SOUR1:GCON OFF	Disable ground connect mode.
:SOUR1:VOLT 0	Channel 1 bias voltage = 0V.
:OUTP1 ON	Turn on channel 1 source output.
:INIT	Trigger reading.
:CALC1:DATA?	Request optical power reading.
:OUTP1:OFF	Turn off channel 1 source output.

* Unit must be addressed to talk after :CALC1:DATA?

Using the temperature controller

The Model 2500INT-IGAC includes a temperature control module to maintain the indium gallium arsenide detector at the proper temperature for optimum operation. To use the controller:

1. Connect the controller TEC and sensor connections to the detector body.
2. Connect the controller to the appropriate power source.
3. Turn on the power and set the temperature to the desired temperature (typically -10˚C).
4. Allow sufficient time for the temperature to stabilize before use.

3
Maintenance

Handling and cleaning precautions

Dust

Cover the optical port opening when not in use to prevent internal contamination of the Model 2500INT. Inconsistencies on the internal surface of the sphere will cause inaccuracies in measurements.

Cleaning

- Clean any exposed connector using a cleaning kit supplied by the connector manufacturer or high-grade isopropyl alcohol and a cotton swab.
- To clean with alcohol and a swab, dab the tip of a cotton swab in alcohol and then shake off any excess alcohol. The tip should be moist, *not dripping* wet. Stroke the swab tip gently across the surface of the connector and around the connector ferrule.
- Either allow the connector a minute to dry or blow dry the connector using clean compressed air. Be careful when using compressed air because improper use may deposit a spray residue.

Calibration

The Model 2500INT should be calibrated once a year. Contact your Keithley representative or call the factory directly to inquire about these services.

Service Form

Model No. _____ Serial No. _____ Date _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❑ Intermittent ❑ Analog output follows display ❑ Particular range or function bad; specify

_____

❑ IEEE failure ❑ Obvious problem on power-up ❑ Batteries and fuses are OK

❑ Front panel operational ❑ All ranges or functions are bad ❑ Checked all cables

Display or output (check one)

❑ Drifts ❑ Unable to zero ❑ Unstable

❑ Overload ❑ Will not read applied input

❑ Calibration only ❑ Certificate of calibration required ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

_____

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

Specifications are subject to change without notice.

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