Agilent 81002FF Operating Notes

Agilent Technologies

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The Structure of this Manual

This manual is divided into three parts:

- *"Introduction" on page 9* gives you some general information about the Integrating Sphere and its use.
- *"Applications of the Agilent 81002 FF Integrating Sphere" on page 17* gives you some information about particular applications of the Integrating Sphere.
- *"Installation and Maintenance" on page 25* contains details about installation and maintenance.
- *"Specifications" on page 31* contains additional information not required for routine day-to-day use.

Contents

Figures

Introduction

This chapter introduces the features of the Agilent 81002FF Integrating Sphere.

The Integrating Sphere is a universal accessory for the optical heads of the Agilent 8163A Lightwave Multimeter, Agilent 8163A Lightwave Measurement System, Agilent 8166A Lightwave Multichannel System, or the HP 8153A Lightwave Multimeter. It enables measurements of high optical power levels up to 10 Watts, and/or sources with a high numerical aperture of up to NA 0.5.

You can also measure large emission sources, including ribbon fiber connectors with up to 12 fibers with NA 0.3. The Integrating Sphere scrambles the input polarization of polarized light sources.

Here you will find a quick description of the accessory, and how to use the Integrating Sphere to make power measurements.

What is an Integrating Sphere ?

An integrating sphere consists of two hemispheres that are mated together to form a spherical cavity. The inside of the sphere is made of a highly reflective material that reflects diffusely.

Figure 1 Integrating Sphere

Radiation is launched into the sphere through an input port. This radiation reflects randomly off the sphere's interior walls. Because of the geometry, high reflectivity, and diffuse reflectance of the sphere's interior walls, an integrating sphere converts input beam distribution into a very uniform spatial radiation distribution.

The radiation level of the distributed light is directly proportional to the amount of radiation introduced into the sphere. A detector mounted on the output port of the sphere measures the intensity of the radiation.

The integrating sphere behaves like an attenuator in front of the detector. Because of the optical transmission loss from the integrating sphere's input port to its output port, you can launch very high optical power levels into the integrating sphere without causing detector saturation problems.

The integrating sphere operates as a light collector. The sphere captures diverging beams from a laser diode or an optical fiber, as well as beams from spatially distributed sources, like laser arrays or fiber optic ribbon cables. The integrating sphere also captures collimated laser beams.

Power measurements are independent of beam polarization. Polarized radiation launched into the input port leaves the output port virtually unpolarized. The numerous diffuse and random reflections at the sphere wall scramble any polarization state. This means that the output radiation of the sphere consists of a mixture of many different polarization states, with the total being virtually unpolarized.

Power measurements are insensitive to beam alignment. This is also a result of the unique integrating property of the integrating sphere.

The integrating sphere is an ideal device for measuring the total power of visible and near infra-red radiation. The integrating sphere operates as a geometrical coupler; it couples a certain percentage of the input signal to the connected optical head and the remainder is absorbed by the sphere itself.

The usable wavelength range of the integrating sphere is only limited by the wavelength dependence of the reflectance of the used material. This material has sufficiently high reflectance in the visible (> 95%) and near infra-red (> 98-99 %) wavelength range.

The design of an integrating sphere always involves a trade off between optical loss and performance. Optical performance is related to the uniformity of radiation distribution over the interior of the sphere. In general, optical performance increases with the size of the sphere.

The Agilent 81002 FF Integrating Sphere

The Agilent 81002 FF Integrating Sphere is an accessory for the Agilent 8163A Lightwave Multimeter, Agilent 8163A Lightwave Measurement System, Agilent 8166A Lightwave Multichannel System, and the HP 8153A Lightwave Multimeter. It can be used with all Agilent Technology Optical Heads and all HP Optical Heads.

The Integrating Sphere is compatible with all connector adapters and bare fiber adapters Agilent 81000xx, which can be used with these optical heads.

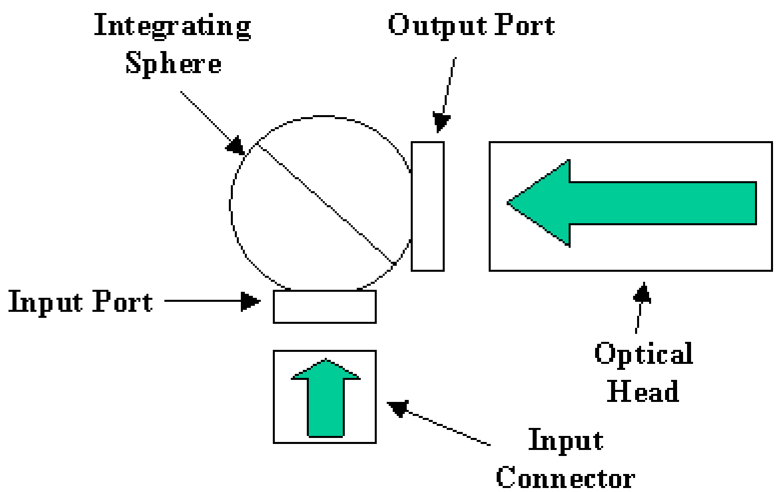

Figure 2 Connections to the Agilent 81002 FF Integrating Sphere

The Agilent 81002 FF Integrating Sphere has three main advantages, it allows measurements with:

- high optical power levels,
- large emission sources, either widely diverging point sources (high numerical aperture (NA)) or light sources with large beam diameters,
- polarized optical sources; it scrambles the input polarization.

The Agilent 81002 FF Integrating Sphere allows the measurement of high optical power levels up to 10 W (+40 dBm) due to its typical optical attenuation of 40 dB. The optical loss of the integrating sphere shifts the dynamic range of a connected optical head by +40 dB to higher power levels.

For example, the optical head HP 81524A with a power range of +0 dBm to -90 dBm mated to the Integrating Sphere has a ‘new’ power range of +40 dBm to -50 dBm.

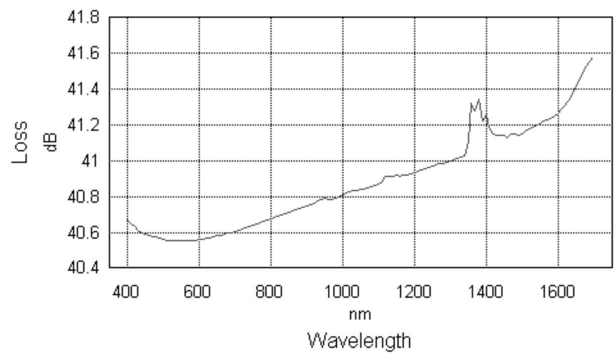

Figure 3 **Variation of loss with wavelength**

The integrating sphere operates over a wide wavelength range: from 450 nm to 1650 nm. The reflectivity of the sphere’s walls changes with the wavelength of the light source. Figure 3 shows how this affects the loss of the Integrating Sphere.

The Integrating Sphere is designed to connect to the following Optical Heads:

- Agilent 81623A Optical Head,
- Agilent 81624A Optical Head,
- Agilent 81625A Optical Head,
- HP 81520A Optical Head,
- HP 81521B Optical Head,
- HP 81524A Optical Head, and
- HP 81525A Optical Head.

An Optical Head connected to the Integrating Sphere can be used for both relative and absolute optical power measurements.

Relative Optical Power Measurement

To measure relative optical power:

1 Attach the Integrating Sphere to the optical head.

2 Attach the appropriate connector or bare fiber adapter to the input port of the Integrating Sphere.

3 Perform the relative measurement in dB.

Absolute Optical Power Measurement

For absolute optical power measurement the loss of the Integrating Sphere is measured as a reference. The loss of the sphere for a particular set of readings is dependent on the wavelength characteristics of the chosen light source and on the mechanical tolerances of the individual Integrating Sphere.

To measure the optical loss of the Integrating Sphere:

1. Connect a standard laser diode source of the appropriate wavelength, having output power of 1 mW output power or less to a standard fiber cable (single or multimode fiber with NA < 0.25).
2. Take a reference value (0 dB) by connecting this fiber directly to the optical head.
3. Connect the Integrating Sphere to the optical head.
4. Attach the appropriate connector or bare fiber adapter to the input port of the Integrating Sphere.
5. Perform the loss measurement.
6. Set the CAL value of the HP 8153A Lightwave Multimeter to the measured loss value (for example -40 dB) so that it can be taken into account for future absolute power measurements.
7. Set the measurement units to Watts; the display should indicate the output power of the laser source (for example 1 mW).

Optical Beam Distributions

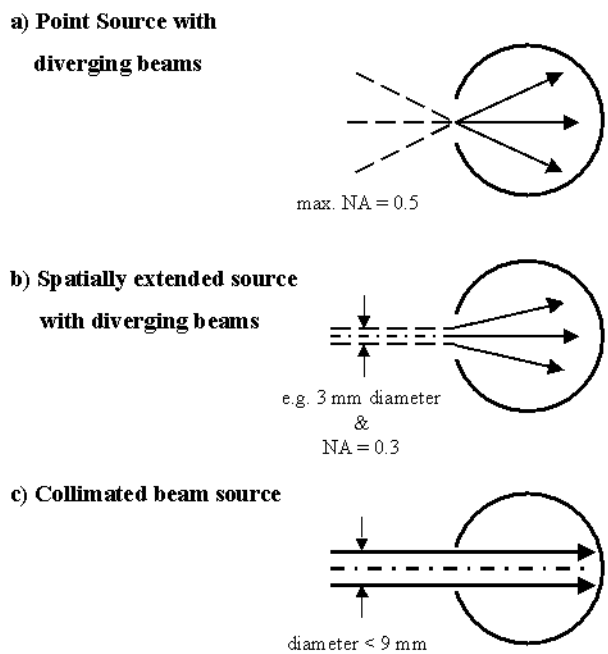

Figure 4 Beam distribution at the Integrating Sphere's input port

The input port of the Agilent 81002 FF Integrating Sphere accepts different types of optical beam distributions. The following optical beam distributions are illustrated in Figure 4:

a point source with diverging beam distribution, for example, a diode laser or single fiber,

b spatially extended source with diverging beam distribution, for example, a laser array or ribbon fiber,

c collimated beam source distribution, for example, the parallel beams of a gas laser or a parallel beam after lens collimation.

Applications of the Agilent 81002 FF Integrating Sphere

This chapter deals with specific applications of the Agilent 81002 FF Integrating Sphere. These applications include high power, high numerical aperture, and ribbon fiber applications.

High Power Application

The Agilent 81002 FF Integrating Sphere allows you to perform optical power measurements of up to 10 W. The Integrating Sphere acts as an attenuator; only one part in 10,000 (40 dB) of this optical power reaches the photodetector of the optical head.

Almost all of the optical power is absorbed by the Integrating Sphere itself causing an increase in the temperature of the sphere material. The outer surface of the Integrating Sphere radiates the absorbed energy to the surrounding air.

For a sphere with inner radius, R, of 25 mm, and sphere multiplier, M, (which accounts for multiple reflections in the sphere) of 25, after numerous reflections, an input power level, P_{MAX}, of 10 W will create a maximum integral power density, E_{MAX}, of:

$$E_{MAX} = \frac{P_{MAX}}{Area_{sphere}} M = \frac{P_{MAX}}{4\pi R^2} M = \frac{10}{4\pi(25)^2} 25 \frac{W}{mm^2} = 0.032 \frac{W}{mm^2}$$

NOTE To prevent a “hot spot”, never focus the input power onto the sphere wall at the first strike.

For single mode fiber with numerical aperture (NA) of 0.1 at first strike, the radiated area on the sphere wall has a radius, r,of 5 mm. In the near infrared region, the sphere material has an absorption coefficient, α, of approximately 0.01. At first strike, the optical power density of this radiated area, E_{spot}, is:

$$E_{spot} = \frac{P_{MAX}}{Area_{spot}} \alpha = \frac{P_{MAX}}{\pi r^2} \alpha = \frac{10}{\pi(5)^2} 0.01 \frac{W}{mm^2} = 0.0013 \frac{W}{mm^2}$$

This example illustrates that for a light source of 10 W optical power and a fiber with low divergence (NA = 0.1) a “hot spot” is not produced at the Integrating Sphere’s surface. This consideration is much less critical for sources with wider diverging beam distributions, for example laser diodes and fibers with NA > 0.1.

High NA Application

The main advantage of the Integrating Sphere is its radiation collecting function. The Agilent 81002 FF Integrating Sphere can be used with high numerical apertures sources.

The two openings in the sphere wall, the input and output ports, disturb the perfect integrating function of the Integrating Sphere. The positions and size of the openings for the input and output ports of the Agilent 81002 FF Integrating Sphere are designed to optimize the sphere’s integrating function.

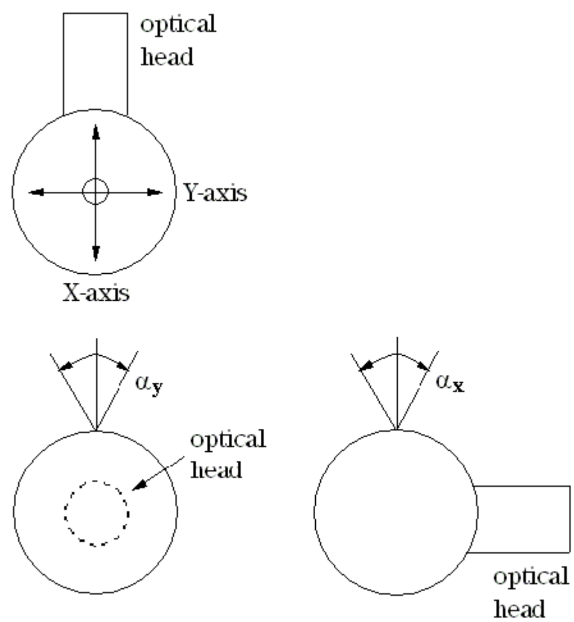

Figure 5 X-axis and Y-axis relative to input and output port

Figure 5 defines the position of the X-axis and Y-axis relative to input and output ports. The X-axis intersects both the input and output ports, while the Y-axis intersects the input port alone. A single mode fiber with NA = 0.1 was tilted in the plane of the X-axis and Y-axis to measure the loss change relative to angle. Figure 5 describes the angles α_x and α_y indicating the inclination of each fiber in the plane of each axis. The end of the fiber is always positioned in the center of the opening of the input port.

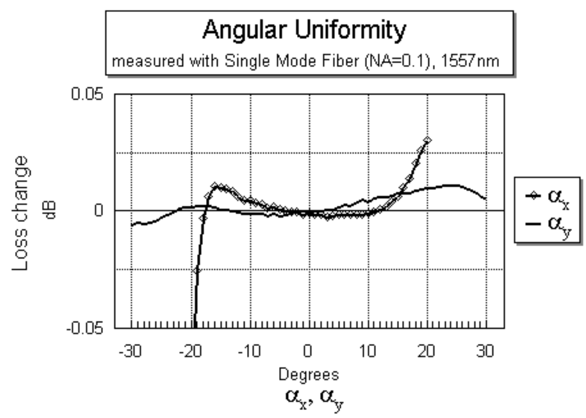

Figure 6 Angular Uniformity

Figure 6 shows the effect of tilting the fibers in this way. Angular uniformity in the plane of the Y-axis is better than in the plane of the X-axis.

The difference in angular uniformity is important for use with laser diodes. Laser diodes have an asymmetric beam distribution output. The source axis with the wider beam distribution should be oriented to the Y-axis to get more precise measurement results.

Ribbon Fiber Application

Today’s ribbon fibers consist of up to 12 fibers positioned in a linear array with each fiber spaced 0.25 mm apart. In the case of a 12-fiber array, total length is 2.75 mm. A fiber array is not a point source, it is an array of point sources with diverging beam distributions.

Optical power measurement of these ribbon fibers requires a large area detector with very uniform responsivity. Large area detectors have an active area of 5 mm diameter. These detectors have a uniformity of the responsivity of typically ±0.04 dB to ±0.08 dB, but only in central 80% of the diode diameter. Power measurements require uniform responsivity; limiting the usable active area to 4 mm.

The output of the ribbon fiber has a large beam distribution, so optical power measurement using a 5 mm detector is not sufficiently precise or uniform.

The Integrating Sphere offers a power measurement with a lateral uniformity of ±0.003 dB for a 6 mm active diameter, as shown in Figure 7 (the X-axis and Y-axis refer to Figure 5). The integrating sphere operates as a large area detector with a very uniform active area of 6 mm diameter.

This makes the Agilent Technologies 81002 FF Integrating Sphere a good choice for optical power measurements with ribbon fibers.

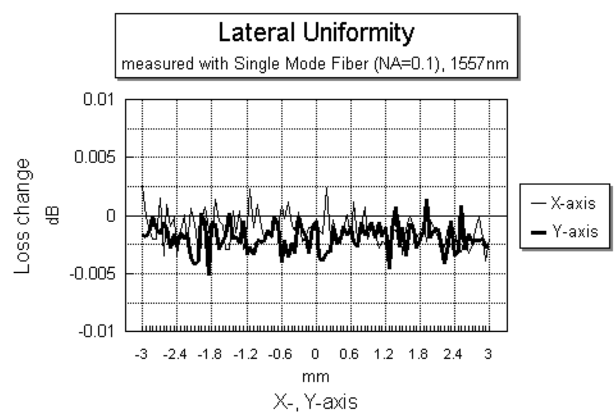

Figure 7 Lateral Uniformity

Hints for Handling

NOTE Never pour oil, such as immersion oil, into the Integrating Sphere!

NOTE Clean with dry compressed air.

NOTE Never focus the input power onto the sphere wall at the first strike!

Installation and Maintenance

The Agilent 81002FF Integrating Sphere is produced to the ISO 9001 international quality system standard as part of Agilent Technologies' commitment to continually increasing customer satisfaction through improved quality control.

Safety Considerations

Laser Safety

The Integrating Sphere may be used with high power lasers. Refer to the appropriate laser safety documentation for the particular light source used.

Initial Inspection

Inspect the shipping container for damage. If there is damage to the container or cushioning, keep them until you have checked the contents of the shipment for completeness and verified the Integrating Sphere mechanically.

If the contents are incomplete, mechanical damage or defect is apparent, or if the Integrating Sphere does not pass the operator's checks, notify your nearest Agilent Technologies Sales/Service Office.

Operating and Storage Environment

The operating environment ranges for temperature and humidity are determined by the Optical Head used. Refer to the appropriate documentation for these limits.

Temperature and Humidity

Protect the Integrating Sphere from temperature extremes and changes in temperature that may cause condensation within it.

Claims and Repackaging

If physical damage is evident or if the instrument does not meet specification when received, notify the carrier and the nearest Agilent Technologies Service Office. The Sales/Service Office will arrange for repair or replacement of the unit without waiting for settlement of the claim against the carrier.

Return Shipments to Agilent Technologies

If the instrument is to be shipped to a Agilent Technologies Sales/Service Office, attach a tag showing owner, return address, model number and full serial number and the type of service required.

The original shipping carton and packing material may be reusable, but the Agilent Technologies Sales/Service Office will provide information and recommendation on materials to be used if the original packing is no longer available or reusable.

General instructions for repacking are as follows:

1. Wrap the Integrating Sphere in heavy paper or plastic.
2. Use strong shipping box. Single wall corrugated carton (Material 1.40 per DIN 55468), which is the equivalent of 200-pound bursting strength material, should be adequate.
3. Use an appropriate shock absorbing material around all sides of the Integrating Sphere to provide a firm cushion and prevent movement inside the container.
4. Seal the shipping container securely.
5. Mark the shipping container FRAGILE to encourage careful handling.
6. In any correspondence, refer to the instrument by model number and serial number.

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Any adjustment, maintenance, or repair of this product must be performed by qualified personnel. Contact your customer engineer through your local Agilent Technologies Service Center. You can find a list of local service representatives on the Web at:
http://www.agilent-tech.com/services/English/index.html

If you do not have access to the Internet, one of these centers can direct you to your nearest representative:

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Canada:	(905) 206-4725
Europe:	(31 20) 547 9900
Japan:	Measurement Assistance Center (81) 426 56 7832 (81) 426 56 7840 (FAX)
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Specifications

The Agilent 81002FF Integrating Sphere is produced to the ISO 9001 international quality system standard as part of Agilent Technologies' commitment to continually increasing customer satisfaction through improved quality control.

Characteristics

- **Insertion Loss**[1]: typ. 41 dB ±1 dB at 1310 nm and 1550 nm.
- **Return Loss**[2]: typ. > 60 dB.
- **Maximum Input Power**: typ. 40 dBm (10W).
- Power density ≤ 0.13 W/mm^2 at distance = 50 mm behind input aperture (NA ≥ 0.1 at 10 W).
- **Wavelength range**: 450 nm to 1650 nm.
- **Optical signal input**[3]

  Applicable signals:
  - **point source / single fiber**: SM, MM, NA ≤ 0.5.
  - **open beam (parallel)**: parallel beam Ø ≤ 7 mm.
  - **large area emission (Ribbon fiber)**: Ø ≤ 3 mm, and NA ≤ 0.3.
- **Angular uniformity**: for typical dependency, see Figure 6.
- **Lateral uniformity**: for typical dependency, see Figure 7.
- **Dimensions**: 80 mm x 80 mm x 100 mm.
- **Weight**: 350g (772 lb).
- **Operating Temperature**: 0° to 40° C, non-condensing.
- **Relative Humidity**: ≤ 95%, non-condensing

[1] For typical wavelength dependency, see Figure 3. The Integrating Sphere has depolarizing properties, and therefore reduces the polarization dependence of the applied detector.

[2] Return loss of sphere measured with standard single-mode fiber.

[3] Input aperture of sphere Ø ≤ 9 mm.

Index