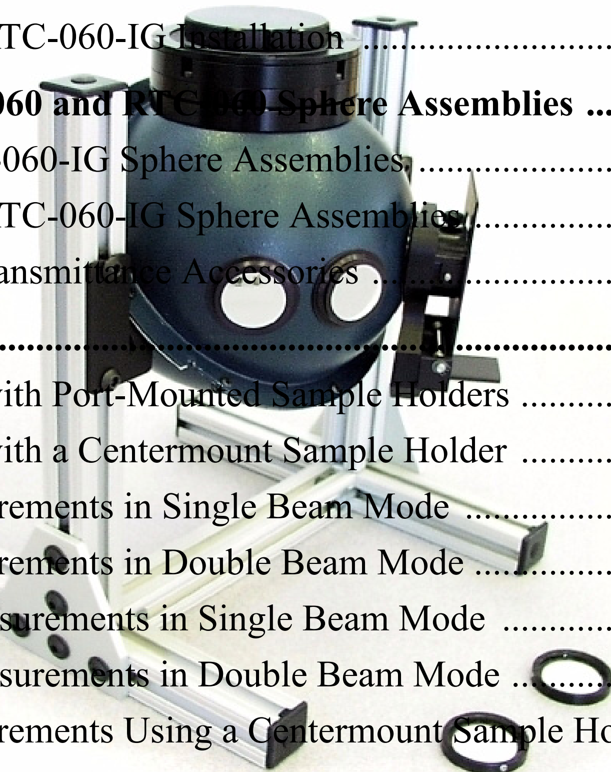
Reflectance and Transmittance Measurement Integrating Spheres



SX-02484-100, Rev. 2

Introduction

An integrating sphere is an optical component that can serve one of two purposes: either as a uniform source or as a light measurement device. The light measurement spheres described in this instruction manual can be used to measure the reflectance or transmittance of light through a sample medium. Labsphere offers two standard products for reflectance and transmittance measurement, both products available in one of two reflective coatings. The RT-060-SF and RT-060-IG sphere assemblies constitute our most basic reflectance measurement product. The RT-060-SF is coated internally with Spectraflect, our highly diffuse reflective coating over the 300 - 2400 nm spectrum. The RT-060-IG is coated with Infragold, designed for use in the 0.7 - 20 µm wavelength spectrum. The RT-060-SF and RT-060-IG sphere assemblies are suitable for all geometric transmittance measurements, and reflectance measurements in the specular included (9°/h) and specular excluded (9°/d) geometries. The alternate to the RT-060 Series light measurement sphere is the RTC-060 Series. The RTC-060-SF and RTC-060-IG integrating spheres provide similar measurement capabilities to the basic sphere design as well as reflectance measurement capabilities at variable angles of incidence. The reflectance material characteristics of the RTC-060-SF and RTC-060-IG are identical to the RT-060 Series.

Custom Labsphere components usually are identifiable by the "CSTM" prefix used in the part name and the "CY" or "CA" prefix in the part number. These products typically are very similar to the standard products except for port location and size, port attachments, and possibly the internal reflectance material used. Specifications for the RT and RTC sphere assemblies can be viewed in Appendix A of this instruction manual. Typical reflectance data for the Spectraflect and Infragold coatings is provided in Appendix B.

This instruction manual provides assembly instructions and operating information regarding the standard RT-060 and RTC-060 series products and custom reflectance and transmittance measurement spheres similar to the standard product. If your system is custom, choose the instructions for the standard product sphere assembly closest to your sphere configuration.

Sphere Assembly	Labsphere Part No.	Spectral Range	Measurement Capabilities (Single or Double Beam)
RT-060-SF	AS-02484-100	250 - 2500 nm	9°/h and 9°/d Reflectance Measurement All geometries of Transmittance Measurement
RT-060-IG	AS-02485-100	0.7 - 20 µm	9°/h and 9°/d Reflectance Measurement All geometries of Transmittance Measurement
RTC-060-SF	AS-02484-000	250 - 2500 nm	8°/h and 8°/d Reflectance Measurement All geometries of Transmittance Measurement Variable Angle Reflectance and Transmittance Measurement Cuvette Transmittance Measurement
RTC-060-IG	AS-02485-000	0.7 - 20 µm	8°/h and 8°/d Reflectance Measurement All geometries of Transmittance Measurement Variable Angle Reflectance and Transmittance Measurement Cuvette Transmittance Measurement

Table 1. RT and RTC integrating sphere capabilities.

Labsphere reflectance and transmittance integrating spheres are composed of two joined hemispheres, both coated with a highly diffuse reflectance coating. During reflectance or transmittance measurements, light entering one of the five sphere ports strikes the coated walls of the sphere and undergoes many diffuse reflections before exiting the device through a separate port or the 1/2-inch detector port located at the top or bottom of the sphere. The illumination from the sample beam is reduced across the wavelength spectrum by the transmittance of the sample located at the transmittance port or the reflectance of the sample mounted at the sample reflectance port. The spheres are adjustable in height and are mounted rigidly either on a 6" x 6" anodized aluminum base plate or an extruded aluminum frame.

Unpacking and Inspection

Your reflectance and transmittance integrating sphere assembly was thoroughly inspected before shipping. All Labsphere instrumentation is packaged and shipped in reinforced shipping containers. Carefully check the components after unpacking for any damage that may have occurred during shipping. If there is any such damage, file a claim immediately with the freight carrier and contact the Labsphere Customer Service Department at

(603) 927-4266.

The RT-060-SF and RT-060-IG includes the following components:

Integrating sphere assembly
1/2" to 1/4" port reducer
Two SH-100-0-SF sample holders
Four 1" port plugs
One LTRP-100-C light trap
Tool kit
Instruction manual

The RTC-060-SF and RTC-060-IG includes the following components:

Integrating sphere assembly
1/2" to 1/4" port reducer
Two SH-125 sample holders
One SH-100 sample holder
Two 1" port plugs
Two 1.25" port plugs
Two center-mount sample holders
One center-mount port plug
One LTRP-100-C light trap
Tool kit
Instruction manual

Optional attachments and accessories:

Calibrated or uncalibrated diffuse reflectance standards
Special center-mount devices
Detector assemblies
SC 6000 Radiometer and Control (standard Labsphere radiometer)
KI-120 Kohler Illuminator

Installation and Assembly

Use one of the following procedures to assemble your sphere assembly ready for storage. When assembling the RT-060-SF or RT-060-IG, take care to install the attachments to the correct sphere port. The sphere should be stored in a cabinet where no potential for internal contamination exists.

RT-060-SF and RT-060-IG Installation

The set screws for all devices attached to the RT-060-SF or RT-060-IG sphere assemblies accept a 1.5 mm hex wrench.

1. Screw the steel mounting post into the 1/4-inch boss at the bottom of the integrating sphere and mount the assembly onto the base plate.

Figure 1. Top view of the RT-060-SF sphere assembly. The setup for the RT-050-IG is identical to the one shown here. Attachments to the RT-060 series sphere assemblies must be installed at their correct locations.

2. The sample holders consist of a mounting plate, dovetail and spring-loaded clamp assembly that holds the sample against the port.
    a. Install the mounting plate and dovetail for the sample holders at the Port No. 1 and 2 locations shown in Figure 1. Tighten the two set screws along the edge of the plate so the dovetail is horizontal.
    b. Slip the clamp assembly for each sample holder over the dovetail now at each port.
3. Install the PR-050-250-SF/IG port reducer over the detector port frame, if desired. The purpose of this device is to limit the detector port collection area to within the active area of the sphere detector and thereby reduce the throughput of the integrating sphere. Reducer installation is not necessarily required for accurate measurements, however, the presence of a powerful sample or reference beam may saturate the detector if the reducer is not installed.

4. Install the sphere detector, if available, at the north pole port frame.
5. Install port plugs over the exposed sphere ports and store the sphere assembly in a clean, dry location.

RTC-060-SF and RTC-060-IG Installation

The RTC series integrating sphere assemblies include five sample holders: two center-mount sample holders, two 1.25-inch diameter sample holders and a single one-inch sample holder device. The set screws for all attachments accept a 1.5 mm hex wrench.

1. The beam port sample holders consist of a mounting plate, dovetail and spring-loaded clamp assembly that holds the sample against the port.
    a. Install the mounting plate and dovetail assemblies for the 1.25" diameter sample holders at the appropriate port locations. Tighten the two set screws for each device.
    b. Install the mounting plate and dovetail assembly for the one-inch diameter sample holder at the beam port directly opposite the 1.25" sample port. Tighten the two set screws.
    c. Slip the clamp assembly for each sample holder over the dovetails now at their corresponding port.
2. Install the PR-050-250-SF/IG port reducer over the detector port frame, if desired. The purpose of this device is to limit the detector port collection area to within the active area of the sphere detector and thereby reduce the throughput of the integrating sphere. Reducer installation is not necessarily required for accurate measurements, however, the presence of a powerful sample or reference beam may saturate the detector if the reducer is not installed.

Figure 2. Assembling the RTC-060-SF.

3. Install the sphere detector over the reducer or detector port frame, as applicable.
4. Install the center-mount port plug into the center port.
5. Install the remaining port plugs over the corresponding exposed sphere ports and store the sphere assembly in a clean, dry location.

Description of the RT-060 and RTC-060 Sphere Assemblies

The RT-060 and RTC-060 integrating spheres are designed specifically for transmittance or reflectance measurements. If your application is not one of these, a general purpose sphere may be more useful. The RT-060 and RTC-060 series sphere assemblies described in this instruction manual are categorized as *double beam* optical devices. The term *double beam* is used here to imply the port accommodation for the sample beam and an additional beam called the *reference beam*. A reference beam is used in spectroscopy to correct for fluctuations that may occur in the sample beam. When used with integrating spheres, the reference beam provides an added benefit of eliminating the presence of substitution error in reflectance and transmittance measurements.

The double beam configuration typically requires the use of a beam splitter and two shutters, one to control the beam at either entrance port to the sphere so that only one beam is present in the sphere at a time. If these optical components are not available, the RT or RTC sphere can be operated in *single beam* mode with a slight reduction in measurement accuracy. The reference beam ports are closed off or plugged when operating in single beam mode.

The light source can be monochromatic or full spectrum. The light source does not need to be a laser, however, the beam must be collimated or focused so the full cross-section fits inside the reflectance port on the far sphere wall. A quick inspection of the If the source is full spectrum, either a spectrometer is required for sensing the sphere illumination or the reflectance or transmittance data represents an average value between the upper and lower wavelength limits.

Both RT-060 and RTC-060 products feature a single half-inch diameter detector port. Labsphere offers four detector assemblies that mount over a detector port frame: the SDA-050-U-RTA-CX silicon photodiode, IDA-050-RTA-CX InGaAs photodiode, GDA-050-U-RTA-CX germanium photodiode and the PDA-050 photomultiplier detector. Information regarding detector characteristics is available in the Labsphere product catalog.

The difference between RT-060 and RTC-060 capabilities is angle of incidence during reflectance measurements. The RTC-060-SF and RTC-060-IG sphere assemblies include a center mount sample holder (CMSH) that positions the sample at variable angles inside the integrating sphere. The RT-060 and RTC-060 do not have a center mount feature. Since transmittance samples are always mounted outside the integrating sphere, there is no difference in transmittance capability between the two product series.

RT-060-SF and RT-060-IG Sphere Assemblies

Figure 3. Front view of the RT-060-SF integrating sphere.

The RT series spheres are coated with either Spectraflect for the RT-060-SF sphere or Infragold in the case of the RT-060-IG product. Optimum spectral ranges for these products are listed in the specifications of Appendix A and typical reflectance values for each coating is provided in Appendix B. The user may find it possible to obtain reflectance data slightly beyond these ranges, however, the accuracy of actual reflectance and transmittance measurement data may depend on the detector installed at the detector port. Sample holder and port plug components accompanying the RT-060-SF and RT-060-IG are coated with Spectraflect or Infragold respectively.

The RT series integrating sphere assemblies feature five beam or sample ports spaced strategically about the horizontal perimeter of the integrating sphere and a single 1/2" diameter port at the north pole. A port reducer is included with the package to reduce the port size from 1/2" to 1/4" diameter. The five one-inch diameter ports may appear to be identical but they are not. Two selected ports may be different by one or two design considerations:

- The location of some ports are based on a specific angle of incidence.
- Some ports are baffled, some are not.

The one-inch ports visible in Figure 3 are designated, from left to right, the reference beam entrance port, transmittance port and specular exclusion port respectively. The port designations on the rear RT-060 hemisphere are, from left to right in Figure 4, the reference port and sample reflectance port. A port schematic of the RT-060 sphere assemblies is provided in Appendix C.

Standard and optional attachments for the RT-060-SF and RT-060-IG integrating spheres are listed in the previous chapter entitled *Unpacking and Inspection* and are described in more detail in the next chapter. Sample holders and other attachments identified in the figure must be installed at the proper port locations or the reflectance and transmittance data generated may not be accurate. The one-inch port plugs may be installed at any port not in use. Attachments fasten directly to a port frame by two set screws that accept a 1.5 mm hex wrench.

Although all one-inch ports have a similar port frame, the reference and sample reflectance ports are intended to hold sample holders. These ports are baffled to prevent initial strike radiation from reaching the detector port at the north pole. Either port is adequate to fill the sample port function, however, the reference port in Figure 4 does not have the corresponding specular exclusion port on the opposite hemisphere. During transmittance applications, reflectance standards are loaded at both ports for both the 100% baseline and sample scans. During the sample scan, the transmittance sample is loaded at the transmittance port. During reflectance applications, reflectance standards are loaded at the both ports during the 100% baseline scans while the reflectance sample is loaded at the reflectance port during the sample scan.

Figure 4. Rear view of the RT-060-SF sphere.

The sphere geometry of the RT-060-SF and RT-060-IG is illustrated in Appendix C. Port locations on the front hemisphere are offset from the radial axes of the rear hemisphere reference and reflectance ports by 9° to accommodate near normal sample beam incidence during 9°/h and 9°/d reflectance measurements. The beam entrance ports shown in the schematic accommodate the sample and reference beams. Normally, these ports either will remain open during your application or some may be covered by a port plug if not in use. The specular exclusion port provides an exit point for the specular component of the reflected sample beam during 9°/d reflectance measurements. During 9°/d reflectance applications, the LTRP-100-C light trap should be installed at this port to absorb the specular reflected light.

The RT series integrating sphere assemblies include two spring-loaded sample holders, one for the reference and sample port. The sample holders attach to the port frame and mount either a reflectance standard or sample at the port surface. Each sample holder features a shelf for adjusting sample height. When loading an object at the sample or reference port, the reflective surface of the object should completely fill the port area.

RTC-060-SF and RTC-060-IG Sphere Assemblies

The RTC-060 Series spheres are coated either with Spectraflect for the RTC-060-SF sphere or Infragold in the case of the RTC-060-IG product. Optimum spectral ranges for these products are listed in the specifications of Appendix A and typical reflectance values for each coating is provided in Appendix B. The user may find it possible to obtain reflectance data slightly beyond these ranges, however, the accuracy of actual reflectance and transmittance measurement data may depend on the intensity of the sample and reference beams and the detector installed at the detector port. Sample holder and port plug components accompanying the RTC-060-SF and RTC-060-IG are coated with Spectraflect or Infragold respectively.

The RTC-060 Series integrating sphere assemblies feature five beam or sample ports spaced strategically about the horizontal perimeter of the integrating sphere, a center mount port at the north pole and a single 1/2" diameter port at the south pole. The sphere is mounted on an extruded aluminum frame to accommodate the detector port and height adjustment.The five one-inch diameter ports may appear to be identical but they are not. Two selected ports may be different by one or two design considerations:

- The location of some ports are based on a specific angle of incidence.
- Some ports are baffled, some are not.

The one-inch ports visible on the front hemisphere in Figure 5 are designated, from left to right, the transmittance port, specular exclusion port and reference port respectively. The port designations on the rear RT-060 hemisphere are, when viewed from left to right, the reflectance port and reference beam entrance port. A port schematic of the RTC-060 sphere assemblies is provided in Appendix C.

Figure 5. RTC-060-SF with center mount sample holder.

The RTC series sphere assemblies feature three 1" diameter beam ports, two 1 1/4" diameter sample ports, one 1/2" diameter port and a center-mount port. The 1/2" port is located underneath the sphere and mounts a sphere detector. A port reducer is included with the package to reduce the port size from 1/2" to 1/4" diameter. Information regarding integrating sphere detector characteristics is available in the Labsphere product catalog.

The RTC series spheres are coated with either Spectraflect for the RTC-060-SF sphere or Infragold in the case of the RTC-060-IG product. Optimum spectral ranges for these products are listed in the specifications of Appendix A. The user may find it possible to obtain reflectance data slightly beyond these ranges, however, the accuracy of actual reflectance and transmittance measurement data may depend on the detector installed at the detector port. Sample holder and port plug components accompanying the RTC-060-SF and RTC-060-IG are coated with Spectraflect or Infragold respectively.

The sphere geometry of the RTC-060-SF and RTC-060-IG is illustrated in Appendix C. Port locations on the front hemisphere are offset from the radial axes of the rear hemisphere reference and reflectance ports by 8° to accommodate near normal sample beam incidence during 8°/h and 8°/d reflectance measurements. The beam entrance ports shown in the schematic accommodate the sample and reference beams. Normally, these ports either will remain open during your application or some may be covered by a port plug if not in use. The specular exclusion port provides an exit point for the specular component of the reflected sample beam during 8°/d reflectance measurements. During 8°/d reflectance applications, the LTRP-100-C light trap should be installed at this port to absorb the specular reflected light.

The RTC series integrating sphere assemblies include three spring-loaded sample holders, two 1.25-inch sample holders for the reference and sample ports and a single one-inch device for the transmittance port. The center-mount port accommodates one of two variable angle center-mount sample holders included with the RTC-060 Series products. These sample holders are used for measuring reflectance factor or transmittance at selectable angles.

Reflectance and Transmittance Accessories

Labsphere manufacturers accessories to accompany a reflectance and transmittance integrating sphere. These accessories include sample holders, light traps and port plugs.

Port-Mounted Sample Holders

Port-mounted sample holders are included with the RT-060 and RTC-060 sphere assemblies as standard product for positioning samples and reflectance standards at the various sphere ports. Sample holders vary in port diameter, angle of incidence and reflectance coating. a one-inch diameter port frame.The RT-060 spheres include two SH-100-0-SF or SH-100-0-IG sample holders. The RTC-060 Series spheres include a single SH-100-0-SF or SH-100-0-IG and two 1.25-inch sample holders. The 1.25-inch sample holders fit only the 1.25-inch reflectance or reference ports on the RTC-060 sphere assemblies - these sample holders will not fit a one-inch port. Sample holders and their characteristics are listed in Table 2.

Sample Holder	Labsphere Part No.	Port Size	Incident Angle	Reflectance Coating
SH-100-0-SF	AS-02606-008	1"	0°	Spectraflect
SH-100-8-SF	AS-02607-008	1"	8°	Spectraflect
SH-125-8-SF	AS-02607-010	1.25"	8°	Spectraflect
SH-100-0-IG	AS-02606-108	1"	0°	Infragold
SH-125-8-IG	AS-02607-110	1.25"	8°	Infragold

Table 2. Port-mounted sample holders for the RT-060 and RTC-060 Series sphere assemblies.

Port-mounted sample holders are manufactured in two pieces: a mounting plate and a clamp. The mounting plate fits over a standard Labsphere one-inch or 1.25-inch port frame in the normal fashion, fastened by two set screws. The inside surface of the plate is coated by the same reflectance material as the integrating sphere so that scattered light from the knife-edges of the device re-enters the integrating sphere. The clamping device rides along a dovetail rail attached to the bottom of the mounting plate, thereby providing a means of varying the clamping pressure. The rail and clamp feature accommodates sample thicknesses up to one inch.

The mounting plates on some sample holders are wedge-shaped to accommodate 8° near-normal angles of incidence and reflection and direct the specular component of the sample beam to the specular exclusion port. A secondary purpose of this design is to avoid loss of the specular component of the reflected beam at 0° angle of incidence during hemispherical measurements. The wedged sample holders are available in the one-inch and 1.25-inch variety. The 1.25-inch sample holders are only available with the 8° wedge to fit the RTC-060-SF and RTC-060-IG reflectance and reference ports. Each sample holder features a shelf for adjusting sample height. The clamping device is hollow to accommodate a sample beam up to 3/4-inch diameter for transmittance applications.

Figure 6. SH-100-0-SF sample holder.

Center-Mounted Sample Holders

The port-mounted sample holders described in the previous section limit reflectance measurement applications to 8° or 9° angles of incidence. A center-mount sample holder positions the sample at the center of the integrating sphere, thereby providing added capabilities to the reflectance sphere applications. These additional capabilities include the ability to measure hemispherical reflectance as a function of incidence angle, as well as the ability to measure the combined transmittance and reflectance of a translucent sample.

Sample Holder	Labsphere Part No.	Hold Mechanism
CMSH-RTC-CUV-SF	AS-02728-000	Cuvette
CMSH-RTC-CLIP-SF	AS-02750-000	Spring Clip
CMSH-RTC-JAW-SF	AS-02486-000	Movable Jaw

Table 3. Center mount sample holders compatible with the Spectraflect RTC-060-SF sphere assembly.

Three center-mount sample holders listed in Table 3 are available for use with the RTC-060 series integrating spheres. The spring clip and movable jaw type sample holders accompany the RTC-060-SF and RTC-060-IG sphere assemblies as accessories in the standard packages.

Figure 7. CMSH-RTC-CLIP-SF clip style sample holder.

The sample holder in Figure 7 is called a *spring clip* sample holder. This sample holder is ideal for holding rigid translucent reflectance or transmittance samples, such as a small sheet of plastic - it fits into the center mount port on the RTC-060-SF. The CMSH-RTC-CLIP-IG is identical to the CMSH-RTC-CLIP-SF, except the internal components are coated with Infragold. The sample is held securely by a spring-loaded clip that positions the sample in the sample beam path at the center of the integrating sphere. A baffle at the far end of the sample holder prevents first strike radiation off the sample from reaching the detector port. The clip and baffle assembly is attached to a calibrated dial on the sample holder body that rotates 360° in the horizontal plane, thereby controlling the angle of incidence to the sample beam. The clip style sample holder can hold samples up to 1.25" high, 2" wide, and 1/4" thick.

When utilizing the clip style sample holder, the background correction or blank portion of the reflectance measurement is recorded with the empty sample holder loaded in the sphere. A reflectance standard is not required because the empty transmittance port and the surface at the sample reflectance port serves as the standard with the reflectance value equal to one. The surface at the sample reflectance port can be a calibrated or uncalibrated Spectralon reflectance standard or a port plug.

Since there is no backing to the sample held by the clip, radiation collected by the sphere may represent light transmitted through the sample in addition to reflected light.

CAUTION: Care should be taken when working with center-mount sample holders so the Spectraflect or Infragold coating is not soiled or damaged. Wear gloves when handling the reflectance materials and exercise care when loading and unloading samples.

The jaw style sample holder is designed for reflectance samples larger than the maximum thickness capability of the CMSH-RTC-CLIP-SF or CMSH-RTC-CLIP-IG. The CMSH-RTC-CLIP-SF is illustrated in Figure 8.

Figure 8. CMSH-RTC-JAW-SF sample holder.

The knurled knob shown in the figure operates the two jaws simultaneously so the sample is always positioned at the center of the integrating sphere. The jaws style sample holder can handle samples up to 1.4" x 2" x 0.5". It can accommodate a small light trap or other absorbent material behind the sample for removing the transmitted component of the sample beam. When utilizing the jaws style sample holder, a reflectance standard must be loaded in the jaws for the background correction portion of the reflectance measurement. The reflectance standard can be a calibrated or uncalibrated piece of Spectralon or some other material of known reflectance. When properly loaded into the sample holder, the angle of incidence by the sample beam to the sample surface is indicated by the rotary dial

Only one rotary dial assembly is included with the RTC-060-SF or RTC-060-IG - the jaws and clip style sample holders must share the same attachment. Use the following procedure to change the sample holder from one style to the other:

1. Place a piece of tape along the side of the top ring marking the exact location of the zero indicator line on the rotary dial. Note the orientation of the two metal dowel pins on the bottom ring of the dial.
2. Loosen and remove the four Phillips head screws visible on the top of the rotary dial assembly.
3. Lift off the top ring cover to expose four 4-40 cap screws recessed into the body of the rotary dial. The graduated dial cannot be removed but will hang loosely on top of the top ring as demonstrated in Figure 9.
4. Loosen and remove the four cap screws using the 3/32" hex wrench provided in the tool kit. Pull the bottom ring off the rotary dial assembly, thereby exposing the entire length of the white painted cylinder.
5. Carefully grasp the exposed painted cylinder and unscrew the cylinder and sample holder assembly until the recessed post cap screw is visible underneath. The threading is right-handed.

Figure 9. Rotary dial with the top ring removed.

Figure 10. Removing the cylinder and sample holder from the remaining rotary unit.

6. Loosen the cap screw with the 9/64" hex wrench as demonstrated in Figure 8. Make sure the screw is backed out at least 3/8" to disengage the sample holder stem.
7. Lift the cylinder and sample holder stem out of the rotary unit.
8. Remove the existing sample holder stem from the cylinder as shown in Figures 10 and 11 and install the alternate style sample holder in its place.
9. Mate the cylinder and new sample holder stem to the rotary unit so it is oriented at the same angle as the previous device. Press the stem down into the center hole so the cap screw from Step No. 6 can engage the hole in the stem. Tighten the cap screw so the sample holder is secure.
10. Screw the painted cylinder back into the rotary unit, this time making sure the threads re engaged correctly.
11. Re-install the bottom ring, making sure the metal alignment pins correctly align to the zero tape mark on the rotary device, as noted previously in Step No. 1, and tighten the four cap screws.
12. When installing the top ring cover, make sure the zero indicator on the dial lines up with the indicator tape. Install the four Phillips head screws.

The CMSH-RTC-CUV-SF sample holder positions a standard 10 mm cuvette at the center of the integrating sphere. There is no rotary dial on this sample holder - the cuvette is always positioned for normal incidence. The CMSH-RTC-CUV-SF is not standard for either the RT-060 or RTC-060 sphere assemblies - it is an optional component. When utilizing the CMSH-RTC-CUV-SF, the operator should take precautions to avoid spillage from the cuvette onto the sphere reflective surface.

Figure 11. The rotation of the sample holder is checked by a cap screw in the rotary body.

Light Trap

Figure 12. LTRP-100-C light trap.

A light trap is a black chamber that absorbs incident light from all directions and at all wavelengths but does not re-radiate the light back to the sphere. The LTRP-100-C is a simple device with no moving parts. The device installs over a one-inch diameter port frame on any sphere assembly described in this instruction manual with the standard two set screws. A standard Labsphere LTRP-100-C light trap is included in the RT-060 and RTC-060 standard packages. When used for diffuse reflectance applications, the light trap is installed over the specular exclusion port. During hemispherical measurements a port plug is installed over the specular exclusion port.

Operating Procedures

The following procedures can be used to obtain reflectance and transmittance spectra using Labsphere reflectance and transmittance integrating spheres. A single beam procedure is provided for reflectance and transmittance measurements in event only one beam source is available. If two beam sources are available, Labsphere recommends the double beam procedures. In every case, the beam setup should be constructed around the sphere assembly and aligned to the appropriate ports on the integrating sphere prior to entering the reflectance or transmittance measurement procedure. In most cases, a laser or filtered light source will be used to produce the reference and sample beams. When constructing the beams, the user should keep in mind that an integrating sphere is an optical device that will attenuate the beam signal. The attenuation characteristics of the sphere depends on wavelength. The throughput for a six-inch diameter Spectraflect sphere without a center-mount device is approximately 7% at wavelengths under 1000 nm and much less than 7% at wavelengths greater than 1000 nm. Throughput for the Infragold integrating spheres without the center-mount device is approximately 1.5% from .7 µm to 1 µm, and 2.5% above 1 µm.

The Labsphere SC 6000 radiometer instrument is capable of recording signal ratios and includes a memory feature for applying dark current corrections. This instrument and the standard Labsphere detector assemblies are not included with the standard RT or RTC series products, but can be purchased as an option.

The reflectance and transmittance measurements using the comparison method require the recording of the 100% signal called a *baseline scan*. The baseline scan typically is recorded first with a reflectance standard loaded at the reflectance port. The *sample scan* typically is recorded immediately following the baseline scan with the sample positioned at the reflectance or transmittance port. Since light from the environment can leak through the open port of the integrating sphere, all measurements should be conducted in a dark room.

Beam Alignment with Port-Mounted Sample Holders

The utilization of the port-mounted sample holders accompanying the reflectance and transmittance sphere assemblies ensures the most accurate reflectance and transmittance measurements. The sample holders mount a reflectance standard or sample securely against the sample port at a known angle of incidence with least potential for undesirable scattering. Beam alignment on the port-mounted sample holders is easiest to perform.

1. Install the sample holder at the reflectance and reference ports and load a reflectance standard at each port. If the application is an RT-060 transmittance measurement in double beam mode, install a port plug over the reference port and install the sample holder at the transmittance port.
2. Illuminate the sphere with the sample beam through the transmittance port so the spot is centered on the reflectance port.
3. Examine the spot on the reflectance port through another open port. Adjust the light source, if necessary, so the beam is centered on the reflectance port and does not spill over to the sphere wall.
4. Hold a white card in front of the transmittance port outside the sphere and make sure the entire sample beam enters the sphere without clipping the sample holder or port frame. Adjust the light source if necessary.
5. Repeat the last two steps of this procedure until the beam is centered on both ports and no clipping exists.
6. Repeat the previous steps for the reference beam, if applicable.

Beam Alignment with a Centermount Sample Holder

Extra care may be required when loading reflectance standards or samples into the center-mount sample holders to ensure that the sample and reference beams strike their intended targets unobstructed. Depending on the size of your reflectance sample and the size of the beams, beam alignment and sample holder loading may prove to be difficult. Use the following procedure when loading an object in a center mount device:

1. Load the calibrated reflectance standard at the reflectance port and the uncalibrated standard at the reference port.
2. Load the sample into the sample holder. If using the jaws style device, adjust the depth of the object so the reflective surface is approximately even with the front edge of the jaws. If using the clip style device, make sure the object is positioned at the center when placed in the integrating sphere.
3. Insert the sample holder assembly into the sphere so the positioning pins in the rotary dial mate with the locator holes on the top centermount platform.
4. Set the rotary dial to the *measurement angle of incidence*. The sample surface is normal to the sample beam when the dial is set at 0°.
5. Illuminate the sphere with the sample beam and block the reference beam, if applicable.

DANGER: Laser emission can be an extreme hazard to eyesight. Exercise care when checking the alignment of laser beams. Do not view the actual or reflected laser beam directly.

6. Use a white card or infrared display card as appropriate to locate the sample beam at the entrance port and at the reflective sample surface. The beam should not clip the edge of the entrance port and the reflecting surface of the loaded object must fill the sample beam completely. Adjust the sample beam, as necessary, so these conditions are met.
7. Block the sample beam and open the shutter to illuminate the sphere with the reference beam, if applicable. Use the white card or infrared display card technique to locate the reference beam at the entrance port - the reference beam should not clip the edge of the entrance port. Observe the path of the reference beam through the integrating sphere - the beam must not clip the sample holder or any other object inside the sphere before it reaches the first strike target area at the reference port. The reference beam should be centered roughly on the standard at the reference port without clipping the port frame. Adjust the reference beam path so these conditions are met.
8. Unblock both sample and reference beams so the sphere is illuminated by both beams. Rotate the centermount dial to an angle location where neither beam is obstructed by the sample or sample holder before it strikes the respective reflectance or reference port. If a location does not exist, adjust the sample position within the sample holder and repeat the last three steps until the beams are aligned and the unobstruction criteria is met. This angle is designated the *baseline scan position*.
9. Install port plugs over all ports not in use for recording the baseline scan.

Reflectance Measurements in Single Beam Mode

This procedure should be used if only one beam source is available using the port-mounted sample holders. All reflectance measurements in single beam mode are susceptible to substitution error. The magnitude of this error is dependent on sample beam wavelength and the actual reflectance of the sample.

DANGER: Laser emission can be an extreme hazard to eyesight. Exercise care when checking the alignment of laser beams. Do not view the actual or reflected laser beam directly.

1. Align the sample beam using the port-mount sample holder beam alignment procedure.
2. Load an uncalibrated reflectance standard at the reference port and a calibrated reflectance standard, if available, at the sample reflectance port. If a calibrated standard is not available, an uncalibrated standard can be used with the typical data in Appendix B. If the reflectance measurement is in the 9°/d or 8°/d geometry, install the light trap at the specular exclusion port. Install port plugs over all remaining ports except the sample reflectance port and the sample beam entrance port. When utilizing the RTC-060-SF or RTC-060-IG, the centermount plug should be installed when collecting data.
3. Turn on the sample beam. Block the beam from the sphere and record a dark current reading or dark scan.

Figure 13. RT-060-SF hemispherical reflectance measurement.

Figure 14. RT-060-SF diffuse reflectance measurement in single beam mode.

4. Illuminate the sphere with the sample beam and record the baseline scan. Block the sample beam once the data is recorded.
5. Replace the reflectance standard at the sample reflectance port with the sample. Record a dark current reading or scan.
6. Illuminate the sphere with the sample beam and record the sample scan. Extinguish the sample beam when the data is recorded.
7. Calculate the reflectance factor:

$$R(\lambda) = R_{Std}(\lambda)\left(\frac{S_S(\lambda) - S_{Dark}}{S_{Std}(\lambda) - S_{Dark}}\right)$$

where $R_{Std}(\lambda)$ is the reflectance data for the calibrated reflectance standard,

$S_S(\lambda)$ is the detector or spectrometer signal recorded with the sample loaded at the sample port,

$S_{Std}(\lambda)$ is the detector or spectrometer signal with the reflectance standard loaded at the sample port, and

S_{Dark} is the detector signal recorded for the respective dark current measurements.

Reflectance Measurements in Double Beam Mode

This procedure can be used to record 9°/h or 8°/h reflectance data for the RT series spheres or the RTC series spheres respectively in double beam mode. When utilizing the RTC-060 Series sphere, the centermount plug should be installed.

DANGER: Laser emission can be an extreme hazard to eyesight. Exercise care when checking the alignment of laser beams. Do not view the actual or reflected laser beam directly.

1. Align the sample and reference beams using the port-mount sample holder beam alignment procedure.
2. Load an uncalibrated reflectance standard at the reference port and a calibrated reflectance standard, if available, at the sample reflectance port. If a calibrated standard is not available, an uncalibrated standard can be used with the typical data in Appendix B. If the reflectance measurement is in the 9°/d or 8°/d geometry, install the light trap at the specular exclusion port. Install port plugs over all ports not in use.
3. Energize the reference and sample beam light source and allow a sufficient time for warm-up and stabilization.
4. Block off the reference and sample beams from the sphere and record a dark current reading.
5. Illuminate the sphere with the reference beam and record the detector current as part of the baseline scan data. Block the reference beam once the data is recorded.

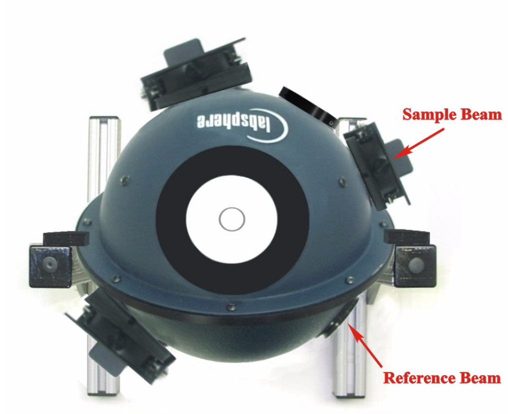


Figure 15. RTC-060-SF hemispherical measurement in double beam mode.

Figure 16. RTC-060-SF diffuse measurement in double beam mode.

6. Illuminate the sphere with the sample beam and record the detector current to complete the baseline scan. Block off the sample beam once the data is recorded.
7. Replace the reflectance standard at the sample reflectance port with the sample. Record a dark current reading or dark scan.
8. Illuminate the sphere with the sample beam and record the detector current or spectrometer reading for the first part of the sample scan. Block the sample beam when the data is recorded.
9. Illuminate the sphere with the reference beam and record the final part of the sample scan data. Block the reference beam or extinguish the light source when the data is recorded.
10. Calculate the 9°/h or 8°/h reflectance factor:

$$R(\lambda) = R_{Std}(\lambda)\left(\frac{S_{Sample}(\lambda) - S_{Dark}}{S_{Ref}(\lambda) - S_{Dark}}\right)_S \left(\frac{S_{Ref}(\lambda) - S_{Dark}}{S_{Sample}(\lambda) - S_{Dark}}\right)_{Std}$$

where $R_{Std}(\lambda)$ is the reflectance data for the calibrated reflectance standard,

$S_{Sample}(\lambda)$ is the detector signal recorded with the sample beam lit,

$S_{Ref}(\lambda)$ is the detector signal recorded with the reference beam lit,

S_{Dark} is the detector signal recorded for the dark current measurements,

subscript "*S*" indicates measurements taken with the sample loaded at the sample port, and the

subscript "*Std*" indicates measurements taken with the calibrated standard loaded at the sample port.

Transmittance Measurements in Single Beam Mode

This procedure can be used to record transmittance data using the RT series spheres or the RTC series integrating spheres in the single mode of operation. Sphere configurations for transmittance measurements are identical to Figures 15 and 16 except that the sample holder and sample is positioned at the transmittance port during the sample scan.

DANGER: Laser emission can be an extreme hazard to eyesight. Exercise care when checking the alignment of laser beams. Do not view the actual or reflected laser beam directly.

1. Align the sample beam using the port-mount sample holder beam alignment procedure.
2. Load uncalibrated reflectance standards at the reference and reflectance ports. Install port plugs over all ports not in use.
3. Energize the sample beam light source and allow a sufficient time for warm-up and stabilization.
4. Block off the sample beam from the sphere. Record a dark current reading or dark scan.
5. Illuminate the sphere with the sample beam and record the baseline data. Block off the sample beam once the data is recorded.
6. Load the sample at the transmittance. If recording a diffuse measurement, install the light trap at the reflectance port. Record a dark current reading.
7. Illuminate the sphere with the sample beam and record the sample scan data.
8. Extinguish the light source and calculate the 9°/h or 8°/h transmittance:

$$T(\lambda) = \frac{(S_{Sample}(\lambda) - S_{Dark})_S}{(S_{Sample}(\lambda) - S_{Dark})_{Empty}}$$

where $S_{Sample}(\lambda)$ is the detector signal recorded with the sample beam illuminating the sphere,

S_{Dark} is the detector signal recorded for the dark current measurements,

subscript "*S*" denotes measurements taken with the sample loaded at the transmittance port, and

subscript "*Empty*" indicates measurements taken with an empty transmittance port.

For transmittance measurements, the empty transmittance port serves as the standard.

Transmittance Measurements in Double Beam Mode

This procedure can be used to record transmittance data using the RT series spheres or the RTC series integrating spheres without the center-mount sample holder. Sphere configurations for transmittance measurements are identical to those in Figures 15 and 16 except that the sample is positioned at the transmittance port during the sample scan.

DANGER: Laser emission can be an extreme hazard to eyesight. Exercise care when checking the alignment of laser beams. Do not view the actual or reflected laser beam directly.

1. Align the sample and reference beams using the port-mount sample holder beam alignment procedure.
2. Load uncalibrated reflectance standards at the reference and reflectance ports. Install port plugs over all ports not in use.

3. Energize the reference and sample beam light source and allow a sufficient time for warm-up and stabilization.
4. Block off or extinguish the reference and sample beams. Record a dark current reading.
5. Illuminate the sphere with the reference beam and record the first part of the baseline scan. Block off the reference beam once the data is recorded.
6. Illuminate the sphere with the sample beam and record the second half of the baseline data. Block off the sample beam once the data is recorded.
7. Load the sample at the transmittance. If recording a diffuse measurement, install the light trap at the reflectance port. Record a dark current reading.
8. Illuminate the sphere with the sample beam and record the detector current or spectrometer data as the first part of the sample scan. Block the sample beam when the data is recorded.
9. Illuminate the sphere with the reference beam and record the last half of the sample scan. Extinguish the light source when the data is recorded.
10. Calculate the 9°/h or 8°/h transmittance:

$$T(\lambda) = \left(\frac{S_{Sample}(\lambda) - S_{Dark}}{S_{Ref}(\lambda) - S_{Dark}}\right)_S \left(\frac{S_{Ref}(\lambda) - S_{Dark}}{S_{Sample}(\lambda) - S_{Dark}}\right)_{Empty}$$

where $S_{Sample}(\lambda)$ is the detector signal recorded with the sample beam lit,

$S_{Ref}(\lambda)$ is the detector signal recorded with the reference beam lit,

S_{Dark} is the detector signal recorded for the dark current measurements,

subscript "*S*" denotes measurements taken with the sample loaded at the transmittance port, and

subscript "*Empty*" indicates measurements taken with an empty transmittance port.

For transmittance measurements, the empty transmittance port serves as the standard.

Reflectance Measurements Using a Centermount Sample Holder

The RTC series sphere assemblies include two center-mount sample holders for accommodating θ°/h reflectance measurements at variable angles of incidence. The measurement procedures for using the centermount devices are much the same as with the port-mounted sample holders, however, the presence of the sample holder reduces the throughput of the sphere and sometimes obstructs the path of the reference beam. The procedure for loading a sample in a centermount sample holder is provided at the beginning of this chapter.

Reflectance standards at Labsphere are calibrated in the 8°/h geometry. Consequently, the reflectance data accompanying the standard or the data in Appendix B theoretically may be valid only at the 8° angle of incidence - not necessarily the angle of incidence required by the application. The user may find it useful to record data for the reflectance standard measurement at 8° as well and carry out the calculations for comparison to the calculations made in this procedure.

The beam ports on the RTC series spheres serve their same purpose during variable angle measurements as they do without the centermount device installed - only the geometry is different. This procedure can be used to record θ°/h reflectance data using the RTC-060-SF or RTC-060-IG sphere assembly.

1. Align the beams using the procedure at the beginning of this chapter.
2. Load a calibrated reflectance standard at the reflectance port and an uncalibrated standard at the reference port. Install port plugs over all ports not in use.
3. Energize the reference and sample beam light source and allow a sufficient time for warm-up and stabilization.
4. Make sure the centermount sample holder dial is in the *baseline scan position* described in the beam alignment

procedure. Block off the reference and sample beams from the sphere and record a dark current reading.

5. Illuminate the sphere with the reference beam and record the first portion of the baseline scan. Block the reference beam once the data is recorded.
6. Illuminate the sphere with the sample beam and record the remaining half of the baseline data. Block off the sample beam when the data is recorded.
7. Rotate the centermount holder dial to the *measurement angle of incidence*.
8. Block both reference and sample beams and record a dark current reading.
9. Illuminate the sphere with the sample beam and record the first sample scan data. Block off the sample beam once the data is recorded.
10. Illuminate the sphere with the reference beam and record the last set of sample scan data.
11. Calculate the θ°/h reflectance factor:

$$R(\lambda) = R_{Std}(\lambda)\left(\frac{S_{Sample}(\lambda) - S_{Dark}}{S_{Ref}(\lambda) - S_{Dark}}\right)_S\left(\frac{S_{Ref}(\lambda) - S_{Dark}}{S_{Sample}(\lambda) - S_{Dark}}\right)_{Std}$$

where $S_{Sample}(\lambda)$ is the detector signal recorded with the sample beam illuminating the sphere,

$S_{Ref}(\lambda)$ is the detector signal recorded with the reference beam unblocked,

S_{Dark} is the detector signal recorded for the dark current measurements,

subscript "*S*" indicates measurements taken with the centermount dial at the *measurement angle of incidence*,

subscript "*Std*" indicates measurements taken with centermount dial at the *baseline scan position*, and

$R_{Std}(\lambda)$ is the reflectance data for the calibrated reflectance standard at the reflectance port.

Eliminating Potential Errors During Reflectance Measurements

The following tips are provided to reduce the impact of potential errors in reflectance and transmittance measurement data:

- Labsphere reflectance and transmittance measurement integrating spheres are designed for double beam operation, but they can be used in a single beam mode. Single beam integrating sphere measurements are always susceptible to substitution error. If single beam operation is utilized, substitution error can be minimized by selecting a calibrated reflectance standard close to the anticipated reflectance of the intended sample.
- When operating in double beam mode, the energy of the two beams should be well matched. The path lengths of the beams should be relatively close and differences in transfer optics minimized.
- The standard Labsphere detector assemblies generate a broadband spectral response and will detect background ambient light from the laboratory that enters the integrating sphere. Measurements should be made in a dark room and dark current readings performed.
- It is possible that a *baseline scan position* described in the previous procedure does not exist for a sample loaded in a centermount sample holder. In this case, it might be useful to trim the edges of the sample or even make small adjustments to the beams.

The use of multi-frequency lasers may distort reflectance or transmittance data due to the spectral power distribution of the laser and non-uniform spectral response of the integrating sphere and silicon detector. Selective spectral filtering is recommended in this case.

Maintenance

There is no maintenance associated with the reflectance and transmittance spheres. Refer to the guidelines in the appendices for cleaning instructions.

Appendix A Specifications

RT-060-SF	
Dimensions	7" x 7" x 13"
Optimal Spectral Range	300 - 2400 nm
Reflectance Measurement Geometries	9°/h, 9°/d
Sphere Diameter	6"
Coating	Spectraflect
Beam Height	7.8" - 10"
RT-060-IG	
Dimensions	7" x 7" x 13"
Optimal Spectral Range	0.7 - 20 µm
Reflectance Measurement Geometries	9°/h, 9°/d
Sphere Diameter	6"
Coating	Infragold
Beam Height	7.8" - 10"
RTC-060-SF	
Dimensions	10" x 6" x 13"
Optimal Spectral Range	300 - 2400 nm
Reflectance Measurement Geometries	8°/h, 8°/d, θ°/h
Sphere Diameter	6"
Coating	Spectraflect
Beam Height	5.1" - 7.6"
RTC-060-IG	
Dimensions	10" x 6" x 13"
Optimal Spectral Range	0.7 - 20 µm
Reflectance Measurement Geometries	8°/h, 8°/d, θ°/h
Sphere Diameter	6"
Coating	Infragold
Beam Height	5.1" - 7.6"

Appendix B Typical Reflectance Values

Typical Spectraflect Reflectance Values

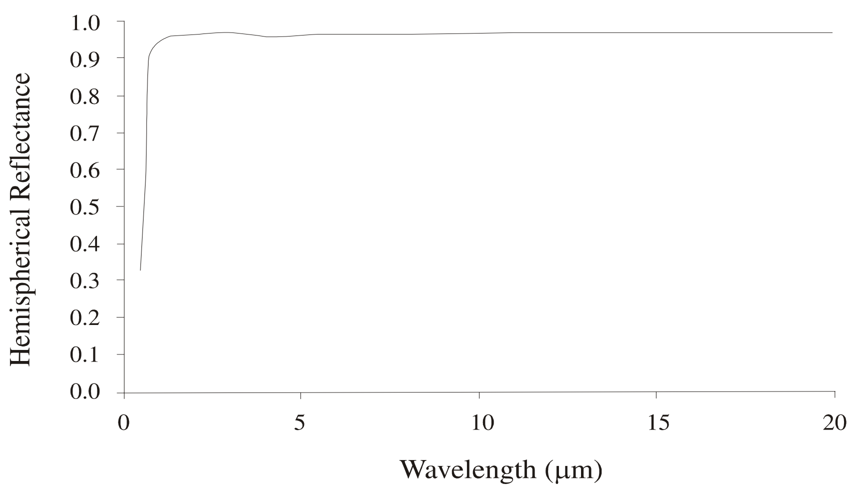
Wavelength	8° Hemispherical Reflectance
250	.94
300	.96
400	.98
500	.98
600	.98
700	.97
800	.97
900	.97
1000	.97
1100	.96
1200	.95
1300	.95
1400	.93
1500	.92
1600	.92
1700	.92
1800	.91
1900	.86
2000	.85
2100	.86
2200	.87
2300	.84
2400	.82
2500	.77

Typical Spectralon Standard Reflectance Values

Wavelength	Spectralon 8° Hemispherical Reflectance
250	.973
300	.984
400	.991
500	.991
600	.992
700	.992
800	.991
900	.991
1000	.993
1100	.993
1200	.992
1300	.993
1400	.991
1500	.992
1600	.992
1700	.988
1800	.989
1900	.981
2000	.976
2100	.953
2200	.973
2300	.972
2400	.955
2500	.960

Typical Infragold Reflectance Values

Wavelength (nm)	Reflectance	Wavelength (nm)	Reflectance
350	0.351	1900	0.957
400	0.328	1950	0.958
450	0.363	2000	0.959
500	0.399	2050	0.961
550	0.579	2100	0.964
600	0.759	2150	0.963
650	0.842	2200	0.963
700	0.925	2250	0.962
750	0.931	2300	0.962
800	0.937	2350	0.961
850	0.939	2400	0.961
900	0.942	2450	0.963
950	0.946	2500	0.962
1000	0.951	2600	0.963
1050	0.952	2700	0.963
1100	0.954	2800	0.968
1150	0.955	2900	0.971
1200	0.957	3000	0.967
1250	0.956	3100	0.966
1300	0.956	3200	0.964
1350	0.956	3300	0.964
1400	0.957	4000	0.962
1450	0.957	5000	0.962
1500	0.958	6000	0.965
1550	0.958	7000	0.965
1600	0.959	8000	0.964
1650	0.958	9000	0.966
1700	0.957	10000	0.967
1750	0.956	12000	0.969
1800	0.956	15000	0.972
1850	0.956		



Appendix C Illustrations

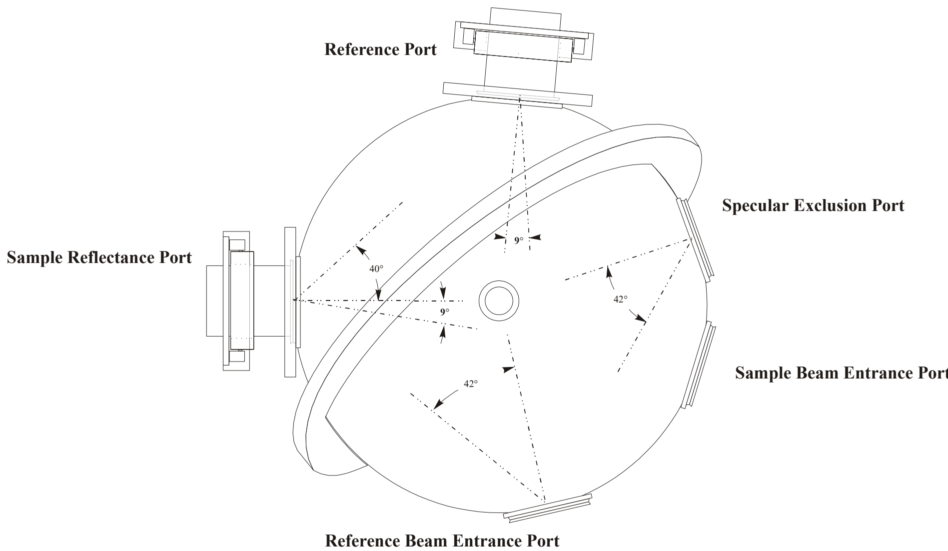
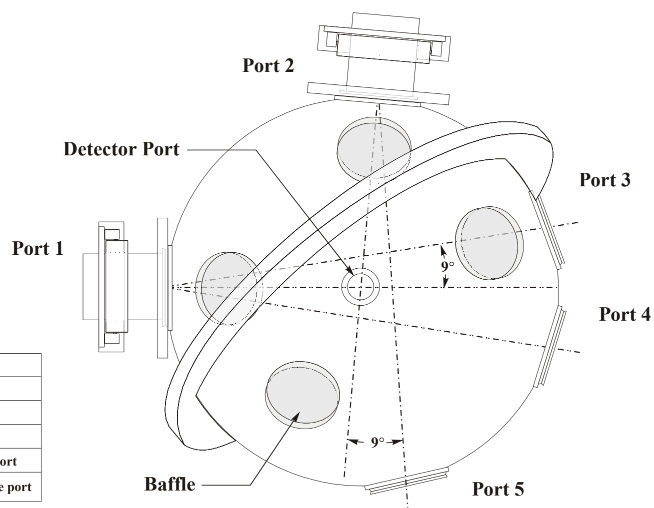


Figure 17. Port incident angles for the RT-060 series spheres.



Port	Utility
1	Sample Reflectance Port
2	Reference Port
3	Specular Exclusion Port
4	Sample beam entrance port
5	Reference beam entrance port

Figure 18. Top view of the RT-060-SF and RT-060-IG integrating spheres.

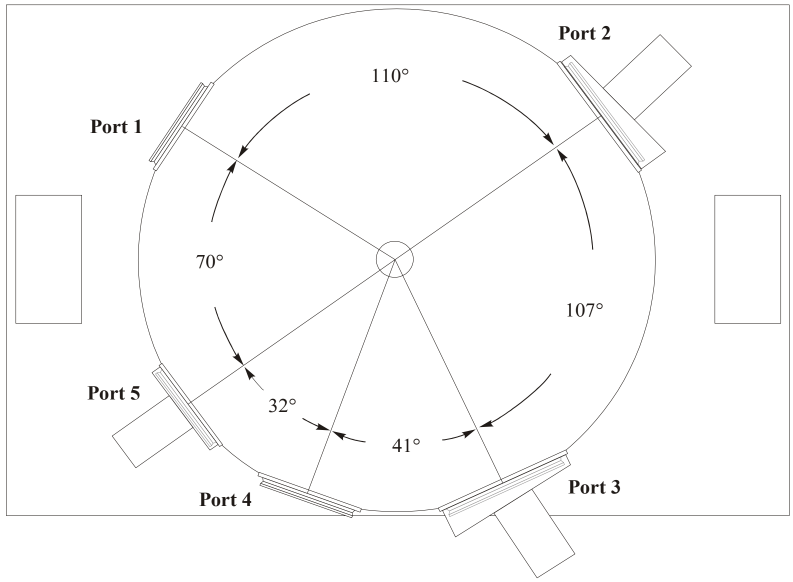


Figure 19. Port incident angles for the RTC-060 series spheres.

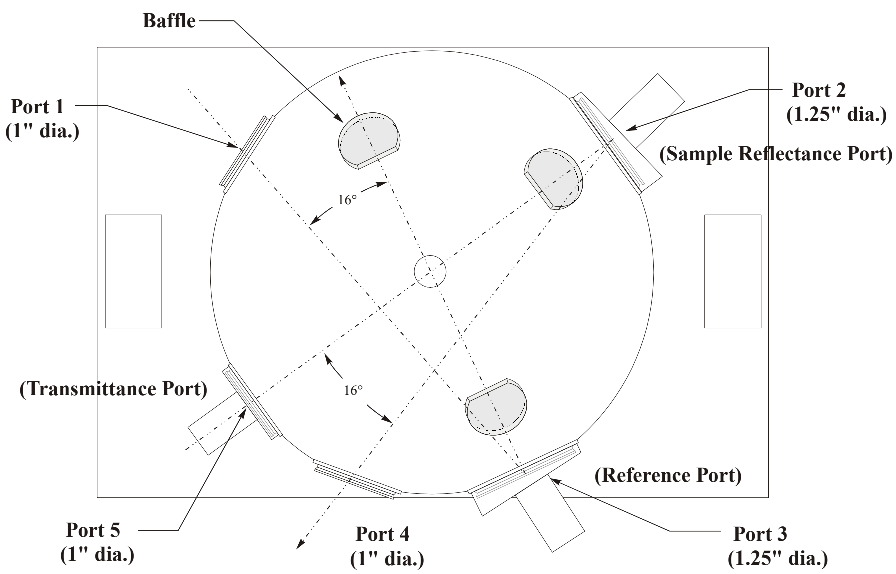


Figure 20. Top view of the RTC-060-SF or RTC-060-IG integrating sphere.

Appendix D Reflectance Material Handling Guidelines

IMPORTANT INFORMATION

CARE AND HANDLING GUIDELINES

Spectraflect® Diffuse Reflectance Coating

To maintain the unique optical and reflectance properties of Spectraflect Diffuse Reflectance Coating, the following handling procedures must be followed:

General Care and Cleaning

1. Wear powder free vinyl gloves whenever touching the coated surface.

2. Never attempt to clean the surface of a coated product with any form of liquid cleaner. Particles that contiminate the surface may be removed with a clean dry, filtered burst of compressed air. The air nozzle should be held no closer than 3 inches. Air compression should be no greater than 30 PSI.

3. Never place the coated surface face down onto another surface, unless it is specifically directed by a procedure.

For further information on the care and handling of Spectraflect coating, please contact the Labsphere Technical Sales Department.

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IMPORTANT INFORMATION

CARE AND HANDLING GUIDELINES

Infragold® Reflectance Coating

1. General Care

The diffuse gold coating used in Labsphere standards, targets, and integrating spheres must be treated with care. Wear clean gloves when handling Infragold products. Protect the gold coating from corrosive chemicals, as well as, from scratching and denting.

2. Cleaning Instructions

If Infragold coating becomes soiled, it may be cleaned using the following procedure:

1. Spray the soiled area with a reagent grade acetone.
2. Rinse the area with a spray of deionized water.
3. Dry the surface by blowing off with clean dry nitrogen or clean dry air.

3. Liquid Cooled Infragold Integrating Spheres

Care must be taken not to over-pressurize the liquid cooled spheres. If pressure at the inlet to the integrating sphere exceeds 40 psi, damage to the sphere will occur. Labsphere suggests using a pressure guage in the coolant line.

For further information on the care and handling of Infragold Reflectance Coating, please contact the Labsphere Technical Sales Department.