

Applications and Use of Integrating Spheres

With the LAMBDA 650 and 850 UV/Vis and LAMBDA 950 UV/Vis/NIR Spectrophotometers



Introduction

Integrating spheres, in combination with UV/Vis and UV/Vis/NIR spectrophotometers, are extremely versatile accessories for high precision reflectance and scattered transmittance measurements on virtually any solid or liquid.

Application areas range from surface characterization of solids to the photometric analysis of turbid, colloidal, transparent and translucent samples. Typical uses encompass quality assurance testing and product development measurements on textiles, dyes, paper and glass.

Key Benefits

- ▶ A choice of 60 mm and 150 mm spheres are available to address the widest range of applications in the industry
- ▶ Modular sampling platform allows quick change of sampling accessories with no set-up
- ▶ Wide range of different sampling configurations allows full materials characterization
- ▶ 150 mm sphere conforms to international measurement guidelines including ASTM, DIN and CIE

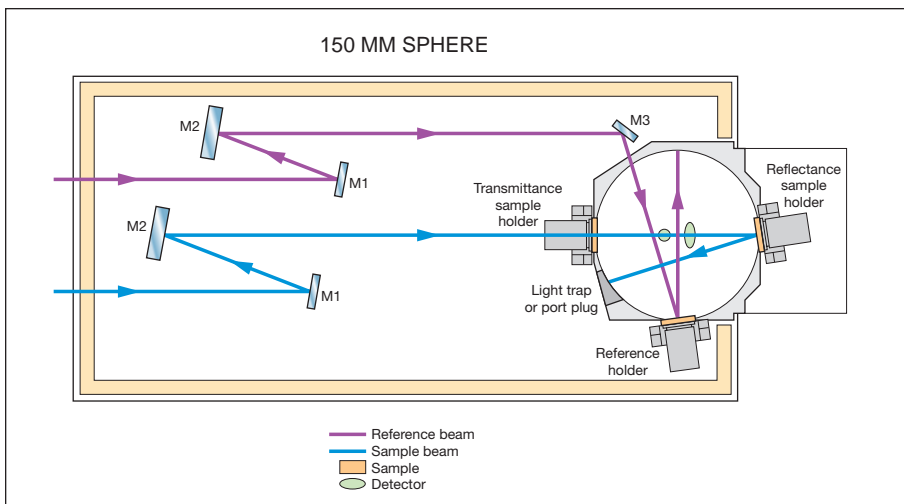


Figure 1. Optical design of 150 mm integrating sphere.

Optical design and sampling configurations

The PerkinElmer 150 mm integrating sphere optical design is shown above. The transmittance sample holder at the entrance of the sphere enables the measurement of light scattering solutions or solids more efficiently than in a standard focusing UV/Vis spectrometer with a conventional detector arrangement. In the latter configuration, light will be lost before it reaches the detector, resulting in significant

photometric errors and uncontrolled variation between samples. The integrating sphere, however, collects all the light which has passed through the sample.

For reflectance measurements, samples are mounted in the rear sample mount. Either total reflectance or diffuse reflectance

only can be measured by placing either a light trap or Spectralon™ plate at the specular reflectance angle (Fig.2).

Measurement on irregularly-shaped solids such as solar cells, textiles, prisms and lenses is also possible using the center-mount option in which the sample is suspended in the middle of the sphere. The center-mount port, complete with positioning wheel for reproducible sampling, is shown being lifted out of the sphere in Fig 3. The transmittance and reference ports are also shown. The reflectance port is located under the light blue cover on the right-hand side of the accessory. Even very large samples, for example sheets of glass, can be brought up to the reflectance port for analysis.

Additionally, for small samples or to sample small areas on larger samples, a small spot kit is available to focus the beam at the entrance, reflectance or center-ports of the sphere.

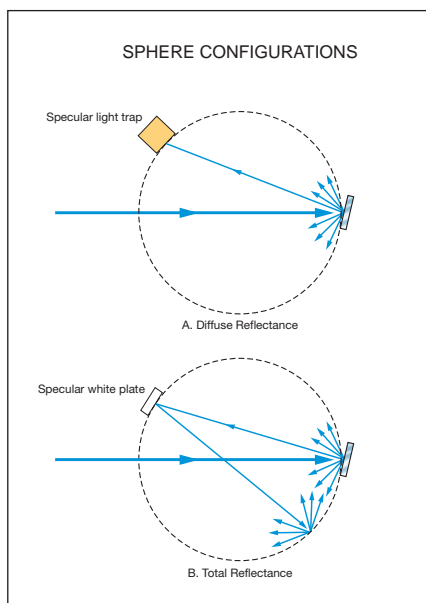


Figure 2. Sampling configurations for diffuse and specular reflectance.



Figure 3. The 150 mm integrating sphere with sampling module lid open.

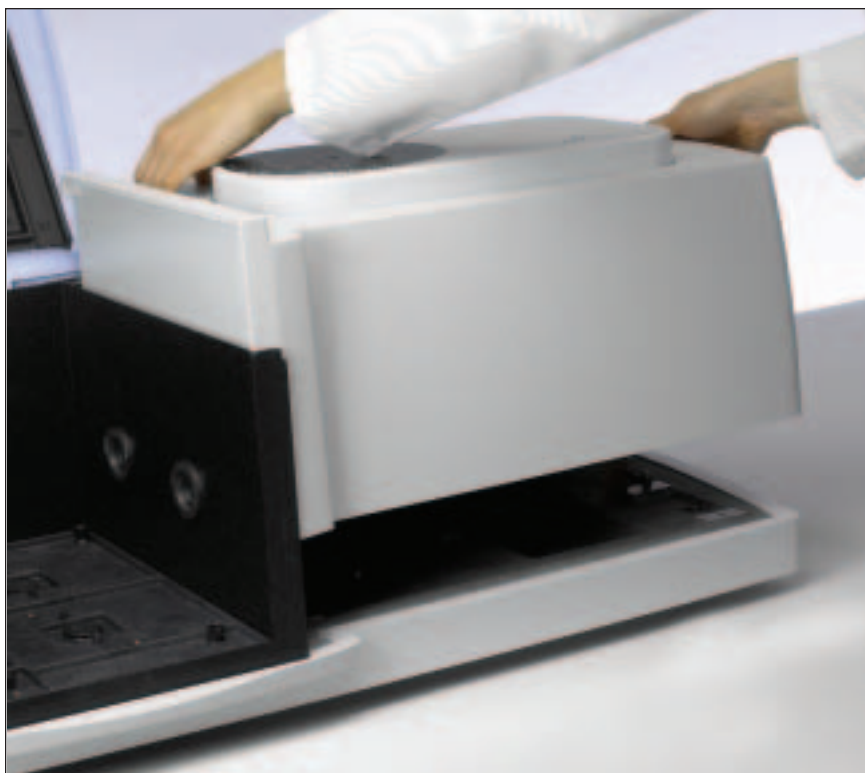


Figure 4. The Universal Reflectance Accessory snaps into the huge second sample area.

Interchangeable sampling modules

In a busy lab, instruments are more valuable if they can be rapidly reconfigured to run different analyses. The LAMBDA™ 650/850/950 family was designed with this in mind. The 60 mm and 150 mm integrating spheres are mounted in intelligent sampling modules located in the huge sampling area which is an integral part of the design. The large sample area provides maximum accessibility for accurate sample positioning and allows larger samples to be easily accommodated. To switch accessories, for example to change instrument configuration from a specular reflectance

measurement using the variable angle URA (Universal Reflectance Accessory) to an analysis which requires the integrating sphere, takes only a few seconds. The new sampling module snaps into place (Fig.4) and the new accessory configuration is immediately

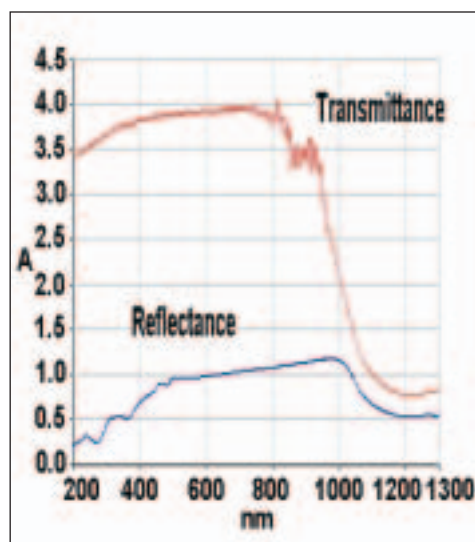


Figure 5. Transmittance and reflectance spectra of a solar cell using the 150 mm integrating sphere.

recognized by the instrument, automatically selecting appropriate measurement conditions. For maximum up-time and higher productivity, no adjustment or alignment is required: as soon as the new sampling module is in place, it's ready to use.

Applications

- The characterization of solar cells

UV/Vis spectroscopy is a convenient method of characterizing the transmission loss of silicon photocells. Since the samples are highly scattering, an integrating sphere must be used. The overlaid spectra show the transmittance at normal incidence and reflectance at 8° incidence (Fig.5).

Using the center-mount facility, the reflectance of the solar cell can be measured at various angles to mimic the passage of the sun across the sky. Reflectance spectra at 10° intervals between 10° and 60° are shown in Fig.6. The thickness of any coating over the silicon cell can be calculated if necessary.

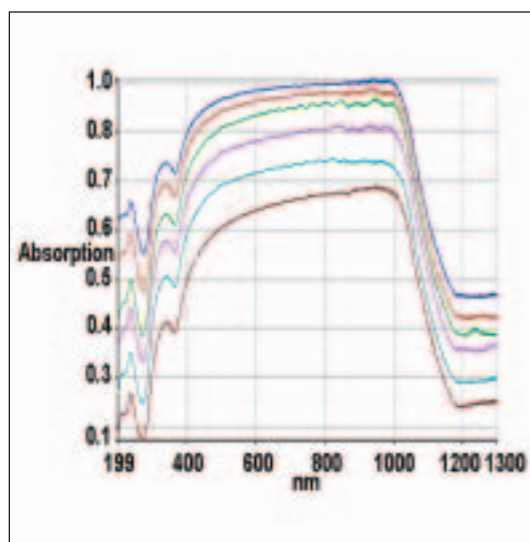


Figure 6. Reflectance spectra at variable angles of a solar cell using the 150 mm integrating sphere with center-mount.

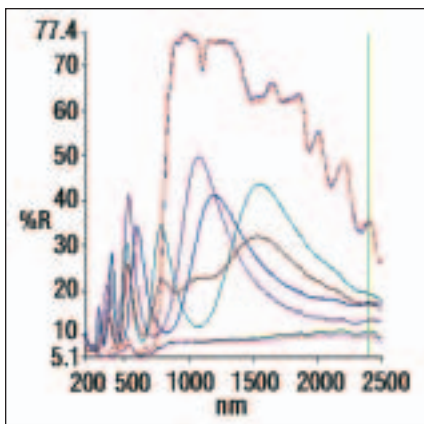


Figure 7. Spectra of security inks on paper money.

• The analysis of security ink

A series of spectra from different examples of paper money were measured on a LAMBDA™ 950. Either a 60 mm or 150 mm integrating sphere is suitable for these measurements. The angle of incidence was 8°. The spectra (Fig.7) show variable reflectance in the visible and near-IR, providing full characterization of each ink across the spectral range.

• Color analysis

For highly accurate color measurements, ASTM recommends the use of a 150 mm integrating sphere. This yields *absolute* color values enabling accurate color matching and inter-lab transfer of color values. Smaller integrating spheres, such as the 60 mm sphere, are also

used for the measurement of *relative* color measurements, for example when the color of a product is verified over time against an internal standard.

Figure 8 shows a series of NPL (National Physical Laboratory) ceramic primary color standards measured on a LAMBDA 650 with a 150 mm integrating sphere with an 8° angle at the reflectance port. The spectra are traceable to international standards such as CIE, ASTM, ANSI, DIN and EN.

• Distinction between specular and diffuse reflectance

Samples with different gloss characteristics or varying surface polishing can be analyzed in specular and diffuse reflectance mode. A standard gloss trap in the 150 mm integrating spheres allows the measurement of the diffuse component only.

• Concentration determination of dyes in textiles

In diffuse reflectance measurements, the Kubelka-Munck function provides equivalence to absorbance in transmission spectroscopy. It is proportional to concentration and thus can be used for quantitative analysis of chemical compounds in solids.

• Determination of food constituents

The analysis of constituents in foodstuffs by NIR reflectance spectroscopy is gaining in importance since

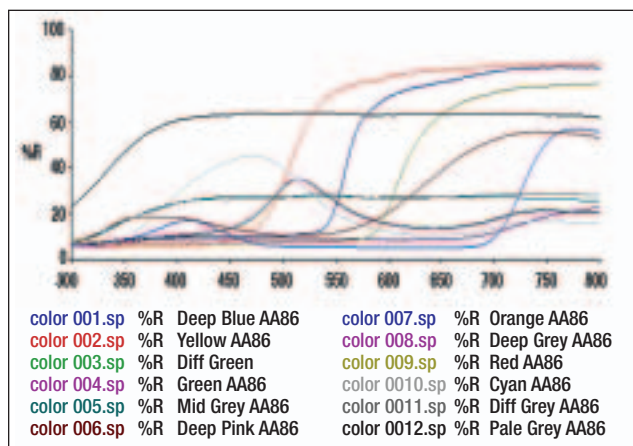


Figure 8. Ceramic primary color standards, measured on a LAMBDA 650 with 150 mm integrating sphere.

little or no sample preparation is required. The LAMBDA 900 integrating sphere system provides excellent qualitative as well as quantitative answers. After calibration the content of fat, protein and water can be obtained in a single measurement.

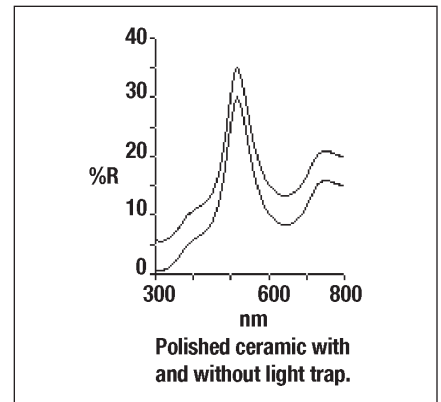


Figure 9. Spectra of polished ceramic with and without light trap, measured on the LAMBDA 850 with the 150 mm integrating sphere.

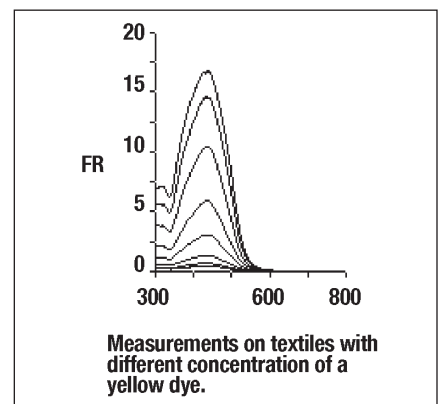


Figure 10. Spectra of textiles with different concentrations of a yellow dye, measured on the LAMBDA 650 with the 60 mm integrating sphere.

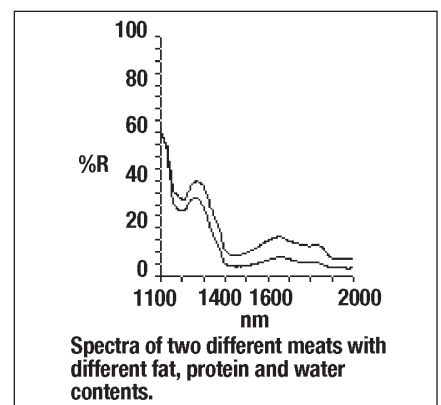


Figure 11. Spectra of two meats with different fat, protein and water content.

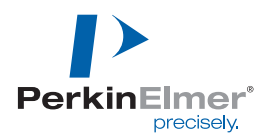
How to choose an integrating sphere – specifications and accessories

The following table shows the integrating sphere options for the LAMBDA™ 650, 850 and 950.

Specifications and accessories for LAMBDA 850 and LAMBDA 950 integrating sphere systems

Sphere Diameter	60 mm	60 mm	150 mm	150 mm	150 mm
Geometry (Transmittance/Reflectance)	0° / 8°	0° / 8°	0° / 8°	0° / 8° (Down viewing)	0° / 8° (Large sample)
Description	Recommended comparative for quality assurance measurements	Recommended for comparative quality assurance measurements – extended range operation	Recommended for absolute measurements, color analysis following CIE guidelines. Options include two types of center mounts for sample positioning in the center of the sphere and a small spot kit	Recommended for the measurement of samples which must be held in a horizontal position, such as powders, granular materials and large irregular samples	Features a large optical compartment allowing the transmittance measurement of large samples. Typical applications include measurements on photographic paper, gel emulsions and glass panels.
Quick- change sampling module	yes	–	yes	–	–
Coating Material	Spectralon	Infragold	Spectralon	Spectralon	Spectralon
Wavelength Range	200 to 2500 nm	900 to 3300 nm	200 to 2500 nm	200 to 2500 nm	200 to 2500 nm
Sample port dimension	15 mm diameter	15 mm diameter	20 mm diameter	20 mm diameter	20 mm diameter
Corrected Baseline	+/- 0.002 A 200 to 2400 nm	+/- 0.002 A 900 to 3200 nm	+/- 0.002 A 200 to 2400 nm	+/- 0.002 A 200 to 2400 nm	+/- 0.002 A 200 to 2400 nm
Absorbance Range (PMT)	6 A (attenuated)	6 A (attenuated)	6 A (attenuated)	5 A (attenuated)	6 A (attenuated)
Absorbance Range (Cooled PbS)	4 A (attenuated)	4 A (attenuated)	4 A (attenuated)	4 A (attenuated)	4 A (attenuated)
Sample Size: Transmittance	100 mm square ~ 50 mm thick	100 mm square ~ 50 mm thick	153 mm square ~ 75 mm thick	300 mm square ~ 25 mm thick	153 mm square ~ 300 mm thick
Sample Size: Reflectance	unlimited	unlimited	unlimited	unlimited	unlimited
Sample center mount (Diameter)	–	–	50 mm	–	50 mm
Gloss trap / light trap (included)	–	–	yes	yes	yes
Center mount jaw style (optional)	–	–	PELA-9038	–	PELA-9038
Center mount clip style (optional)	–	–	PELA-9039	–	PELA-9039
Small spot kit (optional)	–	–	PELA-9048	–	PELA-9048
Cell holder for Integrating Spheres (optional)	C695-1019	C695-1019	C695-1019	–	C695-1019
Powder sample holder set (optional)	PELA-9040	PELA-9040	PELA-9040	–	PELA-9040
Detector	TE-Cooled PbS Hamamatsu R-955 PMT	TE-Cooled PbS Hamamatsu R-955 PMT	TE-Cooled PbS Hamamatsu R-955 PMT	TE-Cooled PbS Hamamatsu R-955 PMT	TE-Cooled PbS Hamamatsu R-955 PMT
Part Number	L6020203	PELA-1021	L6020204	PELA-1001	PELA-1002

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