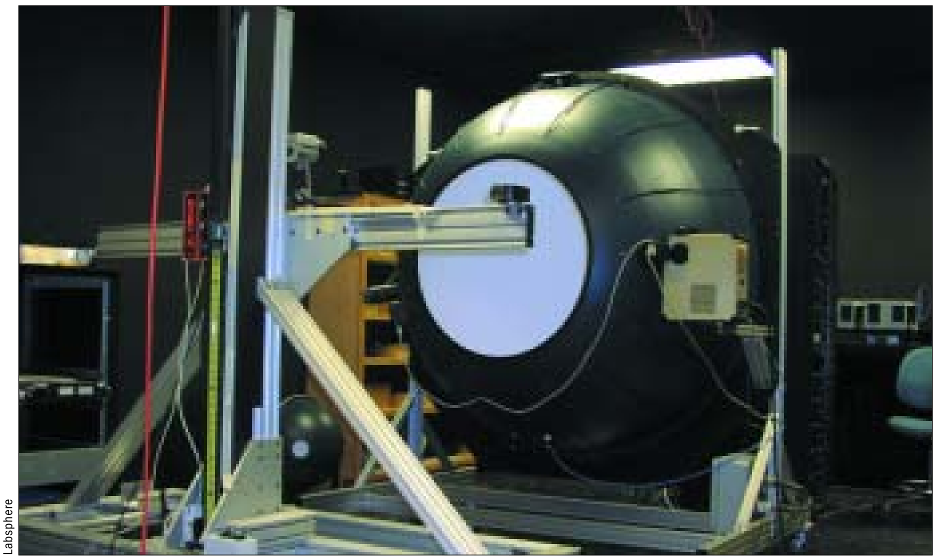
Integrating spheres tackle many tasks

If you want to measure the flux of a lamp or LED, the reflectance of a material, or the power of a laser beam, an integrating sphere is the perfect tool, reports **Greg McKee**.



Labsphere

Ideal source: a large integrating sphere being verified as a light source with 99% radiance uniformity.

The integrating sphere is a simple, yet often misunderstood, device within the world of photonics. It also happens to be one of the most versatile and useful. By changing its configuration, the sphere can function as a reliable optical flux detector, a perfectly uniform source of light or a convenient way to characterize the optical properties of a solid, liquid, or powder.

So, what exactly is an integrating sphere? Put simply, it's a hollow sphere which has its internal surface prepared with a diffusely reflective coating and features a number of ports for either measuring introduced light or producing calibrated light. In addition, the interior of the sphere is equipped with light barriers (called "baffles") to screen any direct light from test objects, lamps or hot spots from directly irradiating the sphere's detector port. The size of an integrating sphere can range from as little as 2.5 cm in diameter to larger than 3 m, depending on the application.

In effect, multiple diffuse reflections from the sphere's interior wall reduce the angular dependence of any introduced light so that it becomes become completely uniform. The result is that any point on the sphere wall produces equal radiance (flux density per solid angle) which is proportional to the flux input. A detector placed on the sphere wall can then be used to monitor or calibrate the light introduced into the sphere.

However, this radiance-equalizing effect also has other uses. It means that an integrating sphere can act as a uniform source of illumination that is ideal for testing the homogeneity and linearity of digital imaging equipment or a CCD array.

Generally, in order for an integrating sphere to perform well, it is important that its internal surface is highly reflective (typically 95% or higher) and highly diffuse. Factors such as the reflectance of the sphere wall, port placement and diameter, and what is being measured or tested are all factors when selecting the right sphere for your application.

Intuition might suggest that the radiance from a point on the sphere wall is equal to the power of the light source divided by the total surface area of the sphere. However, this is not the case. The high number of reflections off the sphere wall dramatically increases the radiance that is present within the sphere.

The factor linking the two is called the "sphere multiplier" and rises as sphere reflectivity goes up and the area of ports cut into the sphere goes down. The term is effectively a figure of merit that should be maximized in order to achieve higher throughput, better light integration and superior performance.

A handy rule of thumb is that, for most integrating spheres encountered in practice (reflectivity of between 95 and 99.9% and a port fractional area ≤ 0.05), the sphere multiplier is usually in the range 10–30.

Selection criteria

Choosing an integrating sphere for any application involves specifying a few basic parameters. These include selecting the optimum sphere diameter based upon the number and size of port openings and peripheral devices. One also has to choose the most appropriate sphere coating bearing in mind the spectral range of the measurements and the precision required. The use of baffles and their effect must also be considered carefully.

> **"An integrated sphere can act as a uniform source of illumination."**
>
> **Greg McKee**

Coatings: When choosing a coating for an integrating sphere, two factors must be taken into account: reflectance and durability. For example, if there seems to be limited light, and the sphere will be used in an environment that may cause the sphere to collect dirt or dust, a durable, cleanable, highly reflective coating should be chosen.

Items located inside the sphere, including baffles, lamps, and lamp sockets absorb some of the energy of the radiant source and decrease the throughput of the sphere. This decrease in throughput is best avoided by coating all possible surfaces with the same ▷

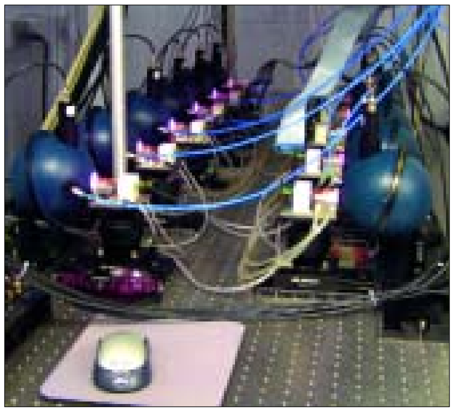
highly reflective coating.

The sphere multiplier is extremely sensitive to the sphere's surface reflectance. A difference of just 2% can change the sphere multiplier and thus radiance by as much as 40%. It is important to ensure that the coating is uniformly distributed and highly reflective across your wavelength range of interest. For example, Labsphere's Spectraflect and Spectralon coatings are designed for operation from the ultraviolet to the near-infrared (250–2500 nm) and both offer a reflectivity exceeding 98%, with Spectralon exceeding 99.8% in the visible region.

Baffles: In general, the light from a source to be characterized should not directly illuminate either the detector element or the area of the sphere wall that the detector views directly. In order to accomplish this, baffles (light barriers) are often used in integrating sphere design. Baffles, however, will add performance uncertainties simply because the integrating sphere is no longer a perfect sphere. It is advisable to minimize the number of baffles used in a sphere design.

Applications

Lamp-flux measurement: Perhaps one of the oldest applications for the integrating sphere is the measurement of total luminous flux from lamps. The technique originated at the turn of the 20th century as a simple and fast method of comparing the lumen output of different lamp types. Today, integrated sphere photometers are used to measure luminous flux and colour parameters of everything from packaged LEDs and lamps for the automotive and general lighting industries, to diffuse backlighting for the displays industry.


NASA

NASA's high-power laser-diode measuring set-up.

Laser power measurement: As well as placing a source directly within a sphere, it is also possible to capture light from external collimated sources such as a free-space laser beam, highly divergent laser diodes, or coupled optical fibres. Because of the unique abilities of an integrating sphere, radiant power measurements are independent of beam polarization and are insensitive to beam alignment. A sphere can be designed for a wide range of incident angles over a large area without affecting the signal at the detector. Additional ports can be added to perform a parallel spectral characterization making it the ideal device for reliable laser-diode testing.

The ideal uniform illumination source: An integrating sphere is a near-perfect means for creating a uniform source of radiance or irradiance. The output aperture of an integrating sphere source, when designed correctly, can produce a near-perfect Lambertian light source, independent of viewing angle.

Reflectance and transmittance: The single largest use of integrating spheres is the measurement of reflectance and transmittance off specular, diffuse or scattering materials. These measurements provide simple, quantitative characterization of materials such as thin films, architectural glass, and turbid liquids. □

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