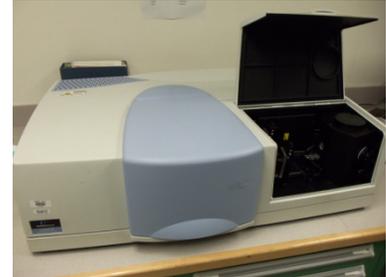




Direct hemispherical solar optical properties

The Perkin-Elmer Lambda 950 with Labsphere 150 mm integrating sphere is a commercial spectrophotometer widely used in the glazing industry to measure reflectance and transmittance in the solar range (300-2500 nm). The main light source is a tungsten halogen lamp which is complemented by a Deuterium lamp for shorter wavelengths. Near infrared wavelengths are detected using a PbS detector and a photomultiplier tube cover wavelengths under 860 nm.



Attributes and Capabilities:

- Wavelength range with integrating sphere 300 – 2500 nm, specular accessory 200-3300 nm, shorter wavelengths possible if purged with N₂.
- Sample size 2x2" to 3x3" is ideal, larger or smaller samples can be accommodated using special procedures.
- Calibrated second surface reference mirror from OMT solutions for high precision reflectance measurements.
- Custom mounted rail for measurement of the bi-directional transmittance distribution function (BTDF)
- Set of angle tubes for measurements at varying angles of incidence at 5 degree increments.



Angle tube with green shade material inserted into the integrating sphere



75 degrees is the largest angle of incidence, the sample is wedged using a sleeve system.

Windows Group Optical Lab (building 90-0014)

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Variable angle of incidence spectroscopic ellipsometry (VASE)

The JA Woollam VASE ellipsometer a commercial ellipsometer that measures the change in polarization as light is reflected from the surface of the studied sample. The method is standard for obtaining optical constants (n , k) as well as thickness for thin film coatings on glass.

The instrument can also be run in goniometer mode for measuring angle-resolved in-plane scattering of opaque samples.



Attributes and Capabilities:

- Wavelength range 300-1700 nm
- Sample size 2x2" to 3x3" is ideal, larger or smaller samples can be accommodated using special procedures.

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Full spherical goniometer

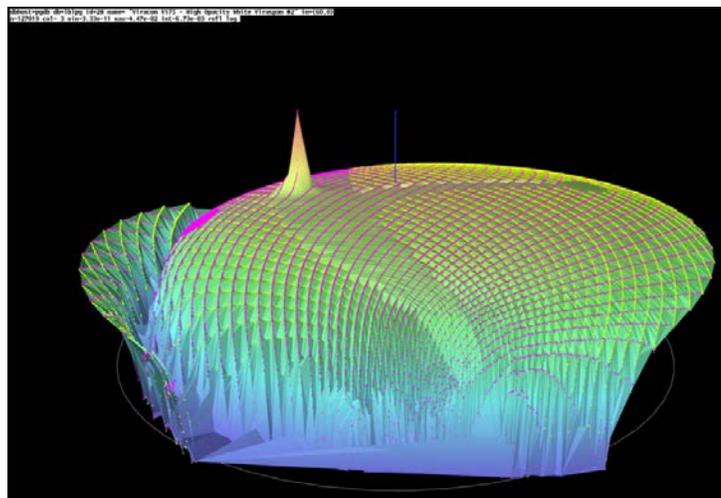
The Pab Advanced Technologies Ltd measures angle-resolved scattering over the full outgoing sphere to obtain the complete outgoing bi-directional scattering distribution function (BSDF) of a material. Using a tungsten halogen light source and filtered Si-detectors it can obtain data in different wavelength bands. The NIR wavelengths are covered with an InGaAs detector. Characterization of 16 angles of incidence and two wavelength bands takes between 10 and 18 hours.

Attributes and Capabilities:

- Ideal sample size to allow measurements at oblique angles of incidence is 3"x10".
- Angle of incidence -80 – 80 degrees
- Silicon and InGaAs detectors combined with filters are used to select wavelength bands to study



Example how data can be visualized, this is the reflectance at 60 degrees angle of incidence for a fritted glass sample. This graph shows one angle of incidence, a complete BSDF typically consists of 145 datasets like this.



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Spectro-goniometer

The Optronic Laboratories OL-750 was built to LBNL specifications to measure specular transmittance and reflectance versus angle of incidence for specular samples. The sample can be rotated and translated with 4 degrees of freedom and the detector moves in the horizontal plane of the instrument (not necessarily the scattering plane of the sample) to measure reflectance and transmittance. The freedom of movement of the detector also allows the instrument to be used for angle-resolved scattering measurements.



Attributes and Capabilities:

- Wavelength range 300-2500 nm
- Sample holder is limited to samples of size between 2x2" and 3x3"
- Angle of incidence -20 – 80 degrees
- Outgoing angle limited by angle of incidence

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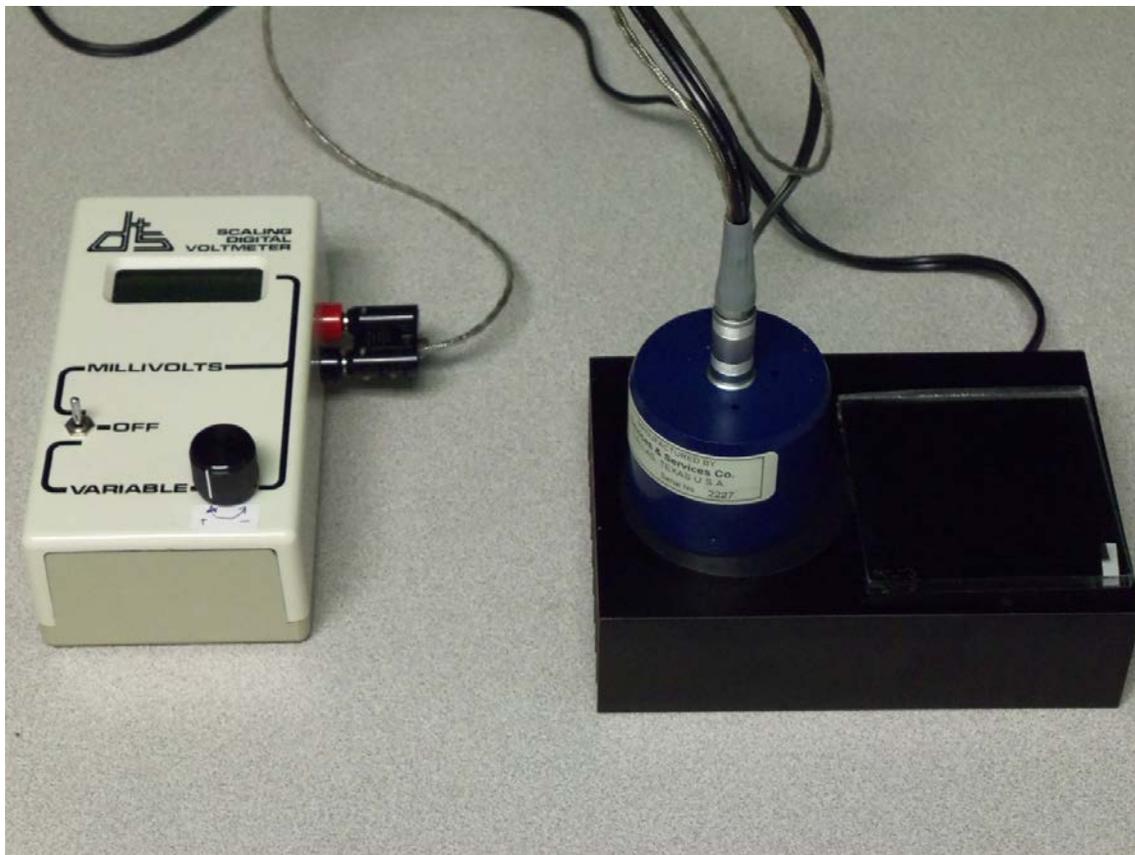


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Hemispherical thermal emissivity

The Devices and Services AE1 RD1 emissometer measures hemispherical thermal emissivity of opaque samples. Traditionally that property is obtained by measuring reflectance using an FTIR spectrophotometer and calculating the integrated emissivity. The reason for FTIRs has been the improved accuracy of those instruments.



Attributes and Capabilities:

- Measured surface area varies from .5" to 1.5" diameter which defines the minimum sample size.
- After a warm-up time of 30 minutes each measurement takes 90 seconds.
- Calibrated using a high and low reference

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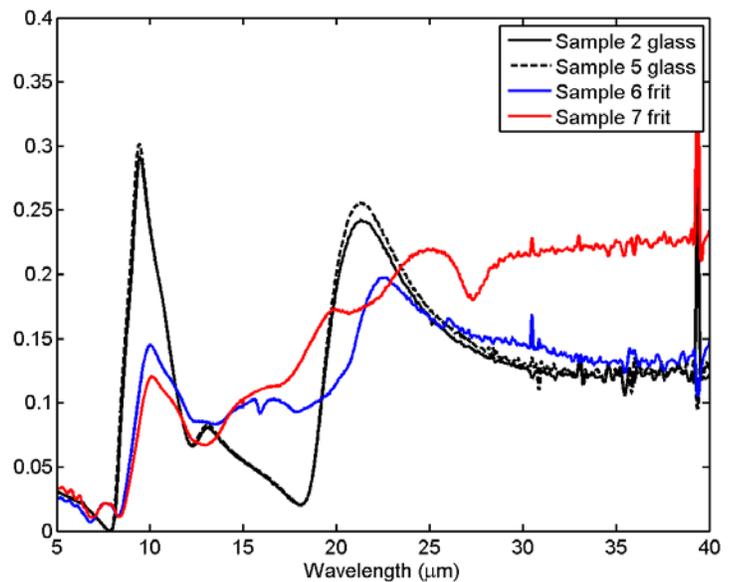


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Fourier-Transform Infrared (FTIR) Spectroscopy

The Perkin-Elmer Frontier FTIR spectrometer measures transmittance and reflectance in the wavelength range from 2.5 μm to 44 μm . measures hemispherical thermal emissivity of opaque samples. The instrument is fitted with a PYKE 10 degree angle of incidence reflectance accessory.



Attributes and Capabilities:

- Ideal sample size to allow measurements at oblique angles of incidence is 3"x3".
- After a warm-up time of 30 minutes each measurement takes 5-10 minutes depending on noise level.
- Calibrated using a gold reference mirror

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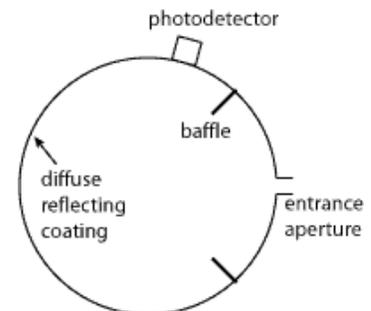
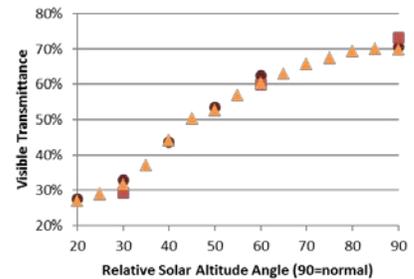
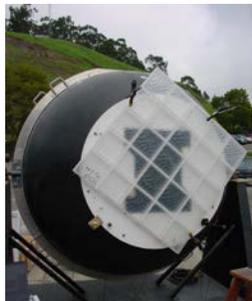


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Large Diameter Integrating Sphere (LDIS)

The large diameter integrating sphere (LDIS) measures total visible transmittance of complex light redirecting/diffusing samples with large scale non-uniformity. The instrument is a sphere 6.5 ft (2 m) in diameter with up to 34 inch measurement aperture (11-15 inch typical).



Attributes and Capabilities:

- Motorized position relative to the sun allows rapid measurement of many incidence angles
- Validates optical models for light redirecting samples under variable angle of incidence
- Basis for NFRC 203 standard development

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