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ACCURATE TRANSMISSION MEASUREMENTS OF TRANSLUCENT MATERIALS

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Accurate Transmission Measurements of Translucent Materials

Unlike transparent materials which transmit light with no appreciable attenuation or absorption, translucent materials often possess certain properties and physical structures that cause incident light to become scattered as it passes through the sample. The scattering that occurs poses some interesting challenges when attempting to measure the transmission of these materials.

There are three basic processes that occur when light strikes an object; it can be either be reflected, transmitted, or absorbed. Other process such as fluorescence can occur due to the presence of shorter wavelength radiation in the irradiating source, however we will not be addressing this directly in this article. In normal or regular transmission measurements of transparent materials where the angle of the transmitted beam can be calculated if the incident angle is known using Snell's law,

$$n_1 Sin\theta_1 = n_2 Sin\theta_2 \quad (1)$$

the measurement setup is fairly straightforward (*Fig. 1.*). A stable source is used to provide illumination and depending on the information required, a radiometer, photometer, or spectroradiometer is used to process the signals. A measurement of the source it acquired by placing it inline with the detector and without the sample in place and the incident flux is recorded as ϕ_i. The sample is then placed between the source and the detector and another measurement is taken and recorded as ϕ_t. The ratio of these two signals is the transmission of the sample and can be reported as either radiant, luminous (photometric), or spectral transmittance.

$$\text{Luminous Transmittance} \quad \tau_v = \frac{\phi_{v,t}}{\phi_{v,i}} \quad (2)$$

$$\text{Spectral Transmittance} \quad \tau(\lambda) = \frac{\phi_t(\lambda)}{\phi_i(\lambda)} \quad (3)$$

No special considerations are needed since the incident beam diameter is roughly the same as the transmitted beam diameter and therefore all of the transmitted light is received by the detector.

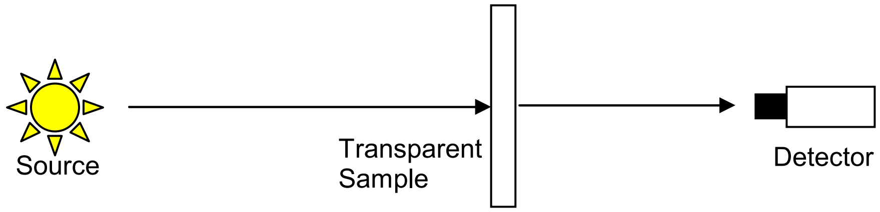

Fig. 1. Regular Transmission Measuremet Setup

This is not so with translucent materials. When incident light impinges on a translucent material, it tends to scatter and diffuse and therefore the angle of the transmitted light no longer obeys Snell's law (*Fig. 2.*). This results in much of the transmitted light missing the detector. It is this diffuse transmission of light that requires special attention and proper selection of detection optics to ensure all transmitted light is collected and processed.

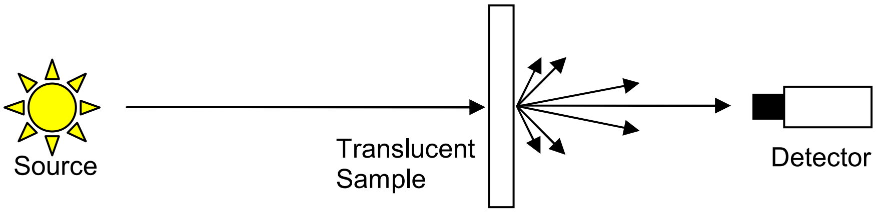

Fig. 2. Regular Transmission Measurement Setup

To effectively collect all diffusely and non-diffusely transmitted light, it becomes necessary to select a large angle collection optic. By virtue of their design, integrating spheres are perfect for this type of measurement. By placing the sample up to the input port it becomes possible to collect even the highest angle rays (*Fig 3)*. It is not, however, a straightforward measurement as when measuring transparent samples.

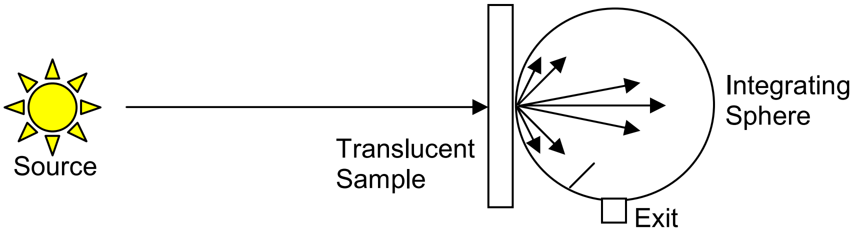

Fig. 3. Diffuse Transmission Measurement Setup

At first glance it may seem as though we can simply take a measurement of the light incident on the input port, ϕ_i, place our sample up to the sphere port and take another measurement of the transmitted light, ϕ_t, calculate the spectral transmittance. Although this sounds like a logical approach, we have not taken into account the fact that by placing the sample up to the sphere port, we have effectively changed the response of the sphere. Without a sample in place, it is clear that some of the incident light is allowed to escape back through the input port. Placing a sample against the port also allows some of the transmitted light to escape through the input port, however in different proportion than with no sample in place. In addition, light is also re-reflected back into the sphere from the sphere side of the sample and is spectrally dependent on the composition of the sample. *(Fig. 4)*.

Fig. 4 Light path with and without sample in place

To account for the changes in integrating sphere response due to sample placement, it becomes necessary to utilize *two* sources, one for irradiating the sample and the other for determining the spectral response changes. It is important to note that both sources must have the same spectral distribution when using the "double beam" method for transmission measurements. A representative setup for measuring total transmission, τ_T, is shown *(Fig. 5)*,

$$\text{Total Transmission} \quad \tau_T = \tau_R + \tau_D \quad (4)$$

where τ_R is the regular transmission and τ_D is the diffuse transmission.

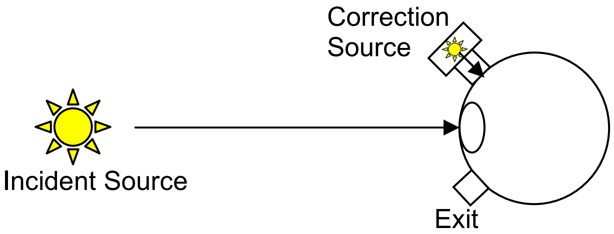

Fig. 5 Typical setup for measuring diffuse transmission using "double beam" method

The double beam method for measuring diffuse transmission of translucent materials consists of 4 separate steps:

1) Take measurement of *Incident Source* without sample in place and *Correction Source* off
2) Take measurement of *Correction Source* without sample in place and *Incident Source* off
3) Keeping *Incident* Source off, install sample against port and again take measurement with *Correction Source*
4) Take measurement with *Incident Source* with *Correction Source* off.

Steps one and two combine to provide and general calibration for the system by dividing the flux obtained from the *Correction Source*, ϕ_{CS} by the flux of the *Incident Source*, ϕ_i. Step three is essential for the spectral and intensity correction of the system due to the presence of the transmitting samples at the integrating sphere port. This is generally referred to as the *sample calibration,* ϕ_{cal}*,* and is specific to the individual sample under test. The measurement is recorded as $\frac{1}{\phi_{cal}}$. If the spectral characteristics, inherent diffusivity, or transmission of the sample changes, a new sample calibration *must be performed*. A final measurement of the sample is obtained with the incident source and recorded as ϕ_S. The total spectral transmission, τ_T, of the sample can then be calculated.

$$\text{Total Spectral Transmission} \quad \tau_T(\lambda) = \frac{\phi_{CS}(\lambda)}{\phi_i(\lambda)} * \frac{1}{\phi_{cal}(\lambda)} * \phi_S(\lambda)$$

Using this approach, test results show a marked difference between measurements made using the 2 beam and 4 beam methods. It is also worth noting that looking at Fig. 6 it is clear that the differences obtained using a spectroradiometer and the 4 beam method are not simply a constant shift, but rather spectrally dependent on the color and composition of the samples being tested.

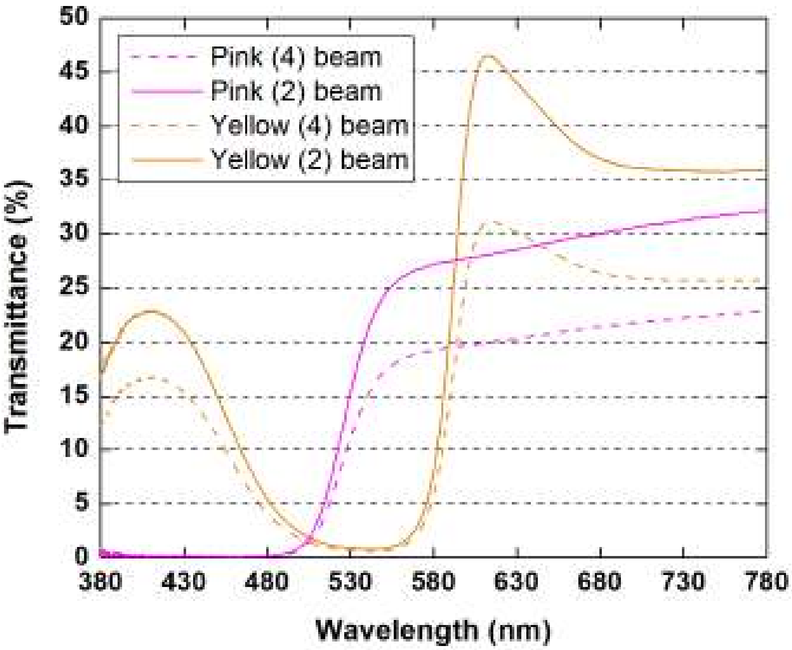

Fig. 6 Comparison of 2 beam vs. 4 beam method for measuring diffuse transmission