

Issues Defining Transmittance Haze

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Scattering Samples

Many industries are interested in controlling the degree to which light scatters when it passes through a material. Some industries want to maximise scattering to stop us from being able to see through a material, for example for privacy glass. Others want to minimise scattering to ensure we can see clearly through the material, for example for plastic packaging. Figure 1 shows photographs of two samples with different types of scattering.

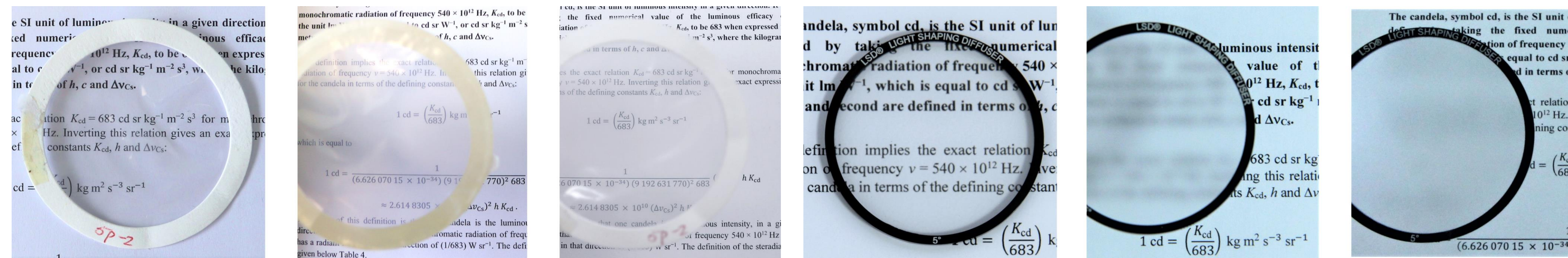


Figure 1: Photographs of two different scattering samples 5P-2, left, and H5, right, taken with the samples held at distances 0 mm (left), 50 mm (middle), and 120 mm (right).

The photos of the samples in Figure 1 demonstrate the visual effects caused by the scattering of the two samples. Both transmit most of the incident light but differ in the angular distribution of transmitted light:

- 5P-2 is a cellulose nanofibril sample [1]. A high fraction of light is transmitted without any scattering, so we can read the text at all three distances. At the larger distances, there is a loss of contrast due to some wide-angle scattering.
- H5 is a holographic diffusing sample. Most of the light is scattered at small angles. At greater distances this causes a loss of distinctness so we can no longer read the text behind the sample.

In order to control scattering, we need to be able to quantify it. Currently, the most widely used metric to describe the scattering as light passes through a material is transmittance haze.

Haze Definitions

CIE International Lighting Vocabulary

According to the CIE ILV [2], transmittance haze is the fraction of light scattered by more than a specified angle from the direction of the incident beam. The effect of transmittance haze on a material is a “reduction in contrast of objects viewed through it”. The CIE definition does not specify what the specified angle is.

Documentary Standards

Several documentary standards describe an instrument for measuring transmittance haze [3, 4, 5, 6] and commercially available instruments base their designs on these. The different standards all define transmittance haze to be the percentage of transmitted light scattered by more than 2.5°. The standards also all specify the use of an integrating sphere with a prescribed geometry as a practical method for approximating the measurement of transmittance haze (see Figure 2).

Differences Between Standards

While the standards agree on the definition and the geometry of the integrating sphere, the standards differ in the specified sphere configurations used in the measurements. Some standards specify the use of a compensation port to keep the sphere reflectance constant for the ratioed measurements, while others do not. This causes the measured haze to vary between the different methods, and even between implementations of a single standard. For example, haze measurements of a single material have been shown to differ by up to 20% on two spheres which both conform to the ASTM standard [7, 8].

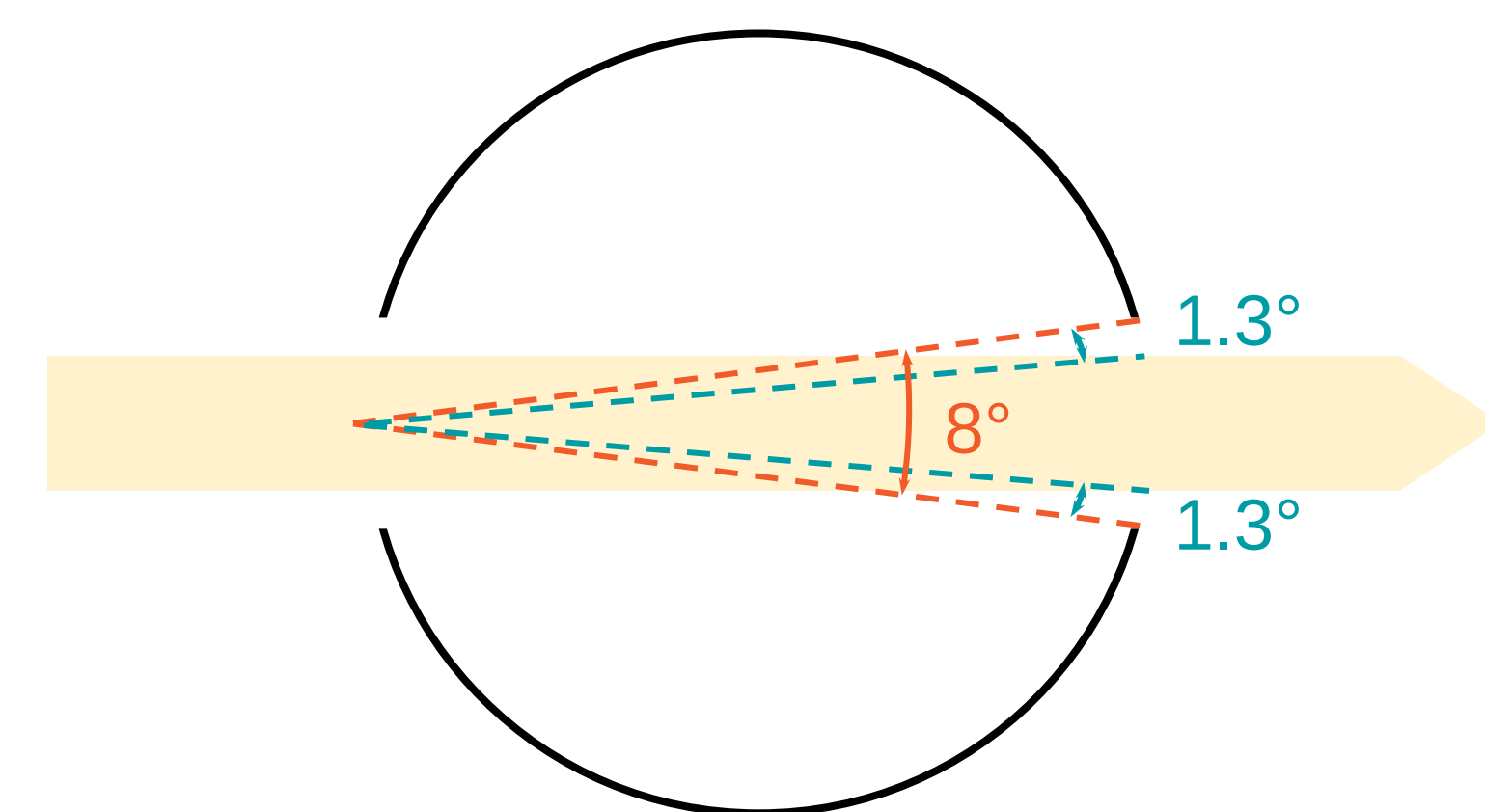


Figure 2: Sphere geometry specified in the documentary standards. The exit port subtends 8° from the centre of the entrance port, a collimated beam is used, and there is an annulus around the collimated beam at the exit port that subtends 1.3° from the centre of the entrance port.

Goniospectrophotometric Measurements

Another method of realising transmittance haze is by measuring the bidirectional transmittance distribution function (BTDF) of the sample over the hemisphere using a goniospectrophotometer. Then, by numerically integrating appropriate parts of the BTDF, the haze can be determined. Figure 3 shows BTDF measurements of the two different haze samples. Note that a perfect diffuser would show a flat line at 0.3. The transmittance haze calculated from these measurements is plotted in Figure 4 and compared with the haze measured using a sphere according to the ISO standard (which does not suffer from the sphere dependence described for the ASTM standard).

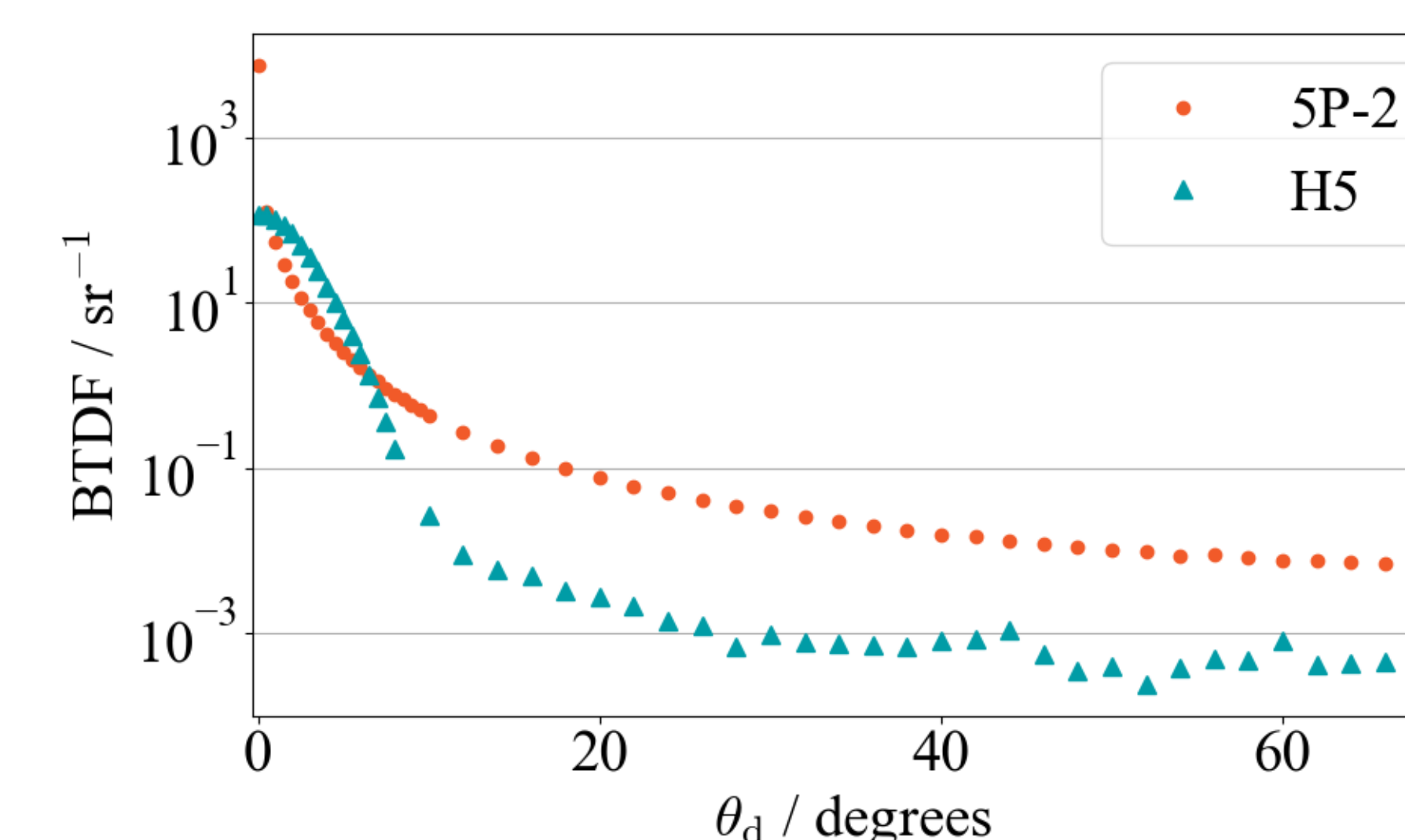


Figure 3: BTDF measurements of the 5P-2 and H5 samples.

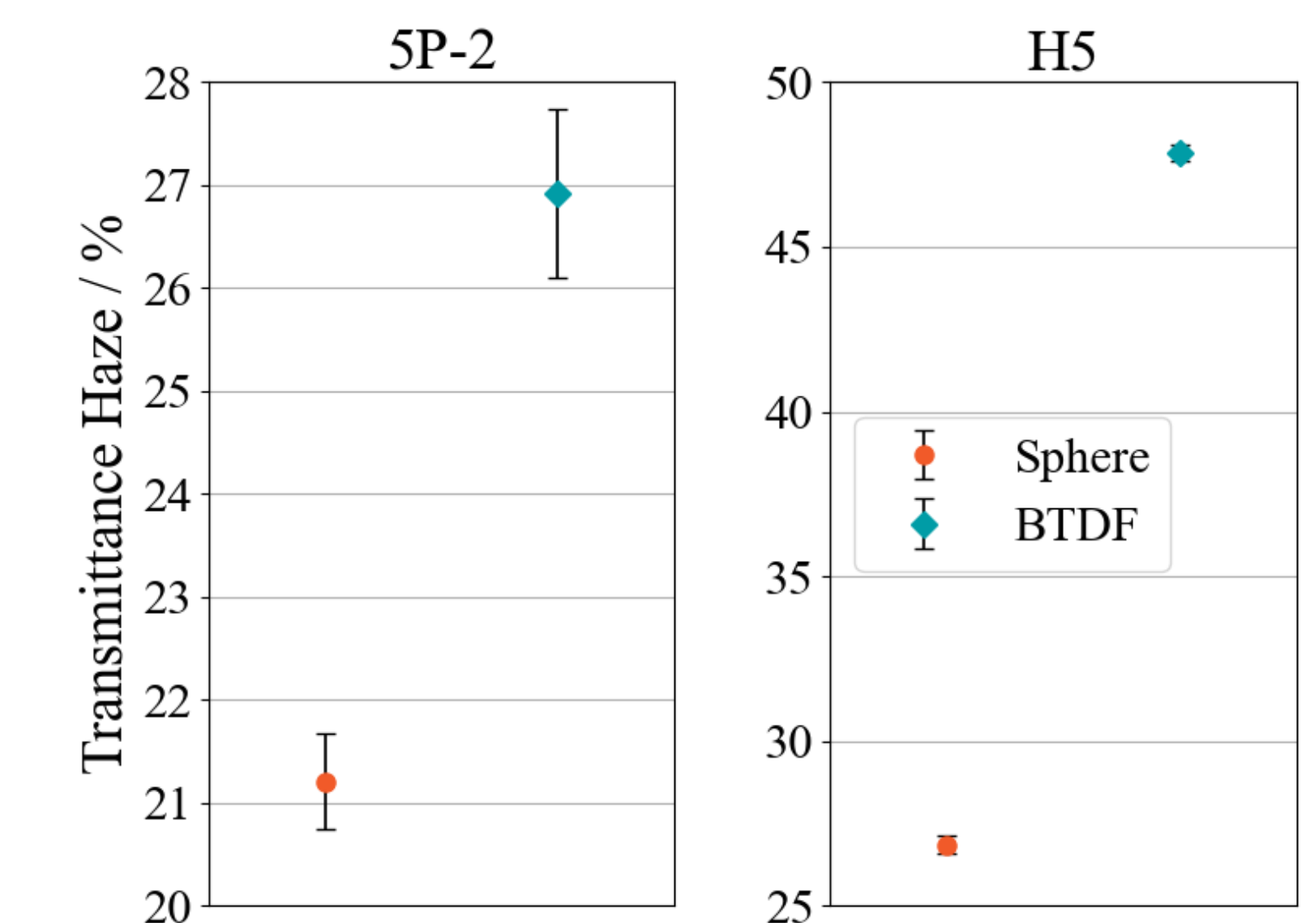


Figure 4: Transmittance haze of the 5P-2 and H5 samples measured using an integrating sphere according to the ISO standard and measured by integrating BTDF measurements.

Improved Scattering Metrics

The transmittance haze values differ greatly between the two realisations. This difference is due to the fact that sphere methods must approximate the ideal geometry to allow for use of a finite sized collimated incident beam and a sensibly sized (small enough) sphere. Therefore, the sphere collects some light scattered by less than 2.5° degrees and loses some that has been scattered by more. The difference observed between the two realisations thus depends on the shape of scattering distribution of a sample in this range. It cannot easily be resolved or corrected for without making BTDF measurements.

The suitability of haze measurements as a proxy for the degree of scattering through a material depends on the visual effect that is intended to be measured. For example, in industries interested in eliminating light scattering, measurement of clarity, which measures very narrow-angle scattering, may be more appropriate than haze. Where the interest is to maximise diffusion of light, another metric relating to the width of the central peak of the BTDF or the overall flatness of the BTDF or the ratio of the narrow angle scattering to the broad angle scattering, may need to be developed.

References

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- [3] ASTM D1003-21 2021 *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics* (ASTM)
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- [5] JIS K 7105 1981 *Testing Methods for Optical Properties of Plastics* (Japanese Industrial Standards)
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