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Optical Spectroscopy

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May 26, 2009

Evaluating Labsphere's new UV-2000

Abstract

Labsphere's Ultraviolet Transmittance Analyzer UV-1000 is established as fast in-vitro testing equipment for sun protection properties in different industries. A new instrument based on the same principals, the UV-2000, is now introduced into the market. One of the first examples available in Europe was provided by Laser-2000 for testing purposes.

Using the technical data sheet of the manufacturer as a meter, the tested UV-2000 at least met these specifications. The instrument can be used down to transmitted intensities as low as the specified 2.7 absorbance units, which really is the instrument's limit due to the noise level. Over a wide transmittance range the UV-2000 responded linearly and was in absolute terms very close to a Perkin Elmer Lambda 950, used as a reference instrument. Wavelength accuracy was verified to be closer than ±1.0 nm as specified. Spectral bandwidth is claimed for the UV-2000 to be below 4 nm, for the instrument tested we determined a value of 1.7 nm. The UV-2000 clearly breaches the UV-1000's limits.

Introduction

The Ultraviolet Transmittance Analyzer UV-1000 of Labsphere was constructed for easy and fast transmittance measurements of samples, which not only absorb UV radiation but additionally show intensive light scattering or fluorescence or both. The instrument was designed for in-vitro measurements of sun protection abilities of samples and was shipped with appropriate software calculating the standardized protection factors commonly used in different industries from the UV transmittance spectra. Over the last decade sun protection properties were steadily increased and the UV-1000 was confronted with ever higher protection factors, which led the instrument to its limits. Now Labsphere introduced the UV-2000 to overcome the limitations of its forerunner. The new instrument is presented not only with sharpened technical specifications but comes with a couple of smart improvements to reproducibility and sample handling in addition to the more obvious changes of the design of hard- and software.

This report exclusively concentrates on the basic properties of the Labsphere UV-2000 as an optical instrument, which provide the essential information on the sample under investigation.

Photometric linearity and accuracy

The response of a photometric device to different light intensities has at least to be unique, but it is much more convenient if in addition it is linear. Neutral density filters provide an easy and accurate way to modify light intensities over a broad wavelength range. Recording transmittance spectra is a very basic function of the UV-2000. Therefore, it is an obvious method to compare the transmittance values of a set of neutral density filters measured on the instrument under investigation with the values measured on a reference instrument.

A set of neutral density filters was measured over the wavelength range 250 nm – 450 nm on the Labsphere UV-2000 and on a Perkin Elmer Lambda 950 as reference instrument (Figure 1).

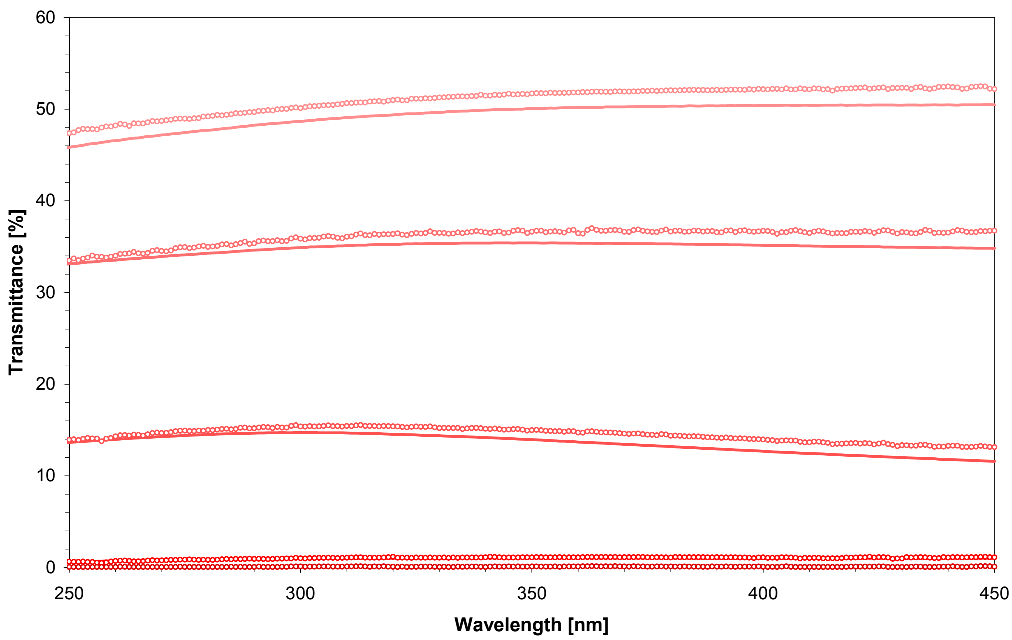

Figure 1 Transmittance spectra of 5 neutral density filters

○ measured on the Labsphere UV-2000

— measured on the Perkin Elmer Lambda 950

There are some minor differences detectable between the two instruments. Due to the unstructured flat spectra of the neutral density filters, a monochromatic analysis (Figure 2) is sufficiently representative for the complete wavelength range under investigation, although the observed differences are obviously not totally independent of the wavelength.

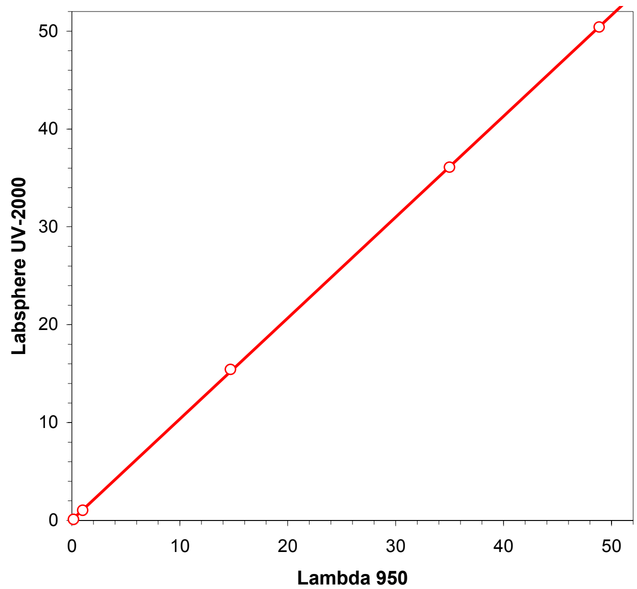

Figure 2 Transmittance at 305 nm

○ experimental data

— linear regression

Figure 2 presents a strictly linear relation of the two instruments over the complete range of the transmitted intensities covered in this survey. Linear regression analysis calculates an intercept of 0.053 and a slope of 1.031, both values are fairly close to the respective ideal values of 0.000 and 1.000. A slope in excess of 1.000 in the representation of Figure 2 means an overestimation of the transmittance measured by the UV-2000. Expressed in more descriptive words, the UV-2000 measures transmittance values some 3 % higher than the Lambda 950. The evaluation shown in Figure 2 was done at 305 nm, because in the transformation into sun protection factors this wavelength range gets a maximum in weight, but the 3 % higher values are rather consistent over the total spectral range of the UV-2000.

However, at very low transmittance values the UV-2000 measurements are below those of the Lambda 950, which is more obvious if transmittance is transformed into absorbance units (Figure 3).

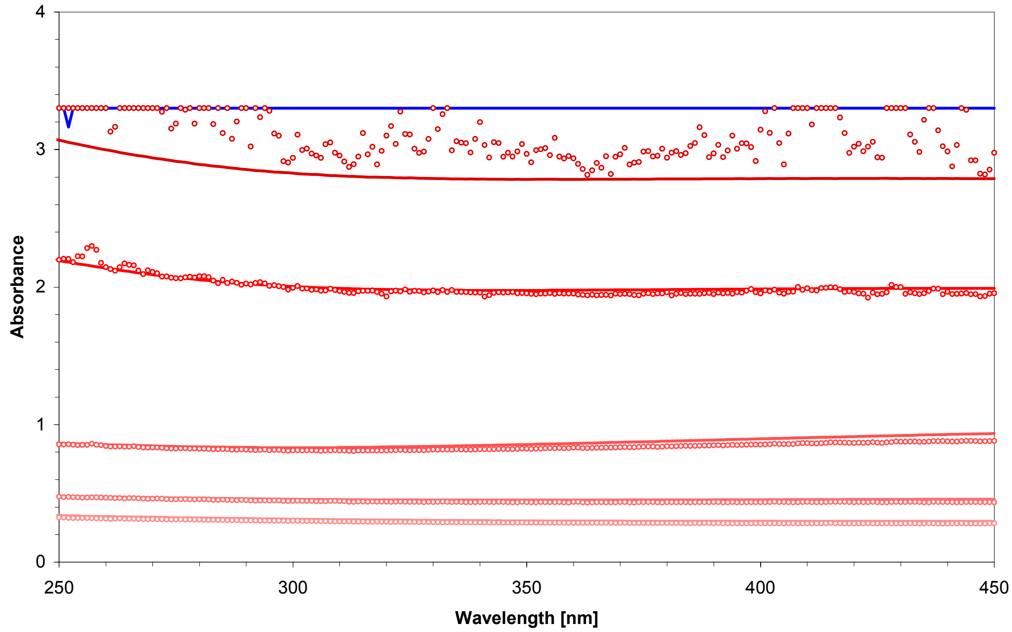

Figure 3 **Absorbance spectra of 5 neutral density filters**

o measured on the Labsphere UV-2000

— measured on the Perkin Elmer Lambda 950

— black metal plate, measured on the Labsphere UV-2000

Absorbances up to values of about 3 can still be measured on the UV-2000, although there is quite some noise due to the low intensity of available light. There is an upper limit of 3.3 absorbance units, which lies above the specified limit of 2.7. The value of 3.3 absorbance units corresponds to a transmittance of 0.05 %, which is measured for a black metal plate. A value of 0.05 % instead of 0.00 % as expected for a totally opaque sample is a rather good match of the intercept of the linear regression shown in Figure 2.

The spectral shape of a neutral density filter is very flat, almost independent of the wavelength. This shape is usually not found in reality, although it is desirable for good UV protection. For a wavelength independent spectrum neither wavelength accuracy nor spectral bandwidth are of any importance. But for this ideal case no spectrophotometer at all would be required. Therefore, the UV-2000's response to a holmium oxide filter was investigated to get information on the instrument's wave-length accuracy and spectral bandwidth.

Wavelength accuracy

Filter A of the validation set of a Labsphere UV-1000 is a clear holmium oxide filter with some distinctive, comparatively narrow absorption bands (Figure 4). For the intended purpose this filter was preferred to the respective filter from the validation set of the UV-2000, which is no longer clear but translucent. This filter was measured on a Perkin Elmer Lambda 950 with the spectral bandwidth set to 1.0 nm and a data point pitch of 0.1 nm as a reference spectrum. The same filter was then measured on the UV-2000 and the spectrum compared to the reference.

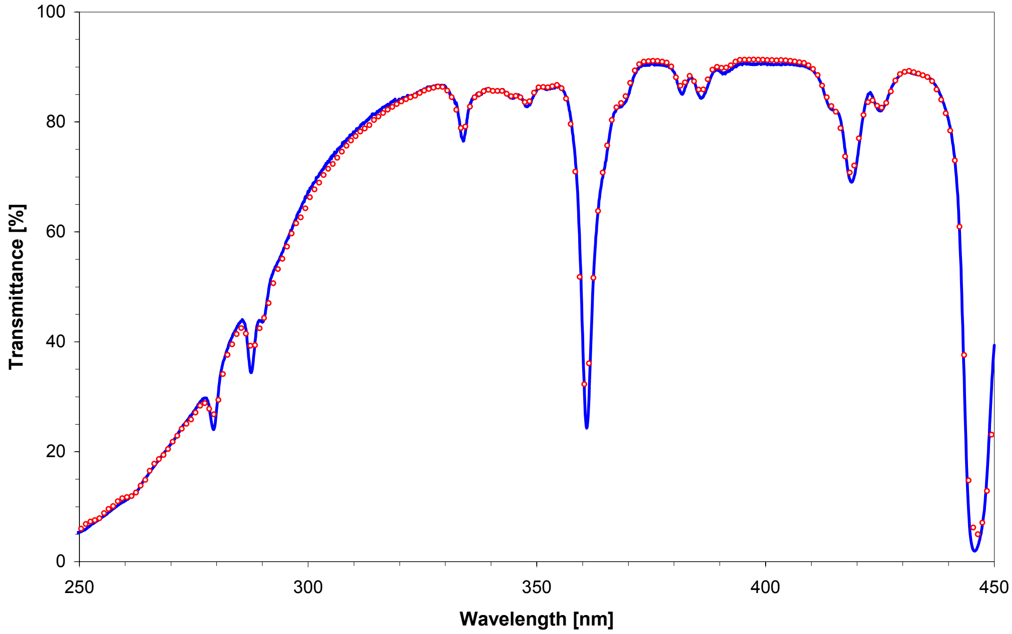

Figure 4 Absorption lines of a holmium oxide filter between 250 nm and 450 nm

○ measured on the Labsphere UV-2000

— measured with a bandwidth of 1.0 nm on a Perkin Elmer Lambda 950

The positions of the absorption bands of a holmium oxide filter can be determined with high spectral resolution due to their slim shapes (Figure 4). The limiting factor is the data point resolution of 1.0 nm for the UV-2000, which is a too coarse raster for precisely pinpointing the transmittance minima of the holmium oxide spectrum. We therefore shifted the UV-2000 spectrum along the wavelength axis until we arrived at a close match of the reference spectrum, rather than just read the lowest measured value of each absorption band. We had to displace the UV-2000 spectrum by 0.6 nm to shorter wavelengths, which is within the specified accuracy of ±1.0 nm for the new Labsphere instrument.

Spectral bandwidth

The influence of an increasing spectral bandwidth is illustrated in Figure 5. The holmium oxide filter spectra there were measured on a Perkin Elmer Lambda 950 at a data point pitch of 0.1 nm but with different spectral bandwidth settings of the monochromator. The absorption peaks do not move along the wavelength axis but with increasing bandwidth they become less intense and broader in shape. There is a clear correlation between the spectral shape and the instrument's bandwidth, which can be used to characterize an unknown spectrophotometer.

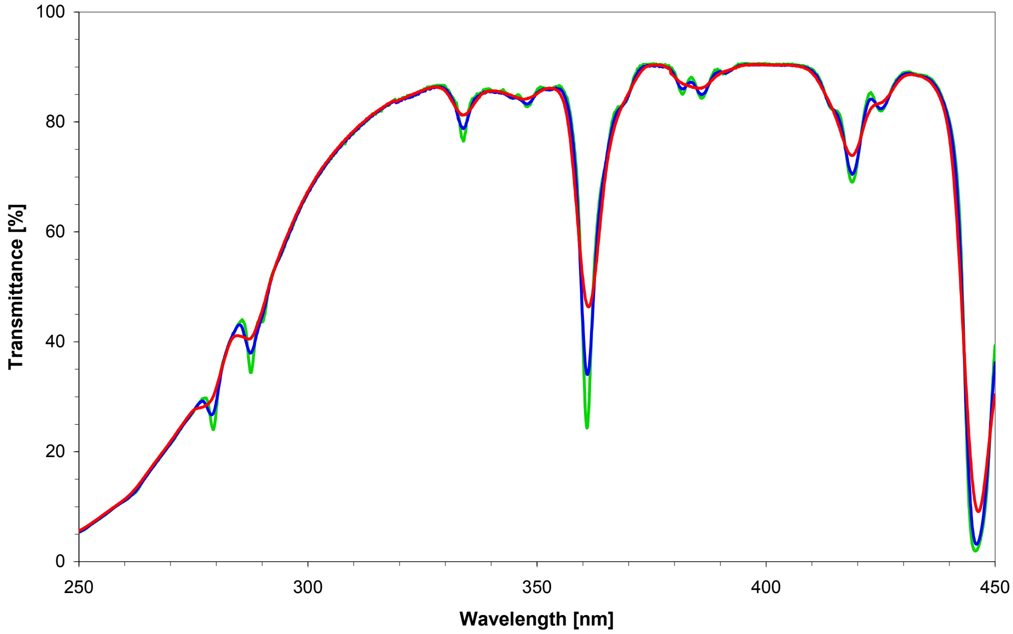

Figure 5 Transmittance spectra of a holmium oxide filter, measured with increasing bandwidth on a Perkin Elmer Lambda 950

- 1 nm bandwidth
- 2 nm bandwidth
- 4 nm bandwidth

There is a prominent absorption band in the center of the spectral range 290 nm – 400 nm, over which the sun protection factor is calculated (Figure 5). This absorption band was selected for the intended bandwidth evaluation. The reference spectrum was determined on a Lambda 950, set to a spectral bandwidth of 0.1 nm. The spectral range for the evaluation was restricted to 330 nm – 390 nm, covering the strong absorption peak at 360.9 nm together with its weak satellites at longer and shorter wavelengths respectively (Figure 6).

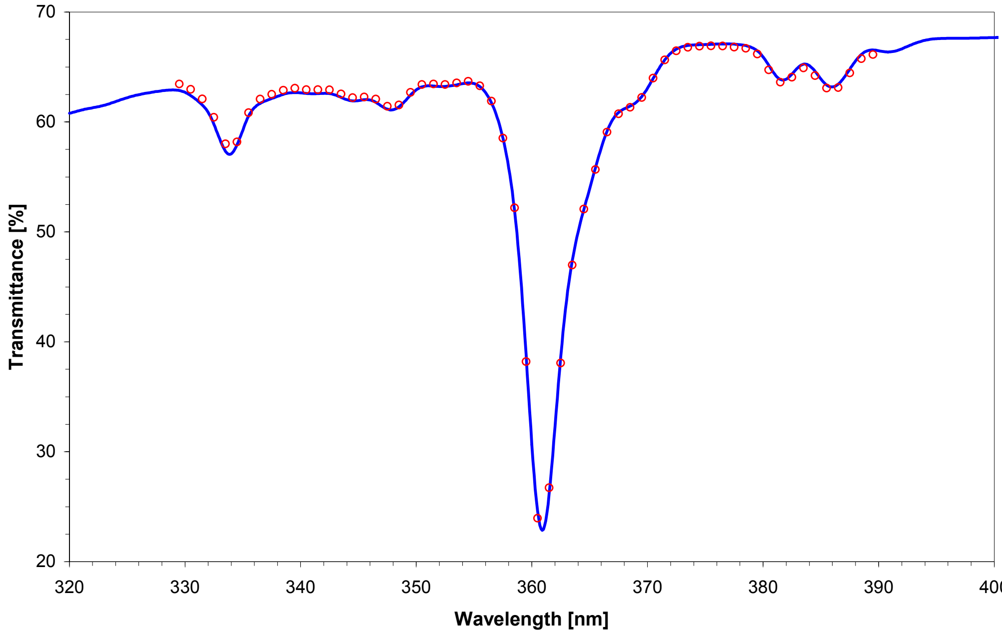

Figure 6 Holmium oxide absorption at 360.9 nm

○ measured on the Labsphere UV-2000

— calculated with a bandwidth of 1.7 nm from a Perkin Elmer Lambda 950 reference spectrum

Figure 6 presents an excellent match of the transmittance data measured on the UV-2000 every 1 nm with a spectrum calculated from Lambda 950 data, measured with a bandwidth of 0.1 nm, collected every 0.1 nm. A spectral displacement of 0.5 nm and a spectral bandwidth of 1.7 nm was used for the calculated spectrum. The small spectral shift, which is almost perfectly reproducing the value calculated for the overall displacement when wavelength accuracy was determined, lies within the 1 nm data resolution of the UV-2000 and reflects the fact that the lowest measured value is not identical with the transmittance minimum of the absorption peak. A spectral bandwidth of 1.7 nm is a very acceptable value; compared to its predecessor, the UV-1000, the bandwidth has been improved by at least a factor of two.

Conclusions

Labsphere's new ultraviolet transmittance analyzer UV-2000 is definitely a next generation instrument. Compared to its predecessor, the UV-1000, the UV-2000 has improved technical specifications and the instrument tested at least met these specifications. We could verify a linear transmittance response with a usable measurement range up to the specified 2.7 absorbance units. Although, spectra become rather noisy at these low transmittance levels, certainly a typical weakness of a fast diode array detection system.

Wavelength accuracy was determined well within the specified limits of ±1.0 nm, which is an appropriate window for a data interval of 1.0 nm. Spectral bandwidth is usually another weak point of diode array systems, which often is confused with number of diodes or even data points per wavelength interval. Spectral bandwidth is specified for the UV-2000 to be below 4 nm, for the instrument tested we determined a value of 1.7 nm. This is of course not per se a good or bad value, it becomes a quality criterion only in connection with the intended purpose of the instrument. For a fixed setup, always a compromise has to be made between the system's ability to follow steep signal changes and its sensitivity or signal to noise ratio. Obviously the UV-2000 is quite well balanced in this respect combining a rather narrow bandwidth with an acceptable noise at low transmitted UV intensities.