Design and Evaluation of Extremely Low-Reflectance Measurement Device

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In order to measure extremely low diffuse reflectance of flat samples or cavity samples, a new device has been set up. The biggest difference between normal reflectance measurement systems is that a supercontinuum source is used as the light source to improve the measured signal-to-noise ratio and to expand the scope of measurement results. The measurement condition is just for 0/d right now. Device performance is continuously improving. Currently, the lower limit of the reflectance measurement can reach to 0.00005 in the range of 1100nm-2000nm , and the relative uncertainty is nearly 15% while the reflectance is near to 0.0005(*k*=2).

INTRODUCTION

The diffuse reflectance of the material is a key supplementary comparison in CCPR. The accuracy of the measured value and uncertainty of diffuse reflectance measurement directly represents calibration and measurement capabilities in this field. The current international comparison is mainly concentrated in the high reflectance, and comparison about extremely low-reflectance (less than 1%) is still blank. With the development of emerging industries or materials, there are more and more requirements focus on low reflectance measurements not only for higher measurement accuracy but also for more widely spectral range.

Therefore, it is of great significance to improve the measurement method and optimize the measurement device to improve the measurement level of diffuse reflectance and reduce the uncertainty of the measurement result of the diffuse reflectance.

EXPERIMENTAL DEVICE

In order to improve the current level of diffuse reflectance measurement in the ultra-black field, a corresponding measuring device is set up, the principle of the device is shown in Figure 1, it is used to measure the diffuse reflectance under 0/d condition.

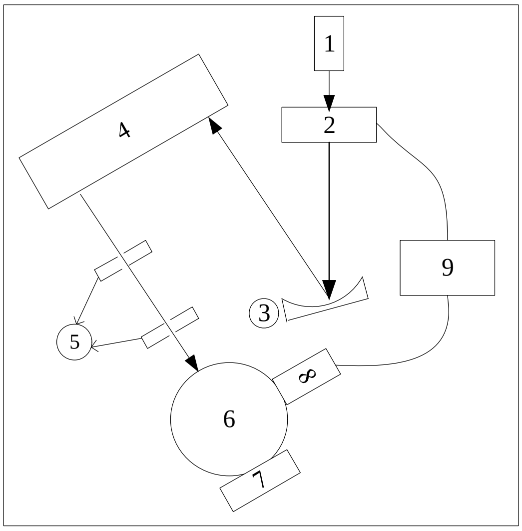

Figure 1. Device Schematic. 1: Supercontinuum Source; 2: Chopper; 3: Concave mirror; 4: Monochromator;5: Aperture; 6: Integrating Sphere; 7: Sample; 8: Detector; 9: Lock-in Amplifier.

The light source adopts SC-PRO-7 high-power supercontinuum source produced by Anyang Laser, with the spectral range of 400nm-2400nm. Its seed source wavelength is 1064nm, and the maximum light power can reach up to 20W. The monochromator is iHR550 produced by HORIBA Scientific and the scanning range is 250nm-2000nm with 3 gratings and filter wheel. The detector is InSe, also bought by HORIBA Scientific, part number is DSS-PSE020T, spectral rang is 1.0μm-4.5μm. The Lock-in Amplifier is SR830 produced by Stanford Research Systems.

The light emitted by the supercontinuum source passes through the chopper and the concave mirror, and then enters the monochromator. In the monochromator, the light passes through the filter wheel, the collimator, the diffraction grating, and the focusing lens and reaches the exit slit. The emitted light enters the integrating sphere after passing through the two apertures, and irradiates the sample vertically through the sample window on the integrating sphere coated with PTFE.

PARAMETER SETTINGS

In order to protect the monochromator, the light source energy was adjusted to 40% of full power, not 100%.The chopper frequency was set to 200Hz to 270Hz to obtain a higher signal form SR830. The entrance slit and exit slit of the monochromator were both set to 2mm, nearly 6nm bandwidth. The grating was selected as 600lp / mm blazed grating, the filter is Lp-1000 which can only pass the wavelength more than 1000nm. In order to obtain greater dynamic range, we connected the detector to SR830 directly, without using the manufacturer's amplifier. The integrating time for each wavelength point is set to 1s.

MEASUREMENT RESULTS

The background signal (using pressed PTFE as sample) and zero signal (no sample) were measured at 1000nm-2000nm range are shown in Figure 2.

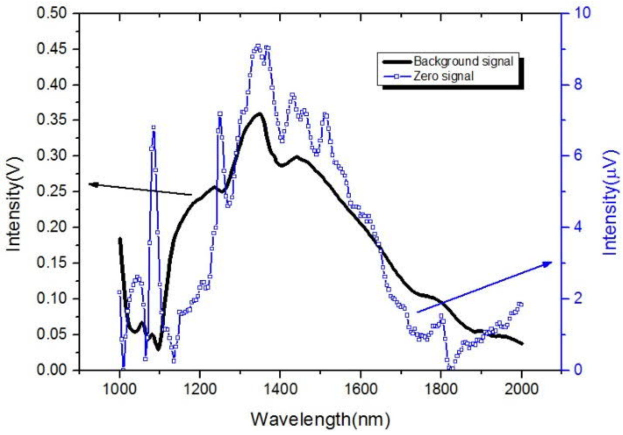

Figure 2. 1000nm-2000nm background and zero signal

From the measured results, due to the similarity between the zero signal (mainly caused by stray light, the background signal from acquisition system and so on) and the background signal, it can be considered that there is a possibility of further reduction for the zero signal of the system.

If we divided “Zero signal” to “Background signal”, the result is shown in Figure 3. It can be known that the device can measure samples with diffuse reflectance as low as 0.00005 in 1100nm to 2000nm. Obviously, if we subtract zero signal before each measurement, lower reflectance may be obtained. The results in the red box in Figure 3 are unreliable abnormal results, which may be caused by the seed source of the pulsed light source. We expect to solve this problem in further experiments.

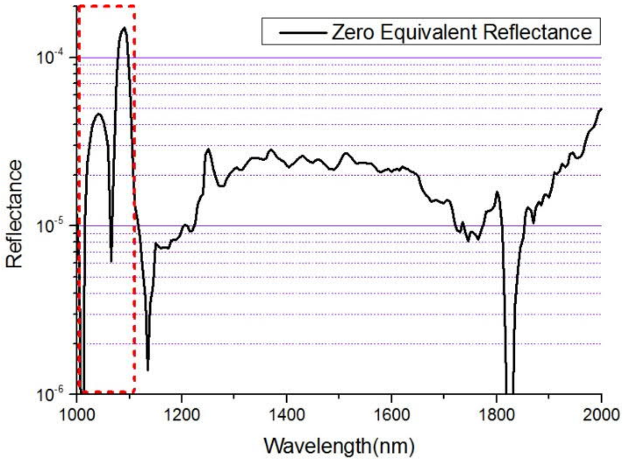

Figure 3. 1000nm-2000nm lower measurement limit

Normally, the measurement sequence is: measure the PTFE (its reflectance value is calibrated in NIM), zero, and the sample, from the measured data, the diffuse reflectance of the sample can be calculated out, shown in Figure 4.

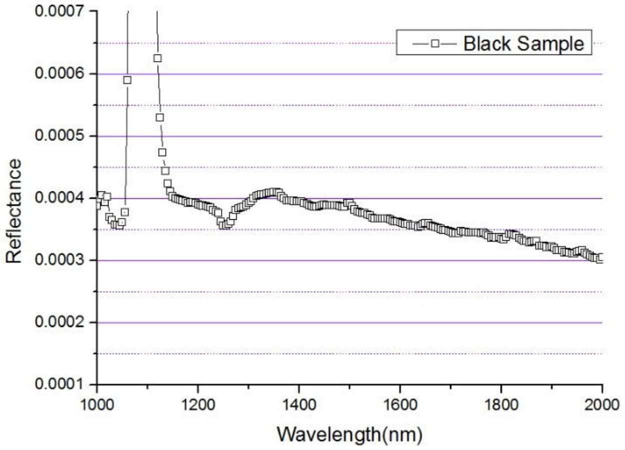

Figure 4. 1000nm-2000nm sample diffuse reflectance

It can be seen from the figure that the diffuse reflectance level of this sample is about 0.0004. The relative uncertainty in our current preliminary estimates is about 15 % (*k*=2).

The final purpose of this device is to achieve the low reflectance measurement in the 500nm-2000nm waveband, however, at this stage only the extremely low diffuse reflectance measurement in the near-infrared region of the 1100nm to 2000nm band achieved preliminary results.

ACKNOWLEDGEMENT

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