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Application News

No. A617

Spectrophotometric Analysis

LiDAR Evaluation System: Measurement of Transmittance of Bandpass Filters

LiDAR, an abbreviation for Light Detection and Ranging, is one type of optical sensor technology. The distance and angle to a remote measurement target and its nature can be analyzed by scanning laser light on the target and measuring the scattered light and reflected light. LiDAR systems have already been installed in aircraft and satellites and used as a ranging technology for research in geology and seismology. LiDAR has also attracted attention recently as a technology for use in self-driving automobiles.

In automated driving, LiDAR takes the place of a human driver and must operate the vehicle appropriately by detecting traffic signals, the road width, oncoming vehicles, pedestrians, and other conditions. LiDAR is extremely important as a technology for sensing objects that may become obstructions during driving, and thus is a key technology for realizing automated driving.

Because the laser light scanned from the LiDAR device is transmitted through a sensor cover such as the auto emblem and irradiated on remote measurement objects, it is necessary to understand the optical properties of the materials to be used, such as the transmittance of the sensor cover for the laser in the LiDAR. The LiDAR viewing angle is also one important performance feature. For example, when a LiDAR device is mounted on the front of a vehicle, the widest possible viewing angle is necessary to cover a wide area in front of the car.

At present, many LiDARs use semiconductor diode lasers that emit pulses with a near infrared wavelength of 905 nm, but in laser safety regulations in the United States and other countries, the laser pulse output is limited to prevent danger to human eyesight. Since the LiDAR detection range when using a 905 nm laser is limited to 30 to 40 m, technologies capable of detecting objects at greater distances are being developed by using a higher laser output with a long wavelength 1,550 nm laser which is safer for the human eye (1).

The wavelength regions and quantity of laser light transmitted through the sensor cover vary depending on the incident angle of the laser and the position of the sensor cover. In other words, the optical properties of the cover material have a large influence on the performance of the LiDAR. Therefore, a wide range of measurements is necessary in a LiDAR evaluation system, for example, by changing the angle of the incident light or changing the wavelength regions.

Application News No. A612A introduced examples of reflectance measurement and transmittance measurement of optical materials. In this article, the optical properties of 905 nm and 1,550 nm bandpass filters were evaluated using a SolidSpec™-3700i UV-VIS-NIR spectrophotometer.

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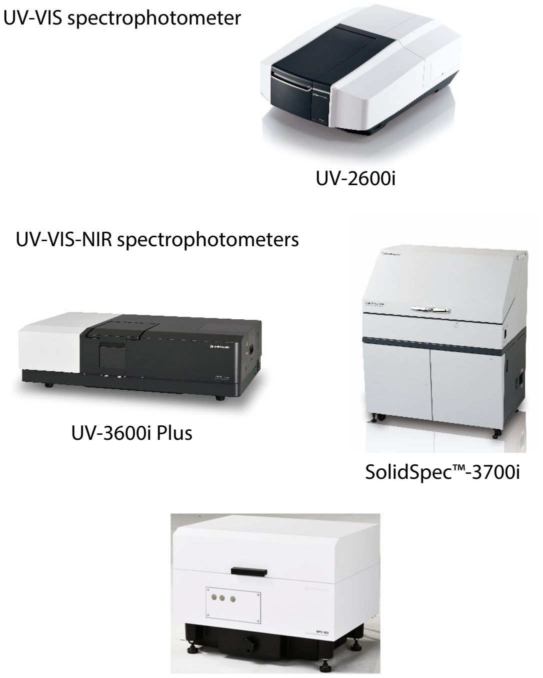
■ Spectrophotometers Supporting LiDAR Evaluation Systems

Because the wavelength regions that can be measured with UV-VIS spectrophotometers differ depending on the type of device, it is necessary to select a suitable device considering the laser light wavelength used in the LiDAR. It is also possible to evaluate the angular dependence of transmittance (incident angle: from 0°) and reflectance (incident angle: from 5°) by using a large sample compartment in combination with a variable angle absolute reflectance measurement unit. Table 1 shows the ranges supported by various Shimadzu devices, and Fig. 1 shows the appearance of the devices.

Table 1 Ranges Supported by Various Devices

Spectrophotometer	UV-2600i	UV-3600i Plus	SolidSpec-3700i
Wavelength region	185-900 nm	185-3,300 nm	240-2,600 nm
Reflectance measurement	Incident angle: 5° - 70°, acceptance angle: 10° - 140°		
Transmittance measurement	Acceptance angle: 0° - 90°		
Sample size	25 × 25 mm - 70 × 70 mm, thickness: max. 15 mm		

* When using the UV-2600i and UV-3600i Plus, a large sample compartment (MPC-2600A or MPC-603A) is necessary in addition to a variable angle absolute reflectance measurement unit.



UV-VIS spectrophotometer

UV-2600i

UV-VIS-NIR spectrophotometers

UV-3600i Plus

SolidSpec™-3700i

Large sample compartment/
variable angle absolute reflectance measurement unit

Fig. 1 Appearance of Devices

Transmittance Measurements

Fig. 2 shows the sample compartment of the SolidSpec-3700i with attached variable angle absolute reflectance measurement unit. Transmittance/absolute reflectance measurements with different incident angles of light with respect to the sample are possible by using the variable angle absolute reflectance measurement unit. When the incident angle is large (approximately 15° or larger), the results are influenced by the polarization property. To avoid this problem, a large polarizer set was used in measurements with angles of 20° or more in this experiment.

First, baseline correction was conducted without setting a sample, after which the sample was set at an arbitrary angle and measured. The positions of the sample and the detector can be adjusted (manually) in 1° units. Table 2 shows the measurement conditions.

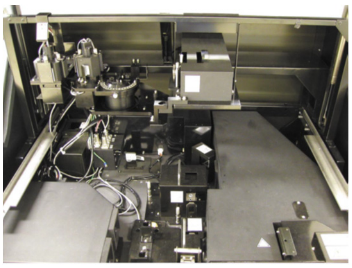


Fig. 2 Sample Compartment of SolidSpec-3700i with Attached Variable Angle Absolute Reflectance Measurement Unit

Table 2 Measurement Conditions

Instruments	: SolidSpec-3700i, Variable angle absolute reflectance measurement unit Large polarizer set
Measurement wavelength range	: 300 - 2,000 nm
Scan speed	: Medium
Sampling pitch	: 1.0 nm
Slit width (automatic switching)	: 8 nm (UV - visible), 20 nm (near infrared)
Light source switching wavelength	: 310 nm

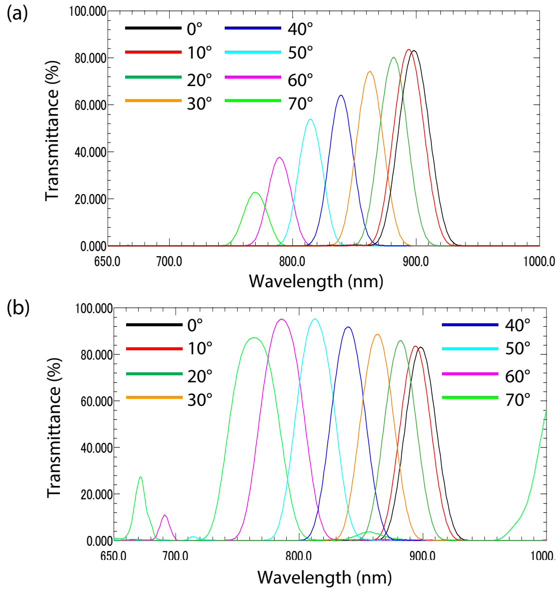


Fig. 3 Results of Transmittance Measurement of 905 nm Bandpass Filter (a) s-Polarized Light (Polarizer: 0°), (b) p-Polarized Light (Polarizer: 90°)

Fig. 3(a), (b) and Fig. 4(a), (b) show the results of transmittance measurements of the 905 nm bandpass filter and 1,550 nm bandpass filter, respectively. The incident angles of the light were from 0° to 70° in steps of 10°. Here, s-polarized light means light with an oscillation compound perpendicular to the incident plane, and p-polarized light means the parallel oscillation component.

From Fig. 3(a) and Fig. 4(a), transmittance of the s-polarized light decreased as the incident angle increased, but from Fig. 3(b) and Fig. 4(b), the decrease in transmittance of the p-polarized light was not as large as that of the s-polarized light.

In addition, because these bandpass filters are interference filters which utilize the interference action of thin films, the distinctive feature that the center wavelength changes when the incident angle changes could be observed.

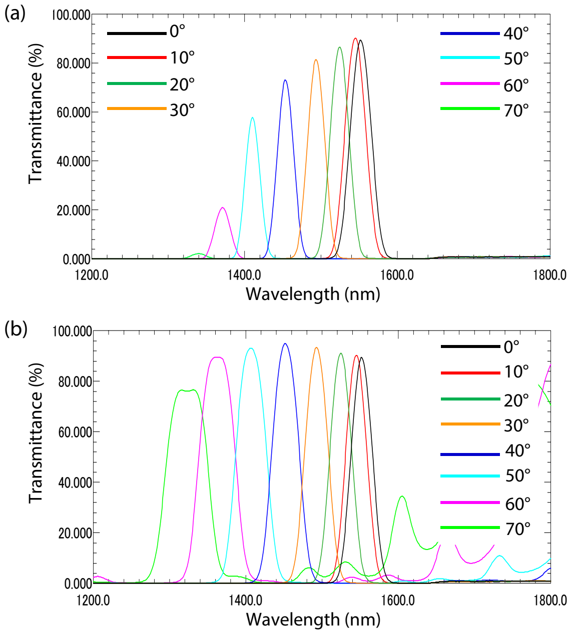


Fig. 4 Results of Transmittance Measurement of 1,550 nm Bandpass Filter (a) s-Polarized Light (Polarizer: 0°), (b) p-Polarized Light (Polarizer: 90°)

Conclusion

In this experiment, 905 nm and 1,550 nm bandpass filters were measured by using a Shimadzu SolidSpec-3700i UV-VIS-NIR spectrophotometer and variable angle absolute reflectance measurement unit. The optical properties of the samples could be evaluated by measuring the transmittance when the angle of the incident light was changed.

<References>
(1) Under the Hood of Luminar's Long-Reach Lidar
https://spectrum.ieee.org/cars-that-think/transportation/self-driving/under-the-hood-of-luminars-long-reach-lidar
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First Edition: Mar. 2020

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