The UH4150AD+: An Instrument for Characterizing Spectroscopic Properties, Intended for Use with Optical Components

Enabling High-sensitivity Analysis and Measurement in the Near-infrared Regime

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1. Introduction

In recent years, near-infrared light at wavelengths between 800 and 1,700 nm—invisible to the human eye—has found use in cameras, sensors, and a wide range of other advanced industrial technologies. This, in turn, has spurred technological advances to accommodate an ever-broadening range of applications, which today include: remote-sensing techniques based on LiDAR (*1), which have begun to be used for technologies such as autonomous driving and smartphones; night-vision cameras, capable of capturing images even at night or in dark environments; security protocols based on facial recognition, iris recognition, or vein recognition; and optical communications, for which demand is growing due to the deployment of 5G. The corresponding improvement in the performance of optical devices has created a need for metrological tools capable of making high-precision measurements of the absorptivity, transmissivity, reflectivity, and other properties of optical components such as lenses and filters. Also, optical components are commonly equipped with band-pass filters—optical thin films, optical absorbers, or other features that allow transmission of only certain specific wavelengths, eliminating unneeded wavelengths—and characterizing these filters with high precision requires instruments with an expanded photometric range (*2), a key performance benchmark.

To meet these needs, we have developed the UH4150AD+ (Advanced Spec Plus) a new addition to Hitachi High-Tech's UH4150 series of instruments for characterizing the spectroscopic properties of optical components. The UH4150AD+ boasts enhanced capabilities for measuring spectroscopic properties in the near-infrared regime and is ideal for making measurements of the optical components found with increasing ubiquity in cutting-edge industrial settings.

Fig. 1 The UH4150AD+ spectrophotometer.

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2. Optical System of the UH4150AD+

2-1. Double-monochromator optical system

A spectrophotometer is an instrument that characterizes the optical properties of substances by using a prism, diffraction grating, or other monochromator element to separate white light into monochromatic components, which are trained on the sample and used to measure its transmissivity and reflectivity. The uses of these instruments span a broad spectrum of academic disciplines and industrial fields, including materials science, environmental studies, pharmaceuticals, and biosciences, and a variety of types of instruments have been developed for various purposes and precision requirements. Spectrophotometers may be broadly subdivided into single-beam and double-beam instruments, with the latter favored by a wide range of users for their outstanding stability. Double-beam spectrophotometers may be further distinguished by whether they incorporate one or two monochromators; compared to single-monochromator instruments, double-monochromator spectrophotometers are less affected by stray light and are thus better suited to measuring the spectroscopic properties of optical films, a task requiring high precision. Spectrophotometers also differ in the range of wavelengths they can measure, which is typically 190-900 nm for ultraviolet/visible instruments and 190-3,300 nm for ultraviolet/visible/near-infrared instruments. The UH4150AD+ (Figure 1) is a double-beam, double-monochromator, ultraviolet/visible/near-infrared spectrophotometer intended for measurements of the spectroscopic properties of optical films.

2-2. Collimated beams

Spectrophotometers can provide two types of data: *transmission spectra*, obtained by measuring the fraction of incident light that passes through a sample and recording this ratio (the transmissivity) for light of various wavelengths, and *reflection spectra*, in which we instead measure the fraction of incident light reflected from the sample (the reflectivity).

Reflectivity measurements may seek to characterize (1) regular reflectivity, in which the reflected light is directed at a specific angle with respect to the incident beam, (2) diffuse reflectivity, in which light is reflected in many directions, or (3) total reflectivity, the sum of the regular and diffuse reflectivities. For optical films, the sample surface is a mirror plane and optical functionality is deployed with respect to the incident angle, so in most cases one measures regular reflectivity. In reflectivity measurements, one may adjust various additional tools as appropriate for given incident angles or sample sizes.

When measuring regular reflection from optical films, the incidence angle is an important quantity. For focused light beams, the incidence angle is not uniform, and shifts in incidence angle can result in discrepancies between measured values and values simulated during the design process for optical films, such as multilayer dielectric films or prisms. In contrast, collimated light beams ensure a constant incidence angle with respect to the sample, enabling high-precision measurement of regular reflection.

Collimated beams also lead to higher-precision transmission measurements. Because the lens optics systems of cameras are designed for collimated beams, the extent to which the incident light is collimated is an important consideration for instruments used to characterize optical components. Collimated beams are also useful for characterizing diffusivity (haze) and for improving the reproducibility of measurements, including sample mounting and positioning. Instruments in the UH4150 series provide incident light capable of approaching perfect collimation arbitrarily closely, thus enabling high-precision measurements.

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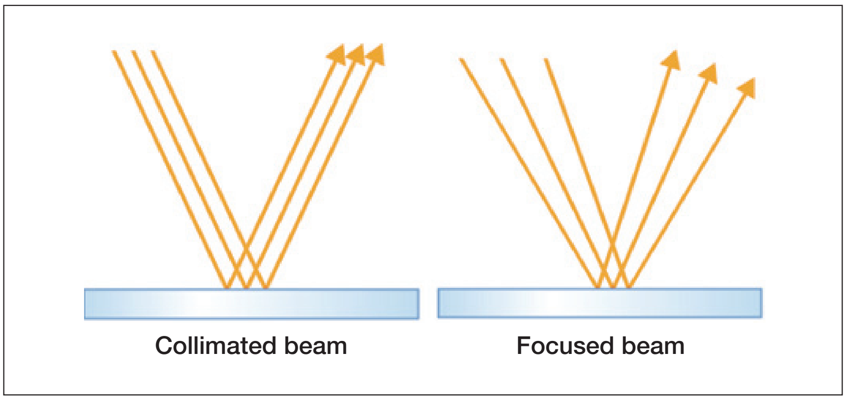

Fig.2 Regular reflection of collimated and focused beams.

3. Key Features of the UH4150AD+

In this section we discuss key features of the UH4150AD+.

3-1. Expanded photometric range in the near-infrared regime

The band-pass filters used in the latest cameras and sensors involve optical films capable of reducing the intensity of unwanted light components by 6 to 7 orders of magnitude (OD 6-7, corresponding to transmissivities in the range 0.0001% - 0.00001%). Improved signal-processing techniques for characterizing low transmissivities enable the UH4150AD+ to make measurements of near-infrared transmissivities as low as OD 7, 100 times smaller than the predecessor instrument. This allows high-precision measurements of weak near-infrared transmissivities that could not previously be measured.

3-2. High-sensitivity InGaAs semiconductor detector

Whereas the predecessor instrument [*3] used a PbS [*4] detector for near-infrared measurements, the UH4150AD+ is equipped with a new high-sensitivity InGaAs [*5] detector. Compared to the previous detector, the new detector allows lower-noise measurements—particularly useful when measuring low transmissivities—and yields more accurate measurement data. The measurable wavelength range is 185-1,800 nm.

3-3. Multiscan feature enables high-throughput measurements

The spectra of band-pass filters—whose purpose is to transmit only light of specific desired wavelengths, blocking transmission of undesired wavelengths—contain both high- and low-transmissivity wavelength intervals. Previous instruments made measurements at constant scan rates for all wavelength regimes, to match low-transmissivity regimes, requiring lengthy measurement times to capture spectra. The new *multiscan* capabilities of the UH4150AD+ allow users to select wavelength-dependent values for scan speeds and other measurement parameters, even for a single measurement. This is illustrated by Figure 3, which shows the multiscan configuration window and a sample spectrum captured by a multiscan measurement; in this case we have subdivided the full range of wavelengths to be measured into 5 subintervals, each with its own set of measurement-parameter values chosen appropriately for the transmissivity expected in that subinterval. Whereas the desired measurement would have required 15 minutes using previous instruments, here it completes in approximately 6.5 minutes, a significant reduction in measurement time.

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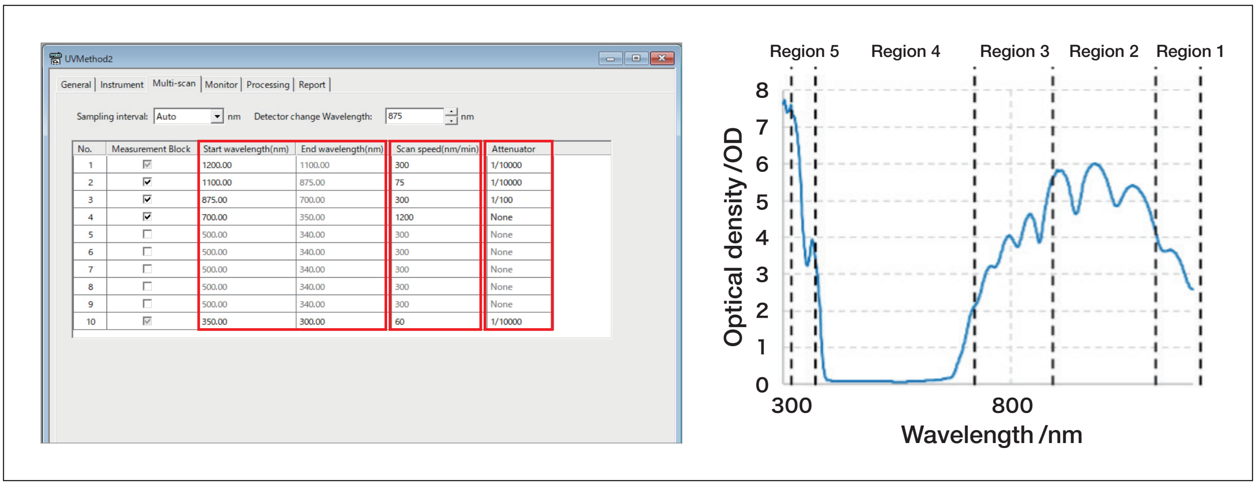

Fig.3 Multiscan configuration window and sample spectrum captured via multiscan measurement.

Table 1 Key specifications of the UH4150AD+.

Item		UH4150AD+	UH4150AD (Predecessor)
Configurable wavelength range		175 — 2,000 nm	175 — 3,300 nm
Measurable wavelength range		185 — 1,800 nm	185 — 3,300 nm
Photometric range	UV/VIS	-2 — 8 Abs	-2 — 8 Abs
	NIR	-2 — 7 Abs	-2 — 5 Abs
Detector	UVVIS	Photomultiplier tube	Photomultiplier tube
	NIR	Cooled InGaAs	Cooled PbS

4. Measurement Case Study: Optical Filter

Figure 4 shows a measured transmission spectrum for a shortpass optical filter designed to transmit visible light—with wavelengths of 800 nm or less—while blocking near-infrared and longer-wavelength light. Note the high OD values observed for wavelengths of 900 nm or longer, which demonstrate that the UH4150AD+ is more than capable of accurately characterizing transmission-blocking components at levels of OD 7 and beyond.

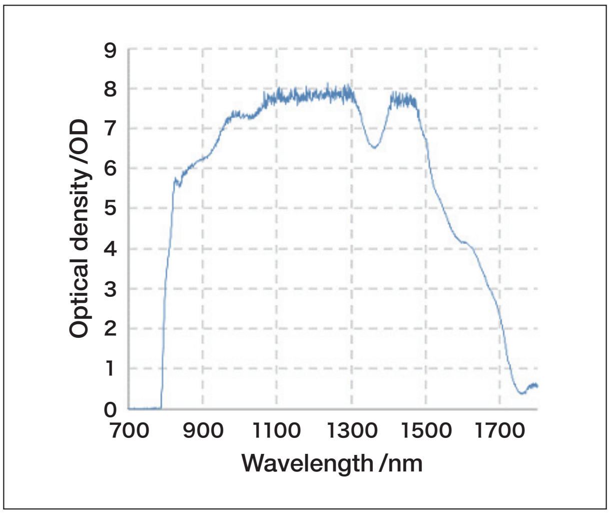

Fig.4 Measured spectrum of a shortpass optical filter.

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5. Conclusions

Spectrophotometers allow measurement of spectroscopic properties, which are key indicator for the optical films commonly used to add various functional capabilities to modern optical components. We are convinced that the UH4150AD+ is the best possible instrument for measuring the behavior of optical components in the near-infrared regime, an area of intense current interest for remote-sensing technologies and other industrial applications. Through the development of instruments like this, Hitachi High-Tech will continue to provide optimal solutions for cutting-edge technological needs, enabling sustainable advances in all industrial fields.

(*1) LiDAR (Light Detection And Ranging): A remote-sensing technique using near-infrared light. A pulsed near-infrared laser is trained on an object of interest and the resulting reflections are detected—together with the associated time delays—to allow three-dimensional visualization of the distances to objects, including remote objects.

(*2) Photometric range: An instrument performance benchmark characterized by optical density (OD) or absorbance (Abs). An increase of 1.0 in OD (Abs) corresponds to a tenfold (one order of magnitude) reduction in transmissivity. An OD of 0 corresponds to 100% transmissivity; an OD of 1 corresponds to 10% transmissivity; an OD of 7 corresponds to 0.00001% transmissivity.

(*3) Predecessor: The UH4150AD ultraviolet/visible/near-infrared spectrophotometer, which uses a PbS detector and offers a measurable wavelength range of 185-3,300 nm.

(*4) PbS: Lead sulfide.

(*5) InGaAs: Indium gallium arsenide.

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