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MEMS-FPI Spectroscopic modules

Contents

1. Overview

The MEMS-FPI spectroscopic module (hereafter called “spectroscopic module”) has a built-in light source, cotrol circuit, and MEMS-FPI spectrum sensor consisting of an InGaAs PIN photodiode and MEMS-FPI tunable filter which can vary its transmission wavelength by changing the applied voltage. Spectrum and absorbance of the near infrared region can be measured by connecting a PC via USB. Peak transmission wavelength shift due to the ambient temperature change is corrected with the control circuit. The product includes evaluation software with functions for setting measurement conditions, acquiring and saving data, drawing graphs, and so on. Furthermore, the dynamic link library (DLL) function specifications are disclosed, so users can create their original measurement software programs.

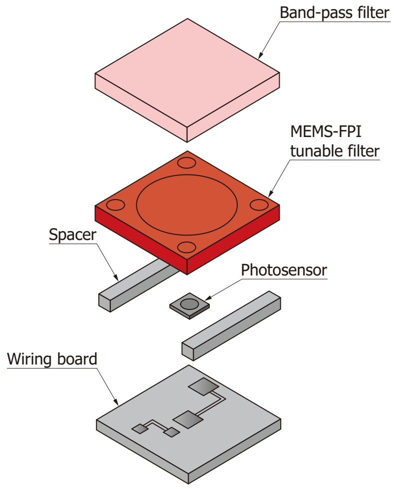
[Figure 1-1] Spectroscopic module (C17552, C17553, C17554)

[Figure 1-2] MEMS-FPI spectrum sensor

2. MEMS-FPI spectrum sensors

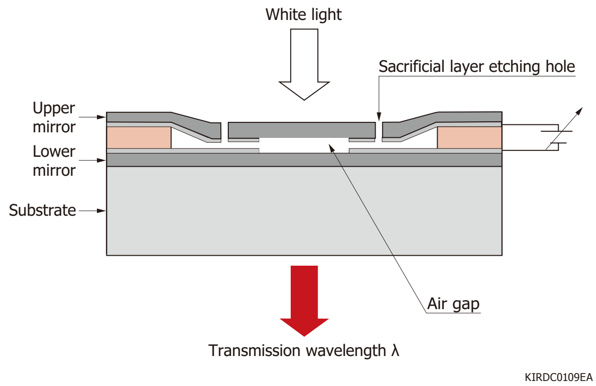
The MEMS-FPI spectrum sensor is composed of a MEMS-FPI tunable filter, photosensor (photodiode), and the like. It has a simple structure in which a MEMS-FPI tunable filter and photosensor is arranged on the same axis as the direction of the incident light. Though this product is a spectral sensor, it uses a single photosensor device and does not require an expensive multichannel photosensor.

[Figure 2-1] Internal structure



The MEMS-FPI tunable filter has an upper mirror and a lower mirror that are placed opposite each other with an air gap in between them [Figure 2-2]. When a voltage is applied across the mirrors, an electrostatic force is produced to adjust the air gap. To facilitate this action, the upper mirror has a membrane (thin film) structure. If the air gap is $m\lambda/2$ (m: integer), it functions as a filter that allows by and large wavelength λ to pass through. Increasing the filter control voltage shortens the air gap by electrostatic force, causing the peak transmission wavelength to shift to the shorter wavelength side.
Silicon is used as the substrate that serves as an infrared-transmitting filter. The mirrors are designed as multilayered dielectric coatings of SiO_2, SiN or Poly-Si, which are typical semiconductor materials.

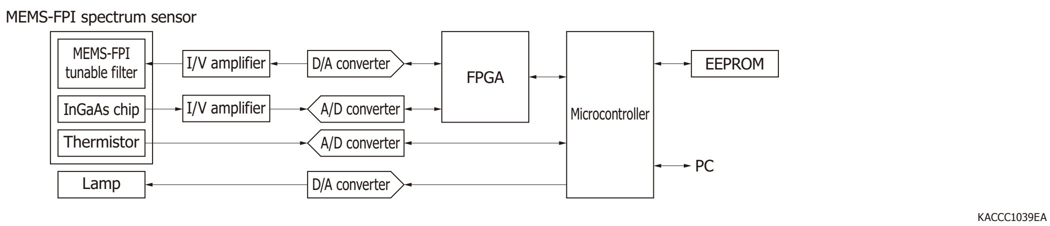
[Figure 2-2] Cross-sectional view of MEMS-FPI tunable filter



3. Control circuit

Figure 3-1 shows a block diagram of the spectroscopic module. The control circuit controls voltage applied to the MEMS-FPI tunable filter. This circuit converts analog output from the InGaAs PIN photodiode in the sensor into a digital signal using a 16-bit A/D converter. It also reads thermistor resistance value and performs feedback control to suppress the peak transmission wavelength shift depending on temperature. The external interface contains a microcontroller and the module can be connected to a PC via a USB cable.
We offer customization for the UART interface (when there is a large quantity). Contact us for detailed information.

[Figure 3-1] Block diagram



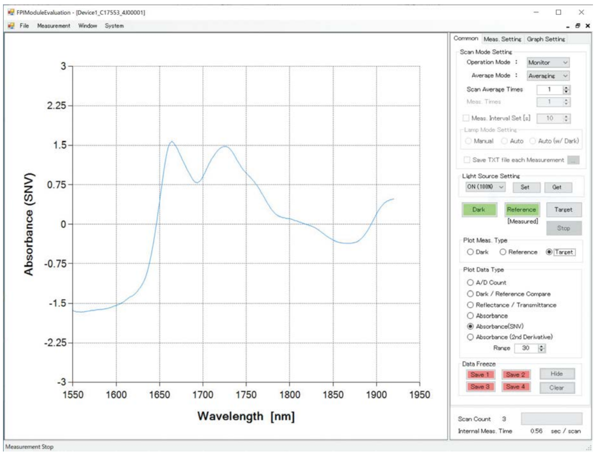
4. Evaluation software

Using the evaluation software supplied with the spectroscopic module, you can control the spectroscopic module, as well as acquire and save measurement data from a PC connected to the module via USB.
By installing the evaluation software into a PC, you can perform the following basic operations.

· Acquire and save measurement data
· Set measurement conditions
· Set built-in lamp
· Acquire module information
  (type number, serial number, spectral response range, etc.)
· Display graphs
· Arithmetic functions
  Comparison with the reference data
  (reflectance, absorbance, etc.)

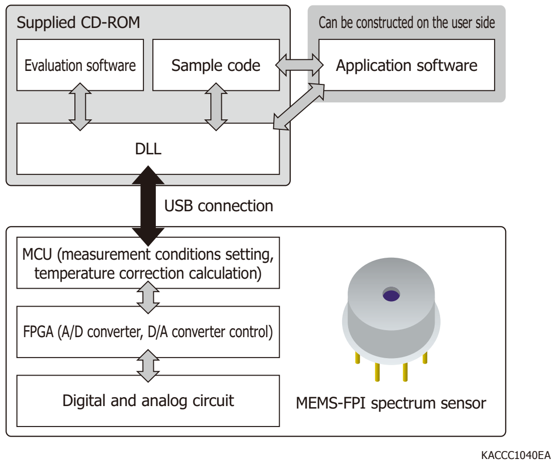
Up to 8 spectroscopic modules can be connected to a single PC for use.
Compatible OS: Microsoft® Windows® 10 (64-bit)
Microsoft® Windows® 11 (64-bit)

[Figure 4-1] Display example of evaluation software



The CD-ROM included in the spectroscopic module contains evaluation software, DLL, and sample software. The evaluation software uses the DLL to control the spectroscopic module. Because the evaluation software cannot directly access I/O and memory, it calls necessary functions from the DLL to control the spectroscopic module, via the device driver and USB interface. Furthermore, using the DLL, users can develop their own original software. The function specifications and software instruction manual are on the CD-ROM.

[Figure 4-2] Software configuration



5. Optical fiber adapter (sold separately)

An adapter is available for easily coupling an optical fiber with an SMA connector to the spectroscopic module [Figure 5-1]. It has a built-in lens, and the window part of the spectroscopic module is replaced with this adapter for use. Using this adapter means that the light source built into the spectroscopic module cannot be used, so a separate light source must be prepared.

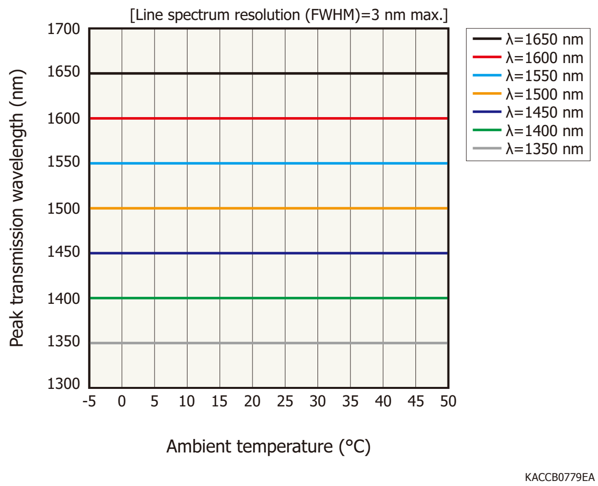
[Figure 5-1] Optical fiber adapter A17587

6. Characteristics

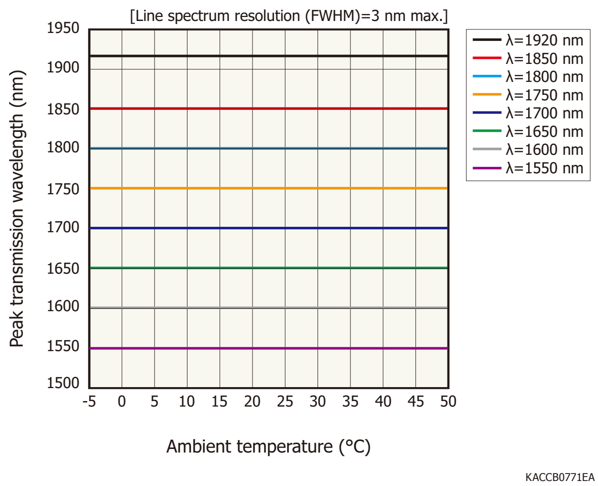
A peak transmission wavelength of a MEMS-FPI spectrum sensor has temperature dependence. The spectroscopic module, with its internal control circuit, performs feedback control to the voltage applied to the MEMS-FPI tunable filter in response to changes in ambient temperature (operating temperature range), suppressing peak transmission wavelength shift. Figure 6-1 shows the relationship between the ambient temperature and the peak transmission wavelength of this module. The wavelength temperature dependence for C17552: λ=1500 nm, C17553: λ=1700 nm, and C17554: λ=1950 nm is ±0.1 nm/°C or lower.

[Figure 6-1] Peak transmission wavelength vs. ambient temperature (typical example)

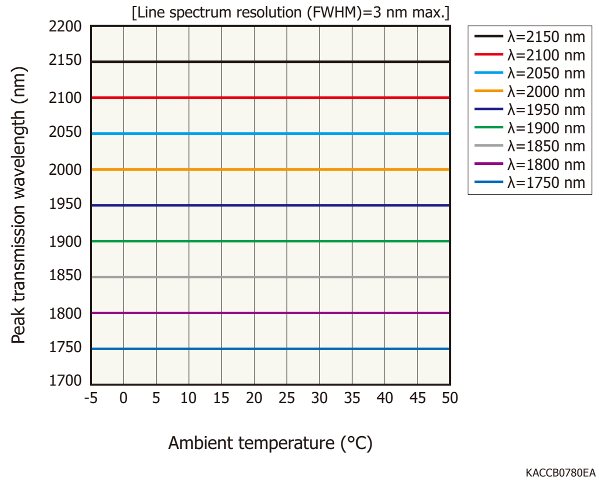
(a) C17552



(b) C17553



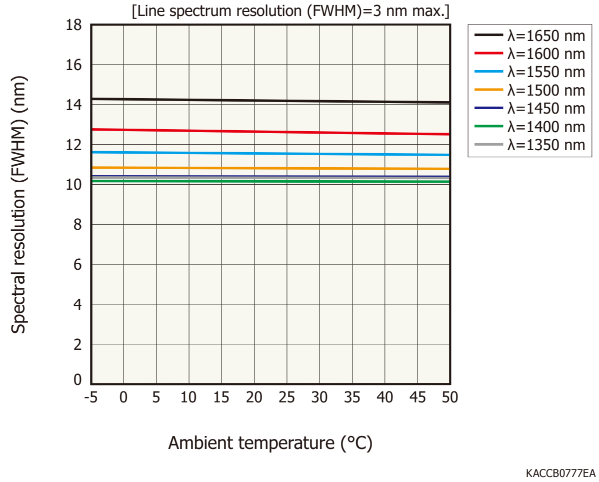
(c) C17554



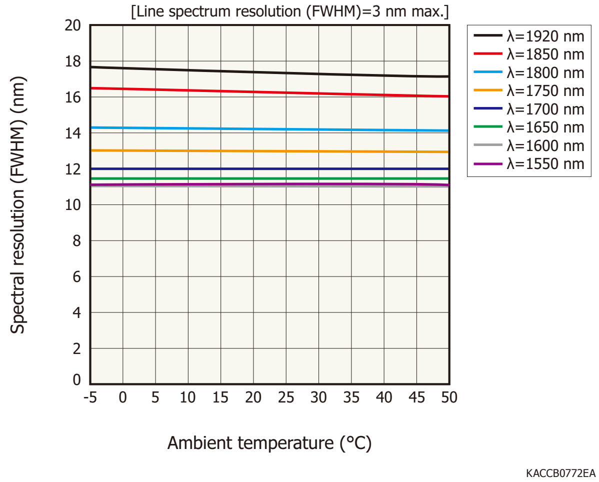
Temperature dependence of the spectral resolution (FWHM) is shown in Figure 6-2. The spectral resolution is almost constant even when the temperature changes.

[Figure 6-2] Spectral resolution vs. ambient temperature (typical example)

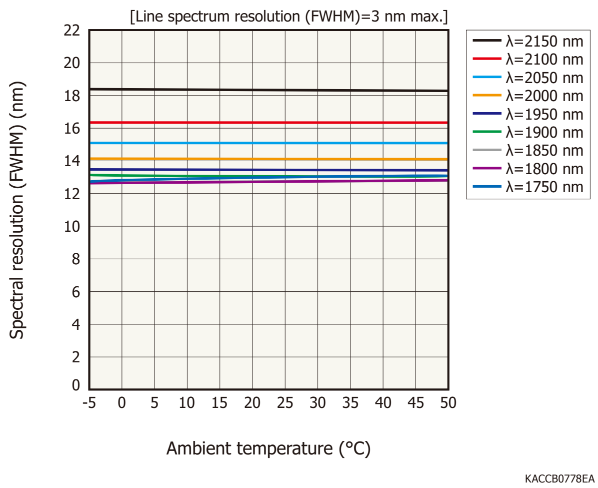
(a) C17552



(b) C17553



(c) C17554



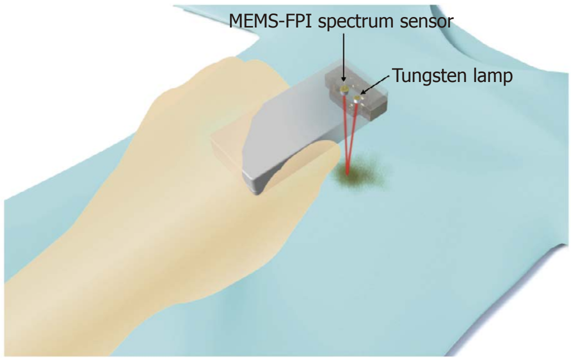
7. Measurement examples

With near-infrared spectrophotometry, absorbance is converted from the measured optical spectrum, then data analysis is done using methods such as standard normal variate (SNV) and secondary derivative.

Reflected light measurement

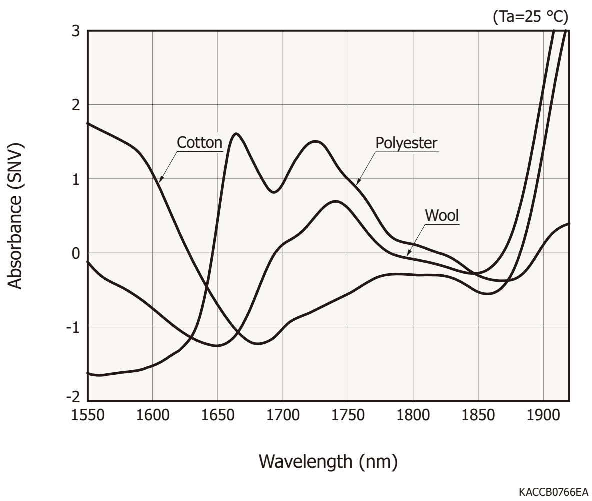
You can measure reflected light using the lamp built into this module. Figure 7-1 shows a measurement example.

[Figure 7-1] Example of reflected light measurement

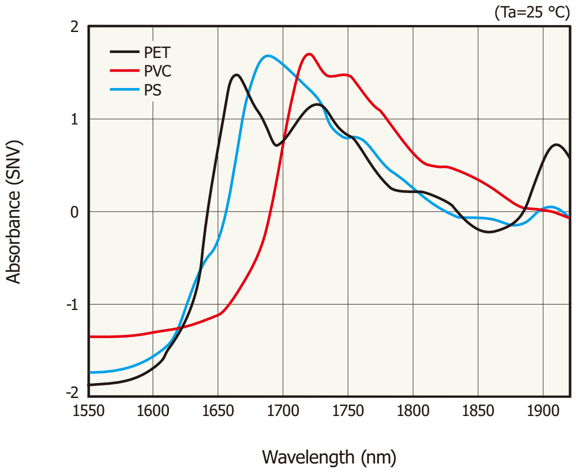


Measurement examples of textile/plastic absorbance are shown in figures 7-2 and 7-3. In the near infrared region, different spectra are seen depending on the material, so it is possible to identify materials.

[Figure 7-2] Absorbance spectra of textile (measurement example)



[Figure 7-3] Absorbance spectra of plastic (measurement example)

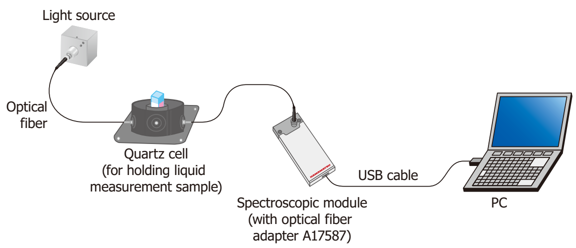


KACCB0773EA

» Transmitted light measurement

Figure 7-4 shows the measurement system of spectra for transmitted light. The light source built into this module is not used at this point. The light source must be prepared separately.

[Figure 7-4] Measurement system of transmitted light measurement



KACCC1245EA

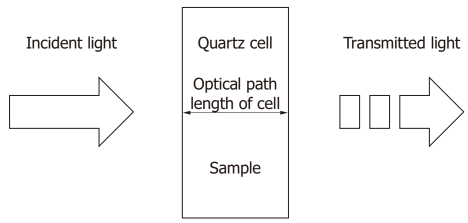


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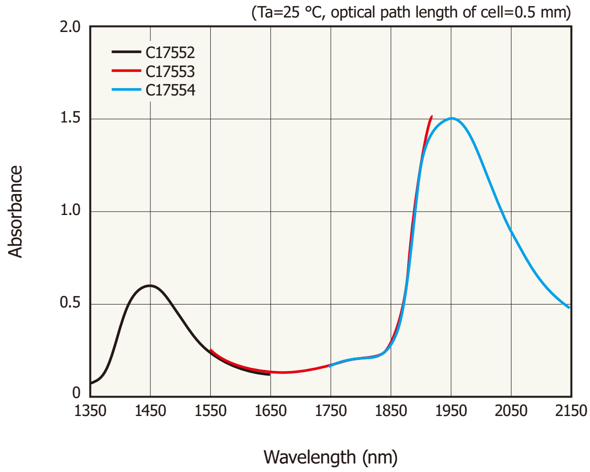
Figure 7-5 shows an absorbance measurement example of pure water. It has detected absorption by OH groups with peaks around 1450 nm and 1940 nm. Ethanol [Figure 7-6] has absorbance spectra different from pure water, such as around 1700 nm.

[Figure 7-5] Pure water absorbance spectra (measurement example)



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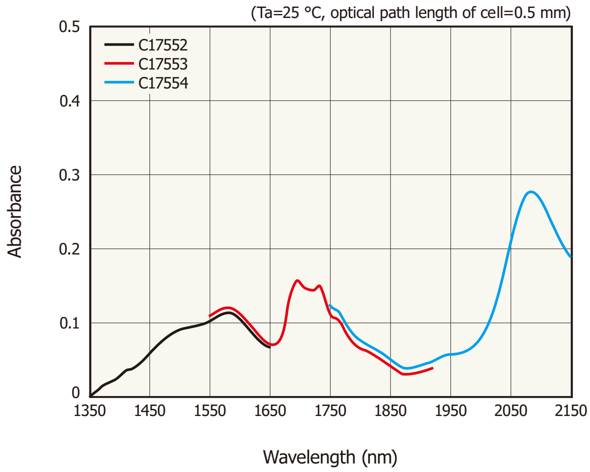
[Figure 7-6] Ethanol absorbance spectra (measurement example)



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8. Q&A

[Q1] What is the difference between a spectroscopic module and an FTIR engine?

Table 8-1 shows the comparison between the spectroscopic module and the FTIR engine. The spectroscopic module is a compact, low-cost module with built-in MEMS-FPI spectrum sensor, light source, and control circuit. The FTIR engine has a wide spectral response range and offers excellent spectral resolution.

[Q2] How long is the measurement time?

The default single measurement time of the spectroscopic module is approximately 0.4 s (when measuring 300 nm width in 1 nm steps) to approximately 0.6 s (when measuring 400 nm width in 1 nm steps). (This excludes time required to calculate and display graph data, because it depends on PC performance.)
Measurement time can be made even shorter by reducing the point average times. In that case noise may increase, so settings must be changed appropriately.

Note: Default settings of the evaluation software of spectroscopic modules
· Min. Wavelength (nm): lower limit of spectral response range
· Max. Wavelength (nm): upper limit of spectral response range
· Step (nm): 1
· Point Average Times: 128
· Meas. Interval (µs): 2.5

[Q3] Is it possible to limit the measurement to arbitrary wavelength points?

The spectroscopic modules C17552, C17553, C17554 can perform measurement with up to 10 wavelength points specified.

[Q4] Is DLL for the spectroscopic modules C17552, C17553, C17554 available?

The DLL is available for spectroscopic modules, so users can create their original software programs.

[Q5] Is it possible to make a custom product to cover a new spectral response range?

If the wavelength ranges of our current lineup cannot cover your wishes, please consult with the Hamamatsu office. Customization is to be considered by learning the requirements (wavelength range, application, expected business scale, etc).

[Q6] Can the spectral response range be further widened?

The MEMS-FPI tunable filter uses the principles of the Fabry-Perot interferometer and functions as a filter that transmits approximately the wavelength λ when the air gap between the upper and lower mirrors is $m\lambda/2$ (m: integer). The MEMS-FPI tunable filter also transmits light components of different orders for transmission wavelengths. Therefore, it is theoretically impossible to extend the spectral response range. Light components of different orders are blocked by the built-in band-pass filter.

[Q7] Are there any demo units (spectroscopic modules) available? The basic characteristics are needed to see before purchase.

Yes, a few demo units have been prepared, so consult with our sales representative, please.

[Q8] There are three different wavelength band types for the spectroscopic modules. Can I buy one and replace the MEMS-FPI spectrum sensor with another type of sensor?

You cannot replace the MEMS-FPI spectrum sensor in the spectroscopic module. You must purchase a spectroscopic module with the required wavelength band.

[Table 8-1] Comparison between spectroscopic module and FTIR engine

Parameter	Spectroscopic module			FTIR engine
Type no.	C17552	C17553	C17554	C15511-01
Built-in sensor	MEMS-FPI spectrum sensors			-
Spectral response range	1.35 to 1.65 µm	1.55 to 1.92 µm	1.75 to 2.15 µm	1.1 to 2.5 µm
Spectral resolution (FWHM) max.	18 nm	21 nm	22 nm	8 nm
Compact size	☆☆☆			☆☆
Cost advantage	☆☆☆			☆☆

[Q9] What is the service life of the lamp built in spectroscopic module?

The estimated service life of the lamp is approximately 15000 hours. The service life varies depending on the use conditions.

[Q10] What is the S/N of the spectroscopic module?

With ambient temperature: 25 °C, gain setting: middle (initial setting), S/N=10000 typ. (about the same for C17552, C17553, C17554).
S/N is given by equation (8-1).

$$S/N = \left(\begin{array}{c}\text{Count value when} \\ \text{incident light is 75\%} \\ \text{of maximum range}\end{array} - \begin{array}{c}\text{Dark} \\ \text{average} \\ \text{value}\end{array} \right) \Big/ \begin{array}{c}\text{Dark} \\ \text{standard} \\ \text{deviation}\end{array} \cdots (8\text{-}1)$$

In order to reduce the noise component, increase the point average times (this will increase measurement time). In order to further reduce the noise component, increase the scan average times.

· Initial setting
Min. Wavelength (nm):
lower limit of spectral response range
Max. Wavelength (nm):
upper limit of spectral response range
Step (nm): 1
Point Average Times: 128
Meas. Interval (μs): 2.5

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