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Optics modules

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1. Overview

The optics module is an optical module for absorbance measurement, with a structure including Si photodiodes, optical filters, and I/V conversion circuits. Si photodiodes of multiple channels do detection by dispersing incident light such as light transmitted through a solution. The generated photocurrent is subjected to photoelectric conversion, and signals of various wavelengths are output as analog voltage simultaneously.
The optics module is a non-dispersive spectroscopic module, with a spectroscopic system that uses optical filters (beam splitters, band-pass filters). The dispersive mini-spectrometer disperses light with a grating, providing an optical spectrum with continuous wavelengths. In contrast, the optics module detects light of up to 10 different discontinuous wavelengths. Optics modules are suitable for applications including blood analysis and water quality analysis, where detection wavelengths are specified, because S/N at the detection wavelengths and the blocking (light-shielding) characteristics of non-detection wavelengths are better than those of the dispersive type.

[Figure 1-1] Optics module C13398 series

2. Features

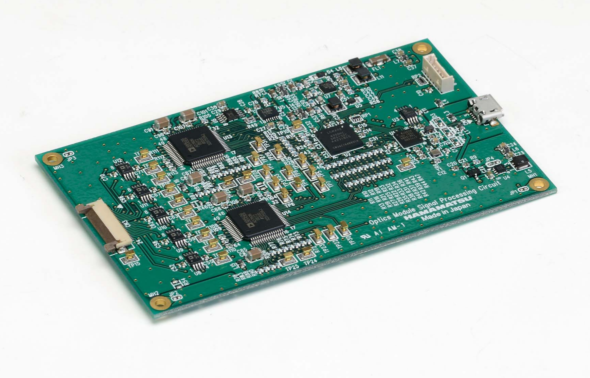
▸ Simultaneous detection of up to 10 wavelengths (C13398 series)

The optics module can simultaneously detect up to 10 wavelengths of light. Combining the C13398 series with the evaluation circuit C13390 (sold separately) makes it possible to convert analog signals to digital signals and send the signals of 10 wavelengths to a PC connected by USB simultaneously.

[Table 2-1] Detection center wavelength (C13398 series)

ch	C13398-01	C13398-02	Unit
1	340	340	nm
2	405	380	
3	450	405	
4	510	492	
5	546	510	
6	570	546	
7	600	578	
8	630	620	
9	660	690	
10	700	White light	

[Figure 2-1] Evaluation circuit C13390



▸ Excellent light-shielding characteristics

Using Hamamatsu mounting technology, assembly technology, and optical technology, we can reduce optical and electrical crosstalk between channels and achieve superior light-shielding characteristics for light with non-detection wavelengths. Doing so enables wide dynamic range and high accuracy measurement.

▸ Flexible customization

We offer custom support for specifications such as detection wavelength and the number of channels [Table 2-2].

[Table 2-2] Customization

Description	Difficulty
Change detection wavelength	Easy
Change half width	Easy to normal
Decreased number of detection channels	Easy
Increased number of detection channels (up to 13 channels)	Normal
Increased number of detection channels (14 channels or more)	Hard
Changes to incident beam system (e.g., change to fiber input type)	Easy
Change circuit gain	Easy
Change case	Normal
More compact size	Normal to hard
Adding functions to the circuit	Normal to hard
Change optical system	Hard

3. Hamamatsu technologies

3 - 1 COB (chip on board)

The optics module uses COB technology to mount photodiodes directly to the circuit board. The COB technology enables the photodiodes to be mounted with high accuracy and the photodiode packages to be made compact.

3 - 2 Optical technology

We have done optical design using optical simulation, realizing a highly reliable optical system that reflects our simulation results.

4. Structure

The optics module consists of the following components.

4 - 1 Beam splitters

Measured light transmitted through the sample is dispersed by multiple beam splitters, and the reflected light is sent to the optical axis of each channel of the photodiodes. The optics module has two types of beam splitters built in (a type that splits light rays and a dichroic type that only reflects light in certain wavelength bands).

4 - 2 Band-pass filters

The band-pass filters only transmit light of specific wavelength bands from light split by the beam splitters, and they reflect all other light. The type and number of dielectric multilayer films in the band-pass filter control the wavelength band that is transmitted. The band-pass filter is a key factor that mostly determines detection wavelength, half width, and light-shielding characteristics of non-detection wavelength.

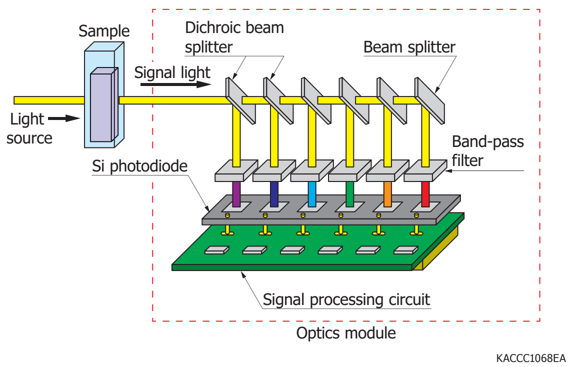
4 - 3 Si photodiodes

Si photodiodes with multiple channels detect light of specific wavelengths extracted by optical filters and output photocurrent.

4 - 4 Signal processing circuits

The low level photocurrent from the photodiodes is converted into voltage through the amplifier. We use high accuracy, low noise components for the circuit board, in order to reduce the effects of leakage current and disturbance noise.

[Figure 4-1] Configuration example of optics module



5. Characteristics

5 - 1 Detection center wavelength

The detection center wavelength is the center wavelength of the detection wavelength band. It is mostly determined by the band-pass filter built into the optics module. There are variations in the detection center wavelengths. These are mainly caused by variations in the dielectric multilayer film thickness of the band-pass filters and the incident angle on the band-pass filters. When the incident angle on the band-pass filter changes, the light path length changes in the dielectric multilayer film through which light passes. The optics module has a structure that gives the dielectric multilayer films of the band-pass filters uniform thickness and reduces variations in the incident angle of light on the band-pass filter, thereby realizing accuracy of ±2 nm detection center wavelength.

5 - 2 Full width at half maximum

The half width of the optics module has a spectral width equal to 50% of the transmission spectrum peak value in the band-pass filter. The narrower the half width is, the better the measurement accuracy at the detection wavelength will be, because a wavelength spectrum near monochromatic light is transmitted. However, the S/N is lower because the transmitted light level is reduced. In contrast, the wider the half width is, the greater the transmitted light level will be. However, non-detection light wavelengths are transmitted, so measurement accuracy at the detection wavelength may decrease.
The transmission wavelength bands of the band-pass filters of the optics module are made to prevent them from overlapping between channels. The half width is set to about 10 nm, with consideration for measurement accuracy and transmitted light level.

5 - 3 Stray light

Stray light is light of wavelengths which photodiodes were not intended to detect. Stray light reduces measurement accuracy at some detection wavelengths. Stray light in the optics module has the following factors:

① Measured light and background light are reflected and scattered by the inside wall of the module, and the photodiode detects part of the scattered light.

② Structural defects cause light rays from adjacent channels to be incident.

③ Depending on abnormalities in the light-shielding characteristics of the band-pass filter, light with wavelengths different from the set wavelength band will be transmitted.

The optics module is designed to reduce stray light. However, it must be used in a dark state to prevent background light from entering. In order to reduce generation of scattered light, collimated light must be illuminated instead of diffused light. Use a collimated lens or SMA fiber adapter to illuminate collimated light (ϕ4 mm or less). Doing this reduced the generation of scattered light and reduces loss due to the diffusion of incident light, thereby improving measurement accuracy. The light-shielding characteristics of the band-pass filter can be shown with the OD (optical density) value, and the higher the OD value is, the better the light-shielding characteristics will be. The OD value is a logarithmic conversion of the filter transmittance (unit: %), expressed by equation (5-1).

$$OD = -\mathrm{Log}_{10}\,(T/100) \cdots\cdots\cdots\cdots (5\text{-}1)$$

T: filter transmittance [%]

The lower the filter transmittance is, the higher the OD value will be. In order to improve the light-shielding characteristics, in the optics module the settings are T≤0.01% and OD>4.

5 - 4 Sensitivity

In ideal conditions, "incident light is perfectly collimated light and light incident on the photodiodes has no loss other than the optical filters", the output P per unit of incident light level in channel n (n=1 to 10) is expressed by equation (5-2).

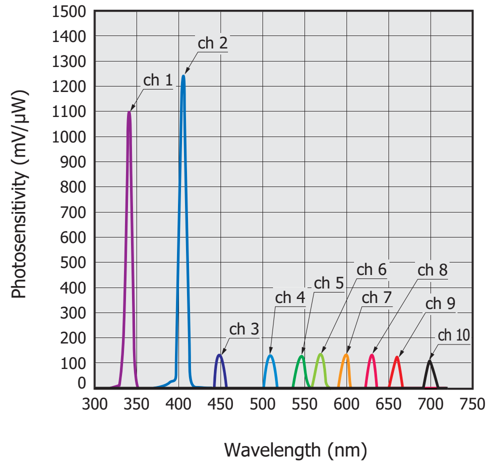
$$P = T_{BS(n-9)} \times T_{BS(n-8)} \times \cdots \times R_{BSn} \times T_{BPFn} \times S_{\lambda n} \times Zt \cdots (5\text{-}2)$$

$T_{BS(n-x)}$: transmittance of beam splitter ch (n - x) [%]
X=0 to 9
When n - x≤1, set$T_{BS(n-x)}$=1
R_{BSn} : reflectance of beam splitter ch n [%]
T_{BPFn} : transmittance of band-pass filter ch n [%]
$S_{\lambda n}$: photosensitivity of Si photodiode at detection wavelength of ch n [A/W]
Zt : conversion impedance [V/A]

Figure 5-1 shows the spectral response of the C13398 series.

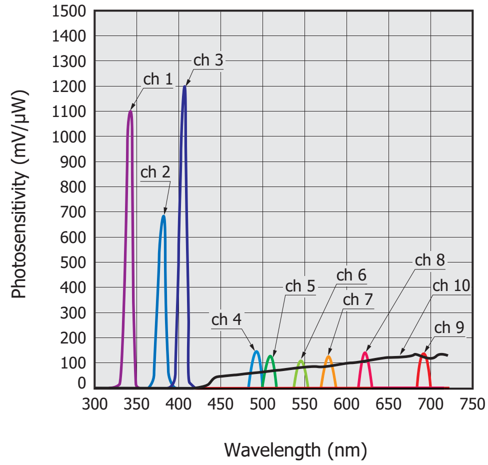
[Figure 5-1] Spectral response
(C13398 series, typical example)

(a) C13398-01



KACCB0459EC

(b) C13398-02



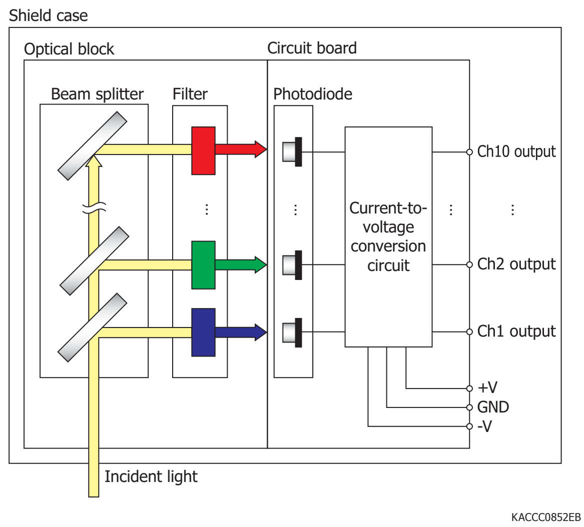
KACCB0460EC

In the optics module, a dichroic beam splitters are used for the beam splitters of some channels. The dichroic beam splitters are surface-coated beam splitters. They have high reflectance in specific wavelength bands. The measured light level is likely to be low in the ultraviolet region, so dichroic beam splitters are used for channels in this detection wavelength band. For this reason, the C13398-01 has high photosensitivity for ch1 and ch2, and the C13398-02 has high photosensitivity for ch1 to ch3.

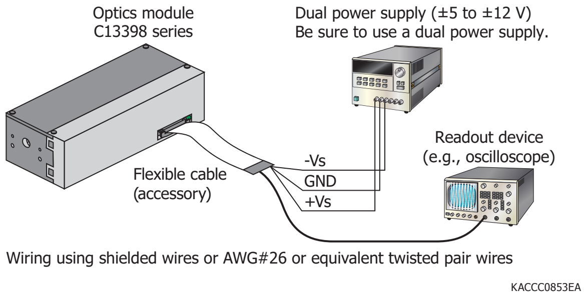
6. How to use

The block diagram and connection example of the C13398 series are shown in Figure 6-1 and Figure 6-2.

[Figure 6-1] Block diagram (C13398 series)



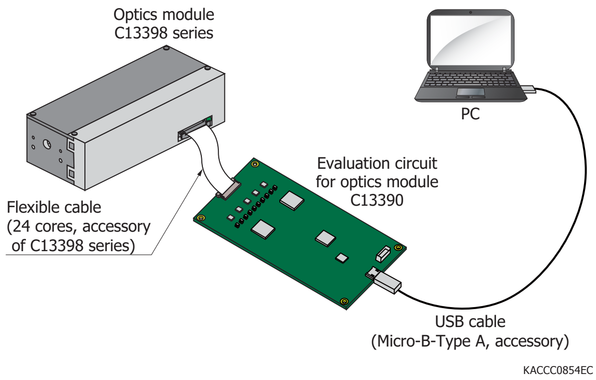
[Figure 6-2] Connection example (C13398 series)



Connect a dual power supply to the power input terminal of the C13398 series flexible cable, and connect a measurement device (an oscilloscope, etc.) to the signal output terminal. The analog output voltage of each channel in the C13398 series can be read out using the measuring device.

Figure 6-3 shows a connection example between the optics module C13398 series and evaluation circuit C13390. Use a flexible cable to connect the C13398 series and C13390, and a USB cable to connect the C13390 and PC. Power can be supplied to the optics module from a PC, and 10 channels of digital output can be acquired to a PC simultaneously.

[Figure 6-3] Connection example with evaluation circuit for optics module C13390

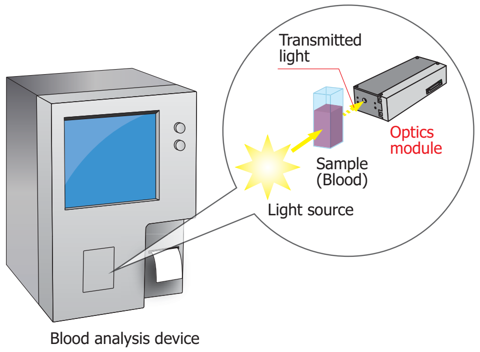


7. Applications

7 - 1 Blood analysis device

In blood analysis devices, the optics module is used to measure the blood absorbance as well as the fluorescence emission when light is incident on blood that has been reacted with a reagent.

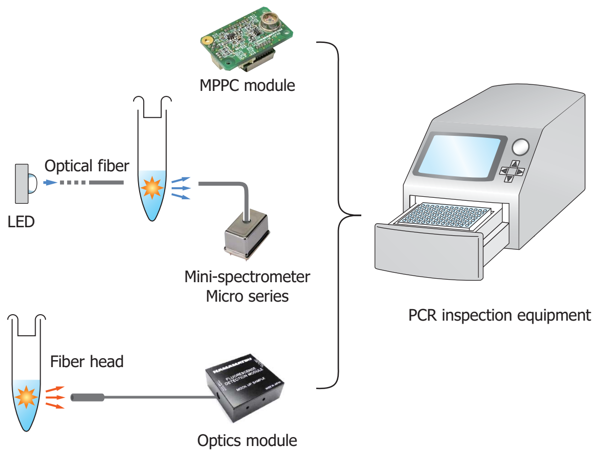
[Figure 7-1] Blood analysis device



7 - 2 PCR inspection equipment

The PCR (polymerase chain reaction) inspection equipment is used in a wide range of applications, including diagnosis of infectious diseases such as COVID-19, genetic testing, and water/soil testing. The optics module is used to detect the fluorescent light generated by illuminating light on DNA with an added fluorescent reagent.

[Figure 7-2] PCR inspection equipment



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www.hamamatsu.com

HAMAMATSU PHOTONICS K.K., Solid State Division
1126-1 Ichino-cho, Higashi-ku, Hamamatsu City, 435-8558 Japan, Telephone: (81)53-434-3311, Fax: (81)53-434-5184
U.S.A.: Hamamatsu Corporation: 360 Foothill Road, Bridgewater, N.J. 08807, U.S.A., Telephone: (1)908-231-0960, Fax: (1)908-231-1218, E-mail: usa@hamamatsu.com
Germany: Hamamatsu Photonics Deutschland GmbH: Arzbergerstr. 10, D-82211 Herrsching am Ammersee, Germany, Telephone: (49)8152-375-0, Fax: (49)8152-265-8, E-mail: info@hamamatsu.de
France: Hamamatsu Photonics France S.A.R.L.: 19, Rue du Saule Trapu, Parc du Moulin de Massy, 91882 Massy Cedex, France, Telephone: (33)1 69 53 71 00, Fax: (33)1 69 53 71 10, E-mail: infos@hamamatsu.fr
United Kingdom: Hamamatsu Photonics UK Limited: 2 Howard Court, 10 Tewin Road, Welwyn Garden City, Hertfordshire AL7 1BW, United Kingdom, Telephone: (44)1707-294888, Fax: (44)1707-325777, E-mail: info@hamamatsu.co.uk
North Europe: Hamamatsu Photonics Norden AB: Torshamnsgatan 35 16440 Kista, Sweden, Telephone: (46)8-509 031 00, Fax: (46)8-509 031 01, E-mail: info@hamamatsu.se
Italy: Hamamatsu Photonics Italia S.r.l.: Strada della Moia, 1 int. 6, 20020 Arese (Milano), Italy, Telephone: (39)02-93 58 17 33, Fax: (39)02-93 58 17 41, E-mail: info@hamamatsu.it
China: Hamamatsu Photonics (China) Co., Ltd.: B1201, Jiaming Center, No.27 Dongsanhuan Beilu, Chaoyang District, 100020 Beijing, P.R.China, Telephone: (86)10-6586-6006, Fax: (86)10-6586-2866, E-mail: hpc@hamamatsu.com.cn
Taiwan: Hamamatsu Photonics Taiwan Co., Ltd.: 8F-3, No. 158, Section2, Gongdao 5th Road, East District, Hsinchu, 300, Taiwan R.O.C. Telephone: (886)3-659-0080, Fax: (886)3-659-0081, E-mail: info@hamamatsu.com.tw

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