HAMAMATSU
PHOTON IS OUR BUSINESS

Optics modules

Contents

1. Overview

The optics module is comprised of Si photodiodes, optical components, and current-to-voltage conversion circuit. Our lineup includes filter type spectroscopic modules (C13398 series) specialized for signal detection of many known wavelengths, and spectroscopic modules with light sources (C16028 series) that make it possible to excite fluorescent reagents and detect the fluorescence.
Generally speaking, spectroscopic methods are broadly divided into dispersive and non-dispersive type. Dispersive type refers to a spectroscopy method that mainly uses gratings, while non-dispersive type refers to spectroscopy methods that mainly use optical filters. Both of our optics modules are classified as the non-dispersive type.
Compared to the dispersive type, its main features are that it can achieve high sensitivity and high-precision signal detection for specific wavelengths, and that it can achieve high S/N ratio detection by taking advantage of the high light blocking performance for non-detection wavelengths. Therefore, it is suitable for applications such as biochemical analysis and water quality analysis, where the detection wavelength is specified.
The spectroscopic module with light sources is equipped with an automatic power control (APC) function for the LED, which suppresses fluctuations in the light intensity and allows a constant light intensity to always be irradiated. Therefore, it is suitable for fluorescence detection, which requires excitation of reagents and detection of low-level light.
Other features of our optics modules include their compact size, which makes them easy to incorporate into equipment, and their ease of installation in various optical systems as entry-level models for evaluation.

[Figure 1-1] Optics module C13398 series, C16028 series

2. Features

- Flexible customization

We offer custom support for specifications such as detection wavelength and the number of channels.

- Excellent light-shielding characteristics

Using Hamamatsu, assembly technology, optical technology and circuit technology, we can suppress 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.

(1) Filter-type spectroscopic module (C13398 series)

- Simultaneous detection of up to 10 wavelengths

C13398 series can detect up to 10 wavelengths of light simultaneously . 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

(2) Spectroscopic module with excitation light source (C16028 series)

- High-precision fluorescence detection

The optical system achieves efficient fluorescent light guidance and low stray light, allowing detection of low-level light of the order of 100 pW.

- Highly stable excitation light source

It is equipped with APC (automatic power control) function, so it is possible to irradiate the measurement target with a constant amount of excitation light.

- Supports detection of two types of fluorescent reagents

It has two sets of optical systems, each including a light source and a detector, so it is possible to measure two types of fluorescent reagents with one module. C16028-01 is compatible with FAM and ROX fluorescent reagents.

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 performed 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.

[Table 4-1] Component

Component	Filter-type C13398 series	C16028-01 with excitation light source
Beam splitters	○	○
Band-passfilters	○	○
Si photodiodes	○	○
Signalprocessing circuits	○	○
Lens	×	○
LEDs	×	○

4 - 1 Beam splitters

The excitation light and measured light that pass through the sample are split by multiple beam splitters, and the reflected light is guided to the photodiodes or fluorescent samples. The optics module has two types: a type that splits light rays at a specific ratio, and a dichroic type that reflects only light of a specific wavelength band.

4 - 2 Band-pass filters

The bandpass filter transmits only light of a specific wavelength band from the light split by the beam splitter or the light from the LED. 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, excitation 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.

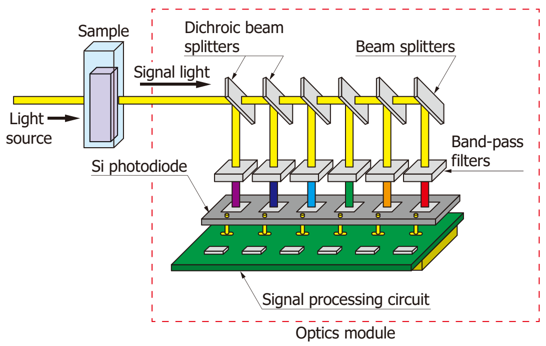
4 - 5 Lens (C16028 series)

Improved light-conductive efficiency of excitation light and fluorescence light allows efficient excitation light irradiation and fluorescence detection.

4 - 6 LEDs (C16028 series)

It is equipped with an LED suitable for exciting the target reagent. It is designed to have an appropriate wavelength band by combining a bandpass filter and a beam splitter to improve the excitation efficiency and blocking performance when detecting fluorescence.

[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.

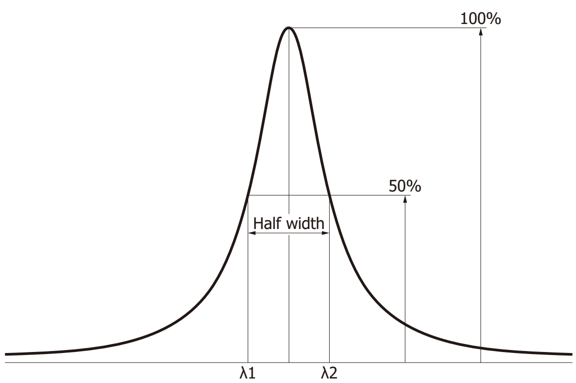
5 - 2 Output wavelength (C16028 series)

The emission wavelength depends on the characteristics of the built-in LED and bandpass filter. There is variation in the emission wavelength, which mainly depends on the variation in the emission wavelength band of a single LED. The spectroscopic module with excitation light source uses LEDs with small variations, realizing a highly accurate emission wavelength band.

5 - 3 Full width at half maximum

The half-width of an optics module is defined as the absolute value $|\lambda 1-\lambda 2|$, where $\lambda 1$ and $\lambda 2$ are the wavelengths at 50% of the peak value in the emission spectrum or spectral sensitivity spectrum.

[Figure 5-1] The half width



The narrower the half-width, the more the wavelength spectrum close to monochromatic light is transmitted, improving the measurement precision at the detection wavelength, but the amount of transmitted light is reduced, resulting in a lower S/N ratio. On the other hand, the wider the half-width, the more light is transmitted, but this can lead to a decrease in wavelength accuracy and an increase in stray light, as light of wavelengths not used for excitation and detection also passes through.
The transmission wavelength bands of the bandpass filters in our optics modules are designed not to overlap between channels.

5 - 4 Stray light

Stray light is light of wavelengths which photodiodes were not intended to detect. Stray light causes the reduction of measurement accuracy and dynamic range. 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 blocking characteristics of the band-pass filter, light with wavelengths different from the set wavelength band will be transmitted.

The optics module is designed for suppressing the 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 input instead of diffused light. Use a collimated lens to input 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. With the C16028 series, lenses are built into the input and output parts, so there are no particular accessories or procedures required by the user.
The blocking 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 blocking characteristics will be. The OD value is a logarithmic conversion of the filter transmittance (unit: %), expressed by equation (5-1).

$$OD = -\log_{10} (T/100) \quad \cdots\cdots\cdots\cdots (5\text{-}1)$$

T: filter transmittance [%]

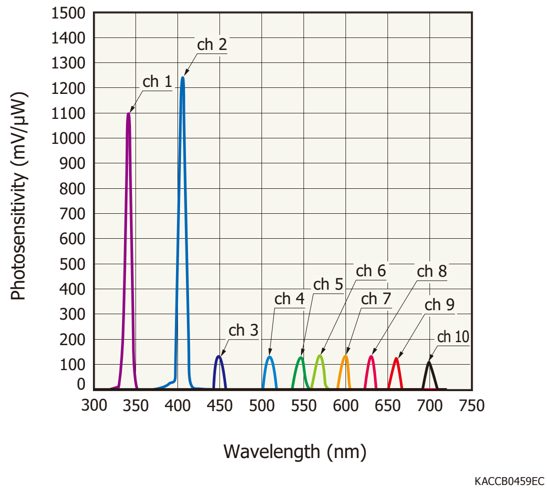
The lower the filter transmittance is, the higher the OD value will be. In order to improve the blocking characteristics, in the optics module the settings are T≤0.01% and OD>4.

5 - 5 Sensitivity

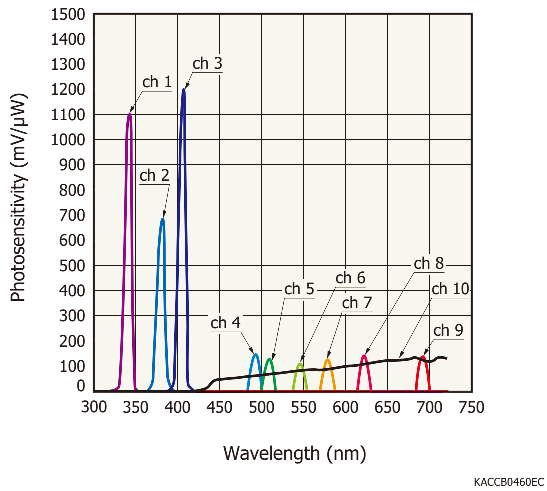
Under ideal conditions where the incident light is completely parallel and there is no loss of the light incident on the photodiode other than through the optical filter, the photosensitivity of the optics module is determined by the reflectance and transmittance of the built-in optical components, the photosensitivity of the photodiode used, and the conversion impedance of the current-to-voltage conversion circuit.
Figure 5-2 shows the spectral response of the C13398 series.

[Figure 5-2] Spectral response
(C13398 series, typical example)

(a) C13398-01

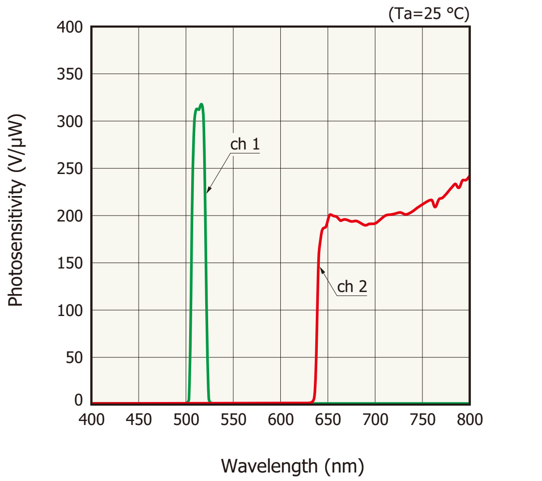


(b) C13398-02



In the filter type spectroscopic module, a dichroic beam splitter is used for the beam splitter of some channels. The dichroic beam splitters are surface-coated beam splitters. They have high reflectance in specific wavelength bands. The amount of measured light tends to be low in the ultraviolet range, a dichroic beam splitter is used for channels in ultraviolet 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.
Figure 5-3 shows the spectral response of the C16028-01.

[Figure 5-3] Spectral response (C16028-01)



KACCB0751EB

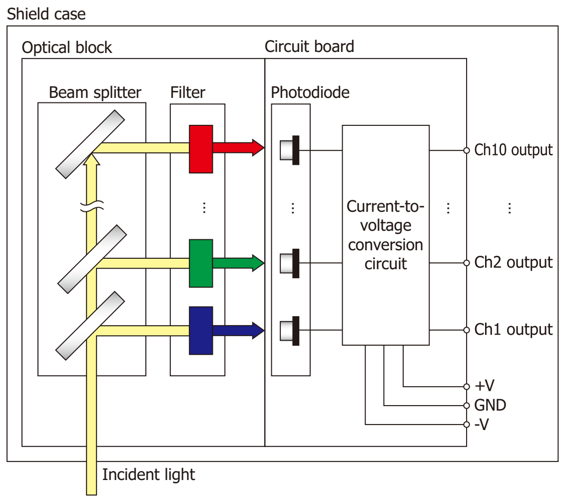
In fluorescence measurement, highly sensitive detection is required to measure the low-level light of fluorescence. For this reason bandpass filters with high transmittance and beam splitters with high reflectance are adopted, and as a result the conversion impedance of the signal processing circuit is high.

6. How to use

(1) C13398 series

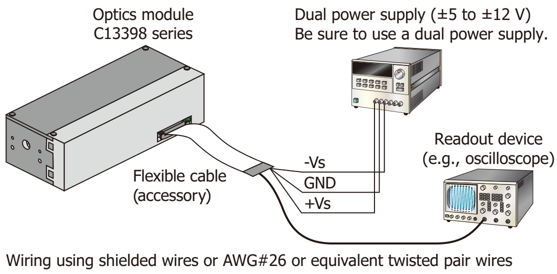
The block diagram and connection example of the C13398 series are shown in Figure 6-1 and Figure 6-2.

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



KACCC0852EB

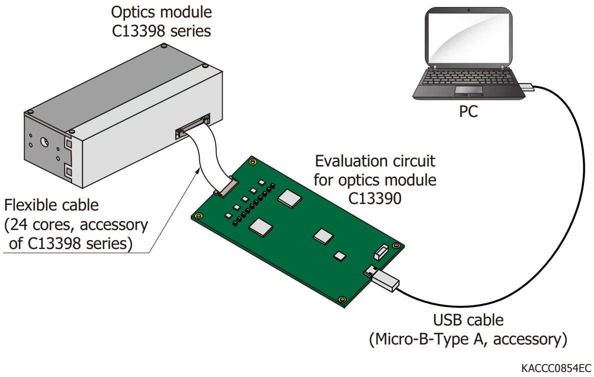
[Figure 6-2] Connection example (C13398 series)



KACCC0853EA

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.

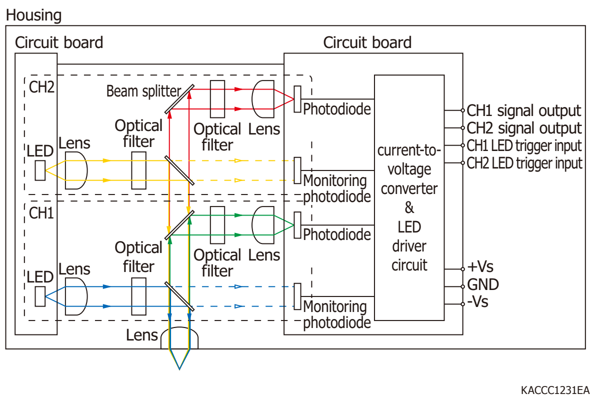
[Figure 6-3] Connection example with evaluation circuit for optics module C13390



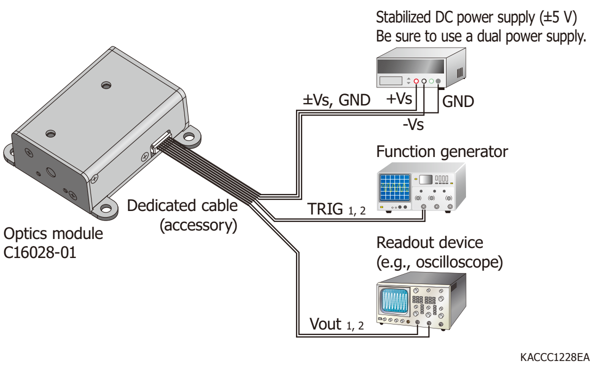
(2) C16028 series

The block diagram and connection example of the C16028 series are shown in Figure 6-4 and Figure 6-5.

[Figure 6-4] Block diagram (C16028 series)



[Figure 6-5] Connection example (C16028 series)



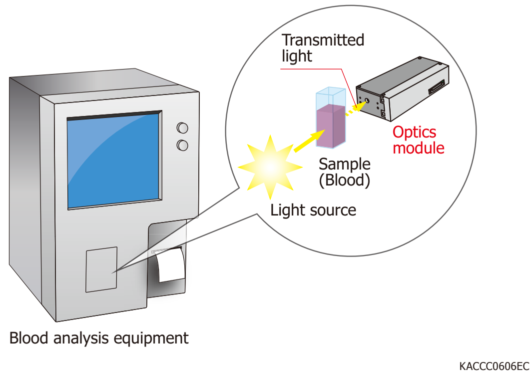
Connect a dual power supply to the power input terminal of the dedicated cable for the C16028 series, and connect a measurement device (such as an oscilloscope) to the signal output terminal. Because the light sources need to be turned on one channel at a time, connect a function generator or similar device to the light source on/off control terminals to turn the light on alternately.

7. Applications

7 - 1 Blood analysis equipment

In blood analysis equipment, 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.

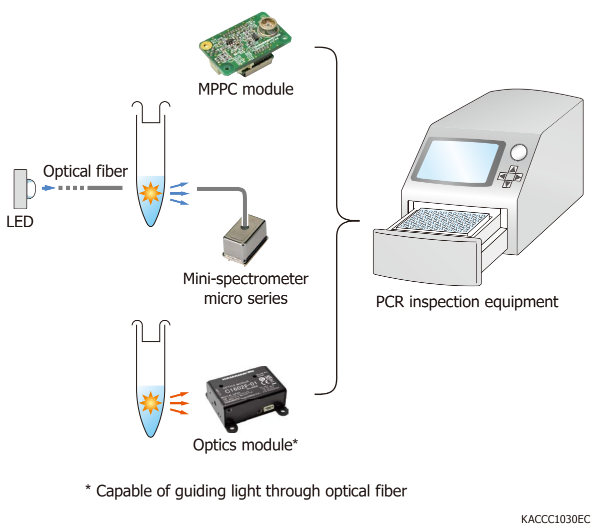
[Figure 7-1] Blood analysis equipment



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



HAMAMATSU

www.hamamatsu.com

HAMAMATSU PHOTONICS K.K., Solid State Division
1126-1 Ichino-cho, Chuo-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, NJ 08807, U.S.A., Telephone: (1)908-231-0960, Fax: (1)908-231-1218
Germany: HAMAMATSU PHOTONICS DEUTSCHLAND GMBH: Arzbergerstr. 10, 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, UK, 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 20044 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.: 1201, Tower B, Jiaming Center, 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.: 13F-1, No.101, Section 2, Gongdao 5th Road, East Dist., Hsinchu City, 300046, Taiwan(R.O.C) Telephone: (886)3-659-0080, Fax: (886)3-659-0081 E-mail: info@hamamatsu.com.tw

Cat. No. KACC9020E02 Dec. 2024 DN