INFRASPEC NR800 NEAR-INFRARED ANALYZER

***NANKO Tomoaki** [*1]   **SEKI Yukihiro**[*1]   **MOTOMURA Naomichi** [*1]*

We have developed a Fourier transform near-infrared analyzer (FT-NIR) with high resolution (4 cm^{-1}) and wide wavelength range (up to 2.5 μm) by a newly developed InGaAs (indium gallium arsenide) photodiode and an actuator with double parallel leaf springs. With this near-infrared analyzer, we can retrieve the target value directly from the spectrum by using the calibration curve for relating the near-infrared area spectrum of liquid samples to the property value of the target. Therefore, this analyzer is very useful for the monitoring of such things as properties. High-resolution (4 cm^{-1}) and measurement of a wide wavelength region (up to 2.5 μm) provide highly accurate measurement and wide range of applications.

INTRODUCTION

In recent years, near-infrared spectroscopic analysis has attracted a great deal of attention as a measurement method for online monitoring and quality control in various industries, and has been brought to the commercialization stage [(1)]. We released the NR500, the first Japanese-manufactured FT-NIR for process use, in response to this trend. However, as near-infrared spectroscopic analysis becomes applicable to a wider range of applications, demand for higher resolution and a wider wavelengths range has increased, in particular, for a 2 to 2.5 μm region where combination tones can be measured. High-resolution measurement improves spectrum separation, which makes the generation of calibration models easier and allows for higher measurement accuracy. Measurement of combination tone range will provide wider range of applications for the spectrometer, such as OH-value measurement. To meet these needs, we have developed the InfraSpec NR800 near-infrared spectroscopic analyzer. The NR800 inherits the various features of the NR500, as well as achieves the high resolution and wide-wavelength measurement mentioned above. This paper reports specifically on the NR800 features and technologies.

*1 Environmental & Analytical Products Div.

FEATURES AND SYSTEM CONFIGURATION

Features

(1) Measurement Range of 0.9 to 2.5 μm for Wavelengths
This covers the combination tone region of 2.0 to 2.5 μm which will open the door to a greater number of applications, such as the measurement of OH values.

(2) High Wavelength Resolution of 4 cm^{-1}
This has been made possible by the development of a new actuator. Resolutions is selectable from 4 cm^{-1} to 64 cm^{-1}.

(3) Multi-channel Measurement
The beam is split at the interferometer and it allows to connect up to four measurement probes and cells respectively. Free from mechanical switching, the analyzer can simultaneously measure a maximum of four channels.

(4) Stream Switching
NR800 enables switching streams and measurement samples corresponding to each path, so that NR800 can be applied to diverse sampling units and measurements.

(5) Multi-component Measurement
The analyzer can accommodate up to 64 calibration models and simultaneous measurement of up to 12 components per stream is available.

(6) Outlier Detection
This enables the NR800 to identify and provide alarm of

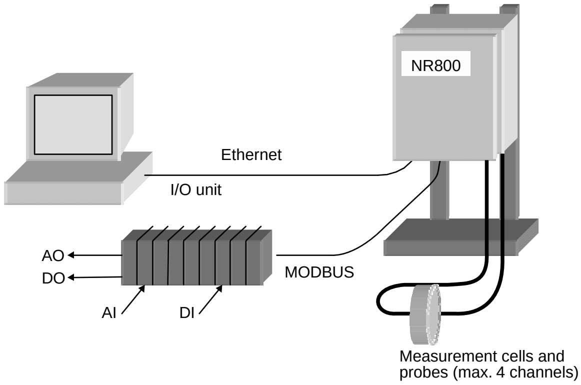


Figure 1 NR800 System Configuration

outlier values based on the Mahalanobis distance and RMSSR (Root of Mean Sum Squared Residuals), when measuring values are recognized as out of the sampling population used for calibration model generation.

(7) Single and Dual Fiber Structures
To eliminate the effect of environmental fluctuations such as temperature, the former model NR500 adopted dual-fiber structure with two fibers (for sample and reference) in parallel. However, since some applications do not require that extent of accuracy, NR800 offers a optional single-fiber structure with the reference fiber installed inside the analyzer.

(8) Explosion-proof Structure
This is required when the analyzer is installed in hazardous area such as refineries and chemical. An optional explosion-proof model NR800 is available. Furthermore, as the measurement point and analyzer are connected by fiber-optic cable, it is also possible to install just the sampling units with the measurement cells in a hazardous area and install the analyzer in a non-hazardous area.

(9) Self-diagnosis
Various self-diagnostic functions are available in NR800 such as monitoring of the source burn out and HeNe (helium-neon) laser life time.

(10) Laboratory Model
Offline measurements for quality control and model generation are often performed in a laboratory or other environments. For this purpose, a laboratory model employing the same interferometer as the process model is available.

System Configuration

Figure 1 shows the system configuration of NR800. The measuring beam from the NR800 passing through the fiber-optic cable is partially absorbed by the sample at the measuring cell, or the probe, and then returns to the NR800. The absorption spectra of the sample is obtained by transforming the signals of absorbed beam with Fourier transform. Measurement values is calculated by applying calibration model to those spectra. The measurement output is provided by either optional I/O unit (hard wire) or by MODBUS communication via RS422.

The measurement values can also be retrieved as analog signals by connecting a special I/O unit.

SPECTROMETER'S CONFIGURATION AND COMPONENTS

Figure 2 shows the configuration of the spectrometer. Like the NR500, the spectrometer adopts the Fourier transform spectroscopic technique. The interference beam from the interferometer is applied to the sample and detects the absorbed beam with a detector. This detected analog signal is converted

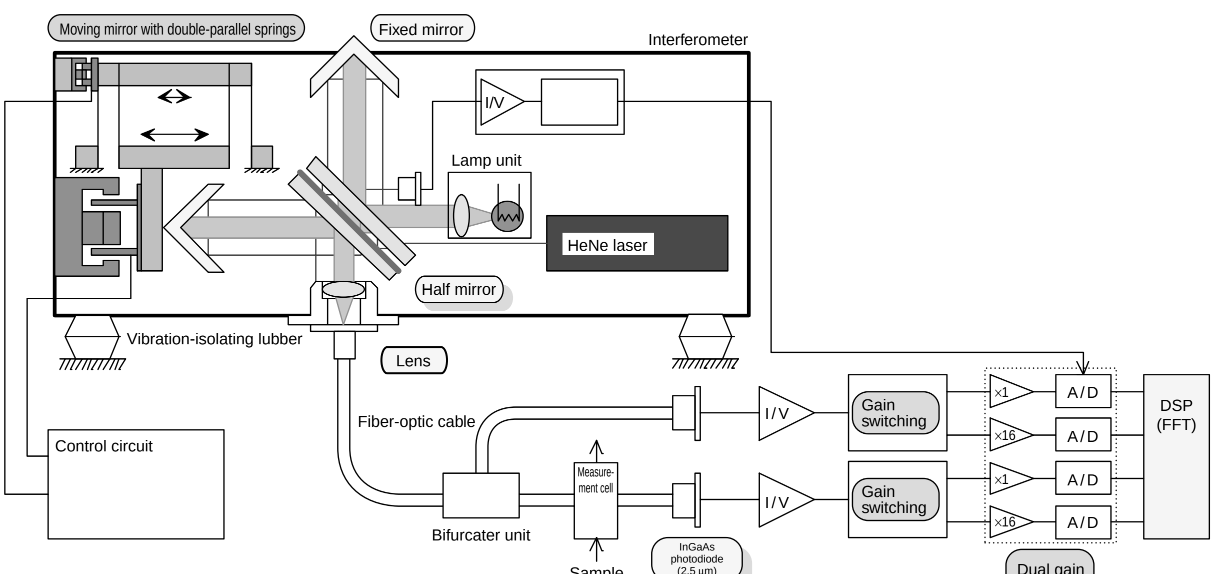


Figure 2 Spectrometer Configuration

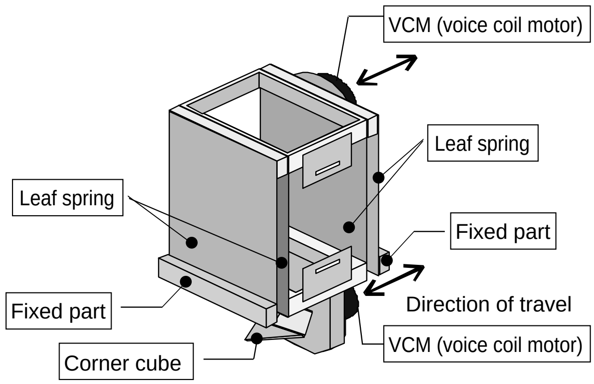


Figure 3 Structure of Moving Mirror Unit

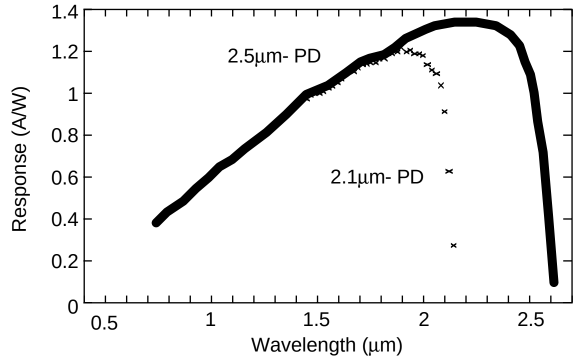


Figure 5 Spectroscopic Sensing Response of Photodiodes

into digital signals, and then applies a Fourier transform to them in order to obtain the sample fs absorption spectra. With the Fourier transform spectroscopic technique, the wavelength resolution is determined by the moving mirror travel distance. To achieve high resolution with the NR800, we developed a moving mirror with double-parallel springs that allow sufficient travel distance while maintaining vibration-resistance and durability. We also developed an InGaAs (indium gallium arsenide) photo detector that can measure spectra in a wide wavelength range with high S/N (signal-to-noise) ratio. In addition, we employed a dual-gain A/D converter and auto switching of the circuit gain to achieve spectrum measurement with higher S/N ratio for samples of superior absorption.

Moving Mirror Unit

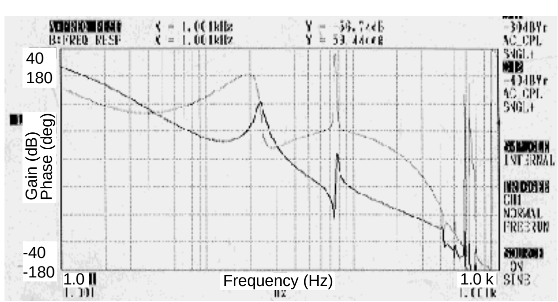
Figure 3 shows the structure of the moving mirror unit. Leaf springs arranged in parallel are used as a support for the block. Parallel leaf springs have high levels of stiffness in directions in which the mirror is not supposed to move and against torsion, and the unit has superior durability due to having a design free from sliding parts. Moreover, to ensure an adequate amount of travel, two pairs of parallel springs (outer and inner springs shown in Figure 3) are used. This enables the springs to cancel out any vertical motion resulting from a mirror movement. To lower resonance produced at the joint of the two pairs, the NR800 detects the positions of the moving mirror and joint and controls the mirror based on the positions so that vibration speeds of the resonance-related frequencies become zero. Figure 4 shows the open-loop characteristics of the moving mirror fs control system, which demonstrates reduction of the influence of the joint resonance.

InGaAs Photodiode[3]

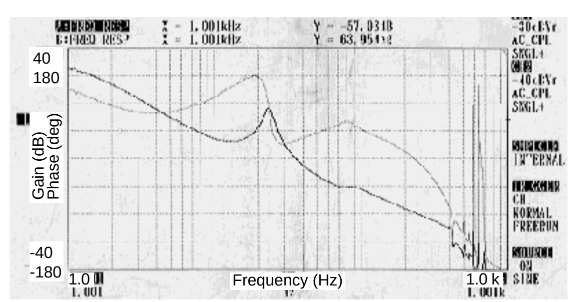
The newly developed InGaAs photo diode provides a wide wavelengths detection range with extremely low dark current. It can cover the range of 2.0 to 2.5 µm, which was not possible with conventional photodiodes. Figure 5 shows the response characteristics of the photodiode up to a wavelength of 2.5 µm.

Dual-gain A/D Converter and Auto Switching of Circuit Gain

The interference signals processed by the Fourier transform spectroscopic technique have the characteristics of increasing in size when the distances from the half mirror to the moving mirror and the fixed mirror of the interferometer are equal (center burst). Therefore, changing the circuit gains between the center-burst point and its surrounding area allows the signals around the center-burst point to be measured with higher S/N ratio. To make use of this, we employed the dual gain for the A/D converter as



a. Without Joint Vibration Control



b. With Joint Vibration Control

Figure 4 Open-loop Characteristics of Moving Mirror Unit

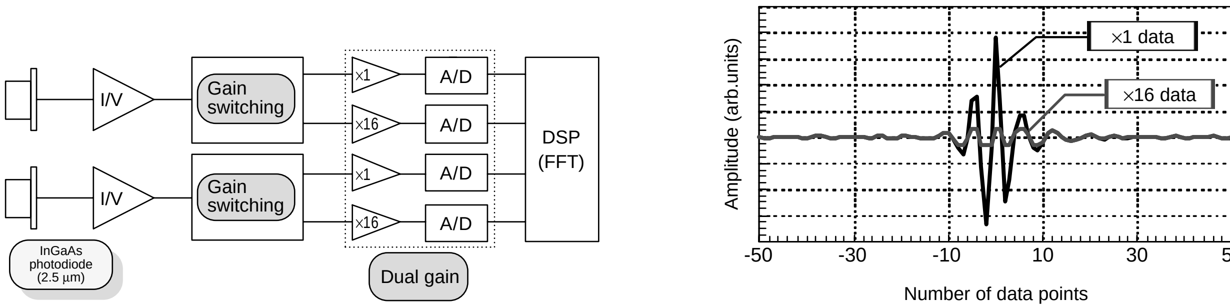


Figure 6 Dual-gain A/D Converter

shown in Figure 6 so as to achieve higher S/N-ratio measurement. The high S/N-ratio measurement has been realized also for measurement of samples with high absorption by switching the circuit gain automatically and appropriately depending on the signal volume.

MEASUREMENT EXAMPLE

Figure 7 shows an example of measurement results of toluene with an NR800. It proves that the newly added range of 4000 to 5000 cm^{-1} has been clearly measured.

CONCLUSION

We have successfully improved the basic performance of the NR800 in terms of measurement wavelength range, resolution, and S/N ratio, as well as upgraded flow path switching and other functions while incorporating such features of the NR500 as ease of use for processes, and reliability. We believe that the NR800 will be useful for an even greater number of applications. ◆

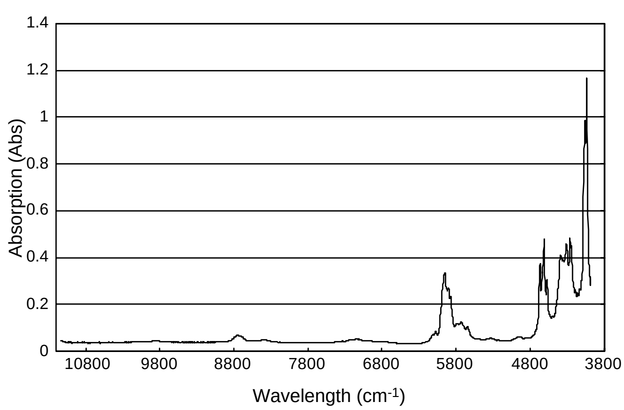


Figure 7 Example of Measurement Results

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