TDLS200 Tunable Diode Laser Gas Analyzer and its Application to Industrial Process

Kazuto Tamura *1
Tomoaki Nanko *2
Yukihiko Takamatsu *1
Junichi Matsuo *3

Yokogawa’s TDLS200 laser gas analyzer, which is based on tunable diode laser spectroscopy, features high selectivity and long-term stability, and offers fast in-situ analysis of even high-temperature or corrosive gases. This report introduces the measurement principle of the TDLS200 and an example of real-time residual ammonia measurement in a flue to control ammonia injection volume during the denitration and dust collection process.

INTRODUCTION

A laser gas analyzer employing the tunable diode laser absorption spectroscopy (TDLAS) method has a feature capable of measuring the concentration of the sample gas with high selectivity for gas components and without contact only by irradiating the gas sample with light from a tunable diode laser. Thus fast and accurate in-situ measurements can be performed in process lines under various measurement conditions. For example, measurements can be performed at normal temperature and up to temperatures as high as 1500 °C, and in environments with fluctuating pressure. It can also measure corrosive or highly hazardous gases. Use of the accurate and highly responsive measurement signals produced by the analyzer for process control systems helps improve yields, energy efficiency, and safety in various industrial processes. A simple configuration without moving parts and components with limited lifespan ensures virtually maintenance-free operation and management.

Yokogawa’s TDLS200 laser gas analyzer is a new type of laser gas analyzer evolved for process measurement. Applying a measurement method based on the peak area integration method, it eliminates errors caused by the presence of other gases and pressure changes, which lead to measurement errors. It also enables accurate measurement of the concentration of gas components, even under simultaneous fluctuations in temperature and other factors. This paper provides an overview of the TDLS200 laser gas analyzer and describes its features and measurement principle, and introduces examples of its applications.

INSTALLATION AND CONFIGURATION OF TDLS200 LASER GAS ANALYZER

Figure 1 shows an example of installation and configuration of the TDLS200 laser gas analyzer. The TDLS200 has a launch unit and a detection unit that are usually placed in a facing orientation on either side of the duct (cross duct) through which process gas flows. The cross-duct installation shown in Figure 1 can accommodate ducts up to approximately 20 m wide.

Figure 1 Installation and Configuration Example of the TDLS200 Laser Gas Analyzer

Optical windows separate the interior of the analyzer from the process gas. The light from the semiconductor laser in the launch unit goes through the optical window, the process gas and the optical window of the detection unit and reaches the photodetector. The photodetector converts the power of the received laser beam into an electrical signal. The arithmetic circuit in the launch unit determines the absorption spectrum of the measured component, calculates the peak area of the spectrum, converts it into component concentration, and outputs it as a 4 to 20 mA analog signal.

The optical axis alignment part has a bellows structure that allows easy angle adjustment while maintaining airtightness essential for the industrial process. The connection of the launch unit and the detection unit via the optical axis alignment part enables easy optical axis adjustment not only for regular installation configuration where the
two units are placed on both sides of the pipe as shown in Figure 1, but also for various types of installation like those shown in Figure 2. This makes it possible to determine the installation configuration that best suits the components to be measured and the application to ensure optimal conditions for measurements.

![Figure 1: TDLS200 Installation Configurations](image)

**Figure 2** TDLS200 Installation Configurations

**MEASUREMENT PRINCIPLE OF THE TDLS200 LASER GAS ANALYZER**

The TDLS200 uses the TDLAS method to measure optical absorption spectra peculiar to molecules ranging from infrared to near-infrared due to vibration and rotation energy transition of molecules in the measured component through a semiconductor laser with an extremely narrow spectral linewidth. The optical absorption spectra peculiar to major molecules such as O₂, NH₃, H₂O, CO and CO₂ are in the region from infrared to near-infrared, and measurements of the amount of light absorbed (absorbance) at a specific wavelength make it possible to calculate the concentration of the measured component.

**Infrared and Near-infrared Absorption Spectra Due to Molecule Vibration and Rotation**

Figure 3 shows an example of molecule vibration and rotation mode while Figure 4 shows a typical CO₂ absorption spectrum in the infrared to the near-infrared range. Molecules consisting of two or more atoms absorb light at frequencies specific to the vibration and rotation modes of stretching, scissoring, etc. as shown in Figure 3. The width of absorption band for CO₂ shown in Figure 4 is about 10 nm and the spectral linewidth of each absorption peak is approximately 0.05 nm.

![Figure 3: Examples of Molecule Vibration and Rotation Modes](image)

In contrast, unlike low resolution spectrometers, the TDLS200 uses a laser beam with an extremely narrow spectral linewidth emitted by the tunable diode laser, and its wavelength can be changed by adjusting laser temperature and drive current. This makes it possible to measure a single absorption peak among those in the absorption spectrum like that shown in Figure 5. The distance between CO₂ and H₂O peaks is 0.5 nm or less and cannot be resolved by conventional spectrometers, making it impossible to resolve gas absorption peaks. This example explains the case measuring concentration of CO₂ in the presence of H₂O. A conventional spectrometer will be affected by H₂O spectrum interference. To reduce the effect of interference, measures such as removing interfering gases must be taken prior to measurement.

![Figure 4: CO₂ Absorption Spectrum](image)

**Figure 4** CO₂ Absorption Spectrum

**Component Selectivity of Tunable Diode Laser Spectroscopy**

Figure 5 shows the absorption spectra for CO₂ and H₂O. A wavelength resolution of conventional spectrometers for the infrared to near-infrared region is around 0.3 to 3 nm. This value is equivalent to or larger than the distance between absorption peaks of different gases (0.5 nm or less), making it impossible to resolve gas absorption peaks. This example explains the case measuring concentration of CO₂ in the presence of H₂O. A conventional spectrometer will be affected by H₂O spectrum interference. To reduce the effect of interference, measures such as removing interfering gases must be taken prior to measurement.

![Figure 5: CO₂ and H₂O Absorption Spectra](image)

**Figure 5** CO₂ and H₂O Absorption Spectra

In contrast, unlike low resolution spectrometers, the TDLS200 uses a laser beam with an extremely narrow spectral linewidth emitted by the tunable diode laser, and its wavelength can be changed by adjusting laser temperature and drive current. This makes it possible to measure a single absorption peak among those in the absorption spectrum like that shown in Figure 5. Thus, as shown in Figure 6, one absorption peak that is not affected by interfering gases can be selected for measurement.

Since wavelength selectivity is high and measurements are not affected by other interfering components, there is no need to remove interfering gases prior to measurement, allowing in-situ measurement of process gas.
TDLS200 Tunable Diode Laser Gas Analyzer and its Application to Industrial Process

Measurements of Component Concentration Using Peak Area Integration Method

The TDLS200 is capable of measuring an accurate spectrum without being affected by interfering components by sweeping the oscillation wavelength of the semiconductor laser around a single absorption peak of the component to be measured.

Although an absorption spectrum obtained by the TDLS200 isolates it from interfering components, the shape of the spectrum varies depending on the broadening effect caused by the following factors: gas temperature, gas pressure, coexisting gas components. Therefore measurements subject to such environmental changes require compensation. Figure 7 shows the changes of a 0.76 µm-band single absorption spectrum of O₂ with a 10% O₂ concentration caused by temperature changes, pressure changes and inclusion of CO₂, N₂ or He as background gases respectively.

The TDLS200 sweeps a wavelength using a semiconductor laser and measure absorption spectra, and calculate component concentration from the spectrum area employing the peak area integration method. Table 1 shows a comparison of the influence of each factor on the peak area integration, peak height and 2f methods.

<table>
<thead>
<tr>
<th>Factors causing changes</th>
<th>Peak area integration method</th>
<th>Peak height method / 2f method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas temperature</td>
<td>Nonlinear</td>
<td>Nonlinear</td>
</tr>
<tr>
<td>Coexisting gas components</td>
<td>No effect</td>
<td>Nonlinear</td>
</tr>
</tbody>
</table>

Conventional methods used so far include the peak height method that calculates the concentration of measured components from the peak height of absorption spectra, and the 2f method that calculates the concentration of the measured component from the P-P (Peak to Peak) value of the waveform generated by the frequency doubling modulation from a wavelength scanning signal. However, all of these methods were greatly affected by changes in temperature, pressure and coexisting gases. In contrast, the peak area integration method is theoretically not affected by changes in coexisting gas components and spectrum area remains constant. And the spectrum area changes linearly with pressure changes in principle.

As shown in Table 1, the effect of temperature, pressure and coexisting gas components on the peak height method and the 2f method are nonlinear, which makes compensation difficult when more than one of these factors are involved. Since the peak area integration method permits linear compensation for gas pressure changes and non-linear compensation for gas temperature changes, it ensures accurate compensation.

Examples of Industrial Applications

...Measurements of Residual NH₃ Concentration in Flue Gas

The TDLS200, thanks to its capability of fast in-situ measurement in actual processes, can be applied to high-speed control where signals indicating component concentration measurements essential for management are directly delivered to process control systems, and can be applied to real-time management of process states as well. The TDLS200 can thus
help improve various industrial processes. In this section, we will introduce measurements of residual NH₃ concentration in flue gas. Note that optimum combustion control applications have been reported in another Yokogawa technical report \(^{(1)}\). Please refer to that report for details.

Ammonia (NH₃) gas is injected into flue gas to remove NOx (denitrification), increase the efficiency of a dust collector and prevent corrosion. Excess NH₃ injection increases the running costs and the amount of residual NH₃, resulting in generation of foul odors. Therefore, the amount of NH₃ in the exhaust gas must be measured, controlled and monitored. For example, the exhaust gas denitrification equipment for a large combustion furnace uses the DeNOx SCR (selective catalytic reduction) process, where NOₓ is reduced to N₂ and H₂O by NH₃ injection and selective reduction catalyst, and residual NH₃ concentration (ppm level) in the flue gasses is measured online.

Conventional NH₃ meters that use indirect NOx measuring methods such as the chemiluminescence detection and ion electrode method have slow response and require sample line equipment involving heated pipes to prevent NH₃ adhesion and large maintenance costs depending on such a complex measurement system. On the other hand, as shown in Figure 8, the TDSL200 is installed directly into process lines and measures NH₃, which substantially improves responsiveness and maintainability. In addition, the highly responsive NH₃ concentration signals can be employed in NH₃ injection control to optimize NH₃ injection.

Figure 10 shows the changes in NH₃ injection volume and measurement values of TDSL200 in the case where denitrification equipment for improving the efficiency of the dust collector and preventing corrosion is not equipped with; TDSL200 is installed at point A in Figure 9.

**Figure 8 Use of TDSL200 in Denitrification Equipment for Measurement and Injection Control of NH₃**

**Figure 9** shows an installation location examples of the TDSL200 in an exhaust gas denitrification process of a boiler.

**Figure 10 NH₃ Injection Volume and Changes in Measured Values of TDSL200**

**CONCLUSION**

This paper has presented an overview of the TDSL200 laser gas analyzer and described its features, measurement principle, and applications. The high component selectivity, fast response and ease of maintenance achieved by this technology and product assure its application in a broad range of industrial processes. These include not only use in the NH₃ measurement applications introduced in this paper, but also in measurements of CO and O₂ in optimum combustion control, measurements of minute amounts of water in electrolytic plants, etc. We expect the TDSL200 to greatly contribute to the preservation of the environment and reduction of running costs through its applications to process control not limited to monitoring.

**REFERENCES**


* TDSL is a trademark of Yokogawa Electric Corporation.