TDLAS

Model 5100 Series Gas Analyzer

Based on Tunable Diode Laser Absorption Spectroscopy (TDLAS)

Introduction

Tunable Diode Laser Absorption Spectroscopy (TDLAS) has become an accepted technology for crucial on-line gas analysis applications. The high reliability of the solid state lasers used in TDLAS instruments is the result of decades of technology development for the Telecom industry. Correspondingly, TDLAS-based instruments tend to be very robust, reliable and require minimal maintenance.

Three key measurement attributes of the TDLAS technique are: specificity for the analyte, high sensitivity, and fast response speed. The specificity of TDLAS is the result of the extremely high

Model 5100

Model 5100
ATEX Zone 1

Model 5100 HD
ATEX Zone 1

Model 5100 HD GP, Div 2 and
ATEX Zone 2 Version

Advantages of a Laser Based Analyzer

- High spectral resolution and accuracy
- Fast response time
- Non-contact measurements
- Reference cell provides assurance that the laser is locked at the correct wavelength
- Broad dynamic range of measurements
- Cost effective - no consumables or moving parts
- All digital protocol – original feature of the instrument design

Features and Benefits

- ***Real-Time Performance Monitoring***
  Laser line-lock verification using internal reference cell
- ***Non-contact Measurement***
  Laser source and the detector are isolated from the process. Non-contact measurement offers low maintenance.
- ***All Digital Signal Processing***
  Microcontroller capable of sophisticated signal processing
- ***Web-Based Interface***
  To interrogate the analyzer remotely, all you need is the IP address of the analyzer
- ***Connectivity***
  Modbus, Ethernet and analog
- ***NEMA 4 Enclosure Houses the Electronic Components***
  Designed for outdoor installation
- ***Fully-Integrated Sample Handling***

spectral resolution achievable. Emission bandwidths for tunable diode lasers are very narrow, which results in the ability to isolate a unique absorption line of an analyte species. A second advantage of TDLAS is the ability to rapidly tune the lasers, so techniques like wavelength modulation spectroscopy (WMS), which yield dramatic sensitivity enhancements over a direct absorption approach, are easily implemented. Because TDLAS is an optical technique, it also offers a very fast response speed. The high specificity, sensitivity, and response speed of TDLs make them very suitable for a variety of process measurements.

Absorption Spectroscopy with Tunable Diode Lasers

Absorption spectroscopy is the science based on the measurement of the attenuation of light by matter. Quantitative measurements are made by the application of Beer's law, which compares the amount of light passing through a sample containing an absorbing species to that observed in the absence of the absorbing species. Thus, the measurement is based on the ratio of these two quantities. Monitoring a low concentration of an analyte, which does not strongly absorb the light, requires measuring a small change in the detector response relative to a large background (i.e., the light passed through the sample in the absence of the analyte). Thus, the sensitivity of the method is limited to the noise present in the background measurement. To enhance sensitivity, zero background techniques have been developed. One of these techniques is WMS.

The Wavelength Modulation Technique

WMS is a variation of absorption spectroscopy which can provide a substantial increase in the signal-to-noise ratio. In WMS, the output wavelength of the laser is modulated by a carrier frequency. As the wavelength is scanned through the absorption line of the analyte, attenuation of the laser energy by the sample results in amplitude modulation of the signal recorded by the detector. Demodulation of this detector signal at the second, or higher harmonic frequencies, produces a signal that is proportional to analyte concentration. If no analyte is present in the sample path, then the demodulated signal does not contain any background, and is therefore considered a zero-background technique. This transforms the conventional ratiometric measurement, where two large signals are compared, into a technique where a small signal is detected in the absence of any background. Thus, WMS results in higher sensitivity than a traditional absorption spectroscopy measurement.

AMETEK Solution

We provide our customers a robust solution in the form of the TDLAS-based AMETEK 5100 series analyzers, which offer a number of significant features compared to other laser-based analyzers in the market. The 5100 series contains offerings that are based on extractive sample systems, many of these are designed for hot/wet sample systems, requiring no additional sample conditioning. These analyzers are sensitive tools for measuring low levels of gas concentrations, even in the presence of interfering species. The high resolution of TDLAS in combination with chemometric methods effectively removes the impact of interfering species. Ease of service, nearly 100% uptime, and low installation cost are some of the benefits of the AMETEK 5100 series. The field-proven AMETEK 5100 series analyzers provide best-in-class performance and offer features not found on competing products.

A dual laser TDLAS setup (shown on right) consists of two tunable diode lasers, transmitting optics, sample cell, receiving optics and detectors. The emission wavelengths of the tunable diode lasers are tuned over the characteristic absorption lines of the analytes in the sample. This causes a reduction of the measured signal intensity, which can be detected by a photodiode and then used to determine the gas concentration.

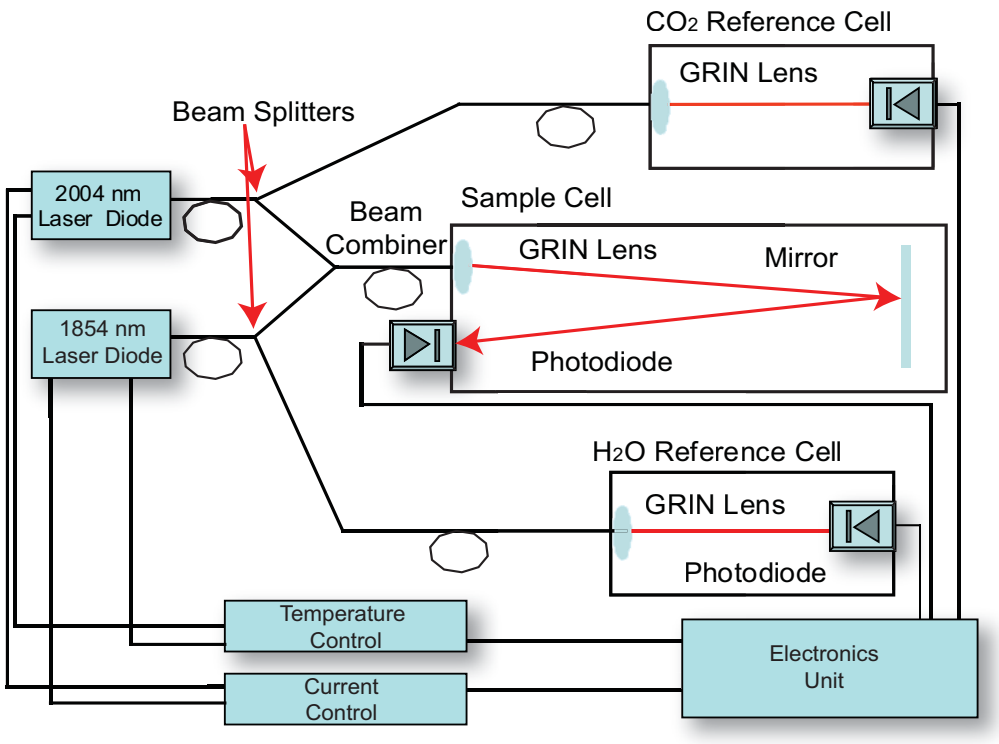


Figure 1: Dual laser TDLAS set up

The Model 5100 HD can be configured with single/dual lasers and single/dual gas cells. In a two-laser two-cell configuration, two different gas streams can be simultaneously monitored. One specific application is the measurement of wet and dry natural gas streams for H_2O levels. This dual cell configuration is superior to stream switching with a single gas cell which would require long equilibration periods when switching from wet to dry streams. Dual lasers systems can also be used for the monitoring of two gas species at the same time.

The Analyzer

Why use TDLAS technique?

Direct absorption spectroscopy relies on the measurement of a small change in a large signal. Noise introduced by the light source or optical system will impact the measurement sensitivity. The sensitivity of a direct absorption spectroscopy system is typically limited to an absorbance of ~10^{-3}; while WMS yields sensitivity improvements of 10 – 100 times. Therefore, TDLAS is better suited for low-concentration measurements.

What are the key attributes of a tunable diode laser source?

Diode lasers are small, possess high radiance, have long life, and can be modulated at high frequencies. The key characteristics are:

1) Excellent specificity for the analyte. This is due to the extremely high spectral resolution achievable.

2) High sensitivity – Ability to tune the laser so techniques like Wavelength Modulation Spectroscopy can be employed to dramatically enhance the sensitivity.

3) Fast response – TDLAS is an optical technique.

Why is the diode laser a preferred source and how long do they last?

Diode laser operates at near room temperature, are small, possess high output radiance, have narrow line widths, and are tunable.

Diode Lasers have a typical MTBF of 15 years.

What is the effect of higher sample pressure?

Higher sample pressures cause collisional broadening, which results in a reduction of the observed peak intensity. This effect limits the detection sensitivity and signal-to-noise ratio. The AMETEK 5100 series instruments measure both temperature and pressure of the sample gas to provide compensation with an advanced algorithm.

Can we measure O_2 using TDLAS technique?

Oxygen has a weak absorption band in the vicinity of 760 nm, which can be used for TDLAS-based measurements. Even though oxygen is not a strong absorber, this spectral region is essentially free from background interferences and provides for reliable measurements of oxygen. The standard 5100 HD instrument provides a sensitivity of better than 0.1% (v/v).

Can we monitor two streams simultaneously with one analyzer?

Yes, model 5100 HD with dual lasers and dual cells can be configured for monitoring two streams.

How is the window fouling accounted for?

Fouling of the optical surfaces is inevitable over a period of time. Detection and demodulation performed at the laser-modulation frequency enabled the instrument to normalize the spectra, without the need for a separate measurement of the laser power. This makes the system immune to changes in the received laser power due to attenuation of the light energy from build up on optical surfaces. However If the surfaces are significantly contaminated, causing excessive loss of light at the detector, the analyzer will alarm, indicating the need for maintenance to clean the optical cell.

What are the differences between 5100 Vertical and 5100 HD models?

5100 Vertical is designed with a single laser and sample cell, so it can only be used for single-analyte applications. Further, the system is only provided with optional heating for freeze protection, so it is not suitable for sample streams with a high dewpoint.

Is the laser a potential ignition source? What is its classification?

No, it is not an ignition source, the laser classification is 1 m or 3 b (depending on wavelength).

What are the wetted parts of the analyzer?

316 SS, 304 SS, fused silica, gold, Teflon, corning glass C0550, and elastomeric O-rings (O-ring options include Viton, Kalrez, EPDM, and Buna-N).

How much gas does the unit vent?

The measurement is not flow dependent. For most applications, we recommend a flow rate of approximately 2slpm, but a range of 1 – 10 slpm can be used.

Measurements / Applications

What gases can be measured?

Small molecules in gas phase. Examples include H_2O, CH_4, CO_2, H_2S, O_2, CO, NH_3 and C_2H_2. All these species can be measured in variety of background gases. Please consult factory for specific application details.

What are the common applications?

Monitoring of H_2O, CH_4, CO_2 and H_2S in natural gas are key applications. O_2 and CO in combustion monitoring, oxygen monitoring in process tank headspace are some of the other process applications.

Since laser diode is tunable, is it possible to measure many components in a TDLAS analyzer?

The TDL tuning range is typically less than 1 nanometer. It is uncommon to find applications for multiple analytes to have absorption lines within this narrow tuning range, but there are exceptions. An example is the measurement of moisture and methane in the vicinity of 1854 nm. Since absorption spectra of moisture and methane have some overlap in this spectral range, the use of an appropriate regression technique is required to extract the analytical information about both gases.

Is low range H_2S measurement in natural gas possible?

Yes. However, measuring H_2S in the NIR portion of the spectrum with TDLAS instruments requires extremely long path lengths to achieve sufficient sensitivity. TDLAS can be used to measure H_2S in the percent level down to 15 ppm in hydrocarbon streams. A practical solution for very low ppm H_2S measurements (0 -10 ppmv) is the AMETEK model 933. The measurement is based on frontal elution chromatography combined with a high resolution UV optical bench.

Is 0-20 ppm moisture measurement in natural gas possible?

Yes, we can do that application, with an accuracy of typically ± 1 ppm.

Calibration

Is calibration of model 5100 in the field necessary?

AMETEK model 5100 series analyzers are calibrated at the factory and will not require field calibrations as they are not affected by traditional sources of span drift.

Can you calibrate the analyzer in the field?

Yes, standard gas bottles can be connected to the analyzer for a single-point span, or zero, check as is common with other types of gas analyzers. The span factor and zero offset are automatically adjusted, if desired, after the calibration check. The span factor and zero offset can also be manually adjusted.

Can we use moisture in N_2 gas bottle to calibrate 5100 analyzer for natural gas application?

5100 analyzer calibration is sensitive to the gas background. Using moisture in N_2 background may introduce a bias into the readings. We recommend moisture in methane background instead. Likewise, for other applications, also use calibration gases with the same background as the sample gas. The best technique for checking analyzer zero is to use a dryer with the actual sample stream.

Installation

What are the installation requirements?

The AMETEK model 5100 is rated for a wide temperature range (-20ºC to +50ºC). If installed outside, exposure to direct sunlight is to be avoided; use of a sun shield is highly recommended.

Should heated sample lines be used?

The use of heated sample lines is always preferred to ensure that a representative sample reaches the instrument. Many small polar molecules are known to stick to metal surfaces resulting in slow response speed of sample systems. The magnitude of the surface effects is reduced if the tubing surfaces are kept hot.

How does laser line-lock work?

The output wavelength of the tunable diode laser is a function of both the diode junction temperature and the injection current. Normally, the diode laser is maintained at a constant temperature and the laser output wavelength is controlled by the injection current. It is important that we have some means of insuring the laser is operating at the right wavelength. Should the wavelength shift even a fraction of a nanometer, the gas analyte will not be properly measured and the analyzer may yield erroneous readings.

The 5100 series analyzers have a sealed reference cell that contains a known concentration of the target analyte. The output from the laser in the 5100 instruments is passed through both the sample gas being measured and the sealed reference cell. The spectra of the analyte sample in the reference cell are monitored and any shift in the observed peak is used as a feedback signal for the temperature control of the tunable laser diode.

Real Time Performance Monitoring

In real time monitoring applications it is very important for the end user to know that the analyzer system is performing properly and that the results are accurate and valid. The AMETEK 5100 series analyzers use a robust method to guarantee users the level of confidence they need in the measurements. The built-in verification feature insures the integrity of the analyzer by constantly checking the instrument's performance while measuring the content of the sealed reference cell.

Validation

The analyzer is also configured for field calibration validation and users can challenge the analyzer response with a known sample such as bottled gas. The instruments software contains routine to assist the user in making both span and zero validation.

It is all digital signal processing...

The AMETEK 5100 makes use of an all digital signal processing approach to tunable diode laser absorption spectroscopy (TDLAS). Traditionally, TDLAS instruments that perform wavelength modulation spectroscopy (WMS) make use of analog circuits to produce the laser drive signals and perform the detection of the harmonic signals. In the AMETEK 5100, the laser drive signals are digitally synthesized, yielding more precise control of the laser output. Further, by eliminating the analog signal processing on the detector circuits, and performing the harmonic detection digitally, the AMETEK 5100 is able to apply more robust detection methods. While most other TDLAS instruments apply a simple peak height measurement to determine the analyte concentration, the AMETEK 5100 applies a multivariate calibration model. The application of this chemometric method enables the AMETEK 5100 to accurately extract the analyte signal, even in the presence of interfering background components.

What differentiates AMETEK 5100 series from the rest....

There are a number of features that make the AMETEK Model 5100 series analyzers truly robust in their performance and reliability. These features include:

- Integrated moisture verification
- Integrated line-lock check
- Designed for outdoor installation
- Sample handling included in analyzer
- Modbus, Ethernet, Web Browser-based interface
- NEMA 4/IP 65 enclosure
- No exposed components
- External junction box – maintenance friendly!

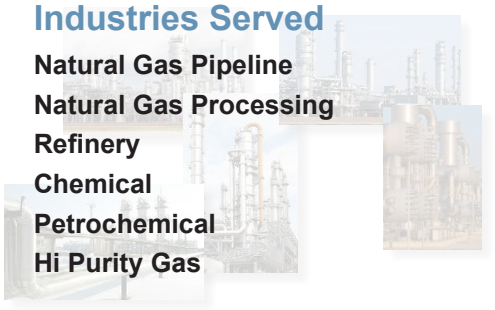
Hazardous area options

Explosion proof versions are available per ATEX, IECEx, NEC and CSA standards.

MODEL 5100 P GAS ANALYZER

TDLAS

Industries Served



Natural Gas Pipeline
Natural Gas Processing
Refinery
Chemical
Petrochemical
Hi Purity Gas

Gases Measured

Moisture
Hydrogen Sulfide
Carbon Dioxide
Carbon Monoxide
Oxygen
Methane
Ammonia
Hydrochloric Acid
Acetylene

The following application and technical notes are available:

5100 HD Moisture Verification (F-0140)
5100 Dual Laser for Measuring Two Analytes in Gas (F-0266)
5100 Moisture Verification (F-0287)
5100 HD Measurement of Process O_2 for Claus SRU (F-0309)
5100 Low Level Moisture Measurement in Natural Gas Using TDLAS (F-0228)

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