

AMETEK Model 5100 HD – A Dual Laser Based TDLAS Analyzer for the Measurement of Two Analytes in Gas

Introduction

AMETEK now offers an analyzer based on Tunable Diode Laser Absorption Spectroscopy (TDLAS), with dual lasers and a single sample cell (also available with dual sample cell). Two separate lasers are installed in the instrument, sharing a common optical path through the sample, enabling it to measure spectra at two different wavelengths. The dual laser platform can measure any two combinations of water vapor, carbon dioxide, carbon monoxide, oxygen, hydrogen sulfide, and others in process or flue gas. The actual concentration levels that can be measured are application dependant.

A key feature of this instrument is the use of sealed reference cells, which contain known amounts of analyte gases measured, for referencing the emission wavelengths of the lasers. Essentially, the use of reference cells enables both the ability to line-lock the laser and to continuously verify the instrument calibration. The analyzer is also configured for field calibration validation and users can challenge the analyzer response with certified blend of cylinder gas. The analyzer is set up to perform an all-digital implementation of wavelength modulation spectroscopy (WMS).

Industrial applications of the AMETEK Model 5100 dual laser include combustion monitoring and trace-species monitoring in process gas, in general. The dual laser configuration is suitable for hazardous area locations worldwide.

Why the AMETEK Model 5100 HD?

AMETEK's Model 5100 HD is the analyzer of choice for the measurement of two gas analytes. The three key attributes are: specificity for the

analyte, high sensitivity, and fast response speed. Tunable diode laser's specificity is the result of the extremely high spectral resolution achievable. Emission bandwidths for tunable diode lasers are on the order of $10^{-4} - 10^{-5} \text{ cm}^{-1}$, which results in the ability to isolate a single rovibrational transition line of an analyte species. A second advantage 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 the AMETEK Model 5100 HD make it very suitable for a variety of process measurements.

Making reliable measurements at low levels where significant interference from other species is present is cumbersome. AMETEK's Model 5100 HD offers chemometric approach to measuring and compensating for interferences. This approach is far superior to physically removing the interfering species utilizing the scrubbing process, which employs often complex and highly specific chemistry. An additional restriction is that the composition of the sample matrix must remain essentially constant, or at least be stable over the interval between the required background measurements. In contrast, implementing a chemometric approach for removing the effects of background interferences can remove the restrictions of the physical separation method and also provide additional measurements from the same spectral data (i.e., the ability to measure the concentrations of multiple species having overlapping spectra).

The Dual Laser Configuration

A schematic representation of the dual laser implementation is shown in Figure 1. In this example, the measurement of water vapor and methane is performed with an 1854 nm DFB laser, and the carbon dioxide measurement is performed with a 2004-nm DFB laser. The outputs of both lasers are coupled into single-mode fibers, which, in turn, are connected to fiber-optic splitters. The splitters are used to divide the optical power for use in the sample and reference measurements, respectively. The “sample” outputs from both splitters are combined in a fiber-optic coupler, enabling a common sample cell to be used for both analytes. Gradient refractive index (GRIN) lenses are used to collimate the output of the single-mode fibers and direct the resulting beams through the sample and reference cells. The sample and reference cells each contain InGaAs-photodiode detectors, which are connected to separate input channels of the electronics unit. With this configuration, it is possible to make simultaneous measurements of unknown samples and known references, which are used to lock the output wavelengths for both lasers.

The WMS is implemented digitally to drive the tunable-

DFB lasers. Further, signals produced by the detectors are digitized, prior to applying signal processing (e.g., phase-sensitive detection, smoothing, etc.). Additionally, in contrast with the common practice of using second harmonic detection (2F), the detection/demodulation in this instrument is performed at the laser-modulation frequency (i.e., “1F” detection). Using the 1F-detection scheme enables the instrument to normalize the spectra, without the need for a separate measurement of the laser power. Specifically, the magnitude of the power envelope of the laser output is contained in the spectra produced by 1F demodulation. After the 1F spectra are normalized, “2F” spectra are calculated.

Built-in Verification

Reference cells are used to lock the output wavelength laser diode. The sealed reference cells contain a known concentration of the analyte in a host gas, which has no absorbance in the spectral range of interest. A block diagram of the wavelength-locking algorithm employed by the instrument is shown in Figure 2. Two nested levels of temperature control

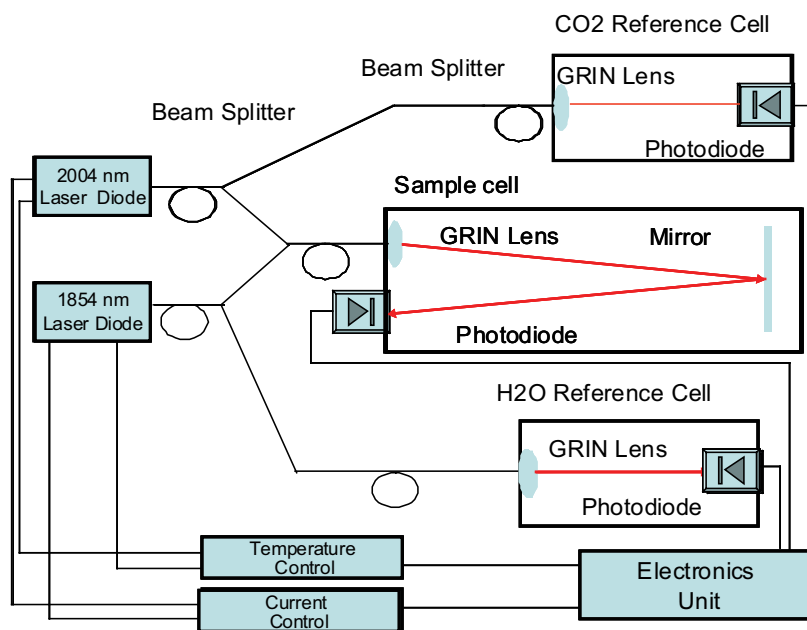


Figure 1: Model 5100 HD Schematic Diagram

are employed to maintain the operation of the DFB laser at the proper wavelength. The first level is a simple PID control loop, which maintains the laser at a target temperature. In the second level, the outer control loop, the spectra of the analyte samples in

the reference cells are monitored. Minor shifts in the observed peak positions are used as a feedback signal for the temperature set point of the inner control loop. Thus, the outer-control loop provides a fine adjustment for the inner-control loop.

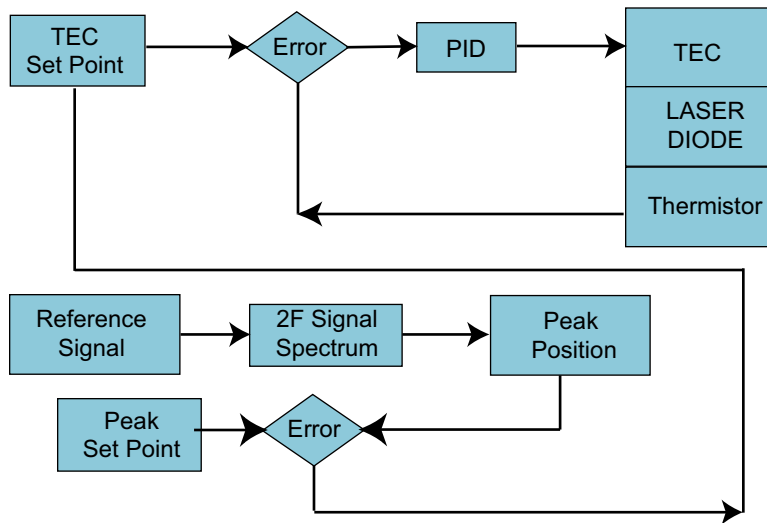


Figure 2: Laser Wavelength-Locking Algorithm

Conclusion

Two separate lasers sharing a common optical path through the sample, enable measurement of spectra at two different wavelengths. The digital signal-processing methods employed in this system enable successful implementation of multivariate calibration, and, therefore, help accurately measure two separate species with completely overlapped spectral responses. The dual laser configuration comes with

built-in reference cells for verification and laser line locking functions that help the analyzer respond accurately and perform reliably.

In the dual laser single cell configuration, two analytes can be measured resulting in significant cost savings. Where the required concentrations of the analytes differ considerably such that different path lengths are required, two sample cells may be used.



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