Process Insights™
Premium Insights Into Process

TECHNICAL BULLETIN

Laser Locking and Optimization Technical Bulletin

Introduction

As a variant of laser spectroscopy, Cavity Ring-Down Spectroscopy (CRDS) is a first principle of physics method. Such methods start directly at the level of established scientific laws and do not make assumptions such as empirical modeling or parameter fitting. Even though, lasers, like all technical devices tend to age and drift over time. Specifically, with laser-based systems, this drift impacts wavelength stability and would manifest as reduced accuracy over time. Every PROCESS INSIGHTS - TIGER OPTICS CRDS analyzer incorporates a Reference Cell, which ensures continuous verification and correction of the laser wavelength to prevent this drift.

Ensuring Wavelength Stability to Counteract Drift

PROCESS INSIGHTS - TIGER OPTICS' analyzers do not require traditional field zero or span calibrations. When we add our laser-locked system with Reference Cell to a fundamental physical principle, our CRDS analyzers become drift-free, which makes their original calibration permanent. Also, with the necessity to calibrate to external standards removed, the method reduces maintenance, downtime, and costs, while improving accuracy. This culminates in a very reliable, simple-to-operate analyzer with low consumable costs not found in many competitors' devices.

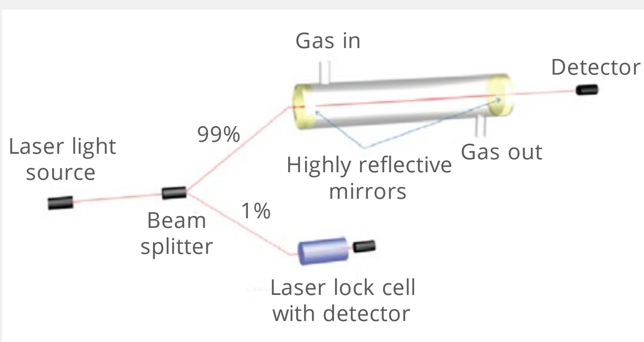
CRDS measures the time (typically, in microseconds) for light to decay ("ring down") inside an optical cavity. When the laser is shut off, the light travels back and forth between two mirrors for up to 100 kilometers, which improves sensitivity. The optical losses in the cavity reduce the amount of light with each pass, allowing us to measure extremely small absorption losses. When N number of target molecules are present in the gas flowing through the cavity, they absorb light, therefore shortening the ring-down time τ, as predicted from the **Beer-Lambert Law**. The amount of target molecules (and their concentration) is directly extracted from the measured ring-down time:

$$N = C \cdot \left(\frac{1}{\tau(\lambda_0)} - \frac{1}{\tau_{zero}} \right)$$

Tau, $\tau(\lambda_0)$, is the ring-down time measured in the cavity when there is an absorbing species in the sample gas (e.g., H_2O in N_2), and the laser is emitting light at a wavelength λ_0 where those molecules will absorb light. Tau zero, τ_{zero}, is the ring-down time of the empty cavity and C is a pre-determined and fixed calibration factor that only depends on the fundamental absorption properties of the selected molecular absorption line. It is critical, however, that the laser maintains the correct wavelength position λ_0 to measure the correct peak ring-down time. Our analyzers have two proven methods to ensure this.

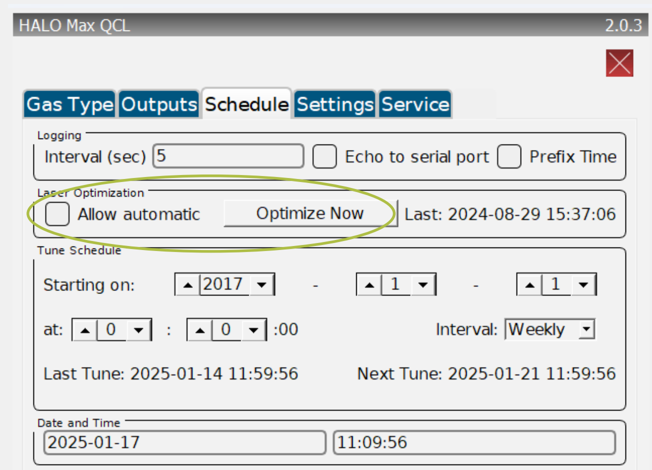
1. Reference Cell

All CRDS analyzers incorporate a Reference Cell that allows the laser to automatically re-center itself on the maximum of the absorption peak. The Reference Cell is a small, permanently sealed glass cuvette with the target gas analyte within. By directing a portion of the laser light to this cell, the analyzer makes periodic verifications and adjustments to ensure the correct laser wavelength. This so-called Centering happens automatically in the background, largely imperceptible to the user. Below illustration shows the arrangement of the reference cell in parallel with the optical cavity.



2. Laser Optimization

The Centering procedure continuously adjusts the laser current to ensure wavelength stability. Most lasers will continuously drift in one direction over time, which means that—over long periods of time—the Centering may have moved the laser current by a significant amount. This can (if left uncorrected) lead to a decrease in laser power, which may affect the instrument's performance. Our Laser Optimization procedure is designed to periodically move the operating current back to its default value by resetting the laser temperature. For analyzers in regular operation, we recommend running the Laser Optimization routine every 12 months to ensure continuous optimum performance. This action can also be automated (see image below).



Another case to use the Laser Optimization is for instruments that were unused for long periods of time. In the absence of regular centering, the laser wavelength might have moved outside the standard centering window. The Laser Optimization will then provide a new operating temperature to bring the absorption peak back in range.

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Process Insights delivers premium analytical sensors, analyzers, instrumentation, software and solutions that are mission-critical to keep your operations, personnel, and the environment safe. Our commitment to customer satisfaction is evident through our diverse range of products, programs, and services, designed to accommodate various budgets and application needs.

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