



Key Points about Tiger Optics Cavity Ring-Down Spectroscopy Analyzers

I. The big difference between us and TDL analyzers, which use absorption spectroscopy

CRDS measures time: the time it takes for light energy to die in the cavity. The external environment, humidity, for example, is NOT a factor. TDL analyzers measure light intensity. The external environment affects their performance. As a result, they are not as stable as our analyzers.

II. How we know what wavelengths to use

Every molecule has its own optical fingerprint -- each molecule absorbs light at certain wavelengths. (These values are found in published, refereed sources, such as the HITRAN database, and are widely used in the scientific community.) At other wavelengths, the same molecule absorbs no light at all. These zero-absorption wavelengths are also documented in the scientific literature.

III. The principle behind our measurements

- A. We measure the concentration by first adjusting the laser temperature to emit light at the wavelength for zero absorption. When the energy in the cavity reaches a pre-set threshold, the laser is shut off briefly. The light travels many passes between the two mirrors, an effective path-length of up to 30 km, before it dies, or "rings down". The decay of the light is caused by optical losses of the cavity. The analyzer measures the time required for the light to die. This "ring-down time" will normally be ~ 85 - 120 microseconds in inert gases. We call this "Tau zero".
- B. Then, the laser is tuned to the second wavelength, the absorption peak, and another ring-down occurs. Here, the combination of optical loss of the cavity, and the absorption of light by the contaminant, causes the energy to die. So the presence of the contaminant means the ring-down time will be shorter. The higher the concentration, the shorter the ring-down time. We call this "Tau measure".
- C. The ring-down decay follows an exponential (e^x) formula, so fluctuations in the intensity of the light do not affect the measurement of the ring-down time.
- D. Under Beer-Lambert law, the concentration of the contaminant in the sample gas is uniquely determined using the inverse of these two ring-down times. For example, for an analyzer built to detect moisture, if the Tau zero is 86 usec and the Tau measure is 28 usec, there is 700ppb of moisture in a (Nitrogen) gas sample.

IV. How our measurements work in practice

- A. In operation, the analyzer does ring-downs constantly, on average more than one per second. (The display shows a rolling average of ring-downs, from 10 to 1000, depending on the "Data Filter" setting the user chooses on the Settings menu.) Gas flows continuously through the analyzer, touching only stainless steel and the dielectrically coated fused silica mirrors. The measurement is not dependent on flow, temperature, or pressure, within our operating specifications. So we can even do



readings with the flow cut off (though moisture levels are known to increase in a closed vessel).

- B. If the concentration level exceeds the maximum range, the analyzer continues to attempt ring-downs. When the concentration drops, ring-downs immediately resume. The analyzer is not disturbed in any way.

V. Why the national labs rely on us

Our absolute, exact measurement involves three variables:

1. The pressure-broadening factor of the sample gas. (A denser gas like N₂ has a different molecular content of (for example) moisture per unit of volume than a light gas like He). These factors are loaded into the gas library of the analyzer, and the user selects the gas type from a menu. We first verify that each gas matrix has no OTHER contaminants absorbing light at the same wavelength as moisture.
2. The wavelength for the contaminant (moisture, in this example). Our LaserTrace and HALO units contain a "reference cell" (a small container of H₂O vapor) to continuously verify the laser is "on peak". The analyzer makes small adjustments to the laser current if needed to maintain the correct wavelength. In addition, we recommend that once per year the user do a "laser temperature scan" to maintain optimal laser emission intensity. This quick one-touch procedure scans the reference cell and automatically resets the current and temperature if needed.
3. The reflectivity of the mirrors. If the mirrors become contaminated, with particles for example, the light will die faster. The measurement is still accurate (both Tau measure and Tau zero will be shorter, but the DIFFERENCE will be unchanged). If the contamination worsens, the noise level would increase, and the Low Detection Limit could eventually be compromised. The user can verify mirror reflectivity by performing a "Tune – Just Tau Zero" with the software. This allows the user to monitor any change to ensure the specified accuracy is still being achieved. We recommend this 2-minute push-button procedure be done monthly, or any time the moisture concentration in the sample gas drops by 100x. In addition, when the concentration is low (< 10 ppb for moisture), the analyzer can do a Tau zero continuously to compensate for any minute changes in reflectivity and cell noise in real time.

For these reasons, our CRDS analyzers have been designated as a "transfer standard" by leading national metrology institutes. Eight national labs have purchased Tiger analyzers for their research and standards verification, because they are absolute, and require no external reference standards. No other laser-based analyzer has this distinction.

VI. Why 70% of our sales are from repeat customers

The cost of ownership of our analyzers is dramatically better than others: there are no consumables, no "extras", and no scheduled external maintenance. Just the two short verification procedures the user will run periodically to verify performance. So uptime is expected to be 99.998%.

Our customers are delighted with the ease of use, intuitive Windows®-based user interface, and fundamental reliability of our analyzers. With 400 analyzers in use worldwide, CRDS is truly "21st Century Spectroscopy."