Unisearch LasIR Tunable Diode Laser System (TDLAS) Maintenance and Test Procedure

May 30, 2025

STI-7801

APPROVED:

____

Sonoma Technology date

____

Fenceline Monitoring Refinery Representative date

Contents

Definitions

Term/Acronym	Definition
Bump Test	Test where gas of a known concentration is introduced to the analyzer to check for response accuracy and precision.
Calibration	Procedure by which a series of standards are used to perform an instrument calibration.
Correlation coefficient	A statistical measure of the strength of the relationship between two variables (e.g., measured vs. theory).
FRC	Fire-retardant clothing
IDLH	Immediately dangerous to life or health
laser	A device that emits Light Amplified by Stimulated Emission of Radiation. The resultant light is often very bright, coherent, and monochromatic.
OAP	Off Axis Parabolic reflector. For the TDLAS, the OAP serves as the collection optic for the return beam after it has traversed the atmosphere. The OAP directs and focuses the return light onto the detector.
OEHHA	Office of Environmental Health Hazard Assessment
NIOSH	National Institute for Occupational Safety & Health
Power	A measure of the energy delivered by the laser beam per unit time. The units of power are typically expressed in watts, milliwatts (mW), or microwatts (µW).
PPE	Personal protective equipment
QA	Quality assurance
QC	Quality control
QAPP	Quality Assurance Project Plan
REL	Reference Exposure Level
Retroreflector	An array of reflective corner-cube optics that reflect light back in the direction of the light source.
SOP	Standard Operating Procedure
TAS	Terra Applied Systems
TDLAS	Tunable Diode Laser Absorption Spectroscopy
Transmission (%)	The ratio of return beam strength to the source beam strength, expressed as a percentage.

1. Applicability/Scope

This SOP includes procedures for the routine maintenance, and gas testing for Unisearch Tunable Diode Laser System (TDLAS) open-path analyzers. This document provides procedures that enable technicians to verify that equipment is performing to expectations and detection and communication links are functioning correctly. This SOP has the steps to conduct routine maintenance and quality control checks and calibrations, while the QAPP or other specific SOPs should be referenced for other related quality assurance (QA) system requirements, including the required frequency of these QA activities (**Section B.6** of the QAPP), criteria that must be met (**Section A.7** of the QAPP), management of the data (**Section B.10** of the QAPP), or corrective actions needed, depending on the outcome of the maintenance activities or QC checks.

***NOTE ***

This procedure should only be used by personnel with experience in the safe use of the analyzer and test equipment.

A number of these maintenance procedures closely follow the manuals provided by Unisearch.[1] Field staff should obtain access to and read these manuals. The QA Audit procedure ensures field verification and calibration of the TDLAS by challenging the instrument with a known concentration of hydrogen sulfide (H_2S) and verifying proper detection and quantification under field conditions.

2. Summary

The Unisearch LasIR H_2S monitoring system (**Figure 1**) is a monostatic open-path remote sensor that uses direct absorption technique. The LasIR sensor consists of an analyzer, transmitter/receiver, and retro-reflector array. The tunable infrared (IR) laser for the LasIR system is housed in the analyzer box and scanned over a small range of wavelengths at high frequency. A fiber optic cable guides the laser light to the transmitter/receiver telescope where it is collimated and sent across the atmospheric path. The retroreflector array at the other end of the path returns the signal to an off-axis parabolic mirror that focuses the light onto a photodiode detector. The electrical signal from the photodiode detector is amplified and returned to the analyzer box, where the absorption spectrum is analyzed to produce concentration data.

Classical least squares fitting of the absorption spectrum allows elucidation of low-H_2S concentrations by simultaneously accounting for overlapping water (H_2O) and carbon dioxide (CO_2)

[1] Unisearch Associates: A. Preinstallation Manual, B. Installation Manual, C. Networking Manual, D. Remote Sensing Optics Manual, E. Operations Manual, H. Troubleshooting Manual, I. Laser Safety Manual, J. Maintenance Manual, LasIRView 2015 Manual, 2018.

absorbance bands. As a result, concentration data for H_2S, H_2O, and CO_2 are provided with correlation coefficients that indicate the "goodness of fit."

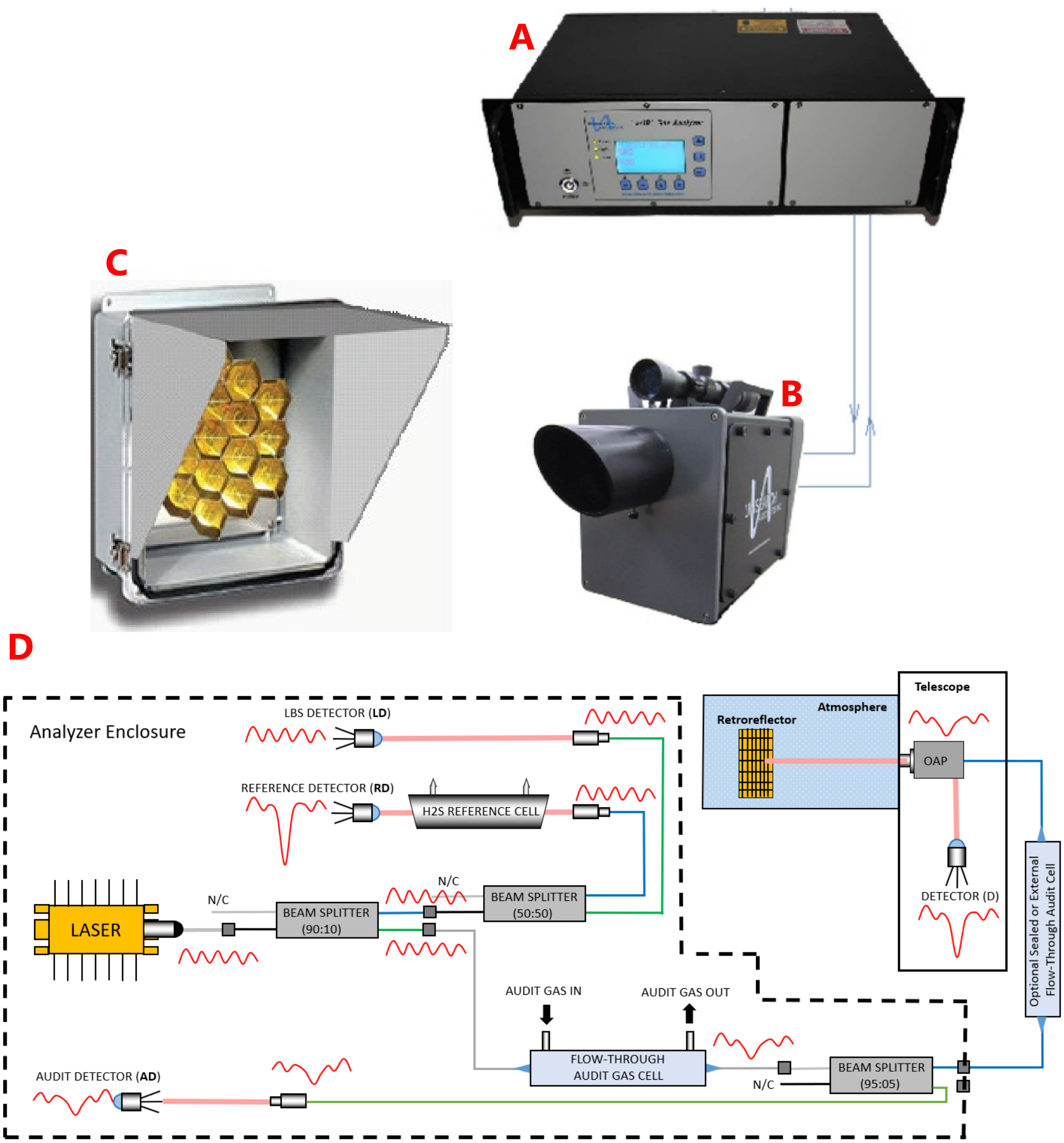
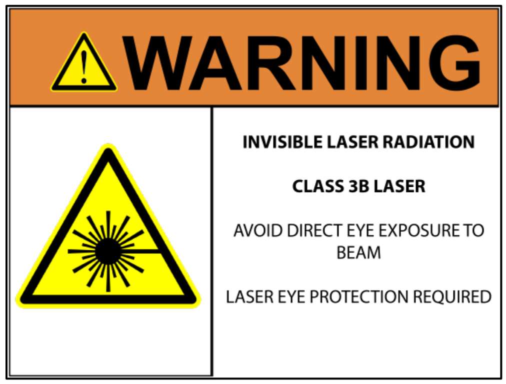


Figure 1. (A) Unisearch TDLAS Analyzer box, (B) telescope, (C) retroreflector, and (D) schematic diagram showing the optical fiber paths and detection points.

3. Health and Safety Warnings

The following information should be noted when preparing work plans and permits for safe work practices.

3.1 Laser Safety



The Unisearch TDLAS produces a class IIIB LASER EMISSION that is INVISIBLE. The laser can cause eye damage if the laser is viewed directly. Unisearch recommends the use of safety procedures consistent with Class II and IIIA lasers. **PROTECTIVE EYEWEAR SHOULD BE WORN WHEN WORKING WITH THE SYSTEM**. Always avoid looking directly into any part of the instrument that can produce laser light, including the transceiver head. Make sure to read the laser safety manual and all other manuals provided with the Unisearch TDLAS instrument.

3.2 Operator Qualifications

Installing, operating, and servicing Unisearch analyzers should only be performed by personnel who are trained in the operation of the system components and are familiar with handling gas delivery and testing equipment. These procedures should not be performed by personnel who do not understand the system, technology, or hazards of the materials involved.

3.3 Safe Work and Hazardous Environment Operation

Work should conform to manufacturer guidance and site health and safety practices. Standard refinery personal protective equipment (PPE) should be worn at all times, including laser safety glasses with side shields, a hard hat, goggles, steel-toed boots, hearing protection, fire-retardant clothing (FRC), an H_2S monitor, and appropriate gloves that are adequate for this procedure. For testing with the flow-through cell using H_2S concentrations in excess of 100 ppm, a second person should always be present as a safety monitor. H_2S levels should be monitored inside the enclosure. Two self-contained breathing apparatuses should be on standby.

The Unisearch TDLAS are not rated for safe operation in hazardous or explosive environments. Using the TDLAS in an area that may contain flammable mixtures or highly corrosive vapors requires special preparation to ensure human safety and safe operation of the equipment.

H_2S is a colorless gas that has an odor of rotten eggs. It is hazardous at low concentrations (the Immediately dangerous to life or health [IDLH] level is 100 ppm, the National Institute for Occupational Safety & Health [NIOSH] 10-min Reference Exposure Level [REL] is 10 ppm, and the California Office of Environmental Health Hazard Assessment [OEHHA] 1-hr REL is 30 ppb). Odor is not a reliable indicator of the presence of hazardous concentrations of H_2S because olfactory senses may be deadened by exposure to concentrations below safe exposure levels. A system for scrubbing H_2S gas from a test apparatus vent is used to prevent release and worker exposure.

This procedure has been written to limit exposure potential and mitigate the hazards of accidental release of the reference gas. Only personnel experienced with handling this material who are familiar with the test procedures and apparatus should perform these testing procedures.

WARNING – Toxic Gas and Eye Hazard. This procedure requires the use of H_2S concentrations as high as 3,000 ppm for the span check. This procedure must be conducted in a well-ventilated area and requires gas monitors, respirators, and the use of fume scrubbers. Make sure you and others fully understand the safety procedures and gas-handling systems required. Always wear proper eye protection having OD>4 above 900 nm. Improper handling of materials or hardware may result in death, serious injury, destruction of property, or damage to the TDLAS. Only qualified individuals should perform analyzer quality assurance audit activities.

4. Routine Maintenance

The TDLAS system is designed to require only modest service and maintenance. **Table 1** summarizes the TDLAS maintenance activities, as recommended by the manufacturer. The frequency of activities may vary from site to site, so always check the QAPP for facility-specific maintenance schedules and acceptance criteria.

Table 1. List of maintenance activities and performance indicator checks for the TDLAS.

Activity	SOP Section(s)
Visually inspect the system. Inspect electrical and optical cables for wear.	4.2
Inspect optics and clean if necessary	4.3, 4.4
Check the alignment to verify there has not been significant physical movement; note that this is automatically monitored as well	4.5
Download data from detector hard drive and delete old files to free space, if needed	4.6
Ensure there are no obstructions in the beam path	4.7
Review and test light and signal levels	4.7
Verify system settings	4.8
Perform bump test and take corrective action as needed	5 (flow-through) 6 (sealed cell)
3-point calibration check	5 (flow-through) 6 (sealed cell)

NOTICE

Perform the following steps before conducting maintenance. Doing so reduces the chances of false notifications to the public and/or clients.

1. Notify the client and project manager of maintenance tasks.
2. Using the field tech tool at ftt.sonomatechmonitor.com, place the equipment into planned or unplanned maintenance mode.
3. Confirm that the data is invalidated on the public website before proceeding with maintenance.
4. When maintenance is complete check the public site <u>for at least 15 min</u> to ensure proper reporting (no calibration data present; data is no longer invalid due to planned maintenance).
5. Take the equipment out of maintenance mode
6. Notify the project manager and client when maintenance is complete.

4.1 List of Equipment

1. Field notebook
2. Tool kit, especially including: hex drivers, complete set of combination wrenches, adjustable wrenches, screwdrivers, etc.
3. Cleaning supplies designated to be safe for use on a Unisearch TDLAS – especially lens paper
4. All relevant PPE, hardware, and procedural guidance per SOP, Safety Plan, and Safe Work Permit
5. Local or remote network link device (as required)
6. External laptop computer with network interface device to the Sentry unit (as required)
7. Unisearch TDLAS equipped with LasIRView software
8. Isopropyl alcohol (≥80%)
9. Distilled water
10. Pressurized sprayers
11. Nitrile gloves
12. Cell bump test apparatus (including panels, regulators, valves, meters, flow controllers etc.)
13. Tubing as required: 1/4” PTFE tubing for gas supply from the bottle to the QA cell
14. Tubing as required: 3/8” PTFE tubing with inline flow indicator from the QA cell to the scrubber
15. Flow regulation system capable of delivering gas 0.1 to 5 L/min at a total system pressure of 3 psig or less
16. Gas scrubber appropriate for gas used. Activated carbon may be used for benzene
17. Zero air supply
18. Reference standard traceable gas blend in nitrogen for detection at about 5X instrument theoretical detection limit or higher
19. Spare reflector for alignment

Related spare parts and equipment are available from Unisearch Associates and are detailed in the Unisearch manuals.

4.2 Visual Inspection

For each measurement site (includes both analyzer and any retroreflectors), complete the visual checks listed below on the form in **Section 10**. When maintenance is complete, file the forms from the "maintenance folder" in the main project folder on the company's shared drive. During visual inspection of the analyzer, complete the following checks.

1. Note and clean any excessive dust buildup on the equipment or analyzers. Use a damp rag to clean dust from surfaces.
2. Eliminate any pests from the sample site, including birds, spiders, rodents, etc., and remove cobwebs. Plug any holes that may serve as entry points for rodents. Work with the Project Manager and client to eliminate more extensive rodent issues.
3. Note the internal condition of the analyzer cabinet. Check for signs of condensation below the HVAC. Note other signs of water damage.
4. Inspect wiring and note and correct any corrosion or cracking insulation. Replace wires that have been chewed-through or show signs of imminent failure.
5. Check HVAC for proper operation by checking for cool air and reviewing cabinet temperature records, if available.
6. Check for corrosion. Common places to check are on top of the cabinet, various components of the instrument mount, nuts, and bolts. Mitigate corrosion by using oil or similar product designed to prevent corrosion.
7. Note and mitigate any condensation or water issues that may adversely affect equipment.
8. Check the door operation.
9. Note anything that may result in eventual degradation of the LasIR system.

For items that cannot be immediately corrected, notify the Project Manager to initiate corrective actions. If it is suspected that any issues that required corrective actions might have adversely affected data quality, note this in the form in **Section 10** and notify the Project Manager and QA analyst assigned to the project.

4.3 Cleaning the Transmitter/Receiver Optics

Only the front surface of the window on the telescope assembly may need to be cleaned on a monthly basis. Use a clean cloth to lightly wipe the front surface of the window. Normal lens cleaning solution can be used if necessary, but dust can usually be wiped away with a dry cloth. Be careful not to scratch the window surface by pressing too hard. The shroud protecting the window from the elements may be removed for cleaning. If necessary, loosen the locking screw on the bottom of the shroud and pull the shroud away from the window housing.

If the inside of the window gets dirty, it is best to remove the window from the housing and clean it rather than open the telescope side covers, as access from these points is limited. You may either remove the shroud and unscrew the locking ring that holds the window in place, or remove the entire front cover by loosening the four screws in the corners. In either case, be careful to keep the

O-ring seals properly seated. Improper seating may result in leaks if rain falls on the telescope, which could damage sensitive electronic components inside.

Document completion of this task using the Maintenance Task Checklist in **Section 8**.

4.4 Cleaning Retroreflector Array

Only the front surface of the acrylic protective window for the retro-reflector needs to be cleaned on a monthly basis. Use a clean cloth to lightly wipe the front surface of the window. A lens cleaner solution can be used if necessary, but dust can usually be wiped away with a dry cloth. Be careful not to scratch the window surface by pressing too hard. If, for some reason, the inside of the window gets dirty, this can be cleaned by opening the enclosure front cover.

Reflector elements may also be cleaned if necessary, but this should be done with extreme care to prevent damage to their gold-coated surfaces. To clean retroreflector cubes:

1. Power down any equipment to prevent electrical shock or damage to the system.
2. Use a gentle stream of distilled water, usually from a weed sprayer or other type of gentle delivery method, to remove any salt or dust build-up on the retroreflector.
3. Repeat step 2 with a gentle stream of 80% isopropyl alcohol.
4. Once the retroreflector has been cleaned and dried, repower any electrical equipment you powered down and clean any spills created while cleaning.

Document completion of this task using the Maintenance Task Checklist in **Section 8**.

4.5 Optical Alignment

Adjust the vertical and horizontal adjustment knobs to maximize signal return power as reported on the OPM-15 power meter. Lock the adjustment knobs (**Figure 2**) in place. Once signal return power is optimized, push on the telescope top and side. If the optical configuration is optimal, this action should not result in a fluctuation in return signal power as measured with the OPM-15; the laser beam size at the retro-reflector should be 2-3 times the diameter of the retro-reflector for this to be true. If a drop in signal return power is observed when pushing on the telescope, it may be necessary to adjust the collimator (see below) to obtain the best beam size and return power. If the beam is smaller than twice the retroreflector size, variation in the power will be observed, which may affect the alignment over time due to flexing of the mounting structure. When the vertical alignment is correct, tighten the locking thumbscrew. For the horizontal sweep, loosen the 5/8” locking nut located underneath the mount base and use the thumbscrew on the right hand side of the mount base (looking from the back) to adjust the horizontal position. When adjustment is complete, tighten the locking nut. Slight adjustment of the vertical alignment may be required after tightening the horizontal alignment-locking nut, as this tightens the rear end of the telescope to the mount, which affects the tilt.

Adjusting the collimator is an iterative process. The collimator affects the size of the beam that illuminates the retroreflector. If the beam size at the retroreflector is too small, the signal return power will be too large and can saturate the detector and result in alignment instability. Conversely, if the collimation results in a beam size that is too large, the beam power will be spread over too large of an area at the retroreflector and will not allow enough light to be reflected back to the detector for an acceptable measurement.

To adjust the collimation:

1. Rotate the collimator either clockwise or counterclockwise 1/16 of a turn and note the change in signal power on the OPM-15. There is wobble in the collimator lens assembly, so the alignment will need to be optimized after each turn.
2. After turning the collimator, optimize the horizontal and vertical alignment.
3. Check the alignment stability by pressing on the top and side of the telescope – if the collimation is adjusted correctly, this will not result in significant power fluctuations. Also check the signal return on the OPM-15 to ensure enough light is reaching the detector.
4. If necessary, repeat steps 1-3 until the signal return is sufficient.

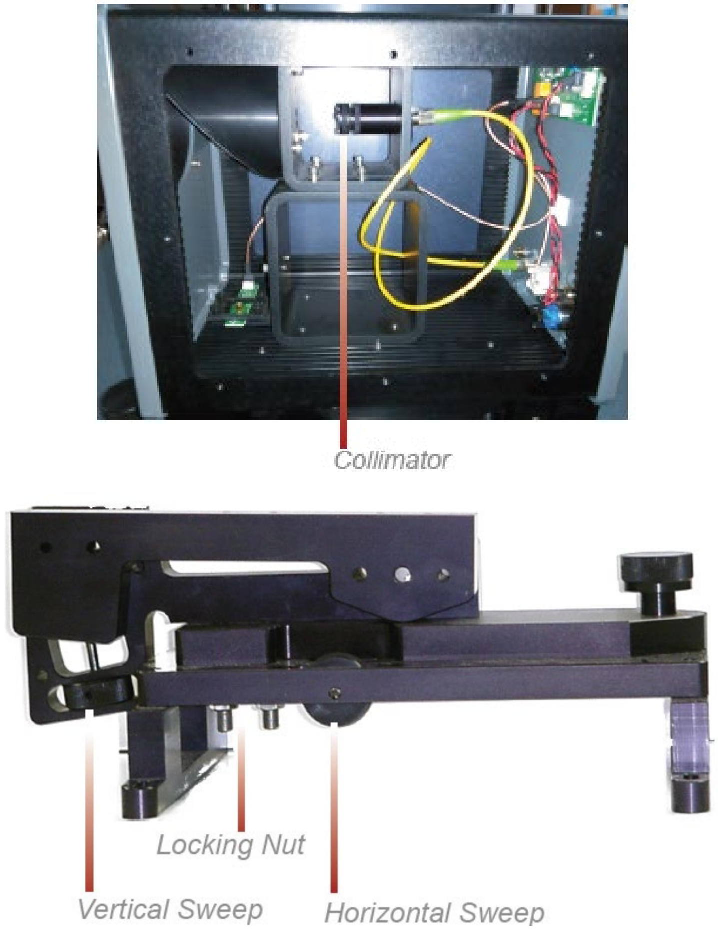


Figure 2. Location of adjustment knobs used for alignment of the Unisearch TDLAS.

Document completion of this task using the Maintenance Task Checklist in **Section 9**.

4.6 Data Management

Under normal operations, the LasIR system works together with a separate program called the TASDAcc to acquire and process raw TDLAS data, and reports 5-min data to the Sonoma Technology-operated data system. The TASDAcc software is developed and maintained by Terra Applied Systems (TAS), the integrator of the Unisearch TDLAS. As depicted in **Figure 3**, the LasIR, TASDAcc, and cellular modem are all connected through a network switch located in the same cabinet as the Unisearch analyzer box. The TASDAcc software handles four main data types: (1) raw data tables from the LasIR Analyzer (as .txt files for each species), (2) spectral data from the LasIR Analyzer (.spectrum), (3) 5-min data for ingestion to the Sonoma Technology data system and display on the public-facing website, and (4) configuration files that archive instrument settings (as either .xml or .cfg).

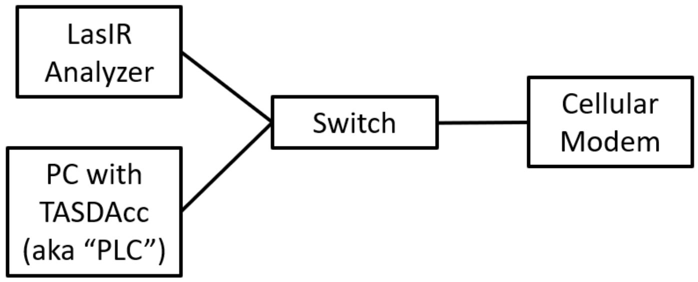


Figure 3. Diagram of local network configuration for the LasIR system.

On a routine basis, all TDLAS data from the PC running the TASDAcc software needs to be backed up on an external drive attached to the PC. To perform this task:

1. Transfer TDLAS files from the PC to the external hard drive (this may be accomplished on a continual basis using a .bat file).
2. Check to ensure all data have been backed up on the external drive for at least the previous quarter.

On an annual basis, the external storage device should be removed and transferred to the client. To perform this task:

1. Ensure the previous year's data has been transferred to the removable storage device.
2. Remove the storage device and replace it with new (empty) one.
3. Deliver the removable storage device with the previous year's data to the client for permanent redundant storage.
4. After data delivery to the client, confirm that all data from the previous year has undergone final QC and that the client has backed it up.
5. Remove the previous year's data from the PC by deleting it.
6. If enough free space cannot be created on the PC by transferring to the external drive, take corrective action with support from the IT department.

Document completion of this task using the Maintenance Task Checklist in **Section 8**.

4.7 Test Light Levels

Although the return light level is monitored continuously and reported with the 5-min data, it is important to verify and document observations of light levels during routine maintenance. Daily observations regarding light levels are documented by Sonoma Technology's analysts. Monitoring light levels over several days allows for the determination of root-cause for problems involving low signal return (e.g. thermal expansion). Field technicians are expected to review historical trends in light levels by utilizing the custom dashboards provided by the data management system. The effect of cleaning on light levels should be noted. Testing light levels at various points in the system can help troubleshoot damaged optical components, such as fibers.

To check light levels in the field, observe the power bar (S) in the scope display or the bar at the bottom of the "Main Running" display (Figure 4) on the analyzer. It should be green in the host trend display. The scope display will turn yellow if the power is low, and will turn purple if the power is very low and the instrument has stopped recording data. On the analyzer, the bar is normally between 25% and 75%. You may also check the percent (P) values on the analyzer display (Figure 4) by cycling to the "Species Information Screen." It should be greater than 5% for proper operation. Low power generally indicates a need for maintenance, such as cleaning the optics, or may also result from low visibility conditions (fog).

If light levels are not adequate, follow the procedure in Section 4.5 (optical alignment) to correct the issue. If low signal return is still observed after optical alignment, test the power at various points in the system using the OPM-15 to identify bad optical fibers or connections. If the source of the low signal strength still cannot be traced, contact Unisearch for further guidance.

Document completion of this task using the Maintenance Task Checklist in Section 8, and document results of this test in the LasIR Response Test Form in Section 9.

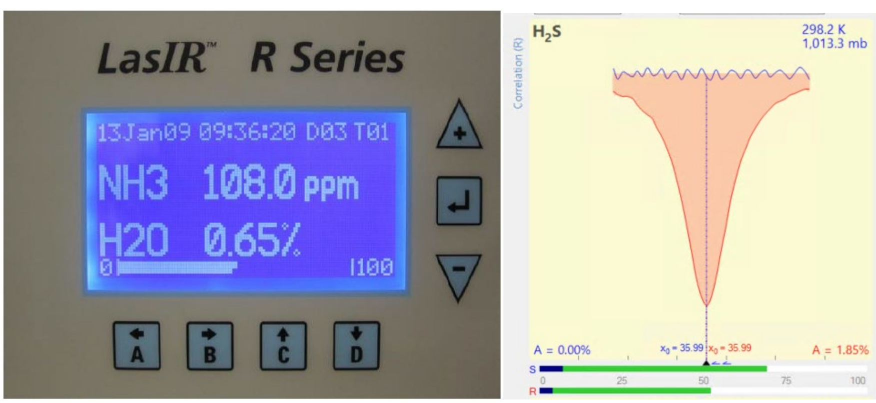


Figure 4. Main running window on instrument front panel (left) and scope display in LasIR View software (right).

4.7.1 Signal Strength Measurements

Light power measured at the detector can occur at several points in the system. There are two gains associated with these measurement points, as indicated in Table 2. The "signal gain" is the amplification placed on the signal itself through electronic hardware, and the "IO gain" is a multiplicative modification of the input-output data streams. Using this table together with the method-appropriate use case, the actual light power at the detector can be determined.

For example, if the signal gain is 2 (signal multiplier of 2), the IO gain stage is 3 (multiplier of 5), and the peak power at the detector is 0.12 mW, then the power displayed via RS232 data stream is:

RS232 **SignalPower** = Signal Multiplier x IO Multiplier x Peak Power = (2)(5)(0.12 mW) = 1.2

The ratio of MODBUS to RS232 signal powers is always 2.5, so in this case the **SignalPower** transmitted via MODBUS is: (1.2) (2.5) = 3

Following this example, by ratioing the power at the detector to the power of the laser (say, 18 mW for this example, can be obtained from instrument data sheets), a %transmission may be calculated:

%transmission = (0.12 mW / 18 mW) 100% = 0.67%

However, if the gains are set to “auto,” as they are during normal operations, it is impossible to know what gain settings are applied and, therefore, what the actual power at the detector is. Therefore, %transmission can only be assessed during routine maintenance.

Table 2. Multiplicative factors associated with gain stages and how they are translated to the Unisearch data files (SignalPower) and through the MODBUS data connection. Note that the ratio of MODBUS to RS232 is 2.5. The ratio of RMS power to peak power is 0.83.

Signal Gain	Signal Multiplier	IO Gain Stage	IO Multiplier	Power at Detector (mA or mW)	Peak Power at Detector (mA or mW)	MODBUS/ Display Power	RS232/TXT Signal Power
1	1	2	1	1	1.2	3	1.2
2	2	2	1	0.5	0.6	3	1.2
2	2	3	5	0.1	0.12	3	1.2
2	2	4	25	0.02	0.024	3	1.2
1	1	3	5	0.32	0.4	5	2
2	2	3	5	0.2	0.24	6	2.4
3	4	3	5	0.25	0.3	15 (or 1.0 if not in Fast gain with error)	6 (or 2.5 if not in Fast gain with error)
4	8	3	5	0.1	0.12	12 (or 1.0 if not in Fast gain with error)	4.8 (or 2.5 if not in Fast gain with error)
2	2	4	25	0.05	0.06	7.5 (or 1.0 if not in Fast gain with error)	3 (or 2.5 if not in Fast gain with error)
3	4	4	25	0.015	0.018	4.5	1.8

Using the OPM-15 Power Meter: When working with the laser power meter (OPM-15, provided with the analyzer, shown in Figure 5) plugged into the back of the telescope "coax out" port, the units the meter provides are in mA, which has a 1:1 conversion to laser power in mW. If a triangle appears on the screen, units will be in µA or µW. If the IO Gain is configured, the power reading will need to be adjusted by that amount, according to Table 2.

Figure 5. Measuring laser power with the OPM-15 meter provided.

Power reported in Unisearch files: The units for "Signal Power" reported in the raw data files downloaded from the LasIR analyzer are in units of mW. If the signal gain is configured to have a multiplier, the reading will need to be divided with that multiplier (Table 2) in order to get the signal power in mW.

Power reported in TASDAcc files: The power reported in the TASDAcc files are pulled from the MODBUS data stream provided by the instrument. Table 2 shows how this power is related to laser power elsewhere in the system.

4.8 System Settings

In the LasIR instrument software, select File > Configure Analyzer. Select "Expert" on the upper right corner of the Configure Analyzer window. View the settings for H_2S, CO_2, and H_2O, and compare these settings with historical settings and provide any explanation for change. For a complete description of the settings and their typical ranges, consult the LasIRView software manual[2]. If you change any settings, document how the settings were changed in the instrument logbook present at the site. Note that all instrument settings are saved on the analyzer on a daily basis.

5. Flow-Through Response Test

The purpose of this procedure is to check the system for expected H_2S response under the installed operating conditions. H_2S standard reference gas is introduced into the optical path by means of a flow-through cell, meaning the entire sample path is included at the time of testing.

[2] Mackay, K., Chanda, A., Mackay, G. Software Manual: LasIRView2015, Application Software for LasIR Analyzers. Rev. 2015-10-01

The Unisearch analyzer enclosure comes equipped with a flow-through cell for use in response testing the LasIR units. This setup requires high-concentration compressed gases to flow through the analyzer in order to affect a response. An alternate way to response-test the analyzers is to use sealed cells as described in **Section 6**.

5.1 Supplies

1. Nitrogen gas
2. H_2S reference gas blend
   - Note that the H_2S reference gas tank and as many of the gas lines as possible should be outside the shelter in the open air. All gas lines should be tested for leaks while filled with nitrogen gas.
3. 1/8″ PTFE tubing for the reference and purge gas lines into the quality assurance (QA) cell
4. 1/8″ PTFE Swagelok tee union to couple the reference and purge gas feed lines into the QA cell
5. 1/4″ PTFE tubing for gas flow lines on the outlet of the QA cell
6. Unisearch external 0.167-m flow cell
7. Length of PTFE 1/4″ tubing with PTFE Swagelok nuts on both ends
8. Length of PTFE tubing to go from external flow cell to scrubbing system
9. A scrubbing system consisting of ½″ ID PTFE tubing, 6″ long, filled with GC Sulfursorb Plus activated carbon absorbent, or equivalent; this volume of absorbent has a minimum capacity of 38 grams of H_2S, which is approximately 1,000 times the amount of H_2S existing in 750 ppm H_2S gas flowing at 0.3 l/min for 100 minutes
10. A max 5 l/min rotameter attached at the exhaust line to view that flow is occurring

5.2 Test Preparation

Depending on the requirements in the QAPP, the path-average concentration will need to be determined using the flow-through cell length, the concentration of standard gas, and the length of the open path. Note that because this is a monostatic system, the total optical pathlength is twice the distance between the telescope and the retroreflector. For example, a 750-ppm blend of H_2S (in nitrogen or air) delivered to the optical path through the 0.167-m flow-through cell and a total path length of 1,000 m provide an approximate 125-ppb path average concentration of H_2S. An example calculation of this is as follows:

$$(H_2S \text{ concentration in cylinder})\ (\text{flow cell length}) = \text{Path Integrated Concentration ppm-m}$$

$$(750\ \text{ppm})\ (0.167\ \text{m}) = 125.25\ \text{ppm-m}$$

Path Integrated Concentration divided by the total optical path length = Path Average Concentration (ppm)

125.25 ppm-m / 1,000 m = **0.125 ppm or 125 ppb H_2S**

5.3 Gas Testing Procedure

1. Flow nitrogen gas and perform an internal zero test with nitrogen. Gas delivery should be about 5-10 psi from the regulator/cylinder, at a flow rate of 0.25 to 0.5 L/min.
2. Assemble test configuration with the Unisearch short flow-through cell (0.167 m) in the path.
3. Assemble the H_2S gas scrubbing system, with gas flow coming from the external flow cell into the column packed with appropriate scrubbing media for H_2S (e.g., Sulfursorb Plus).
4. Flow nitrogen to a stable baseline, typically about five volumes of the cell. The flow of nitrogen can be verified by viewing the rotameter at the exhaust.
5. Monitor readings until a stable zero reading is reached. Continue reading 7-15 measurement cycles.
6. Flow the H_2S reference gas. The H_2S should flow at 0.3 L/min.
7. Acquire replicated measurements, as described in Section 7.
8. Verify that the values are reasonable. If they are not, follow the corrective actions listed in Section 7.
9. Stop the H_2S flow and flow nitrogen to purge the H_2S gas to a stable baseline, typically about five volumes of the cell.
10. Disconnect H_2S and nitrogen gases and remove the external flow cell to return the TDLAS system to open-path monitoring of ambient air.

5.3.1 Clean-Up

1. Dispose of the waste PTFE tube filled with GC Sulfursorb Plus appropriately.
2. Download the .cfg and .spectrum files and save them along with the form at the end of this document.

6. Sealed-Cell Response Testing

The purpose of this procedure is to check the system for the expected H_2S response under the installed operating conditions. H_2S standard reference gas is introduced into the optical path by means of a sealed cell, meaning the entire sample path is included at the time of testing.

Sealed cells filled with a known concentration of H_2S are used for response testing the LasIR analyzers. These sealed cells are fiber coupled and may be connected into the light path as indicated in Figure 1.

6.1 Test Preparation

To meet the testing requirements, you must determine the path average concentrations using the certified cell concentration and the pathlength. An example calculation of expected path average concentration for a 250 ppm-m sealed cell together with a 500 m one-way path is as follows:

$$Path\ Average\ Concentration = (\frac{250\ ppm - m}{(2 * 500\ m)})(\frac{1000\ ppb}{ppm}) = 250\ ppb$$

Prior to testing, you will need to ensure that the cells you have will satisfy the testing requirements.

6.2 Single-Point Bump Test

1. Disable alerts on Sonoma Technology Field Tech Tool (FTT) and put instrument into planned maintenance mode.
2. Disconnect the optical fiber from the instrument “Fiber In” port.
3. Connect the optical fiber from Step 2 to the sealed cell inlet.
4. Connect the optical fiber from the sealed cell outlet to the instrument “Fiber In” port.
5. Wait for response to stabilize before collecting data.
6. Acquire replicated measurements, as described in Section 7.
7. Calculate the average, %error, standard deviation, %CV, and average detection r. Record these values in the test form (Section 9).
8. Verify that the values are reasonable. If they are not, follow the corrective actions listed in Section 7.
9. Disconnect the sealed cell outlet optical fiber from the instrument and reconnect the optical fiber from Step 2 to the instrument “Fiber In” port.
10. Verify the instrument baseline and turn alerts back on in FTT. Take the instrument out of planned maintenance mode.
11. Download .cfg and .spectrum files and save along with the form in **Section 9**.

6.3 Three-Point Calibration

1. For the three-point calibration test, repeat the measurements described in Section 6.1 for the remaining concentrations using additional sealed cells.
2. Plot a curve of measured concentration vs. expected concentration. Then record the r^2, slope, and intercept.
3. Download .cfg and .spectrum files and save along with the form at the end of this document.

7. Data Evaluation, Reporting, and Corrective Action

During these tests, a number (N) of replicated (7 ≤ N ≤ 15), raw time resolution measurements (x_i) of a standard reference material of known magnitude (x_{std}) will be measured. For purposes of this SOP, a "trial" is considered one raw concentration value that is reported at the interval specified by the instrument. The average value of these measurements is calculated as:

$$\bar{x} = \frac{\sum_i x_i}{N} \tag{1}$$

and the sample standard deviation (σ) as:

$$\sigma = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{N-1}}. \tag{2}$$

From these definitions, %error is defined as:

$$\%error = \left|\frac{\bar{x} - x_{std}}{x_{std}}\right| \times 100\% \tag{3}$$

and precision as the coefficient of variation expressed as a percentage (%CV):

$$Precision \equiv \%CV = \frac{\sigma}{\bar{x}} \times 100\% \tag{4}$$

Calculate the concentration.

- Average the concentration of "N" stable measurements.
- Report the %error between the average and the certified value.

  Note: To calculate the certified value that will be seen on the TDLAS from the actual certified instrument calibration gas concentration, you multiply the certified gas concentration by the calibration cell length (0.167 meters) and divide that answer by the path length set in the instrument software. For all TDLAS instruments in operation by Sonoma Technology, the path length is set to 2 meters.

Compile all configuration files, spectra files, and log files into a single folder in the maintenance folder for the project on Sonoma Technology's shared drive.

- The folder should be named "CUS LOC QATest TDL# YearMonDy", where CUS is a 3-letter designator for the customer and LOC is a three-letter designator for the facility location.

If the measurements collected during the test are not reasonable, repeat the procedure without adjustment. If the instrument still fails to meet the QA criteria, retest the following day with no adjustment. Confirm that atmospheric conditions were acceptable for bump testing. If these repeated tests continue to fail under acceptable atmospheric conditions, initiate corrective action to include the following:

- Realign the system and perform the test again.
- Review data for potential interferants, including a detailed check of absorbance spectra in the analysis regions configured for the analyte, noting any excessive noise or unexpected absorbance features
- Consult with the project technical lead to identify abnormal changes to the background
- Examine wavelength calibration
- Investigate any large changes in stray light since the last test and adjust calibration factors as necessary
- Review gas testing apparatus for leaks or other similar problems
- Review and confirm specifications of standard calibration equipment and gases (expiration dates, concentrations, etc.)

In the event of unreasonable results after following all steps outlined above, inform the Sonoma Technology Project Manager and Quality Assurance Manager, who will review the instrument performance parameters in the list above.

8. Maintenance Task Checklist

File this checklist, along with other maintenance documents, in the “maintenance” folder within the main project folder on Sonoma Technology’s shared drive.

Activity	SOP Section(s)	Complete?
Visually inspect the system. Inspect electrical and optical cables for wear.	4.2	
Inspect optics and clean if necessary	4.3, 4.4	
Check the alignment to verify there has not been significant physical movement; note that this is automatically monitored as well	4.5	
Download data from detector hard drive and delete old files to free space, if needed	4.6	
Ensure there are no obstructions in the beam path	4.7	
Review and test light and signal levels	4.7	
Verify system settings	4.8	
Perform bump test and take corrective action as needed	5 (flow-through) 6 (sealed cell)	
3-point calibration check	5 (flow-through) 6 (sealed cell)	

9. LasIR Response Test Form

Technician(s): ______________________________ Date: ____

Site Name: ________________________________ Pathlength: _______________________________________

Reference ID: ______________________________ Reference Cylinder Concentration (ppm):_____________

Test Cell Pathlength (m): ____________________ Path Average Concentration (ppb):__________________

Return Power (mW): _______________________ %Transmission: __________________________________

Replicate	Time	Analyzer Concentration (ppm)	Concentration (ppb)	Correlation
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
Average				
Standard Deviation				

%Error: __________________ **%CV:** _______________________

Signature: ____

Notes:

10. Visual Inspection Checklist

- ❒ Note and clean any excessive dust buildup on the equipment or analyzers.
- ❒ Eliminate any pests from the sample site, including birds, spiders, rodents, etc.
- ❒ Note the condition of the analyzer cabinet internals.
- ❒ Inspect wiring and note and correct any corrosion or cracking insulation.
- ❒ Check HVAC for proper operation by checking for cool air and reviewing cabinet temperature records (if available).
- ❒ Check for corrosion, note anything that needs to be addressed.
- ❒ Note and mitigate any condensation or water issues that may adversely affect equipment.
- ❒ Check for door operation.
- ❒ Note anything that may result in eventual degradation of the LasIR system.

Notes: