Ultra High Sensitivity Aerosol Spectrometer (UHSAS)

0.06 – 1.0 microns

Operator Manual

DOC-0210 Rev E

Software Version 4.1.0

DROPLET MEASUREMENT TECHNOLOGIES
2545 Central Avenue
Boulder, CO 80301-5727 USA

2545 CENTRAL AVENUE
BOULDER, COLORADO, USA 80301-5727
TEL: +1 (303) 440-5576
FAX: +1 (303) 440-1965
WWW.DROPLETMEASUREMENT.COM

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Warranty

The seller warrants that the equipment supplied will be free from defects in material and workmanship for a period of one year from the confirmed date of purchase of the original buyer. The probe owner will pay for shipping to DMT, while DMT covers the return shipping expense.

Consumable components, such as tubing, filters, pump diaphragms and Nafion humidifier are not covered by this warranty.

Laser Safety Warnings

The UHSAS is a Class I Laser Product.

STRICT OBSERVANCE OF THE FOLLOWING WARNING LABELS IS ADVISED.

This instrument contains a Class I laser and Class 4 pump laser. CAUTION: Use of control or adjustments or performance of procedures other than specified in this manual may result in hazardous radiation exposure.

INVISIBLE LASER RADIATION
DO NOT VIEW DIRECTLY
WITH OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

This label is displayed on the top cover (front and back) of the instrument.

INVISIBLE LASER RADIATION PRESENT
WHEN COVER OPEN AND INTERLOCKS DEFEATED
DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

This label is located on the support structure underneath the instrument cover, near the laser interlocks, to serve as a warning if the instrument cover is removed.

AVOID ↑ EXPOSURE
INVISIBLE LASER RADIATION CAN
BE EMITTED FROM THIS APERTURE

This label is located on the optical block and the arrow points to the cleaning port.

Laser Characteristics

	Pump Laser	**Main Laser**
Wavelength	~797 nm	~1054 nm
Maximum power	1.6 W	- 50 mW for leakage through mirror - 1100 W for recirculating power
Maximum exposure time		- 1/10 second for 50 mW - 10^{-9} second for 1100 W

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Part I: Hardware

1.0 Product Description

1.1 Introduction

The UHSAS is an optical-scattering, laser-based aerosol particle spectrometer system for sizing particles in the 0.06 – 1 µm range. The instrument, which is pictured in Figure 1, counts particles in up to 100 user-specified sizing bins.

Figure 1: The UHSAS

The UHSAS is also available as an airborne instrument. Both airborne and ground-based versions can be ordered with two additional features: bidirectional and particle-by-particle capabilities. The bidirectional feature allows another computer to have limited control of the UHSAS and use the instrument to acquire data. The particle-by-particle feature allows the UHSAS to generate additional output data, specifically information on the size and inter-particle time of individual particles. Documentation on these features is available in *UHSAS: Bidirectional Option Appendix (DOC-0240)* and *UHSAS: Particle-by-Particle (PbP) Option Appendix (DOC-0241).*

1.2 Specifications and Features

Technique:	Aerosol spectrometry
Auxiliary Parameters:	Temperature Pressure
Derived Parameters:	Particle diameter
Number Concentration Range:	3,000 per second
Particle Size Range:	0.06 – 1 µm
Aerosol Medium:	Air, 0 - 30 °C (32 - 86°F)
Counting Efficiency:	99%
Lasers:	• Solid-state N_d^{3+}:Y LiF_4: ~1054 nm, 1 kW/cm^2 intracavity circulating power • Pump Laser: ~797 nm, 1.6 W.
Number of size bins:	100 max: • 99 standard bins (98 if both overflow and underflow are enabled) • One overflow bin and one underflow bin
Flow Range:	• Standard sample flow: 1 – 100 Sccm (typically 50); other options available. • Sheath airflow setting: 700 ccm at sea-level, 590 Sccm in Boulder, CO
Flow Control:	Controlled from software; can also be manually adjusted via mass or volume flow controller
Routine Maintenance:	*Daily:* • PSL size check to monitor laser power • Zero check with high-efficiency filtered air sample *Monthly and around field campaigns:* • Full-scale calibration *Annually:* • Flow controller calibration
Recommended Service:	Annual cleaning and calibration at DMT service facility
Data Recording:	• Output file written to computer hard drive • Output data sent to serial port (optional)

1.3 Electrical Specifications

Power Requirements:	100-240 VAC, 47-63 Hz, 200W
Fuse:	BUSS fuse, GMA-2A

1.4 Physical Specifications

Size:	56 x 43 x 24 cm
Weight:	31 kg

1.5 Operating Limits

Temperature:	0 to 30 °C
Altitude:	Sea level to 4 km
Relative humidity:	Non-condensing

2.0 Theory of Operation

The instrument's laser illuminates particles, which scatter light. The system captures the peak light signals that are generated. These signals are used for particle sizing, since the amount of light scattered correlates strongly with particle size.

The instrument consists of 5 general subsystems, described in this section:

1) *Main optical subsystem*—generates the laser light, detects the light scattered by particles, and provides a mechanical enclosure for the optical system and for delivery of the sample aerosol
2) *Flow system*—brings the sample aerosol through the optical interaction region, controls and measures the flows
3) *Analog electronics system*—amplifies and processes the particle signals

4) *Digital electronics system*—analyzes particle signals, bins signals according to user-specified bin mappings, generates a histogram of particles in the specified bins, and communicates with the PC and system monitor/control functions
5) *Onboard PC*—allows user to control instrument and collect and report data

Figure 2 shows a block diagram of how these components work together.

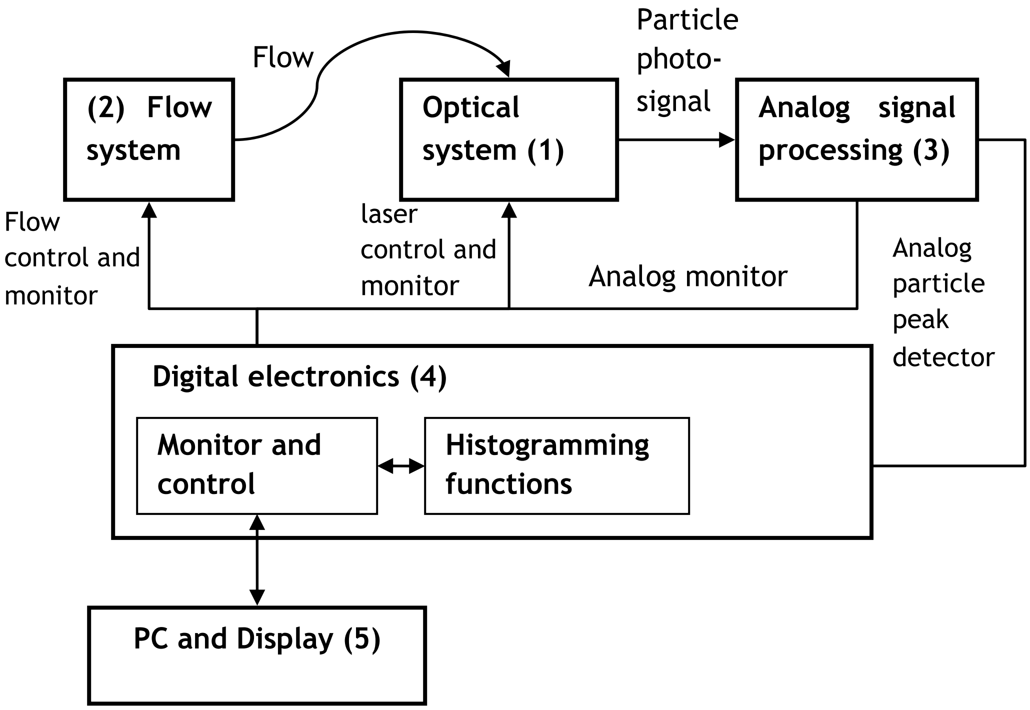

Figure 2: Block Diagram of the UHSAS

2.1 Optical System

The optical system consists of several parts: the laser and associated components and optics; the detection system, including collection optics, photodetectors, and reference monitoring; and the mechanical housing.

2.1.1 The Laser

The laser is a semiconductor-diode-pumped Nd3+:YLF solid-state laser. It operates in the fundamental (TEM_{00}) spatial mode on a 1054 nm laser line with an intra-cavity power of ~1 kW. The pump laser is a temperature-controlled 1 W single-stripe diode at 800 nm, driven by a stable current source. The Nd^{3+}:YLF laser is a high quality factor optical resonator built around an Nd^{3+}:YLF active laser crystal, pumped end-on by the diode laser. The laser mirrors have reflectivities near 0.99999 at the lasing wavelength. The laser mode has a $1/e^2$ intensity diameter of 600 µm. The standing wave laser mode is perpendicular to the flow of particles; the light is linearly polarized with the electric field vector parallel to the flow of particles. Particle scatter is collected in a direction perpendicular to both the particle flow and the laser standing-wave; see Figure 3 and Figure 4 for side and top views of the optical block.

2.1.2 The Detection System

The detection system consists of two pairs of Mangin collection optics capable of collecting light over a large solid angle. The Mangins image the space at which the sample flow intersects the laser mode. The first pair of collection optics, the primary scattering detection system, images onto an avalanche photodiode (APD) for detecting the smallest particles. The other pair, the secondary scattering detection system, images onto a low-gain PIN photodiode for detecting particles in the upper size range of the instrument. The two detection systems are located on the opposite sides of the optic block (see Figure 4: Top View of Optical Block).

Each detector is amplified in a current-to-voltage stage that feeds into the analog electronics system. The amplification allows the system to detect particles as small as 55 nm and 1-10 counts/minute at a zero-count rate. At this particle size, the peak scatter rate corresponds to 100 pW of detected light power at the detector. The size sensitivity is limited by several factors, including a fundamental noise process from the photon-shot noise on the detected molecular scatter from background gas, and a fundamental noise process from the Johnson noise in the photodiode transimpedence feedback resistor.

The imaging optics have an acceptance aperture of 23 mm diameter at a distance of 8 mm from the interaction region. The Mangin reflectors are aluminum coated with reflectivity of 0.9.

In addition to the primary and secondary detection systems, the UHSAS has a reference detector. This detector serves as a reference for changes in laser power.

2.1.3 The Mechanical Housing

The laser and detection optics are built into the optical block, which is a sealed mechanical enclosure. See the following figures.

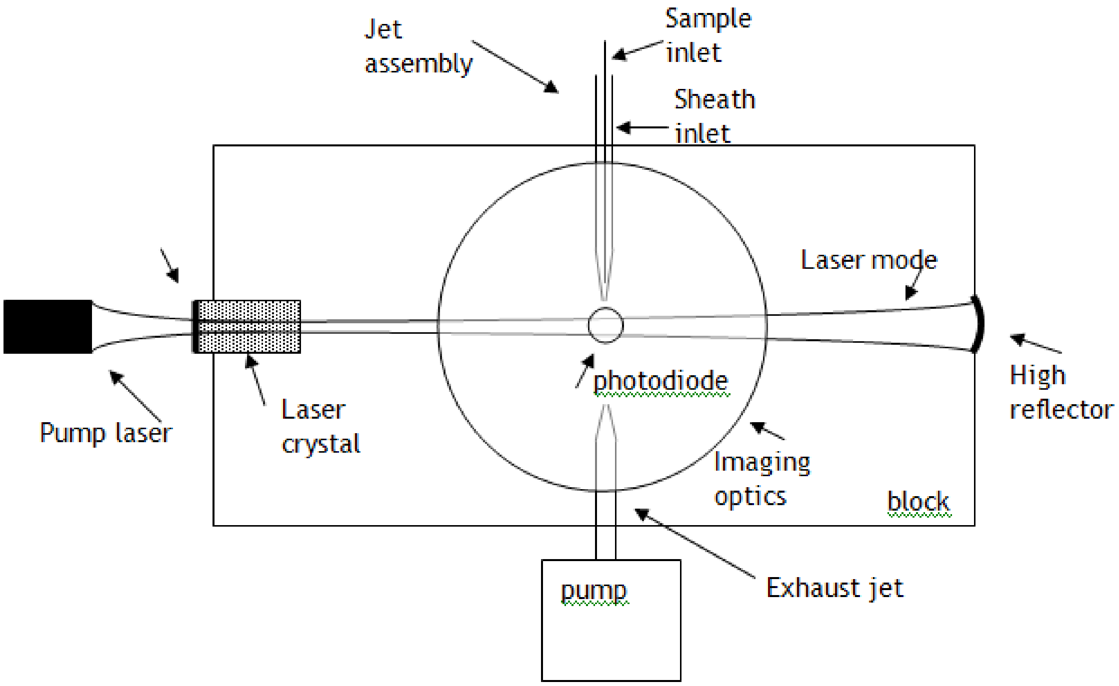

Figure 3: Side View of Optical Block

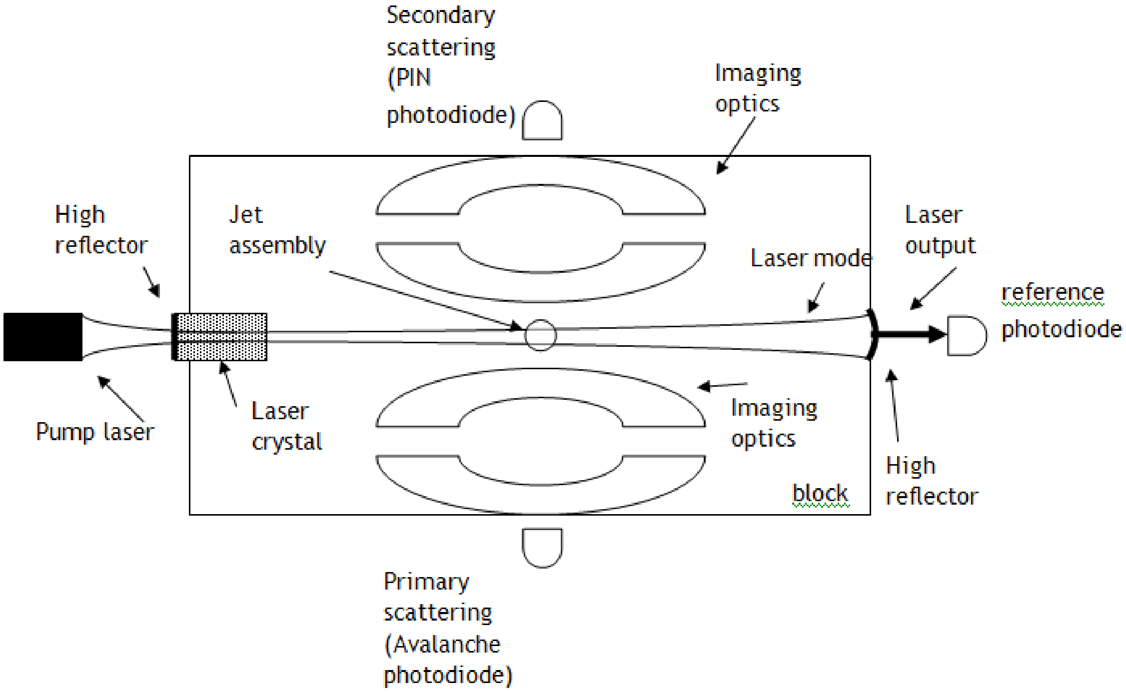

Figure 4: Top View of Optical Block

2.2 Flow System

A pump draws on an exhaust jet, pulling flow through the inlet jet and across the laser mode as illustrated in Figure 5. The inlet jet is an aerodynamically focused assembly with a sample nozzle of 500 μm diameter and a sheath nozzle of 760 μm diameter. The tip of the sheath jet sits within 1 mm of the edge of the laser mode.

Sample flow is between 1 and 100 sccm, typically 50 sccm. The sheath flow is typically 700 sccm. Particle velocity depends on sheath flow rate, but is on the order of 50 to 100 m/sec. Particles are confined to a space that is approximately 10% to 20% of the laser beam diameter, which is 0.5 mm (e^{-2} intensity diameter). This yields a sizing resolution of approximately 2% to 5% of the particle size.

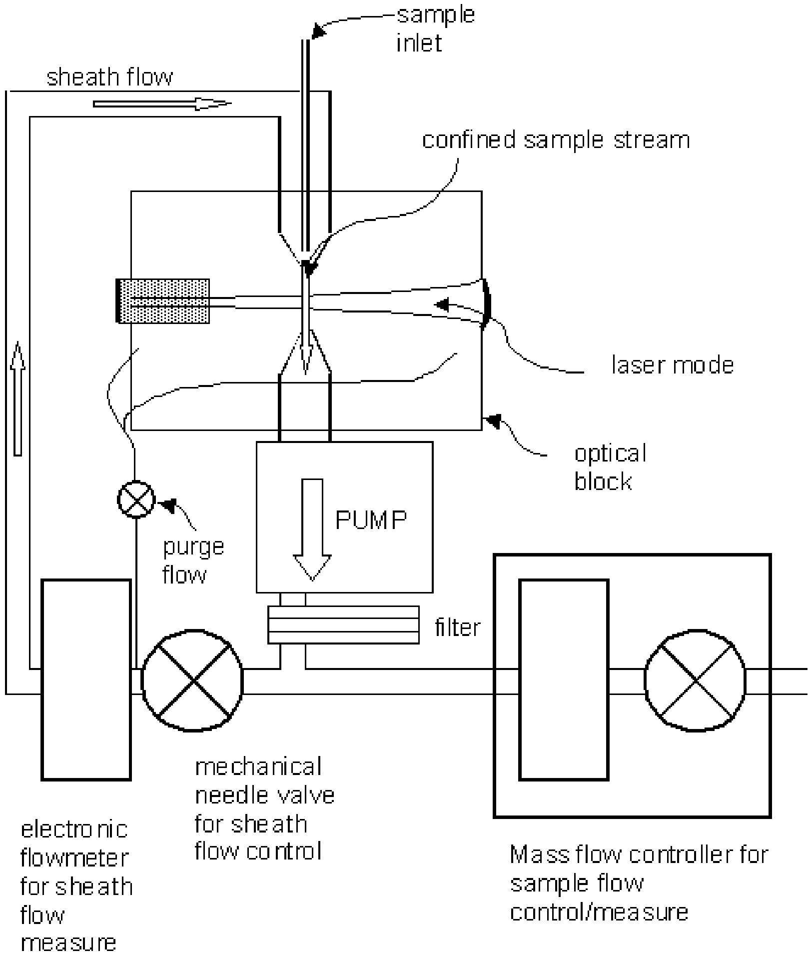

Figure 5: Schematic Diagram of Flow System

2.3 Analog Electronics

2.3.1 Particle Signal Amplification and Tracking

The detector photodiodes produce a photocurrent, which the analog chain then converts to a voltage. The system then processes the resulting signal, which is called the particle signal. The chain is repeated for the primary and secondary detection systems.

After the photodiode transimpedence amplifier magnifies the particle signal, it is mixed with a signal derived from the reference detection system for drift detection.

The particle signal is fed into two different detectors, differing in gain as specified below. In total there are four gain stages: high and low for each of the primary and secondary detection systems.

Gain stage labeling convention

	High gain	**Low gain**
Primary detector	G3	G2
Secondary detector	G1	G0

Gain ratios:
G3/G2 = 50
G2/G1 = 20
G1/G0 = 20

The gain ratios G3:G2 and G1:G0 are pure electrical amplification gain ratios. The G2:G1 ratio is more complicated, since it involves two independent photodetectors with independent electronics that are on opposite sides of the optical block. See the discussion in section 5.2.2.

The gain stages also provide low-pass filtering to the signal. Each gain stage then feeds its own baseline restoration circuit. This restores the 0 Volt baseline, which is disturbed by frequent particle signals after AC coupling. The particle signal is then passed to a peak-hold circuit, which tracks the rise of the signal as a particle crosses the laser and holds the peak value. The digital system then processes the signal and issues a reset.

2.3.2 Laser Power Monitoring

The reference detector is used as a voltage reference and automatic gain control. It is also used for monitoring laser output power, which is directly proportional to the laser cavity power. As the laser power drifts, the instrument maintains calibration. Only large drifts in power (> 25%) require a recalibration of the instrument, since the automatic gain control mostly compensates for small drifts, and the particle sizing sensitivity is a sixth-root function of laser power.

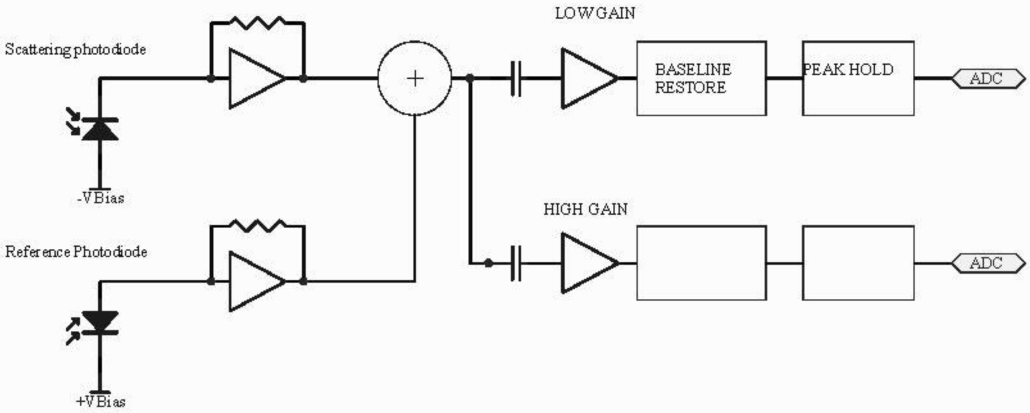

Figure 6: Block Diagram of Analog Electronics

2.4 Digital Electronics System

2.4.1 ADCs and Peak Height Analysis

For each of the four gain stages (2 primary, 2 secondary) there is an associated analog-to-digital converter (ADC). The ADCs run a 16-bit conversion at 500 kHz sample rate. The chain of events is begun as a particle traverses the laser mode and begins scattering light. The particle signal from the highest gain stage on the primary detector (G3) feeds an analog comparator. If the signal exceeds a preset, user-defined threshold, it generates a particle trigger. The threshold value is independent of the particular active bin map; see the entry for **Trigger Threshold** in section 12.0. Under typical operating conditions, the trigger threshold should be set to register the smallest detectable particle (60 nm diameter).

After a trigger is generated, a small delay occurs to allow the particle signal to reach its maximum. Then the four ADCs sample the four peak-held particle signals from the four gain stages. The system first examines the highest gain (G3), then the next-highest, and so on. The first ADC that is not in saturation is the valid particle ADC. The value of this ADC is read and compared to a look-up table of bin boundaries previously loaded into memory via the **Map** tab. Depending on where in the look-up table the particle signal belongs, a counter for the appropriate bin is incremented. (Note that there are some conditions which will invalidate a particle event—for example, if the event falls outside certain timing requirements.) After the particle signal is sampled, a reset is sent to the peak-hold circuit and the cycle repeats for the next particle.

The look-up table is the crux of the peak-height analysis in the UHSAS. The user can reset this table at any time to generate a new bin mapping. Using the relative gains and the calibration curve and points, the instrument automatically converts the bin boundaries to a mapping of voltages at each of the gain stages. The mapping process is transparent to the user and occurs every time a bin map is committed to the instrument.

2.4.2 Monitoring and Control

The digital electronics also monitor and control various onboard systems, as follows.

Monitoring and Control:	Monitoring Only:
• The mass flow controller, which regulates the sample flow • The pump laser diode—this is regulated through enable/disable lines and through current and temperature set points	• The electronic flow meters for the sheath and purge flows (flows are controlled by mechanically-actuated needle valves) • The laser reference from the reference photodiode (sampled on an ADC) • The molecular scattering level (sampled on an ADC) • Additional housekeeping parameters, such as the electronics box temperature and ambient barometric pressure.[1]

Set points for the controlled parameters are stored in configuration files. All monitored parameters are logged with the sample data.

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[1] In the future, these readings may be used for correcting flow meters and noise-cancellation circuitry.

2.5 On-board PC

The onboard PC provides a user interface to the instrument. The monitor is a standard LCD display built into the front panel of the instrument. The user interface is a virtual instrument written in LabVIEW. Communication with the digital electronics system is via internal RS232 (115,200 baud, 8N1). The sampling time of the PC I/O is controlled by the user.

Note that the PC is a modest computer intended primarily for running UHSAS software. Installing and running additional programs on the PC, including anti-virus software, may compromise the performance of the system.

3.0 Unpacking and Setting up the UHSAS

The UHSAS instrument is delivered in a shipping case that contains the necessary cables and other equipment to make the instrument functional. The power cable, keyboard, and mouse for the instrument are located in a pouch in the lid of the box.

To set up the UHSAS, follow the steps below.

1. Remove the instrument from the case by putting your hands in the small Styrofoam cutouts on the sides of the instrument. The handles for the instrument are located in these cutouts. See Figure 7. (*Note:* The 2 small handle-like protectors on the top lid of the instrument are protectors for the inlet. Do not use these as handles).

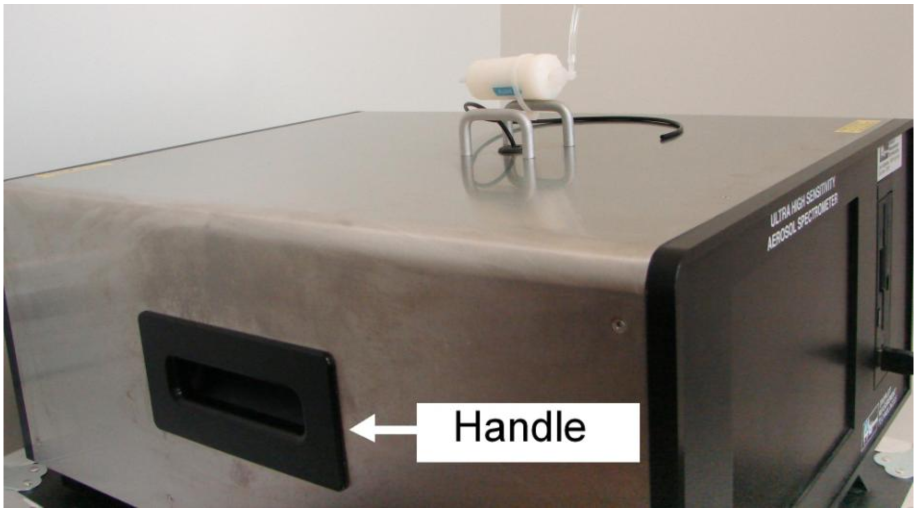


Figure 7: Handle on the Side of the UHSAS

Put your fingers into the handles, which are located about halfway down each side of the case. Lift the instrument from the case, and place it on a stable working area. The front legs of the instrument are hinged so that the front of the instrument case can be elevated (see Figure 1). ***Warning:*** The edges of the instrument legs are sharp. Handle carefully to avoid puncturing cables, and always ship the instrument with the legs folded to avoid damage to the shipping case.

2. The instrument will be shipped with 1.5 inches of extra tubing on the inlet line. This tubing makes a “tail” that fits over the sample needle. See Figure 8.

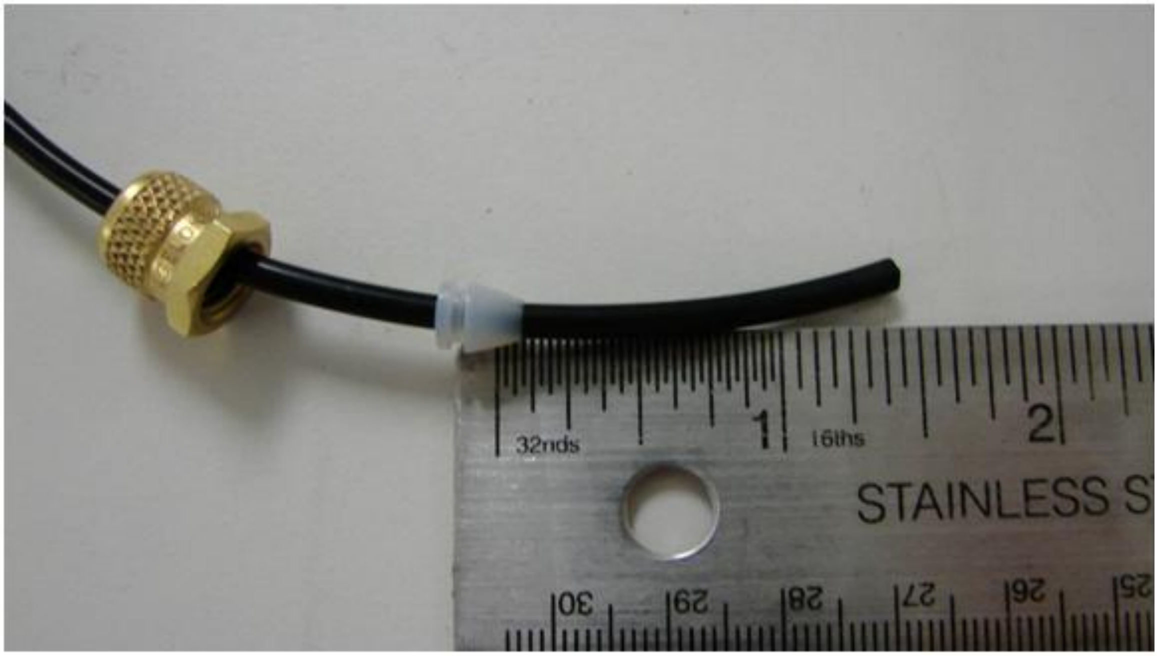


Figure 8: Extra Tubing on Inlet Line

If the sample tubing needs to be reinstalled, use 1/8” (~3.2 mm) outside diameter (OD) conductive silicon or urethane tubing.

3. Connect the keyboard/track-pad to a USB port on the front panel. The USB ports are located just below the floppy/CD combo drive.

4. Make sure the instrument ON/OFF switch is in the off position. The ON/OFF switch is a rocker-type toggle located on the back of the instrument near the power plug.

5. Connect the power cable to the wall power outlet. Input power to the instrument can range from 100-240 VAC 50/60Hz.

6. Connect the UHSAS instrument to an Ethernet network, if desired. The connector (RJ-45 female) for that cable is located on the back of the instrument.

7. If desired, use the serial port connection (9 pin D-connector) located on the back of the instrument to connect to an external data system.

4.0 Using the Instrument

The UHSAS software is designed using LabVIEW, a program from National Instruments that provides a user-friendly virtual instrument (commonly called a vi) panel for the control, data display, and data logging of the UHSAS instrument. The sections below provide an overview of how to use the UHSAS software to start, run, and shut down the instrument. Further details appear in Part Two of this manual.

4.1 Start-Up

1. Before starting the instrument, ensure that the following conditions are met:

   - The keyboard and track-pad are connected to the USB port on the front panel of the instrument
   - The zero filter is in place on the inlet
   - The power switch is in the off position
   - The power cable is connected

2. Turn on the instrument with the power switch located on the back panel.

3. Click on the Spectrometer icon on the desktop to bring up the UHSAS window, shown in Figure 9. Note that the program starts with the **Controls** tab as the default. The **Controls** screen allows the user to set the sample flow and to monitor various parameters.

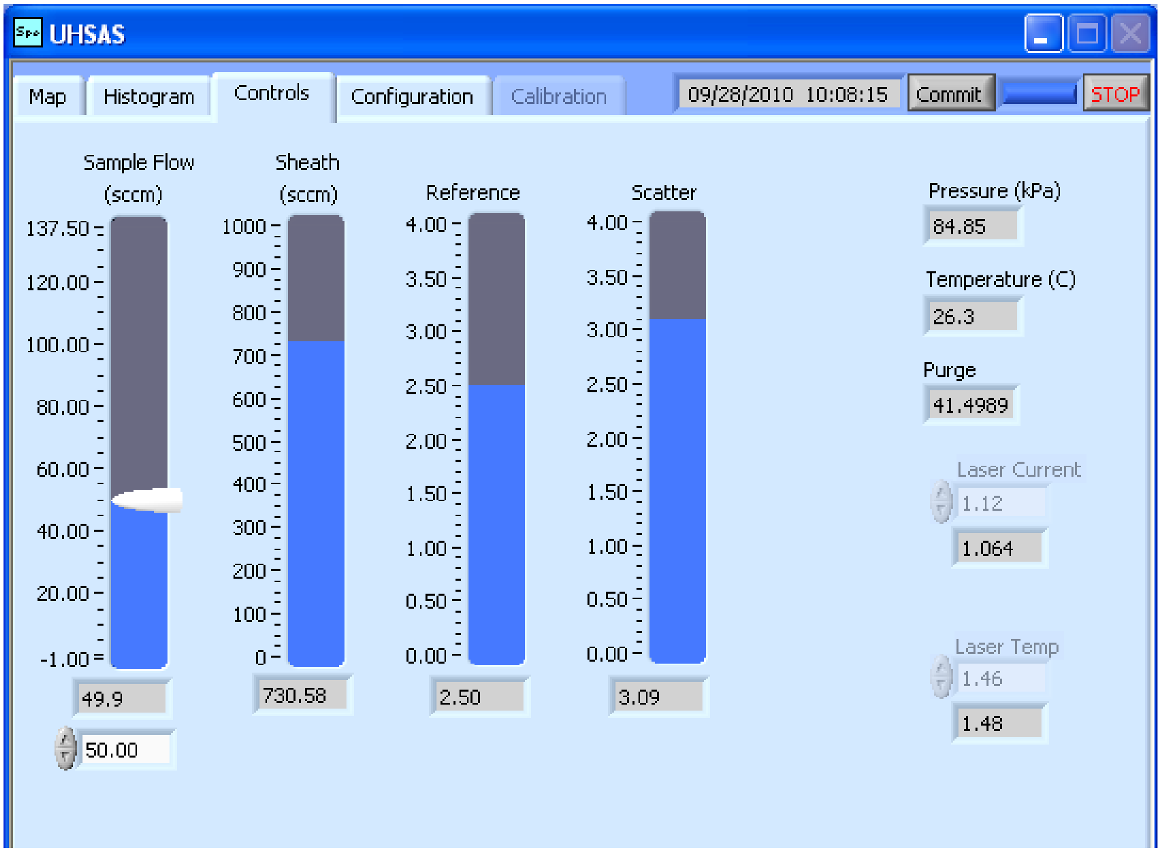
4. Allow the instrument to run for 30 minutes so the laser and various heaters stabilize.

5. On the **Controls** tab, look to see that the **Reference** voltage is 2.5 ± .25 V. If the displayed reference is less than 1.88 V, clean the laser optics as described in section 7.0.

Check the Flows:

6. Look at the **Sample Flow** displayed on the left of the screen. The instrument is calibrated at the factory with a sample flow of 50 sccm, so it is a good idea to set the Sample Flow to this value during the following performance check. Adjust the flow if necessary, either by using the “slider” control or by manually entering a number in the set voltage box at the bottom of the flow indicator.

7. Look to see that the Sheath flow is about 500-800 sccm (700 sccm is typical at sea level).



09/28/2010 10:08:15

Sample Flow (sccm) 49.9

50.00

Sheath (sccm) 730.58

Reference 2.50

Scatter 3.09

Pressure (kPa) 84.85

Temperature (C) 26.3

Purge 41.4989

Laser Current 1.12

1.064

Laser Temp 1.46

1.48

Figure 9: The **Controls** Tab on the UHSAS Software

Perform a Zero-Count:

8. Ensure the zero-count filter is in place, as shown in Figure 10.

Figure 10: Zero Filter on Top of UHSAS Unit

9. Select the **Histogram** tab to display counts versus bin number.

10. Click on the **Run** button near the upper left corner of this window to show the particle accumulations. There should be very few counts.

11. Remove the zero filter for room air sampling. Many counts should appear.

Check Instrument Performance:

12. Introduce a collection of 100-nm particles into the inlet. The NIST SRM 1963 100 nm work well. These are standard reference particles used during factory calibration.

13. The histogram should show a tight distribution with a peak near 100 nm (Figure 11). There should be relatively few particles in bins below and above the peak. The instrument may need calibration the peak is poorly resolved with a broad distribution of particles (Figure 12). Calibration may also be required if the peak is significantly higher or lower than 100 nm. *Note:* Figure 11 through Figure 14 are from an older version of the software; however, for the situations described, the histogram shapes will appear similarly in the new software.

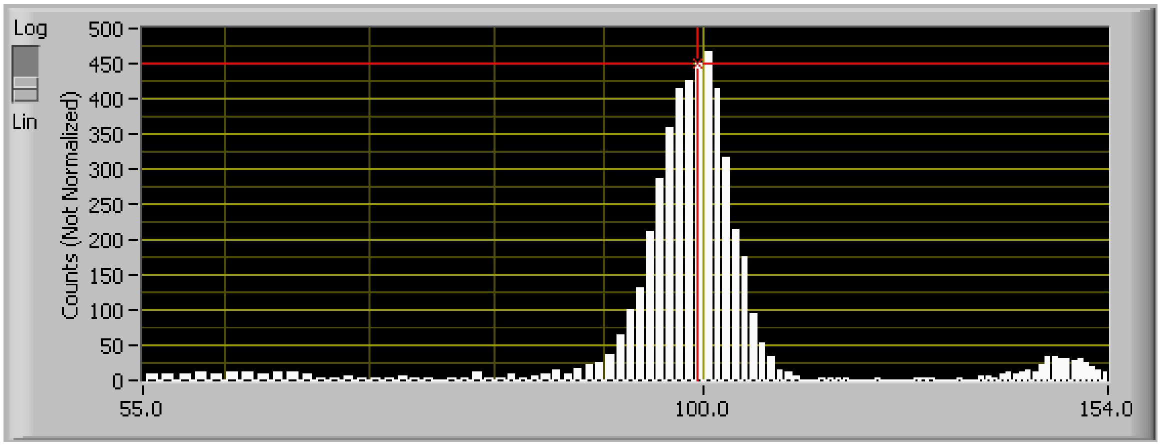


Figure 11: 100-nm Particle Distribution on a Properly Calibrated Instrument

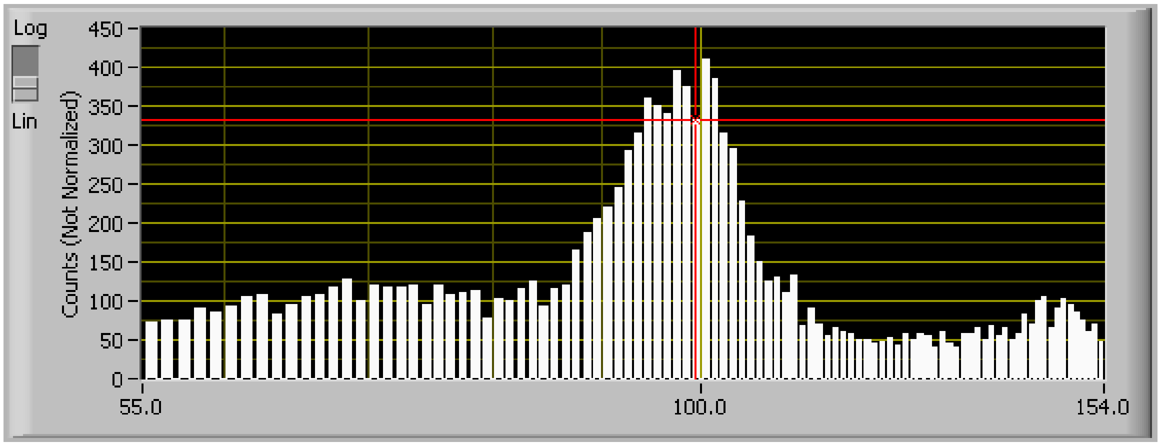


Figure 12: 100-nm Particle Distribution on an Instrument that Needs Calibration

14. Sample the ambient air. The histogram distribution should show a smooth transition of particle counts from small to large bins (Figure 13.) Small “bumps” in the distribution are normal. If you see an uneven distribution of particles around 110 nm and/or 215 nm (Figure 14), this is usually an indication that calibration is needed. The anomalies are near the calibration curve’s gain-overlap regions, which need to be “stitched” together more accurately.

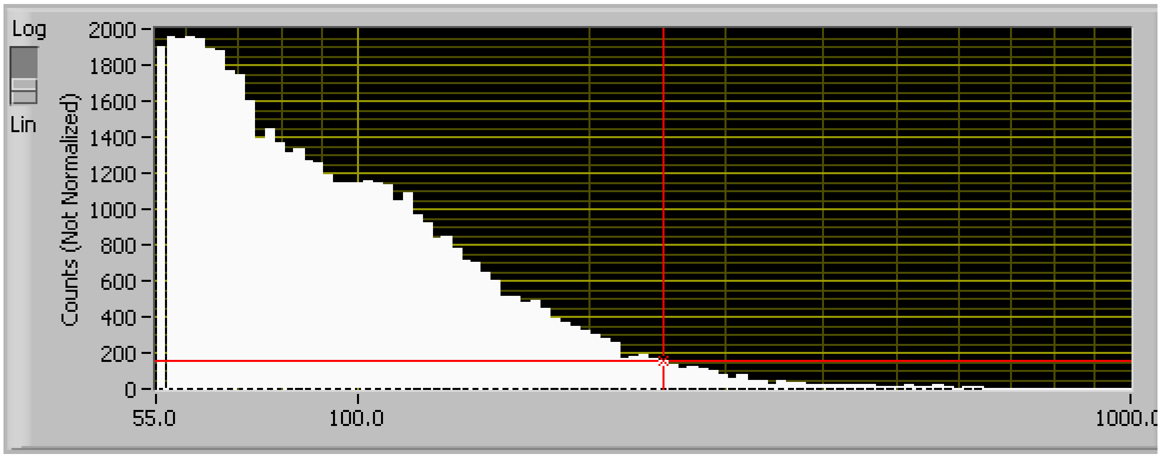


Figure 13: Ambient-Air Distribution on a Properly Calibrated Instrument

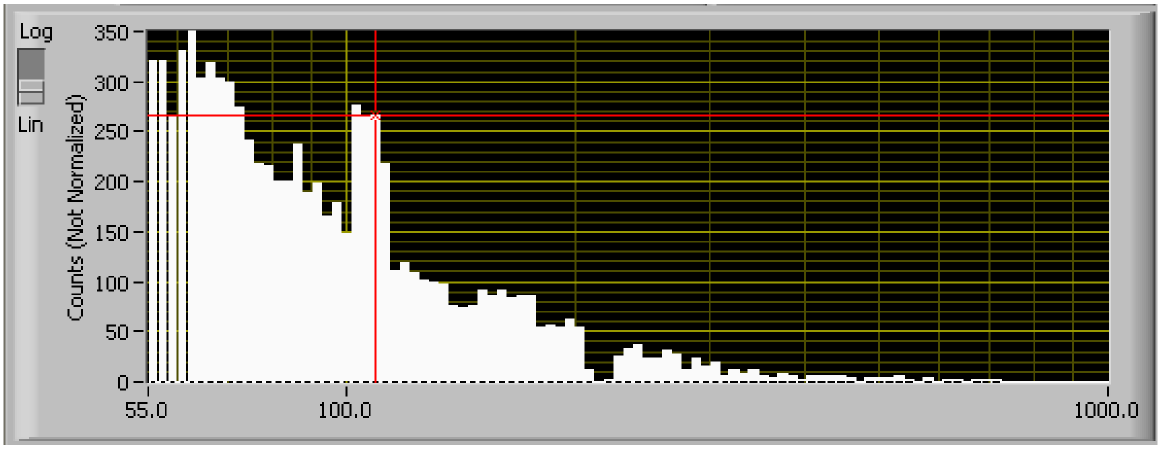


Figure 14: Ambient-Air Distribution on an Instrument that Needs Calibration

The instrument is now ready to use. Record the data if desired, using the **Record** button. You can also set the size range displayed on the histogram using the **Map** tab.

4.2 Shutdown / Power Off Procedure

- If file recording is activated, go to Histogram tab and press the **Record** button to stop recording. The **Record** button will change color from a darker grey to the same color grey as the background.

- Put the zero filter on the inlet line.

- Press the rectangular **STOP** button located in the upper right of the UHSAS screen. This stops the execution of the UHSAS program. Note that you cannot quit by clicking the upper right of the window. Clicking **STOP** ensures proper instrument shutdown and safety.

- Shut down the computer using normal Windows controls. After Windows has completely shut down, turn off the on/off switch located on the rear panel of the instrument.

5.0 Calibration

5.1 Calibration Overview

Calibration is an important process for any particle spectrometer. The UHSAS, with its high resolution and large number of arbitrarily settable bins, poses unique challenges in this area. Several features have been added to this instrument to make the calibration process as easy and accurate as possible.

There are four separate gain stages which must be “stitched” together for accurate, seamless sizing across the full dynamic range of the instrument. These gain stages are labeled in a table in section 2.3.1. There are two types of gains that need calibrating: absolute and relative gains. Relative gains are used to calibrate gain stages to one another. Absolute gain is used to fix the overall scale to a known particle size.

5.1.1 Relative Gain Calibration

The relative gain calibration is mostly automated, though the results can always be altered if the user needs to make slight adjustments. The relative gain calibration works by sampling an ambient air distribution that contains particles of all sizes measured by the UHSAS. The instrument detects a particle on adjacent gain stages, for example G3 and G2, noting the signal size on both gain stages in volts. For example, a 100 nm particle might be 3 V on G3 and 0.060 V on G2. By noting many such events, a relationship between the signal size of a particle on the two gain stages can be determined. Specifically, a linear fit to the data for many events produces a relative gain and an offset between adjacent gain stages. By running this procedure on all adjacent gain stage pairs (G3 and G2; G2 and G1; G1 and G0) a complete specification of the relative gains can be developed. This links the optical and electronic signals across the range of the instrument, which spans 6 decades of signal size in volts. For details on how to use the UHSAS software to set relative gains, see section 5.2.2.

5.1.2 Absolute Calibration

In addition to the relative gains, there is an absolute calibration curve, which correlates the particle signal size in volts to the particle size in nm. Once the relative gains are known, the corrected response for the entire instrument can be formed. Since the wavelength of the instrument is 1054 nm, it is expected that all particles below approximately 300 nm will lie on a sixth-power curve—that is, the particle signal is a sixth-power of the particle size. This has been hard-coded into the instrument by forcing the signals from G3, G2 and G1 to fall on a sixth-power curve. The final gain stage, G0, used for particles from 300 to 1000 nm, has a Mie curve appropriate for the scattering response of the instrument (see Figure 15). It is a complicated function which is calculated and confirmed by test particle measurements. In the event that the user has a preferred curve, empirical or theoretical, this curve can be entered instead.

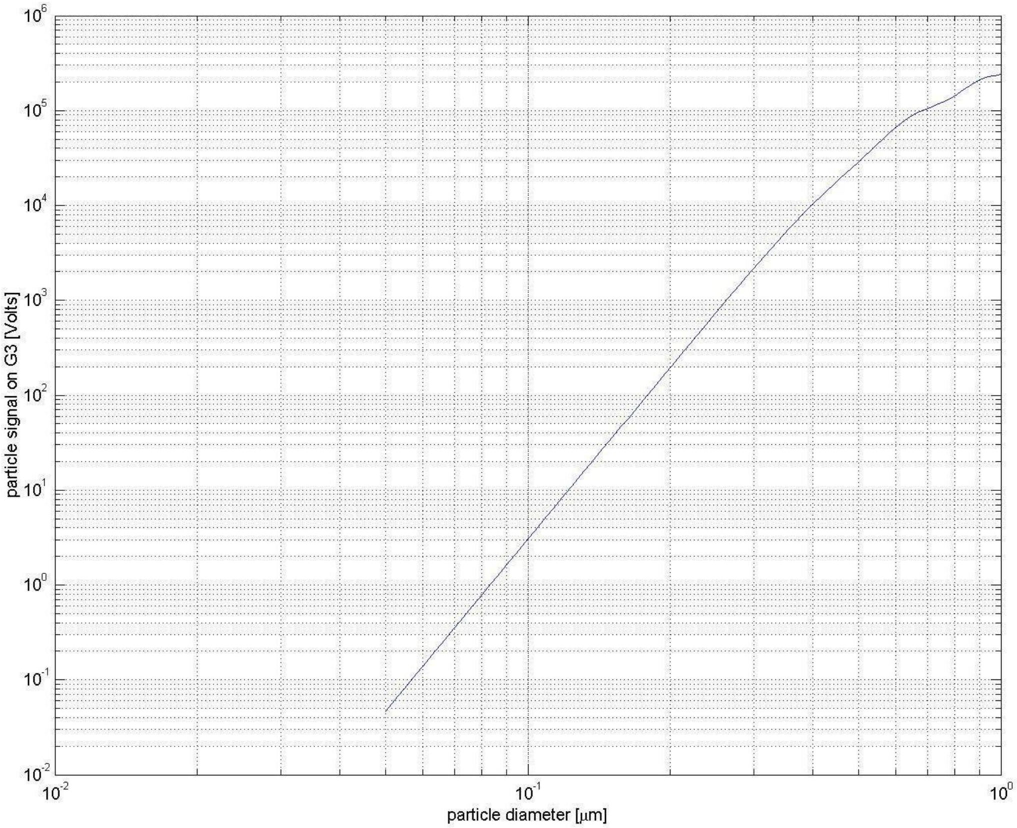


Figure 15: Example Calibration Curve

In principle, if all the relative gains are known accurately, and the calibration curve is known, the instrument need only be calibrated in an absolute sense at one point—at any point, in fact. In practice it is best to use a few trusted particles. For factory calibration, the NIST SRM 1963 100 nm standard reference material is used to fix the calibration at one point. Along with the relative gains and calibration curve, the instrument is then calibrated over its range. Other points in the instrument's range are checked for accuracy with reference particles such as the NIST SRM 1691 269 nm.

In some cases, the user may have preferred particles to use for calibration. In this case as many particles as needed may be used. If the particles do not all fall on the pre-set instrument calibration curve, the calibration curve is altered slightly to ensure that the particles return results that are the stated particle sizes. The information representing signal size for a given particle size is entered in the software and is referred to as a calibration reference point.

Whenever changes are made to the relative gain parameters, the calibration curve, or the calibration reference points, the new parameters are used when the next bin map is generated and committed to the instrument.

5.2 Calibration Procedure

All calibration is performed from the **Calibration** tab on the UHSAS screen. To access this tab, the instrument needs to be in Calibration mode. Users must enter a password on the **Configuration** tab to put the instrument in this mode.

5.2.1 Reasons for Calibration

The calibration curve is shown on the **Calibration Curve** sub-tab. This curve may need to be altered from the pre-set values in order to accommodate several possible inconsistencies:

- Particles that have been inconsistently sized with other methods
- Nonlinearities in the instrument's detection electronics
- Improved empirical data on the non-power-law portion of the curve

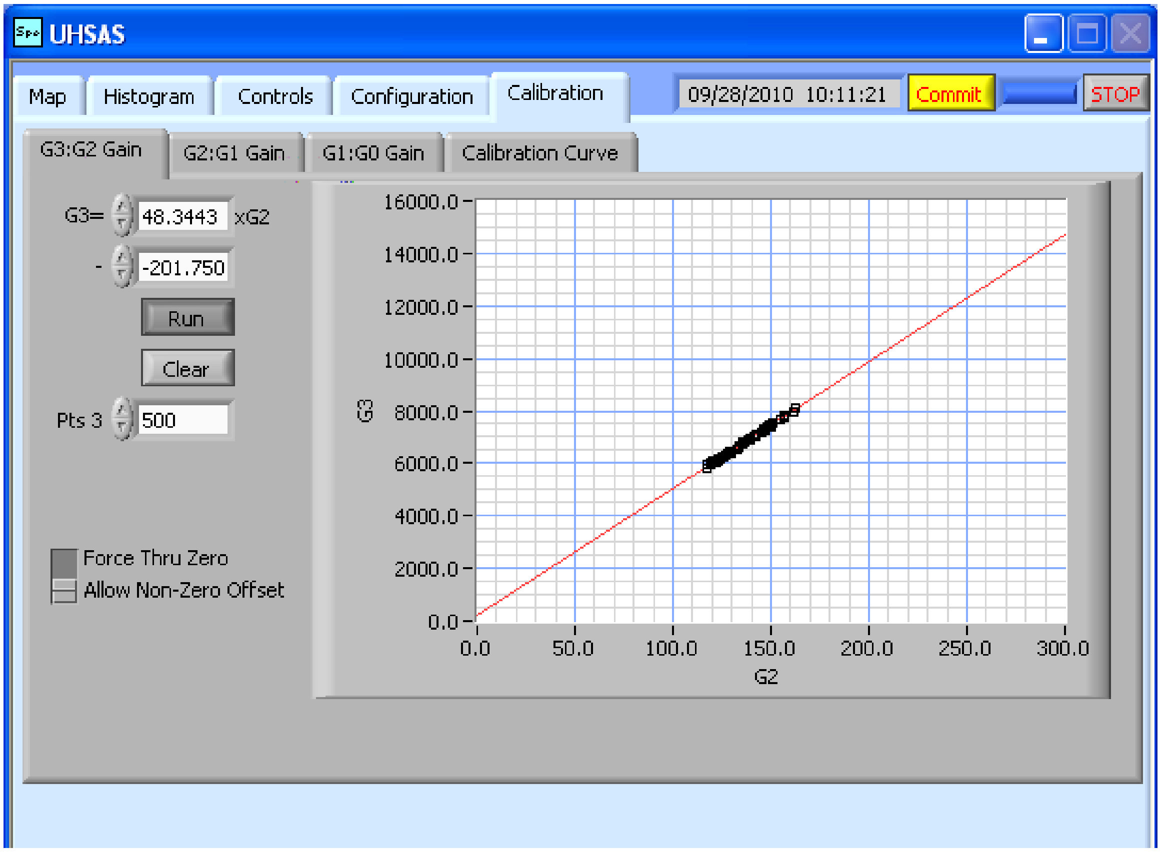
It may also be necessary to recalibrate the size scale of the UHSAS. Some reasons for this include:

- The laser power has dropped and cannot be fully restored
- Internal relative calibration has degraded
- Other types of particles (not PSL) with a different index of refraction are being used
- The calibration must agree with previously used standard materials

The following sections outline the calibration process. A description of additional features on the **Calibration** tab is presented in section 13.0.

5.2.2 Step One: Relative Gain Calibration

1.) If you haven't already done so, commit a size histogram using the **Commit** button.
2.) Ensure the **Reference** value is 2.25 – 2.75 V (see the **Controls** tab).
3.) On the **Calibration** tab, choose the relative gain tab labeled **G3:G2 Gain** and press **Clear**.
4.) Open the sample inlet to ambient air in a normal lab environment (not a cleanroom environment). If this is difficult, arrange some other way for the sample inlet to access a broad distribution of particles from 0.1 µm to 1.0 µm diameter.
5.) Press **Run**. As particles are sampled, they appear on the relative gain plot. (See Figure 16.) Those particles which can be measured on both G3 and G2 will be used to measure the relative gain and offset between these stages. When a minimum number of data points has been reached, the gain parameters begin to appear in the boxes in the top left of the screen. The minimum number of points for a relative gain calibration is hard-coded in the software and varies depending on the gain stages being calibrated. This number is displayed in the **Pts** field. When this number is reached, new points are no longer added to those being displayed and being used to calculate the calibration. The relative gain calibration can also be stopped manually by pressing the **Run** button again. *Note*: while relative gains are being calibrated, the switch in the bottom left of the screen should be set to "Allow Non-Zero Offset."



G3= 48.3443 xG2

\- -201.750

Pts 3 500

Figure 16: Running a Relative Gain Calibration

6.) Once the process stops, the graph should show the data points scattered around a best-fit line.

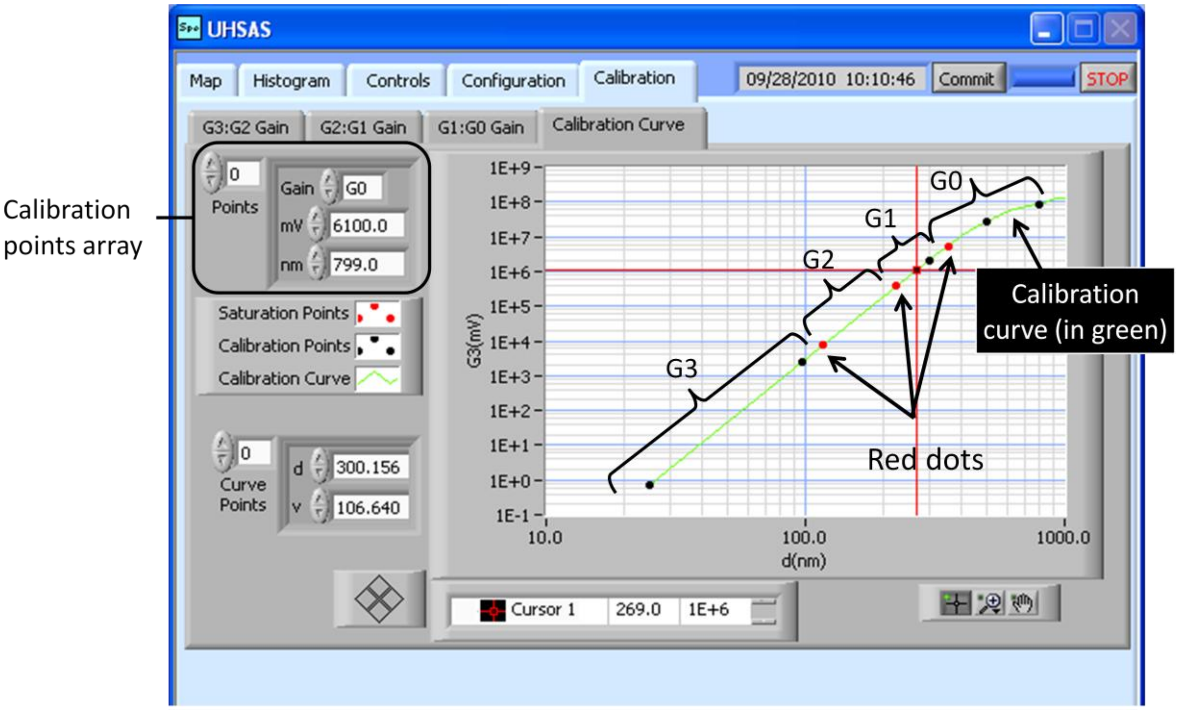
7.) Repeat this procedure for the other relative gain tabs, which are labeled **G2:G1 Gain** and **G1:G0 Gain**. Acquiring a sufficient number of large particles (for G1:G0) may take up to ten minutes, especially at flow rates below 60 sccm. ***Note:*** The program will automatically use the new gain and offset parameters as long as the current session is running; however, if these parameters should be used permanently, they must be saved in the configuration file. To do this, click on the **Save** button on the **Configuration** tab.

Several comments on the relative gains are needed. In the particle-size regions where detection passes from one gain stage to another, there can be discontinuities in the histograms produced. The histograms are very sensitive to the relative gain parameters, which are experimental quantities subject to statistical and systematic error. The stitching region between G2 and G1 is particularly prominent in this regard, since the detection technique changes between these gain stages—they are physically different photo-detectors. The ability to study these transition regions with high resolution can overemphasize the stitching errors. In most cases, the semi-auto-calibration provided should be adequate.

Stitching errors between the gain stages will also be more noticeable for certain choices of bin map. This is especially the case if, near the stitch region, the bin width is less than 1% of the bin center. For instance, say a bin in a stitch region collects 299-301 nm particles. In this case, the bin width (2 nm) is less than 1% of its center (1% of 300 nm, or 3 nm), so stitching errors may occur.

5.2.3 Step Two: Absolute Calibration

1.) Gather a collection of particles to be used as reference particles. Recommended sizes are 100 nm, 269 nm, 500 nm, and 930 nm. Using all four of these sizes will test all the instrument’s gain stages. The instrument can also be tested with just 100 nm particles or with 100 nm and 930 nm particles, but the results will not give as clear a picture of the calibration.
2.) Click on the **Calibration curve** tab. The current calibration curve should be shown.
3.) Clear all data from the calibration points array (see Figure 17) EXCEPT for the 100-nm point on gain stage. To clear a data point, right-click in the cluster box that contains the three point values (Gain, mV, nm) and select **Delete Element**. ***Note:*** The points array displays one point’s information at a time. To see a new point, click on the arrows above the **Points** label. The **Points** field shows the element in the points array that is currently displayed.
4.) With your collection of particles, note in which gain stage each particle will be measured by looking at the size of the particle and the calibration curve. The red dots on the calibration curve indicate the saturation levels of each gain stage—i.e., the largest particles measureable on each stage. For example, the region below the first red dot is covered by G3, the region between the first and second red dots is covered by G2, etc. See Figure 17.



09/28/2010 10:10:46

Points 0

Gain G0

mV 6100.0

nm 799.0

Curve Points 0

d 300.156

v 106.640

Cursor 1 269.0 1E+6

Figure 17: Calibrating the UHSAS

5.) Choose a particle size and begin introducing particles to the sample inlet of the UHSAS.

6.) Go to the **Map** tab and set up a voltage bin map:
   a.) Press **Volts.**
   b.) Choose a gain stage (G3, G2, G1 or G0) appropriate to the particle size.
   c.) Set the range as 100 to 10000 mV.
   d.) Press **Linear.**
   e.) Press **Commit.**

7.) Go to the histogram page and note the peak of the voltage histogram.

8.) Return to the **Calibration** tab and the **Calibration Curve** sub-tab.

9.) Enter the point into a new data point in the calibration points array. The calibration curve in the graph should show a new white point, and the calibration curve should adjust to accommodate the new point.

10.) If the curve looks completely wrong, check that the correct gain stage and data were entered. If needed, remove the 100 nm calibration point.

11.) Repeat for as many particles as needed.

Changes to the calibration curve will take effect on the next bin map commit. For more detailed information on the calibration tab, see section 13.0.

5.3 Calibration Confirmation

5.3.1 Particle Size Calibration Confirmation

In order to confirm calibration of the UHSAS instrument, the following steps should be taken.

1) Confirm that the laser reference level and scattering level are at their original values. If they are not, cleaning may be needed; see section 7.0.
2) Run a monodisperse sample of PSL particles to the instrument sample inlet. These should be PSL standard reference materials from NIST—the NIST 100 nm SRM or the NIST 269 nm SRM. Other manufacturers' particles may not agree with the sizes reported by NIST, and therefore cannot be used to confirm the factory calibration with a high degree of accuracy.
3) Configure a size bin map around the particle size used. A good choice is a bin map with 99 bins, a start value of 0.5 times the nominal size, and a stop value of 1.5 times the nominal size.
4) Start a histogram.
5) Accumulate a sufficient number of counts and confirm that the peak position is in agreement with the known particle size. If it is not, recalibration may be needed.

5.3.2 Flow Rate Calibration Confirmation

UHSAS users should periodically confirm that the sample flow is properly calibrated. To do this, follow the steps below.

1.) Set the sheath flow (700 ccm at sea-level) with the manual valve.
2.) Place a calibrated flow meter in line with the sample inlet.
3.) Compare the results of the flow meter reading to the sample flow monitor on the **Controls** tab. The readings should be very similar.

If the flow meter and **Controls** tab reading differ considerably, the instrument may have a leak. Check to ensure that all tubing is undamaged and tightly connected.

Note: On the **Configuration** tab, the sample flow and sample set parameters are used to convert mass flow signals into flow rates. The parameters are fits to 3rd order polynomials used to describe the response of the flow controller. The parameters can be changed to accommodate other gases. Consult DMT for instructions or revised calibration parameters.

6.0 Safety Procedures and Troubleshooting

6.1 Safety Procedures

CAUTION: Do not operate laser with instrument cover off.

This unit is equipped with a laser safety interlock system. Whenever the cover is removed, 2 mechanical switches are activated. The first turns off the AC power to the laser control module that supplies power to the laser. The second one disables the laser enable line. Under no circumstances should the user disable these safety interlocks. The laser should remain off any time the cover is removed. All safety precautions noted on caution labels should be adhered to.

6.2 Troubleshooting

DMT advises users periodically to perform a zero count test and check the instrument Reference level displayed on the **Controls** tab. These tests and checks should be performed at least once a week to confirm the instrument is functioning properly.

To perform a zero count:

- Install the supplied zero-count filter to the inlet of unit.
- Load a bin map of 55 to 154 nm, as this will help determine if the unit has a leak or it is counting noise.
- Run 5-minute samples. If you get more than a few counts, determine whether these counts reflect noise or a leak. Noise will typically appear in only the first few bins. If the unit has a leak, in contrast, typically there will be an ambient distribution.
- If the unit appears to have noise counts, check the **Reference** level on the **Controls** tab. The displayed Reference should be approximately 2.5 V; if it has dropped by more than 25% (i.e., Reference < 1.88 V), clean the laser optics as described in section 7.0.
- If the unit appears to have a leak, check any external connections between the unit and the filter. Then rerun the zero-count test.
- If an acceptable background zero-count level cannot be attained, do a recirculation check. On the **Configuration** tab, log on with a password to put the system in calibration mode. On the **Map** tab, select time binning, click on the **G3** button, and commit a map with a range from 10 – 300 µs. The resulting histogram should show mostly particles with transit times of less than 100 msec. If there are many particles with

longer transit times, check for leaks in the unit. If necessary, contact a service representative for further assistance.

To check the Laser Reference Voltages:

- Ensure the **Laser Current** is on and **Laser Temperature** is at the correct value.
- Check the **Reference** level on the **Controls** tab. If the displayed Reference is less than 1.88 V, clean the laser optics as described in section 7.0.
- If cleaning does not resolve the problem, contact a DMT service representative for further assistance.

6.3 Manually Adjusting Flow Knobs

The sample and sheath flow knobs should not normally need manual adjustment. In most conditions, using the controls on the **Controls** tab in the software program suffices. In the rare instance that flows need to be adjusted manually, however, this can be accomplished by using the flow control knobs shown in Figure 18.

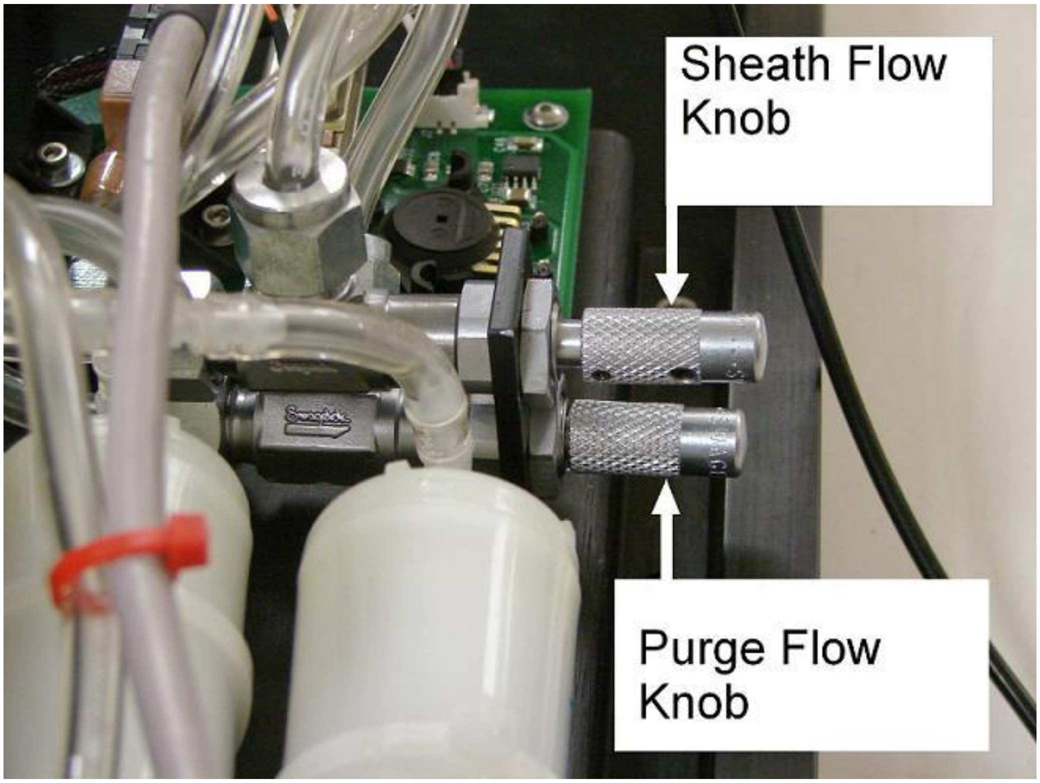


Figure 18: Sample and Sheath Flow Knobs (Rarely Used)

7.0 Cleaning the Laser Optics

Under normal operating conditions, the laser optics should not need to be cleaned very often. However, if the unit is often moved or turned on and off, the optics may need more frequent cleaning. A good indication of whether the laser optics require cleaning is the **Reference** voltage, which is displayed on the **Controls** tab. The initial value for the Reference voltage is typically 2.5 V; the factory value for your particular probe can be found on the last page of the data sheet supplied with the instrument. If this voltage drops by 25% or more, the laser optics will need to be cleaned.

WARNING: The UHSAS uses a high power invisible infrared laser. The optics should only be cleaned by personal familiar with laser safety precautions. Failure to follow safe practices can lead to eye damage or permanent blindness. *In no cases should the laser be operated with a cleaning port removed.*

INVISIBLE LASER RADIATION PRESENT
WHEN COVER OPEN AND INTERLOCKS DEFEATED
DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

To clean the optics, follow the steps below:

1.) After turning off power to the unit, remove the 16 Phillips-head screws holding the cover on. Lift the cover straight up until it clears the unit.

2.) Open the tubing at the joint in the exhaust line. The exhaust line comes out of the bottom of the large black optical block (see Figure 19). Opening the line creates positive pressure in the block and helps keep out contamination.

Figure 19: Opening the Exhaust Line

3.) Lift the power interlock switch at the front corner of the unit and turn on the unit.

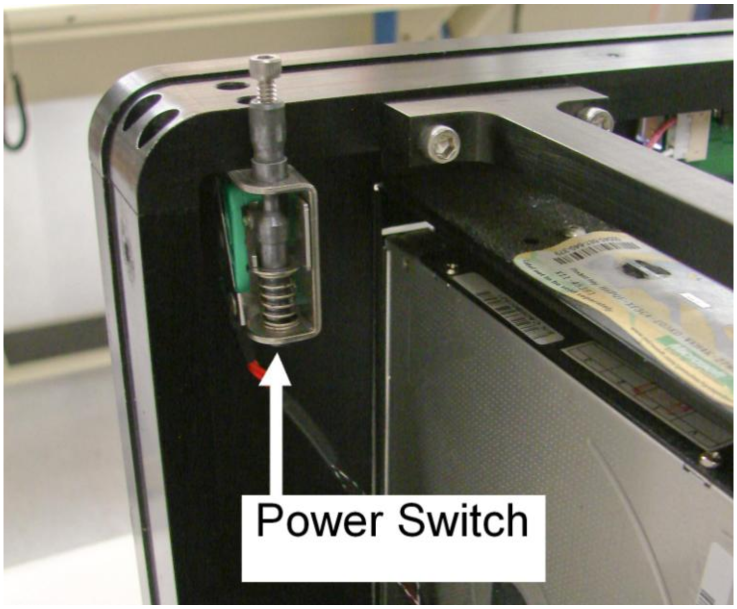


Figure 20: UHSAS Power Switch on Front of Unit

4.) Ensure that the laser interlock switch at the rear is off by pressing it downward and allowing it to spring back to center.

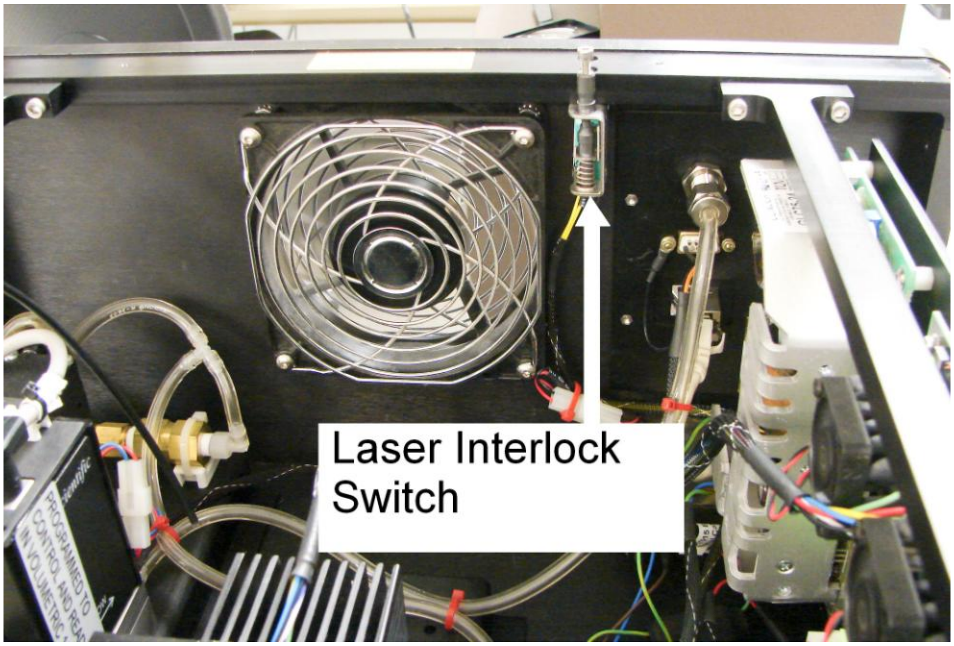


Figure 21: UHSAS Laser Interlock Switch on Rear of Unit

5.) Turn the unit on and start the software program. Check the **Laser Current** reading on the **Controls** tab. It should read zero. If it does not, depress and release the laser interlock switch again. Do not proceed until the laser is off and **Laser Current** is zero.

6.) Locate the cleaning port for the mirror optic at the frontend of the optical block (i.e., the end near the computer display). Generally contamination occurs at the mirror end, so it is important to start cleaning with this optic. Remove the two lock-down screws near the cleaning port (Figure 22), then remove the cleaning port.

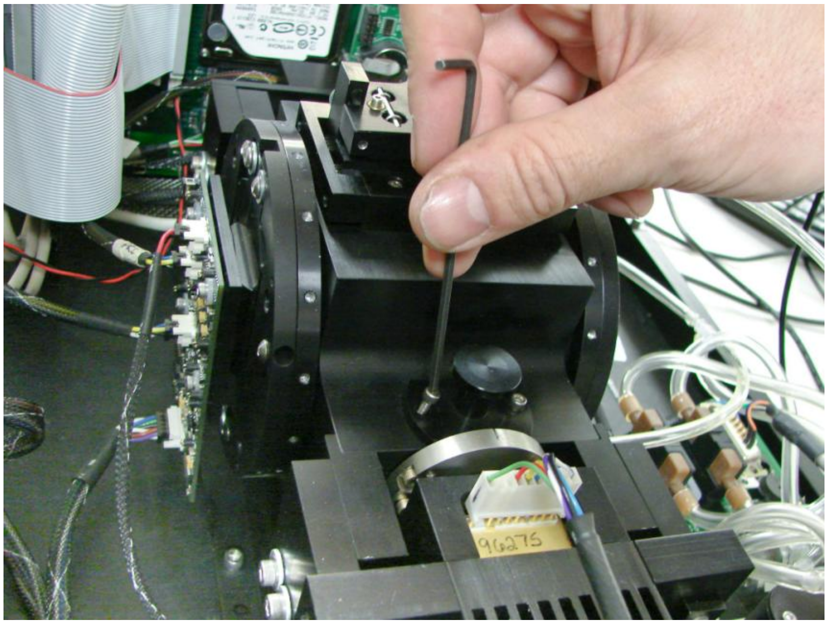


Figure 22: Unscrewing Cleaning Port

7.) Using a cotton swab with a one to two drops of spectra-photo grade acetone, clean the optic (Figure 23). A single gentle swipe in one direction across the middle portion of the optic works the best. DO NOT use a scrubbing or circular motion, as this tends to spread any contamination around and hampers the cleaning effort. Usually 2-3 cleaning swipes using fresh acetone and fresh cotton swab for each swipe is adequate. ***Note:*** Avoid hitting the side of the cleaning port with the Q-tip, as grease from the o-ring can get on the Q-tip and smear the optics.

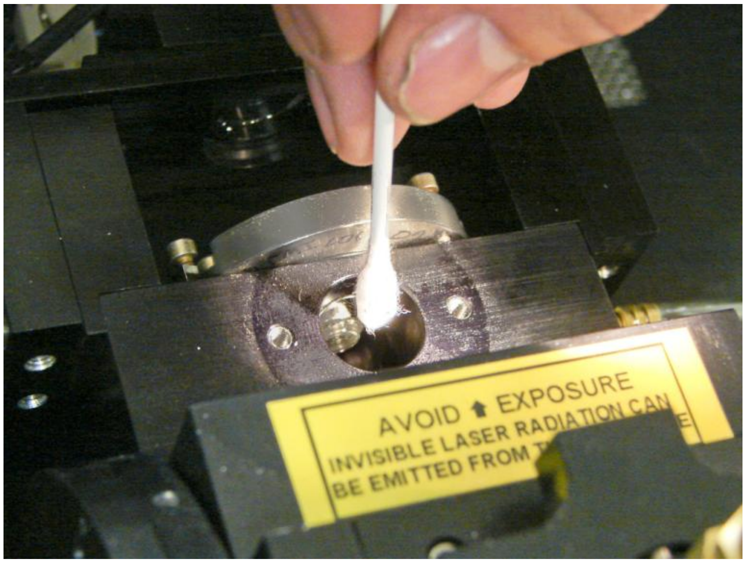


Figure 23: Cleaning the Optic

8.) Replace the port, lift the rear interlock, and observe the laser power for one minute by examining if **Reference** has returned approximately to 2.5 V. If the power is still low, press the rear interlock (the laser interlock) down to OFF and repeat steps 7-8 of the procedure. It generally will take numerous attempts to return the laser to normal power.

9.) Reinstall cleaning port and replace the lock-down screws.

10.) If laser reference power is still low, repeat the cleaning procedure outlined in steps 7-10 for the optic at the back end of the optical block. This is the crystal/laser end. *Use caution*, as the crystal end is delicate and scratches easily. Only clean the crystal end when necessary and with the laser OFF.

11.) Close the tubing on the optical block exhaust line.

12.) Reinstall cover on the unit. Do not install screws into cover until power has been rechecked in case the unit requires more cleaning.

13.) Turn on the laser current and run the instrument normally for 15 minutes to stabilize.

14.) Check the **Reference** and **Scatter** levels of the unit. The cleaning was successful if these values are within 15% of desired values (2.5 V for **Reference,** factory-calibrated value for **Scatter**.) If they are lower than when the cleaning started, the cleaning was unsuccessful.

15.) Repeat above steps until adequate **Scatter** and **Reference** levels have been attained.

16.) Install the 16 Phillips-head mounting screws into the cover. The unit is now ready for use.

In the unlikely event that cleaning does not adequately raise the laser power, consult a DMT service representative for further assistance. If the instrument becomes contaminated, it should be returned to the manufacturer for decontamination, cleaning, and service.

8.0 Communications

A serial port for data transmission to an external data system is available through the back panel. This data stream is ascii text at 115,200 baud, 8N1, tab-delimited. ***NOTE:*** The serial-stream data are transmitted at the same repetition rate as the **Sample Time** specified on the **Histogram** tab; if this sample time is set to five minutes, the serial packet will only be sent out once every five minutes. The header of the serial stream is a channel list in the same format as the first 2 lines of the data file, and it is sent before any data are transmitted. The serial port connector is a standard 9-pin D-connector and can be connected to the serial port of an external computer with a standard female/male straight serial cable. The serial port is determined by the **Broadcast Port COM** parameter on the **Configuration** tab. If this port is set to 0, no data are broadcast.

See your IT support department for assistance with connecting the UHSAS to the local network or internet.

Part II: Software

The UHSAS program is designed in LabVIEW, a software program that provides a user-friendly virtual instrument panel for the control, data display, and data logging of the UHSAS instrument. This manual describes version 4.1.0 of the software.

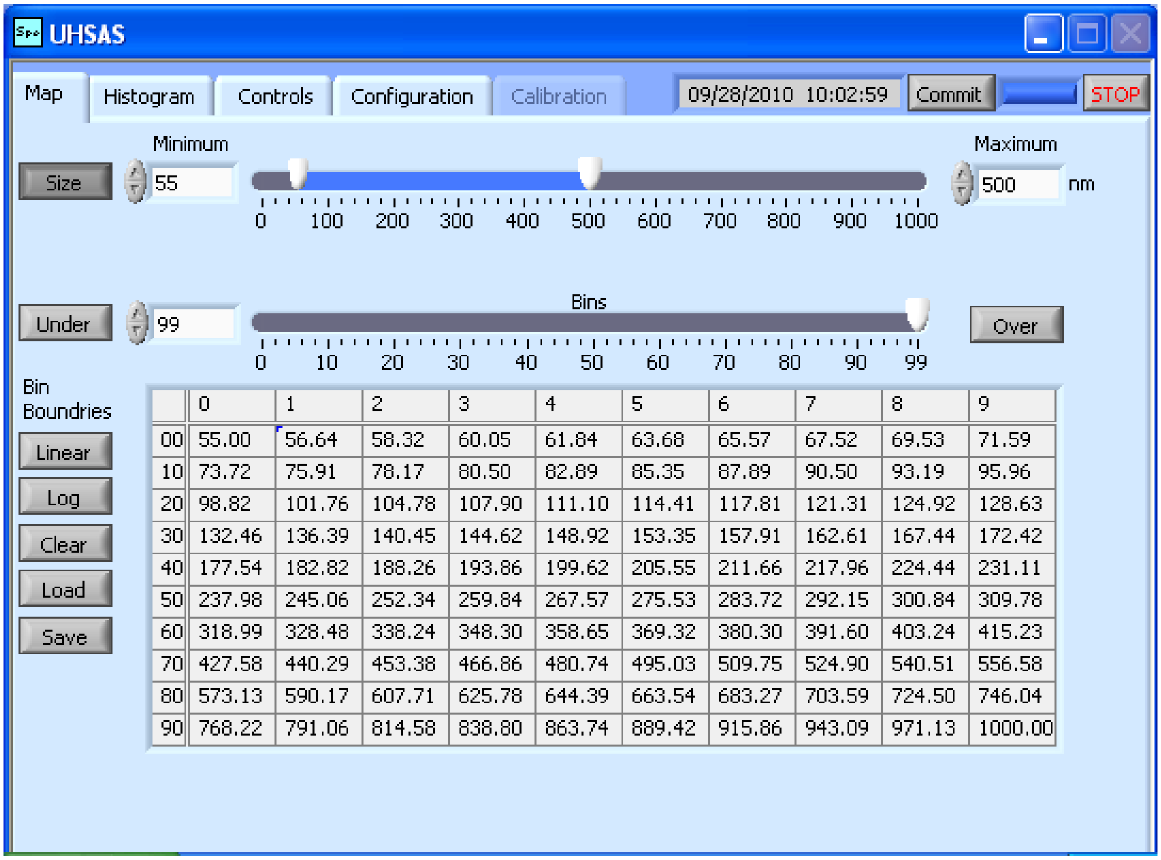
When the UHSAS program is started, five tabs appear at the top of the screen. Clicking on these tabs will bring up different displays, as follows:

1. **Controls Tab** – Monitors and/or controls variables such as sample flow, sheath flow, reference and scatter values, ambient pressure and temperature, and laser current and temperature. The Controls tab is the default screen that appears upon program start-up.
2. **Map Tab**—Allows the user to commit the desired bin map to the instrument. The bin map determines how the UHSAS categorizes and sizes particles.
3. **Histogram Tab**—Displays a histogram of particles and allows the user to set desired histogram parameters. These parameters include whether the histogram displays data linearly or logarithmically, whether the x-axis charts bin number or particle size, and whether the y-axis displays particle count or concentration. This tab also allows users to set the sample time.
4. **Configuration Tab**—Allows the user to view and set system parameters. This tab also allows users to enter a system password which expands access to features and parameters on the Configuration tab and other tabs.
5. **Calibration Tab**—Assists the user in recalibrating the UHSAS.

The sections below provide details about the different screens available by clicking on the tabs.

9.0 Map Tab

The size range displayed on the histogram is controlled through the **Map** tab. The **Map** tab shows the boundaries of the bin width map that is used for the display. The map can be modified in multiple ways depending on user preference.



09/28/2010 10:02:59

Minimum 55

Maximum 500 nm

Under 99

Bin Boundries

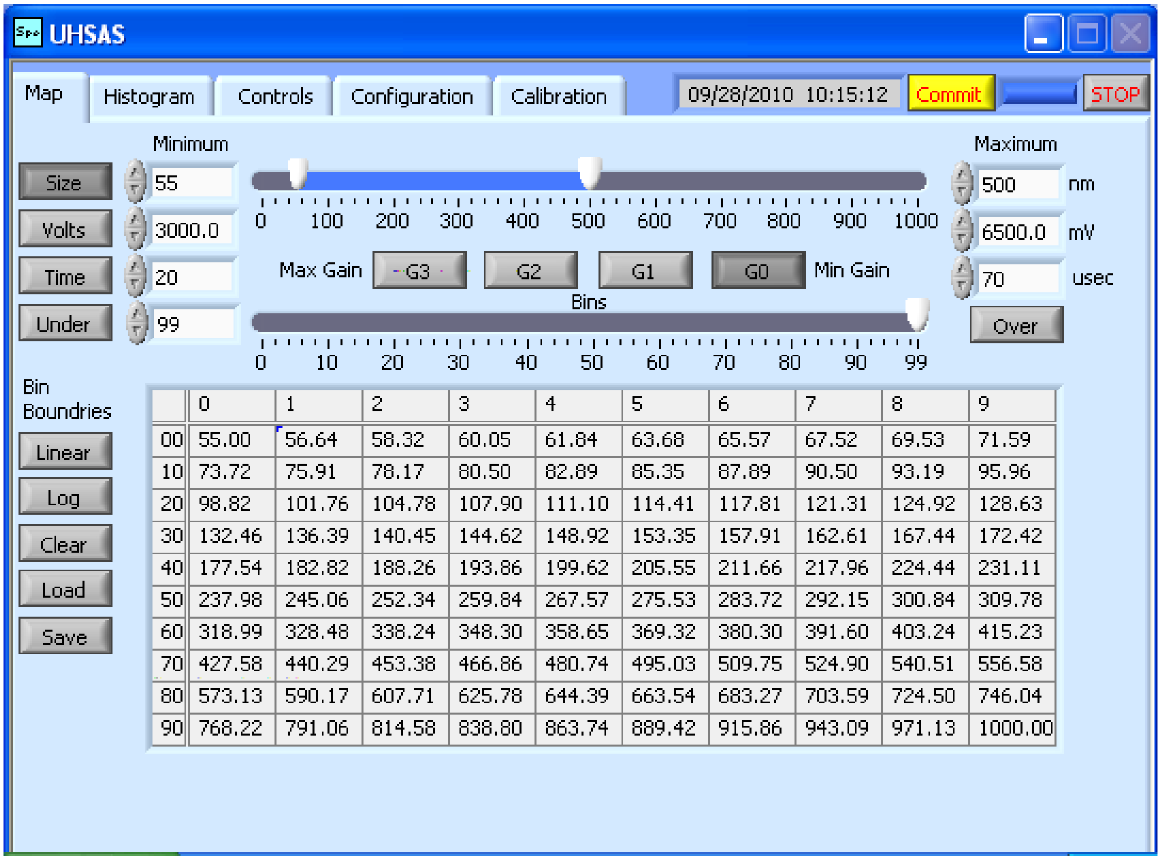
	0	1	2	3	4	5	6	7	8	9
00	55.00	56.64	58.32	60.05	61.84	63.68	65.57	67.52	69.53	71.59
10	73.72	75.91	78.17	80.50	82.89	85.35	87.89	90.50	93.19	95.96
20	98.82	101.76	104.78	107.90	111.10	114.41	117.81	121.31	124.92	128.63
30	132.46	136.39	140.45	144.62	148.92	153.35	157.91	162.61	167.44	172.42
40	177.54	182.82	188.26	193.86	199.62	205.55	211.66	217.96	224.44	231.11
50	237.98	245.06	252.34	259.84	267.57	275.53	283.72	292.15	300.84	309.78
60	318.99	328.48	338.24	348.30	358.65	369.32	380.30	391.60	403.24	415.23
70	427.58	440.29	453.38	466.86	480.74	495.03	509.75	524.90	540.51	556.58
80	573.13	590.17	607.71	625.78	644.39	663.54	683.27	703.59	724.50	746.04
90	768.22	791.06	814.58	838.80	863.74	889.42	915.86	943.09	971.13	1000.00

Figure 24: Map Tab

This tab sets and commits a bin map, which determines the x-axis of the histogram graph. The bin map spreadsheet values are the values that are committed to the instrument.

To set a bin map, follow the steps below.

1. Choose size, volts, or time as the binning criteria using the buttons in the upper left of the screen. Note that you must enter a password on the **Configuration** tab to enable the **Volts** and **Time** buttons; see Figure 25.
    - *Size*: creates a histogram of particle diameters, specified in nm.
    - *Volts*: creates a histogram in voltage space (mV) of the gain stage chosen (G3, G2 G1 or G0).
    - *Time*: creates a histogram of transit times (μs) of the gain stage chosen.



09/28/2010 10:15:12

Minimum

Size 55

Volts 3000.0

Time 20

Under 99

Maximum

500 nm

6500.0 mV

70 usec

Bin Boundries

	0	1	2	3	4	5	6	7	8	9
00	55.00	56.64	58.32	60.05	61.84	63.68	65.57	67.52	69.53	71.59
10	73.72	75.91	78.17	80.50	82.89	85.35	87.89	90.50	93.19	95.96
20	98.82	101.76	104.78	107.90	111.10	114.41	117.81	121.31	124.92	128.63
30	132.46	136.39	140.45	144.62	148.92	153.35	157.91	162.61	167.44	172.42
40	177.54	182.82	188.26	193.86	199.62	205.55	211.66	217.96	224.44	231.11
50	237.98	245.06	252.34	259.84	267.57	275.53	283.72	292.15	300.84	309.78
60	318.99	328.48	338.24	348.30	358.65	369.32	380.30	391.60	403.24	415.23
70	427.58	440.29	453.38	466.86	480.74	495.03	509.75	524.90	540.51	556.58
80	573.13	590.17	607.71	625.78	644.39	663.54	683.27	703.59	724.50	746.04
90	768.22	791.06	814.58	838.80	863.74	889.42	915.86	943.09	971.13	1000.00

Figure 25: Map Tab with Password-Protected Options

2. Specify the range minimum and maximum values, if new ones are desired. This can be done in several ways:
    - Typing a value directly into the **Minimum** and **Maximum** fields.
    - Using the up and down arrows to change the values in the **Minimum** and **Maximum** fields.
    - Using the slider controls to change the minimum and maximum values. The blue portion of the slider bar shows the range that the UHSAS will map.
3. Choose the number of bins. This can be done either by using the **Bins** slider control or by typing in a number in the field to the left of this slider.
4. Click on a **Linear** or **Log** bin spacing to create the bin map.
5. The bin map appears in the bin table. The first cell lists bin 1's lower boundary. The second cell lists bin 1's upper boundary, which is also bin 2's lower boundary. The third cell lists bin 2's upper boundary/bin 3's lower boundary, and so on, until the final cell, which lists the upper boundary of the largest bin.
6. Press **Commit** and wait for commit bar to complete. This process downloads the bin map to the histogram electronics.

Pressing the **Under** button activates the undersized particle display on the histogram. When this option is activated, the histogram will display the underflow bin beneath the smallest particle bin. The underflow bin contains all detected particles bigger than the trigger threshold but smaller than the lower limit of the first bin. (See section 12.0 for a definition of the trigger threshold.) The **Under** button darkens when underflow display is activated.

Pressing the **Over** button activates the oversized particle display on the histogram. When this option is activated, the histogram will display the overflow bin after the last largest particle bin. The overflow bin contains all detected particles larger than the upper size limit of the last bin. The **Over** button darkens when overflow display is activated.

The **Clear** button clears the bin map.

The **Load** button loads a saved file into the bin map, while the **Save** button saves the current bin map to file. Clicking on either button brings up a window that allows the user to navigate to the desired file. By default, bin maps are saved in the `C:\DMT\Spectrometer Support` directory as `.map` files. ***Note:*** The `Last Map.txt` file holds the name of the last map file to be loaded or saved. It should not be edited by the user.

10.0 Histogram Tab

This tab displays histograms, sets integration times, and initiates data logging. It is shown in Figure 26.

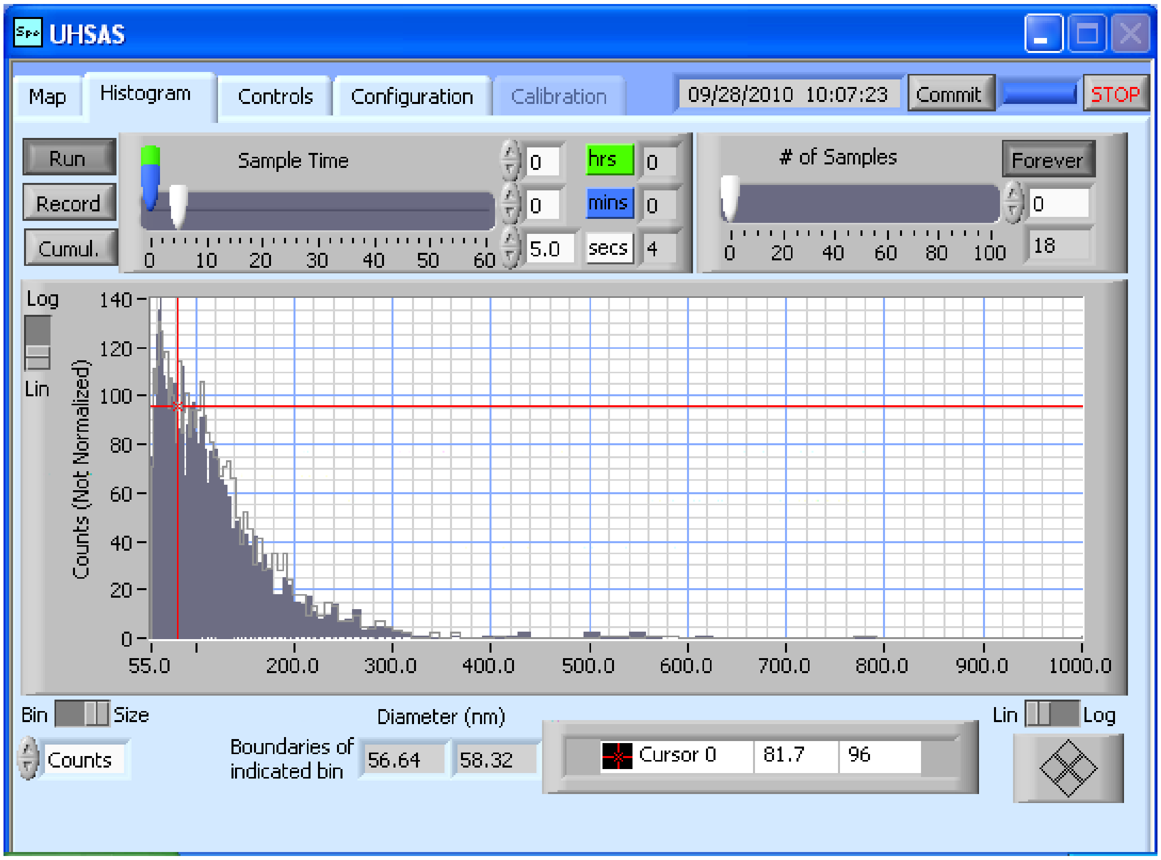


Figure 26: Histogram Tab

The slider bar on the top left of the screen allows the user to set the sample time. This determines the length of time over which counts are accumulated. At the end of the set time, the histogram data are written to the record file, if recording is enabled, and the histogram is reset. If the serial port is being used, this is also when data are broadcast out to the serial port. The sample time is set using the slider controls (the green control for hours, the blue for minutes, and the white for seconds), or by directly entering numeric values into the white fields to right of the slider control. The gray boxes to the right of the “hrs,” “mins,” and “seconds” labels show the time that the current sample has been accumulating.

The controls on the top right of the screen allow the user to set the number of cycles of accumulation time to be performed. When the number of actual samples exceeds this set point, the histogram stops running and the display stops updating. There are several ways to set the number of samples. The user can adjust the slider control, type a number directly in the white box, or click on the arrows to the left of the box. If **Forever** is selected, the instrument cycles indefinitely. The present cycle number is shown in the gray box just above the histogram.

The **Run** button starts data collection and the histogram display. This button also resets the number of samples to zero.

The **Record** button records the histogram data to a file. Clicking on this button will bring up a browser window that allows the user to specify a file location; the default file is `C:\DMT\Spectrometer Data\YYYYMMDDhhmmss.xls`. Choosing an existing file appends the data with a new header.

The **Cumul** button puts the histogram in cumulative mode. In this mode, the y-axis displays particle counts from the current bin plus counts from all larger sized bins. Note that cumulative data do not get written to the recorded data file. Cumulative mode can be entered or stopped while a histogram is stopped or running.

The **Bin/Size** switch in the bottom left specifies whether the x-axis labels display the bin number or the bin boundaries. Note that bin boundaries may be in mV or μsec (i.e., rather than units of size) if volts or time have been selected as the binning criterion on the **Map** tab. Refer to the bin map tab to identify bins, or use the cursor to read the bin boundaries which are reported at the lower left of the page (see following section).

The control at the bottom left of the Histogram tab allows users to specify whether the y-axis should graph counts or number concentration (counts/cm^3).

Moving the red cursor along the x-axis allows the user to examine data from a particular bin in more detail. Specifically, for the selected bin, the program will display the bin boundaries and exact particle count or concentration in the fields at the bottom of the screen. On the histogram display, a red horizontal line appears that highlights the y-axis value for the relevant bin.

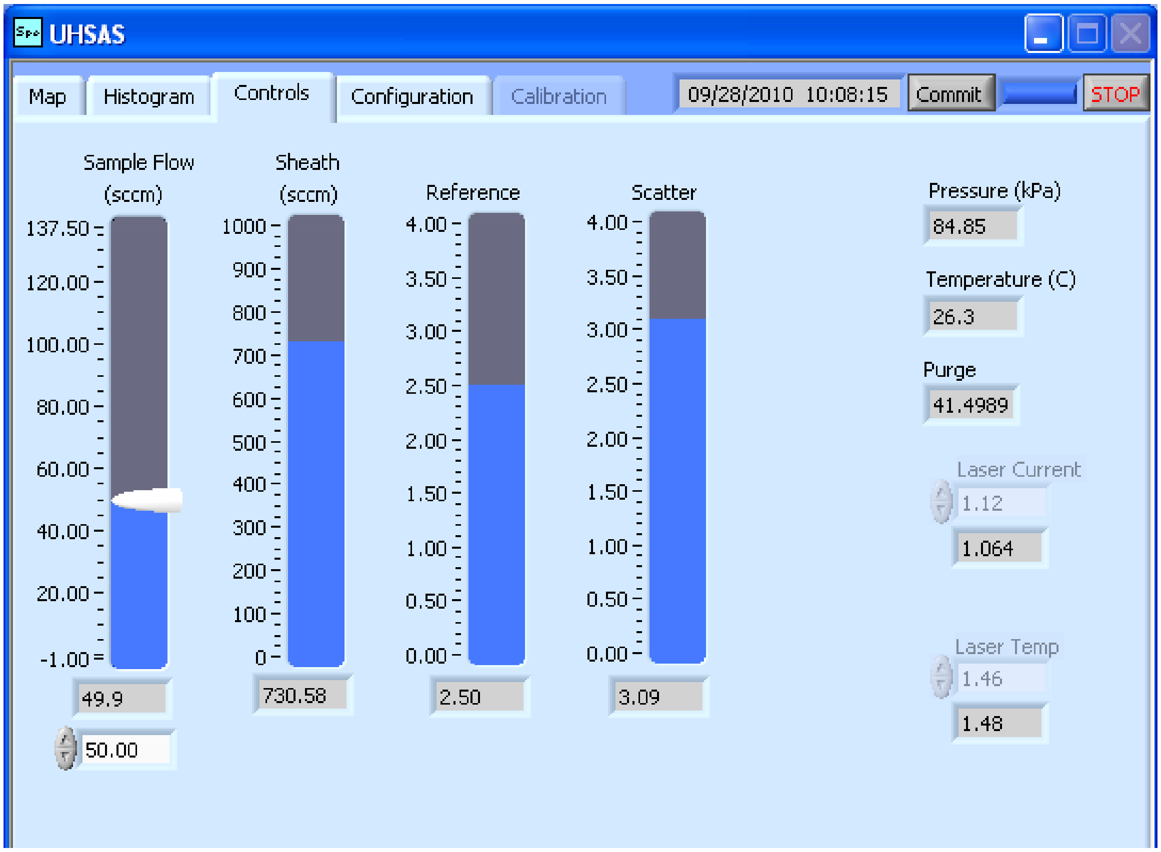
To move the cursor one bin forward or backward from its current location, click on the right-most or left-most squares in the diamond control box.

10.1 Autoscaling

The UHSAS software always autoscales the x axis. The y-axis is autoscaled by default, but can be fixed. For a fixed y-axis, right click in the graph and uncheck the “autoscale y” option. You can also reset the y-axis scale by typing directly into the axis labels. Do not attempt to type numbers into the x-axis labels or select “autocale x” after right-clicking on the graph, as doing so may interfere with the data display.

11.0 Controls Tab

The **Controls** tab sets the sample flow and monitors other parameters including sheath flow, sample block temperature and pressure, and laser and cavity characteristics. The air flows are measured with electronic flow controllers or meters.



09/28/2010 10:08:15

Sample Flow (sccm): 49.9; 50.00

Sheath (sccm): 730.58

Reference: 2.50

Scatter: 3.09

Pressure (kPa): 84.85

Temperature (C): 26.3

Purge: 41.4989

Laser Current: 1.12; 1.064

Laser Temp: 1.46; 1.48

Figure 27: Controls Tab

The **Sample Flow** is both monitored and set on the **Controls** tab. The user can set the sample flow by using the white slider or by typing a number directly into the white box in the lower left of the window. The actual sample flow, which may differ from the set flow, is listed in the gray box underneath the Sample Flow slider control. The actual flow is also indicated by the blue portion of the flow meter.

The meters to the right of the sample flow indicate the current **Sheath flow** (sccm), **Reference** value (V), and **Scatter** value (V). The sheath flow is the flow of the buffer surrounding the sample air; it should be 600-800 sccm. Reference denotes the laser reference voltage from the monitor photodiode. Ideally, this voltage should be between 2.25 and 2.75, although the instrument typically works as long as the reference value is .9 – 2.97 V. The scatter value is the background DC molecular scatter level from the APD, which should read around 2 - 2.5 V when the pump laser is on.

The **Temperature** field displays the ambient temperature, while the **Pressure** field shows atmospheric pressure.

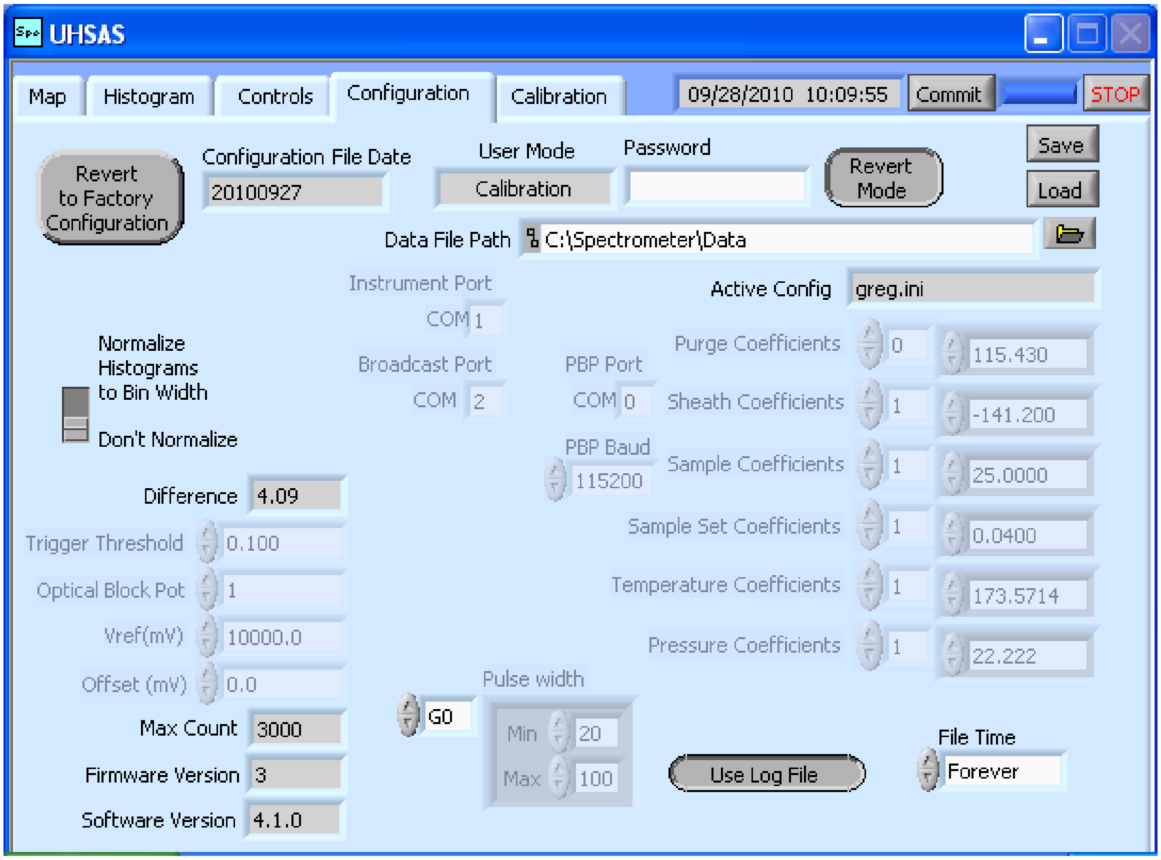
If a purge flow has been installed, the **Purge** monitor displays the purge flow, which should be 20 – 50 sccm. The purge flow provides fresh air for the optics and helps keep them clean.

Laser current displays the pump laser current in amps. The lower display box is the actual current, while the upper display is the set point. The set point is locked, and changing it may degrade the instrument's performance. The actual laser current and the set point should be close but not the same. An **ON/OFF** button appears beneath the actual current when a password has been entered on the **Configuration** tab. Use this button turn the laser current on and off.

Laser temp displays the pump laser temperature in arbitrary units. The lower display box is the actual temperature, while the upper box displays the set point. The set point is locked, and changing it may degrade the instrument's performance. As with the laser current parameter, the laser temp's set point and actual values should be close but not the same. The laser temp value for a laser at room temperature should be approximately 1.0.

12.0 Configuration Tab

This tab displays the instrument configuration parameters. Note that some of these parameters are protected and cannot be changed unless the user logs in by typing a password in the **Password** field and then clicking on the **Enter Password** button. To revert to normal operation (i.e., not a password-protected mode), click on the **Revert Mode** button. Figure 28 shows the **Configuration** tab in Calibration mode.



09/28/2010 10:09:55

Configuration File Date 20100927

User Mode Calibration

Password

Data File Path C:\Spectrometer\Data

Instrument Port COM 1

Broadcast Port COM 2

PBP Port COM 0

PBP Baud 115200

Active Config greg.ini

Purge Coefficients 0 115.430

Sheath Coefficients 1 -141.200

Sample Coefficients 1 25.0000

Sample Set Coefficients 1 0.0400

Temperature Coefficients 1 173.5714

Pressure Coefficients 1 22.222

Normalize Histograms to Bin Width

Don't Normalize

Difference 4.09

Trigger Threshold 0.100

Optical Block Pot 1

Vref(mV) 10000.0

Offset (mV) 0.0

Max Count 3000

Firmware Version 3

Software Version 4.1.0

Pulse width G0

Min 20

Max 100

File Time Forever

Figure 28: Configuration Tab

Clicking on **Revert to Factory Configuration** reverts all the parameters to their original default values. These parameters are stored in separate configuration file, `factory.ini`, which should not be modified.

The **Configuration File Date** field lists the date the configuration file was last modified in YYYYMMDD format.

Clicking the **Save** button saves the present instrument configuration to a file. When this button is clicked, the system will prompt the user for a file name. The file must be saved in the directory `C:\DMT\Spectrometer Support`. As stated above, the factory provided configuration file, `factory.ini`, should not be overwritten.

Note: *Pressing the* ***Save*** *button saves not only the* ***Configuration*** *tab parameters but those on other tabs as well, such as flow rates, sample times, and so on. (The* ***Map*** *tab is the exception; it has its own* ***Save*** *button.) After configuring the UHSAS the way you want it, pressing* ***Save*** *on the* ***Configuration*** *tab will retain the settings you want.*

The **Load** button loads a saved instrument configuration file. The user is prompted for a file name.

The **Data File Path** field specifies the default directory where data files are saved and loaded. This directory can be changed either by typing in a new directory or by clicking on the folder icon 📂 to the right of the path. ***Note:*** When using the folder icon to navigate to a new directory, select the desired directory in the file dialog box and then hit the button labeled “Press ME! Don’t Press Save.” Do not press the **Save** button.

The **Active Config** field displays the configuration file the instrument is currently using.

The **Instrument Port** should be set to COM1.

Broadcast Port indicates the number of the serial port to which the instrument is sending data, if applicable. If a serial port is not being used, the **Broadcast Port** field is set to zero and data are written only to the data file on the computer. Note that the information being sent to the serial port is identical to that going to the data file.

The **Normalize Histograms to Bin Width** switch determines the default normalization setting for the histogram.

The **Difference** field is not used.

Trigger Threshold is a very important and somewhat subtle parameter. It specifies the smallest signal voltage (in Volts on G3) that will register as a particle. It is like the lowest threshold on a typical instrument, in that events that are smaller than this signal size will not initiate a count. Everything above this signal size will initiate a count, as long as the event satisfies the timing criteria. However, in this instrument, the trigger threshold may not have anything to do with the lowest selected bin. For example, the trigger threshold might be set to 0.100 V with this signal size corresponding to a 55 nm particle. The user can select a lowest bin of 60 nm, so that particle triggers between 55 and 60 nm will not appear as counts. (They will appear in the underflow bin if underflow counting is selected; see section 9.0.) Or, the user could select a lowest bin of 50 to 54.9 nm. No counts will appear in this bin, since the trigger threshold is set to a signal size corresponding to a 55 nm particle.

The **Optical Block Pot** is not used.

Vref should be either 10000 mV or 10240, depending on the instrument.

Offset allows user to specify a voltage offset in the electronics chain of the highest gain channel (G3). It is typically a few mV and should not be important.

The **Max Count** field lists the maximum number of particles the UHSAS can process per second. At particle concentrations over this number, the instrument generates a warning and performance may be compromised.

The **Revision #** lists the software revision number, while **Version** displays the firmware revision number.

For each of the gain stages (G0, G1, G2, G3), the **Pulse Width** control sets a window for acceptable particle pulse widths in µsec. A particle pulse must be between these two times for it to be counted.

On the right side of the **Configuration** tab are coefficients for converting the voltages for various sensors and flow controllers into meaningful units. These coefficients are displayed for the following sensors and flow controllers:

- **Purge Coefficients** are for the purge flow sensor.
- **Sheath Coefficients** are for the sheath flow sensor.
- **Sample Coefficients** are for the sample flow sensor.
- **Sample Set Coefficients** are for the sample flow controllers.
- **Temperature Coefficients** are for the electronics box temperature reading in ºK, i.e. the temperature of the ambient air just as it enters the instrument.
- **Pressure Coefficients** are for the ambient pressure (kPa).

The coefficients should not need to be changed, and the controls have been grayed out.

The **Use Log File** button determines whether or not a recording session will generate a log file.

File Time sets the maximum time that data are recorded to a single file. When this time is exceeded, the program starts writing to a new file. New files are synchronized to start in even increments after midnight. For instance, when **File Time** is set to 12 hours, new files start at midnight and noon. The first new file will begin at whichever time comes first—for example, if the initial file was begun at 9:31 a.m., the second file will start at noon. When **File Time** is set to 8 hours, new files start at midnight, 8 a.m., and 4 p.m. When **File Time** is set to every 6 hours, new files start at midnight, 6 a.m., noon, and 6 p.m., and so on. When **File Time** is set to Forever, all data are recorded to the original file and no new files are started until the user stops recording and starts a new file.

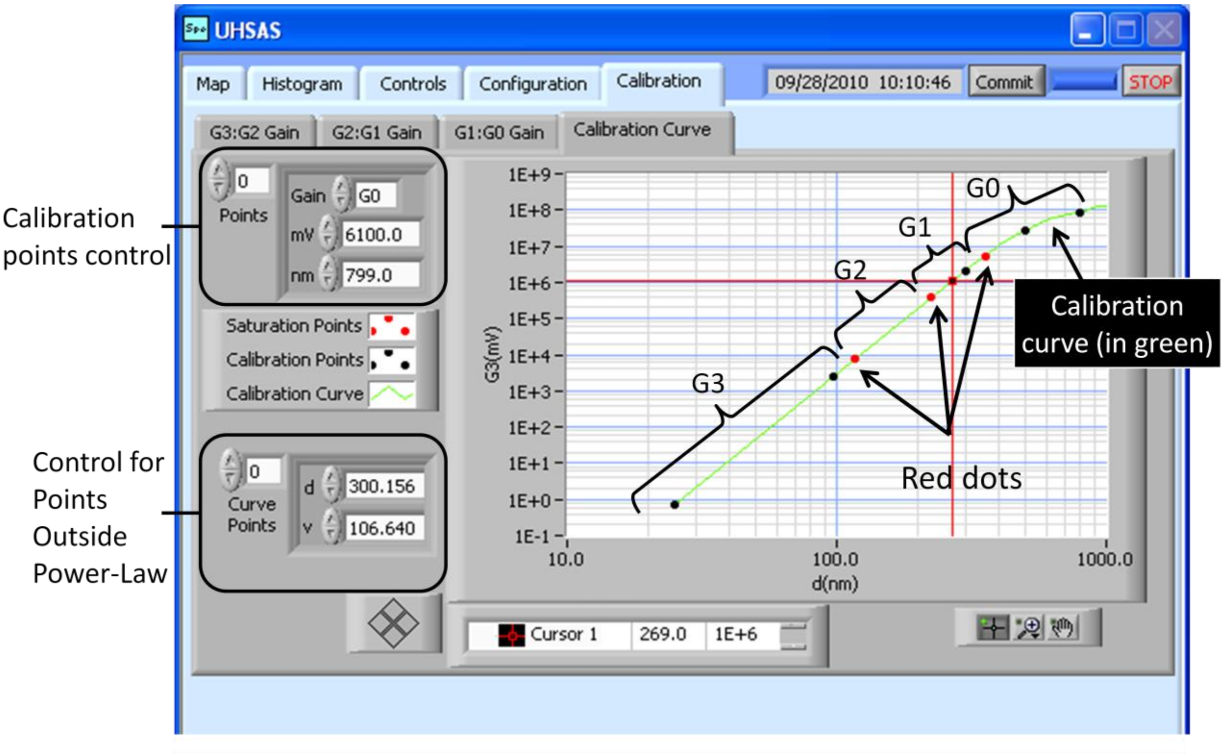
13.0 Calibration Tab

This tab performs the calibration functions of the instrument. It is only accessible when the user has logged on via the **Configuration** tab and the system is in calibration mode. There are several sub-tabs on this tab, which are described in the following sections.

For the theory behind the calibration process and step-by-step instructions on calibrating the instrument, see Section 5.0.

13.1 Calibration Curve Sub-tab

This tab shows the instrument's calibration curve. This curve converts the signal sizes in mV into the voltages as they would appear on the highest gain stage (G3). The different parts of the calibration curve sub-tab are shown below.



09/28/2010 10:10:46

Points 0

Gain G0

mV 6100.0

nm 799.0

Curve Points 0

d 300.156

v 106.640

Cursor 1 269.0 1E+6

Figure 29: Calibration Curve Sub-Tab

13.1.1 Calibration Points Control

The points control specifies the reference calibration particles and their signal sizes. The points control is an array of triplets consisting of the following data:

1.) **Gain**, the gain stage on which the particle signal appears
2.) **mV**, the signal size in mV of the particle signal
3.) **nm**, the size of the particle in nm.

The **Points** field lists the element in the array that is currently being displayed. The array begins with element zero. In Figure 29, the Calibration Points control is displaying element (point) zero.

The number of reference particles determines the length of the array. At least one point needs to be specified to calibrate the unit. This is normally the NIST 100 nm SRM, which appears as ~4000 mV on G3. Any number of reference particles can be used to calibrate the instrument. For instructions on how to measure particles and enter calibration points see Section 5.0. The cal-curve will be interpolated between reference points in log-log space.

13.1.2 Calibration Curve

The calibration curve is shown in green on the graph. The x-axis of the graph shows particle size in nm, while the y-axis shows the instrument response in millivolts as it would appear on the highest gain stage (G3).[2]

The curve is determined by both theoretical and empirical means. On a theoretical level, the power-law relationship (hard-coded into the system) and Mie curve (entered in the control described in section 13.1.3) determine the basic curve. The power-law relationship determines the curve for particles smaller than 200-300 nm, while the Mie curve determines points for larger particles. This theoretical curve is then fitted to empirical data points entered into the **Points** control. These points are shown in white on the graph.

The region covered by each gain stage is indicated by the red dots on the graph. The red dots are the saturation levels of each gain stage—i.e., the largest particles measureable on each gain stage. For example, the region below the first red dot is covered by G3, the region between the first and second red dots is covered by G2, etc.

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[2] Note that the signal size of large particles is on the order of 10^6 mV on G3. Of course, these particles are measured on other gain stages with significantly less overall gain.

As noted above, the calibration points (white dots) provide the absolute calibration of the instrument: they move the curve up and down appropriately to convert voltage on various gain stages to particle size. There are two white points fixed by the instrument—one at 10 nm, and one at 300 nm. Unlike the other calibration points, these are not absolute references. They simply define the region of the instrument described by a power-law curve. They are used for forward and backward extrapolation of the curve from the real calibration points. For example, if the user supplies one calibration point, say at 100 nm, then the 10 nm point will be used to extrapolate a power-law curve downward from 100 nm and the 300 nm point will be used to extrapolate a power-law curve upward from 100 nm.

The red cursor can be moved to see specific x and y coordinates on the curve. These appear as numeric values in the white field beneath the graph.

13.1.3 Control for Points Outside the Power-Law

Above 300 nm, the calibration curve is defined by the calibration points specified in the lower left-hand corner of the screen. This is an array of points which specifies the relative signal size of particles above 300 nm. It is used to specify the *shape* of the calibration curve outside of the power-law response region. More precisely, it specifies the Mie curve of signal size (v) versus particle diameter (d) on the lowest gain channel (G0). The diameters specified are absolute in nm, and the signal size is specified as a relative number. This is the only gain stage that can be set to something other than a 6th power law.

The **Curve Points** field lists the element in the array that is currently being displayed. The array begins with element zero. In Figure 29, the control is displaying element (point) zero.

13.2 G3:G2 Gain, G2:G1 Gain, G1:G0 Gain (the Relative-Gain Sub-tabs)

These tabs are used to perform gain-ratio operations. The graphs show the gain and offset calculated from the sampled data points (Figure 30). This gain and offset, along with the calibration points, are then used during bin-map commitment to provide a seamless transition between gain stages.

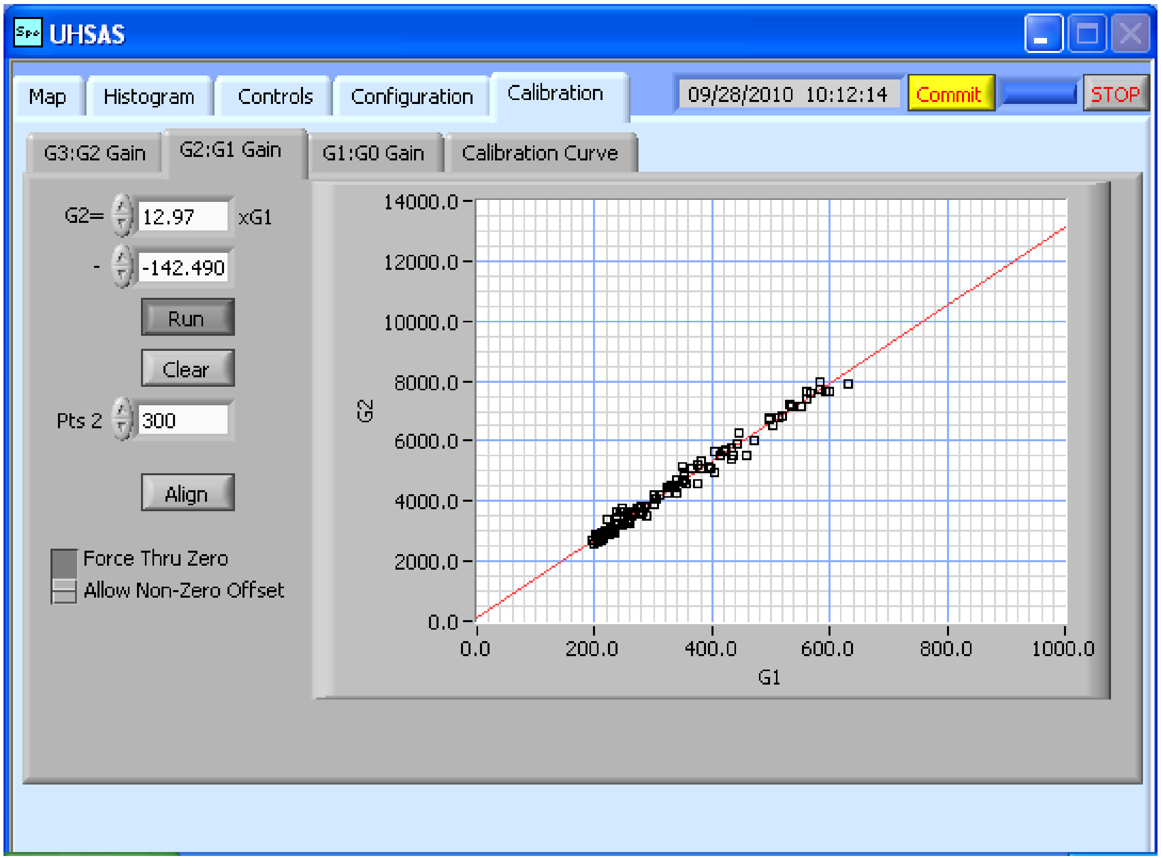

Figure 30: A Relative Gain Sub-Tab

The **Clear** button clears out old data if users have made adjustments.

The **Run** button initiates relative-gain calibration. The process will continue until the user presses the **Run** button again or until the instrument has processed the number of particles stipulated in the **Pts** control.

The **Pts** control sets the number of particles the UHSAS processes before relative-gain calibration is complete.

The **Align** button, visible only on the **G2:G1** tab, is not used.

The switch in the bottom left of the screen indicates whether the gain-ratio function should be forced through the (0,0) point. Typically this control should be set to “Allow Non-Zero Offset.”

For step-by-step instructions on relative-gain calibration, see section 5.2.2.

Appendix A: Output File Data Channels

The UHSAS data file is an .xls file. For each sampling period, the file records the channels listed below. Sampling periods are listed in rows, while data channels are listed in columns.

Date: The current date in mm/dd/yyyy format.

Time: The time at which the current sample began.

Accum. (sec): The current sample time setting, i.e. the number of seconds during which the sample accumulates counts.

Scatter (Volts): The background DC molecular scatter level from the APD, which is typically around 1.5 – 2.75 V. If this drops by 25% or more, the laser optics may need to be cleaned.

Current (Volts): The current being supplied to the instrument.

Sample (sccm): The flow of the sample air, which should be between 1 and 100 sccm. The instrument is factory calibrated at 50 sccm, so this is a good sample flow setting.

Ref. (Volts): The laser reference voltage from the monitor photodiode. Ideally, this voltage should be between 2.25 and 2.75, although the instrument typically works as long as the reference value is .9 – 3.1 V. If the reference voltage drops by 25% or more, the laser optics need to be cleaned.

Temp (Volts): The voltage from the temperature sensor.

Sheath (sccm): The flow of the sheath air, which is typically 700 sccm.

Diff. (Volts): Not used.

Box (K): The temperature of the electronic box, i.e. the temperature just as the sample enters the instrument.

Purge (sccm): The flow of the purge air. The purge flow is used to keep the laser optics clean.

Pres. (kPa): The ambient pressure.

Aux. (Volts): Not used.

Flow (sccm): Not used.

After these channels, the file lists the particle counts for each bin. The bin boundaries appear in the header of each column.

Appendix B: Revisions to Manual

Rev. Date	Rev No.	Summary	Section
10-2-09	A	Reformatted sections and figures; inserted title page, TOC, and legal disclaimer	All
10-14-09	B	Omitted BOM and Schematics Appendix	Appendixes
		Changed/reformatted headings in calibration section	5.0
4-12-10	C	Updated manual generally Revised software sections Updated laser safety information	All
8-30-10	C-1	Revised specifications	1
10-12-10	D	Updated screen shots to reflect new software, updated data path names	All
11-10-10	E	Revised acceptable values for Scatter Volts	Appendix A
		Provided timeline for troubleshooting tasks	6.2