



SP2-XR

Single Particle Soot Photometer - Extended Range

Operator Manual



2400 Trade Centre Avenue
Longmont, CO 80503 USA
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Specifications

Specification are subject to change without notice.

1.1 General Specifications for the SP2 XR

Measured Parameters	<ul style="list-style-type: none"> • Laser (Nd:YAG Laser: 1064 nm) incandescence by single-particle • Light scattering by single-particle
Derived Parameters	<ul style="list-style-type: none"> • Refractory Black Carbon mass • Particle number • Optical Particle Size
Particle Size Range	<ul style="list-style-type: none"> • Scattering signal: 100 – 500 nm optical diameter • Incandescent signal: 50nm – 800 nm mass-equivalent diameter assuming a black carbon density of 1.8 g/cm³
Maximum Data Acquisition Rate	<ul style="list-style-type: none"> • 50,000 particles / cm³ • 10% coincidence at 3,000 Particles/ cm³
Sample Flow Required	30 – 120 volumetric cm ³ /minute user programmable
Sample Inlet Pressure Range	400 mbar – 1013.25 mbar (1 atm)
Sample Temperature Range	0°C to 40°C (32° - 104°F)
Operating Temperature Range	0°C to 40°C (32° - 104°F)
Storage Temperature Range	-20°C to 50°C (-4° - 122°F) non-condensing
Operating Humidity	5 to 95% non-condensing
Data Storage Capacity	400GB – 15 days of continuous data storage with nominal sample concentration of 1,000 particles / cm ³ and a standard flow rate of 100 volumetric cm ³ /minute.

1.2 Electrical Specifications

Power Requirements:	<ul style="list-style-type: none"> • 90 – 230 / 50-60 Hz with DMT supplied power supply • 18-36VDC, (24V Nominal) with direct power connection: <ul style="list-style-type: none"> ○ Power connector is part number RT00104PNH and it mates with RT06104SNH ○ Power surge protection is highly recommended
Power Consumption:	25 W typical / 85 W maximum
Backup Battery Capacity	10.24Wh
Front Panel Connections	VGA and HDMI monitor ports, Two Ethernet ports, 2x USB 3.0 ports, and 2x USB 2.0 ports. 1/8 in. Swagelok® sample connection line, 1/4 in. Swagelok® exhaust line, fan inlet.

1.3 Recommended Maintenance

Weekly Routine Maintenance:	Conduct PSL size check to verify calibration
Monthly Maintenance (and around field campaigns):	Conducting zero check with high-efficiency filtered air sample.
Annual Maintenance and Recommended Service	Annual cleaning and calibration at a DMT certified service facility under normal operating conditions, may need service on a more frequent basis depending on type of environment where the instrument is being used.

1.4 Physical Specifications

Weight:	13 Kg (28.5lbs) for SP2-XR Instrument
Dimensions:	21 cm W x 21 cm H x 42 cm L (Actual) Not including inlet hardware and fuses.
Shipping Container:	61 cm W x 35.5 cm H x 63.5 cm L (Actual) 32.3 Kg (69 lbs.)

General Information

In no event will Droplet Measurement Technologies, LLC (DMT) be liable for direct, indirect, special, incidental or consequential damages resulting from any defect or omissions in this manual.

DMT reserves the right to make changes to this manual and the products it describes at any time, without notice or obligation. Revised editions are found on the manufacturer's website.

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1.5 Safety Information

Laser Safety

The SP2-XR is a Class 1 Laser Product when fully enclosed. Removing the outer enclosure, or the power monitor will expose a Class IIIB laser, 1064 nm, with power of approximately 200 mW. Disassembly of the pump laser can expose a Class 4, 808 nm with power up to 3W. Lasers in this category can cause permanent eye damage with exposures of 1/100th of a second or more depending on the strength of the laser. A diffuse reflection is generally not hazardous but specular reflections can be just as dangerous as direct exposure. Protective eyewear is recommended when direct beam viewing of this class of lasers may occur. Lasers at the high-power end of this class may also present a fire hazard and can burn skin.

CAUTION – Use of controls, adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure. Strict observance of the following Warning labels is advised.

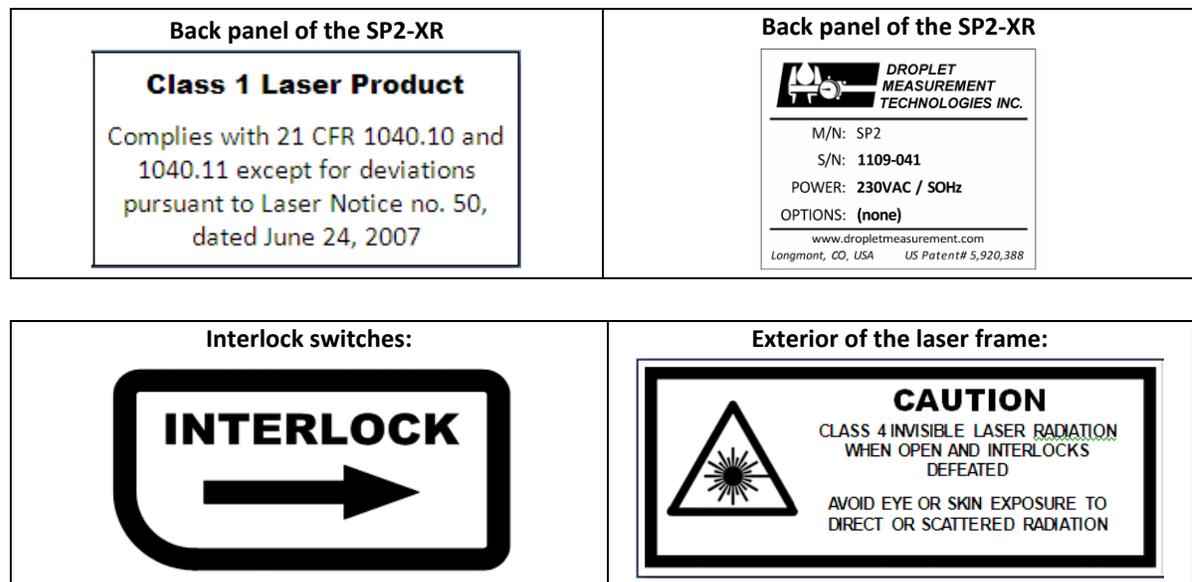


Figure 1: SP2-XR Labels

1.6 Interface Features

The SP2-XR input and output features are shown in Figure 2 below

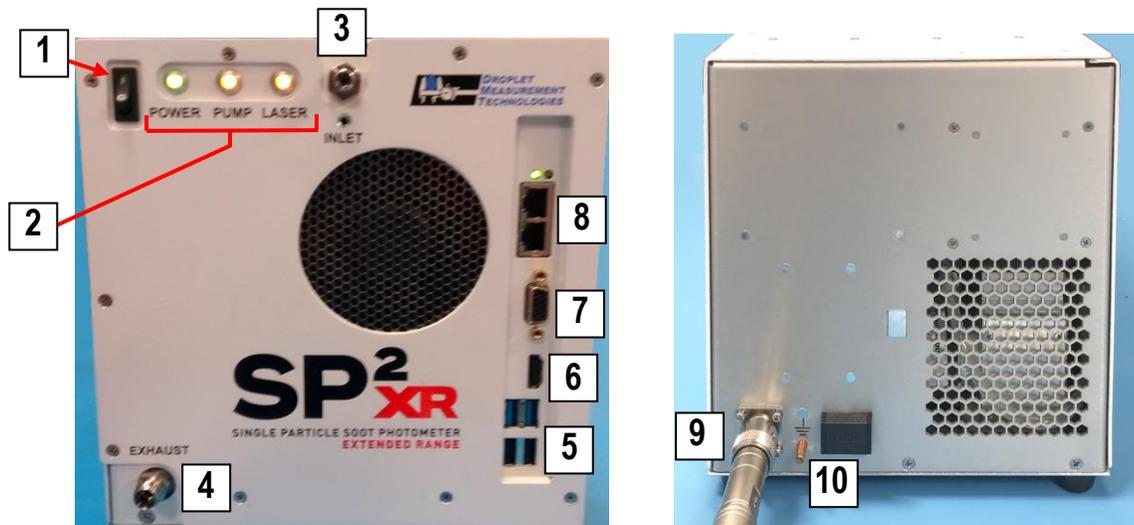


Figure 2: Front and Rear view of the SP2-XR

1	Power switch	6	HDMI Port
2	Function indicators	7	Monitor Port (VGA)
3	Inlet flow (remove plug prior to power-up)	8	Ethernet ports
4	Exhaust flow (remove plug prior to power-up)	9	24 VDC power connection
5	USB 3.0/2.0 ports	10	Optional Ground/Fuse drawer

1.7 Brief Theory of Operation

The Single Particle Soot Photometer (SP2-XR) utilizes a high optical power intracavity Nd:YAG laser to interrogate particles, which both scatter light and absorb energy. The system captures the peak scattered light signals that are generated for each particle. These signals are used for particle sizing, since the amount of light scattered correlates strongly with particle size.

Light-absorbing particles, mainly refractory black carbon (rBC), absorb energy and are heated to the point of incandescence. The energy emitted in this incandescence is measured, and a quantitative determination of the rBC mass of the particle is made. This mass measurement is independent of the particle mixing state, and hence the SP2-XR is a reliable measure of the black carbon mass concentration. Since the SP2-XR detects single particles, the SP2-XR also measures the black carbon mass concentration.

All particles scatter light, regardless of whether or not they incandesce. A scattering detector is included in the SP2-XR, which detects single particle scattering at 1064 nm. The scattering detector can be used to detect non-BC-containing aerosol number and optical particle size.

The SP2-XR uses a sample flow controller to control the flow rate of aerosol sample pulled into SP2-XR. The sample is drawn through the sample inlet and then injected into the optical cavity and surrounded by the recirculating sheath flow air system to ensure that the particles are directed through the laser beam. This enables the system to sample each individual particle in the sample stream.

A single particle scattering measurement is made and a determination as to whether the scattering measurement represents a particle is made. Subsequently, if the particle is Black Carbon, it will absorb the energy from the high optical power intracavity Nd:YAG laser and then incandesce; this is measured along with a determination as to whether the incandescence represents a particle. Figure 3 shown below details the flow system.

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, collects the incandescence, 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

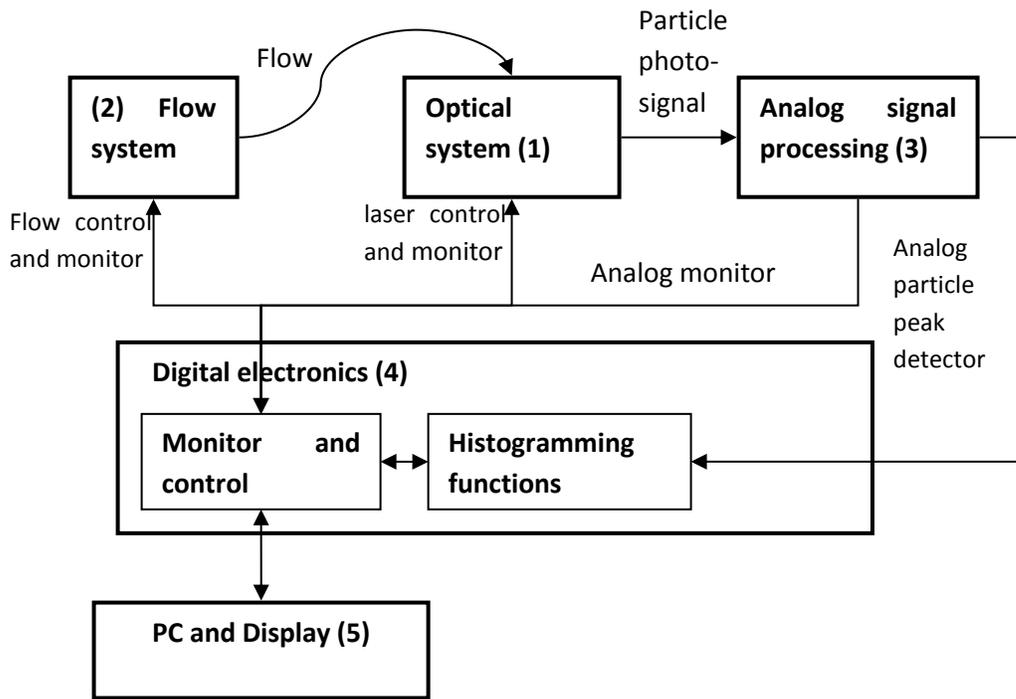


Figure 3: Block Diagram of the SP2-XR

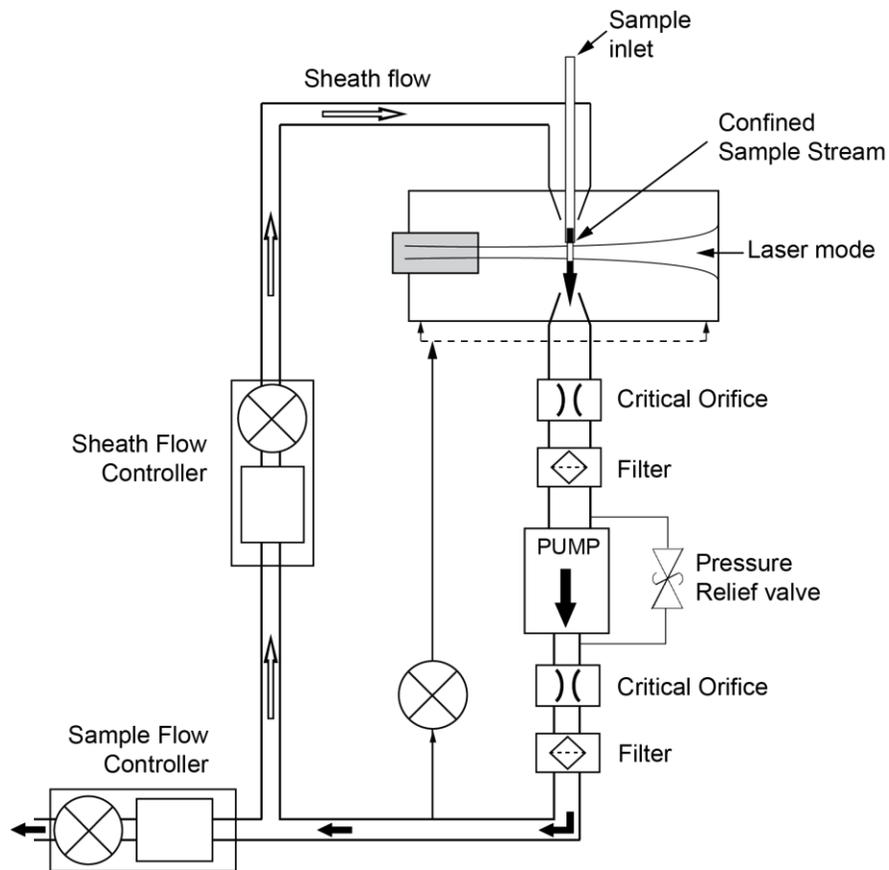


Figure 3: SP2-XR Aerosol Flow

Once the sample passes through the optical cavity it will flow through several filters and then either be used as make-up air for the sheath flow, or it will be ejected through the outlet of the SP2-XR depending on the setting for the sheath flow.

Refer to Appendix A for an expanded discussion on the Theory of Operations.

Introduction

Black carbon or soot particles are ubiquitous in the atmosphere and are emitted by combustion processes. They play a major role in climate forcing by absorbing solar radiation and re-radiating the energy as heat. In addition, black carbon aerosol from open air cooking, contributes to over 4 million deaths worldwide (World Health Organization). Accurate measurements of black carbon particle concentration and temporal and spatial variability are essential for estimating their radiative effects in the atmosphere as well as their effects on human health.

The Single Particle Soot Photometer-Extended Range (SP2-XR) directly measures refractory black carbon (rBC) in individual particles. It uses the same laser-induced incandescence technology as the DMT SP2-D, but with a modified optical design that allows it to be better suited for long-term monitoring applications. In addition to a smaller footprint, the software and firmware included with the SP2-XR provides final data output in real time without the need for two pass processing.

The SP2-XR utilizes a high optical power intracavity Nd:YAG laser. Light absorbing particles, mainly rBC, absorb energy and are heated to the point of incandescence. The energy emitted during incandescence is measured and a quantitative determination of black carbon mass of the particle is made. This mass measurement is independent of the particle mixing state, and hence the SP2-XR is a reliable measure of the black carbon mass concentration. Since the SP2-XR detects single particles, this highly sensitive instrument is ideal for monitoring in remote environments.

○ 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.

The Laser

The laser is a semiconductor-diode-pumped Nd³⁺:YAG solid-state laser. It operates in the fundamental (TEM₀₀) spatial mode on a 1064 nm laser line with an intra-cavity power of ~1 kW. The pump laser is a temperature-controlled 1 W single-stripe diode at 808 nm, driven by a stable current source. The Nd³⁺:YAG laser is a high quality factor optical resonator built around an Nd³⁺:YAG 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. Particle scatter is collected in a direction perpendicular to both the particle flow and the laser standing-wave; see Figure 4 and **Error! Reference source not found.** for side and top views of the optical block.

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 particle sizing signal. The other pair, the incandescence detection system, images onto a PMT module. The two detection systems are located on the opposite sides of the optic 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 50 nm and 1-10 counts/minute at a zero-count rate in the incandescence channel and 100nm and 1-10 counts/minute at a zero-count rate in the scattering channel. 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 transimpedance 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.

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 4: Side View of Optical Block

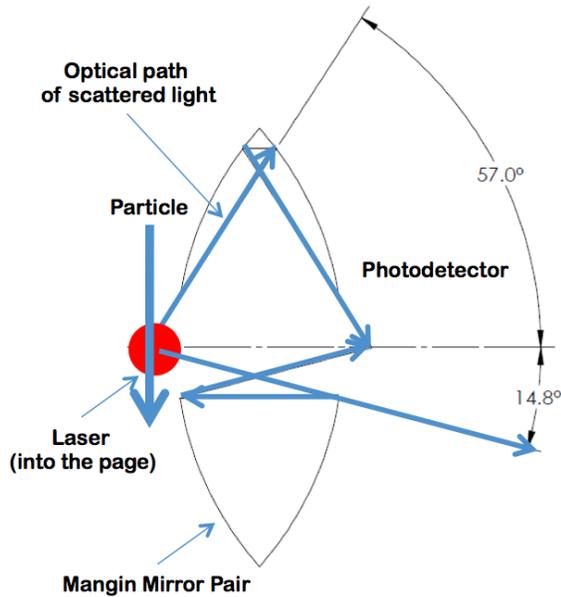
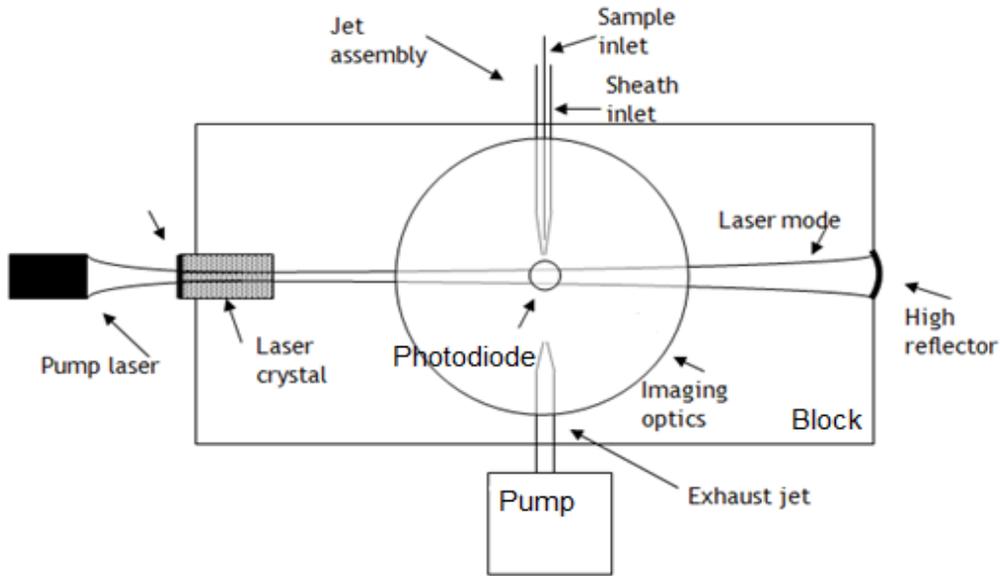


Figure 5: Light Collection Angles

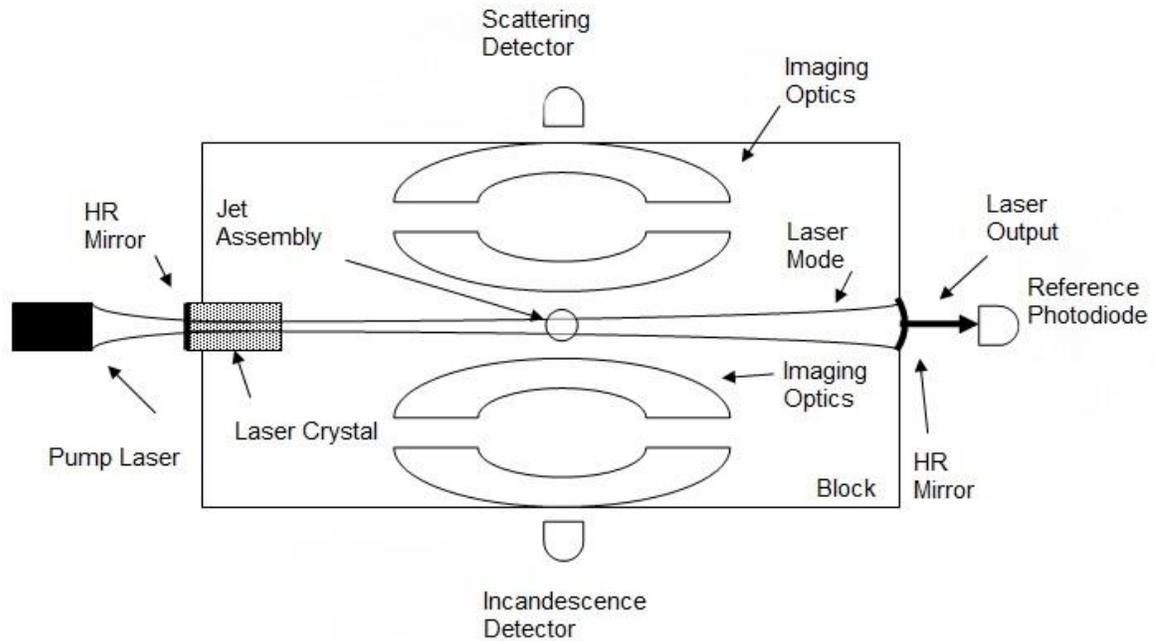
Figure 4 and Figure 5 show two views of the optical cavity. Figure 4 shows the general layout of the aerosol inlet, placement of the solid state laser and particle stream with respect to the mangin mirror pair.

Figure 5 shows the optical path of light collected from scattering by particles that pass through the laser. The detector is located at 90° to the path of the particle through the laser. (The laser can be

envisioned as shining into the page.) The mangin mirror pair collects the scattered light over solid angles of $90^\circ \pm 57^\circ$ ($33^\circ - 147^\circ$), excluding the angles subtended by the circular opening of the mangin mirrors $90^\circ \pm 14.8^\circ$ ($75.2^\circ - 104.8^\circ$).

For the purpose of calculating scattering cross sections with Mie scattering, the collection angles are $33^\circ-75.2^\circ$ and $104.8^\circ-147^\circ$.

The Figure below shows a top view of the optical block:



Unpacking, Setup, Installation, and Power Up

1.8 Unpacking

The SP2-XR is shipped in a case specially designed to fit and protect the contents of the shipment. This case should be saved and used to return the instrument to DMT if service is needed.

The shipment also includes:

- Calibration Documents
- Toolkit
- Alignment Tools
- Benchtop power supply with regional adapters and aircraft power integration cable
- Zero count filter

Check all contents for damage immediately upon receipt and notify the carrier and DMT if any damage is noted.

1.9 Installation

The SP2-XR is shipped with a benchtop power supply (including regional adapters) and an aircraft power integration cable. If using in a laboratory setting, simply follow section 1.10 Setup to proceed.

If using in a mobile setting and/or on an aircraft, care must be taken in mounting the SP2-XR. See Appendix G: Mounting Information to ensure that you take care to mount the SP2-XR properly.

In all cases, good practice and care must be exercised to ensure that the aerosol losses in the sampling system are minimized; including minimizing sample tubing length, ensuring that any inlet that is used is conductive and basic sampling theory is followed.

1.10 Setup

1. Connect the SP2-XR power cable, either remote power or the provided power supply.
2. If using the provided power supply, plug in the appropriate region's adapter. The optional ground is generally used to protect the instrument in an aircraft.

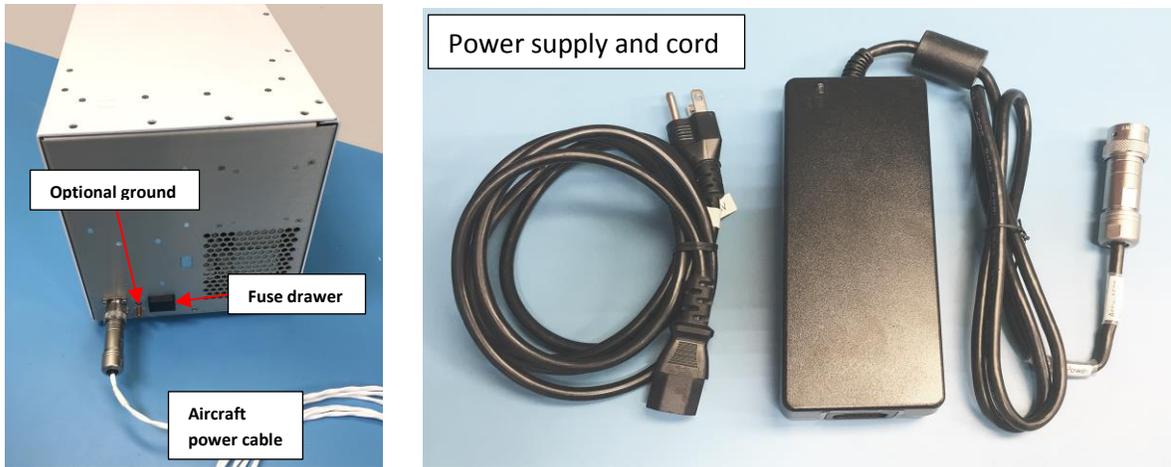


Figure 4: SP2-XR Power Connections and Cables

3. There will be a plug on the inlet and exhaust tube, be sure to remove it before powering up the instrument.

NOTE: The SP2-XR computer is intended for running the software for the SP2-XR instrument. Installing and running additional programs on the computer, including Anti-Virus software, may compromise the performance of the system.



WARNING: If not properly grounded, the instrument can cause an electrical shock. Use a three-conductor cord and a plug appropriate for the location in which the instrument will be used. Connect the plug to a properly grounded receptacle. Be sure to use power-surge protection for your instrument.

4. Power-up the SP2-XR using the **System Power** switch located on the front panel.



Figure 5: SP2-XR Power Switch



5. Start the SP2-XR software by double-clicking the SP2-XR icon on desktop.
6. In the software, go to the **Actions** dropdown menu in the upper left-hand corner of the screen **(A)** or use the indicator buttons **(B)** (Figure 6).

- Click **Start Pump** and wait until the pump can be heard running.

WARNING: Pump must be activated before the laser is turned on.

- Once the pump has started and the sheath air and sample flows are stable, it is safe to toggle the **Laser On**.

NOTE: If the Laser is on and the pump has been turned off, the pump will be prevented from being re-activated until the laser is turned off. Turn off the laser then the pump can be activated.

CAUTION: Make sure the case fans (front panel), and laser cooling fan (underneath) have adequate ventilation. Failure to do so may result in damage to the instrument.



Figure 6: SP2-XR Screen with Actions Tab

1.11 Powering the System Down

- On the SP2-XR software's **Actions** tab (Figure 6) toggle **Laser Off**.

WARNING: Laser Power must be turned off before the pump is turned off.

- Click **Stop Pump**.
- Shut down the SP2-XR software by selecting **File > Exit**.

4. Turn off the SP2-XR instrument by shutting down the computer then using the **System Power** switch located on the left front corner of the unit.

NOTE: *Shutting down the computer does not supplement shutting off the front power switch and shutting off the front power switch does not supplement shutting off the computer. Both must be done to ensure a proper shutdown.*

SP2-XR Software

There are two software levels within the SP2-XR software suite.

- The basic software for control of the instrument: setting flows, visualization of operation, and recording of data is not password protected.
- In the System Settings tab, there is the administrator login window. Entering the administrator password, gives access to the acquisition settings in the single particle tab and config tab. These settings can be dynamically changed to observe the impact on particle acquisition. Any changes made here will not be saved in the .ini file.

These programs are loaded on the C: drive of the SP2-XR and a backup copy is provided on the memory stick shipped with the unit.

In addition, the software to run the camera (vBeam) is installed on the C: drive of the SP2-XR. Please refer to section 1.23 to operate this software.

1.12 Output Data file types

SP2-XR software functions with several different types of files used for data output, a description of these files includes:

- **.INI** – Configuration file – The system settings for the SP2-XR. Each time the program starts, the .ini file is read and those settings are applied to the instrument.
- **PBP .CSV** – Information on the individual peak heights for the particles and measurement times.
- **HK .CSV** – Setpoints, housekeeping and binned particle data recorded at 1 Hz.
- **.SP2b** – Particle by particle data capturing the full signal trace for scattering and incandescent particles. The data is automatically zipped when the preset number of particles is captured.
- **Threshold data files .CSV** – Relates the A/D particle signal counts to the particle size/mass. These tables are developed by the SP2-XR calibration program.

1.13 SP2-XR Quick-Start

When the SP2-XR.exe program is first opened, the main SP2-XR screen will appear with a histogram plot detailing measured particles on the left and time-series plots for recorded parameters on the right (Figure 7). Each of the tabs along the top will bring up a new screen allowing for instrument control or display of parameters.

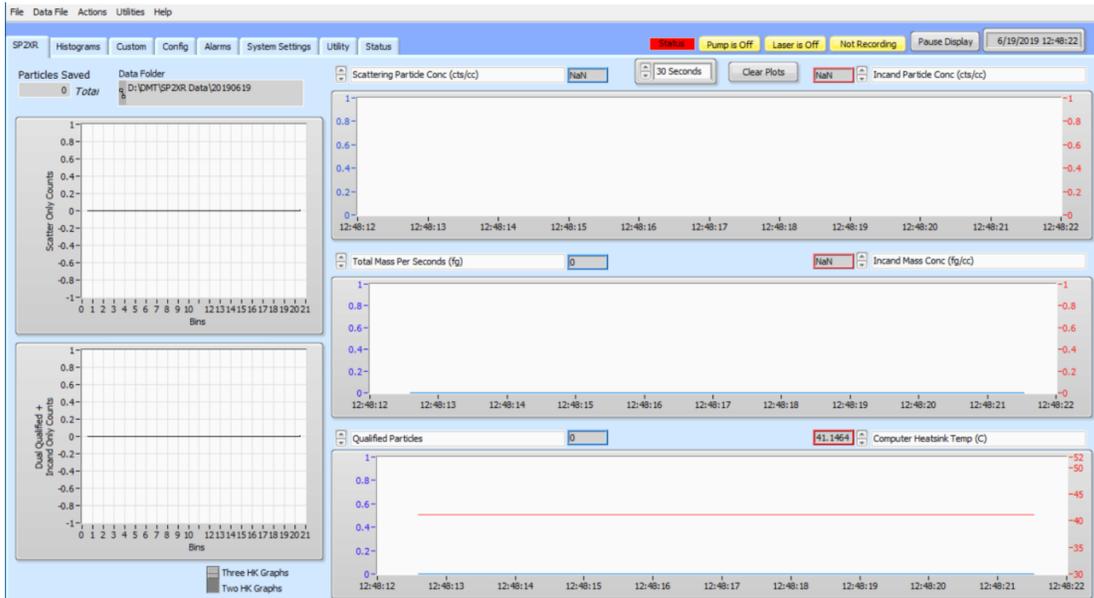


Figure 7: SP2-XR Default Screen

- First, go to the **Config** tab (Figure 8) and make sure that the correct config file is chosen. If the config file is incorrect, instructions for choosing which config file can be found in section 1.17.

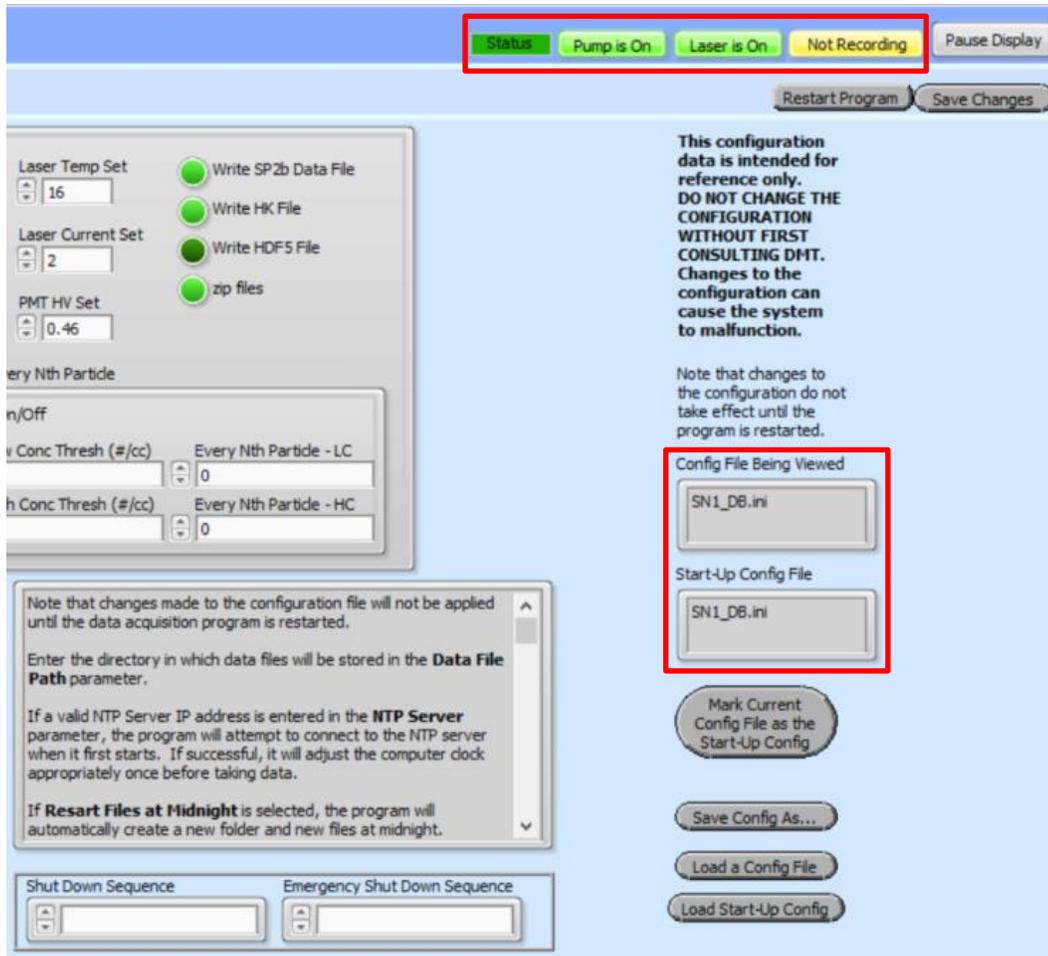


Figure 8: Check the Config file and Status

- Start up the instrument as detailed in section 1.10. ****Start Pump → Laser On****
- Check the status bar in the upper right to make sure the pump and laser are on and running.
- Go back to the Main SP2-XR tab (Figure 9) and set parameter (A) to **“Sample Flow Controller Read, VCCM”**.
- Other parameters can be chosen by using the up and down arrows to the left of the displayed parameter names. Clicking the parameter name will open a drop-down menu with a list of all displayable parameters. A full description of these parameters can be found in Appendix E **“Housekeeping Data files”**.

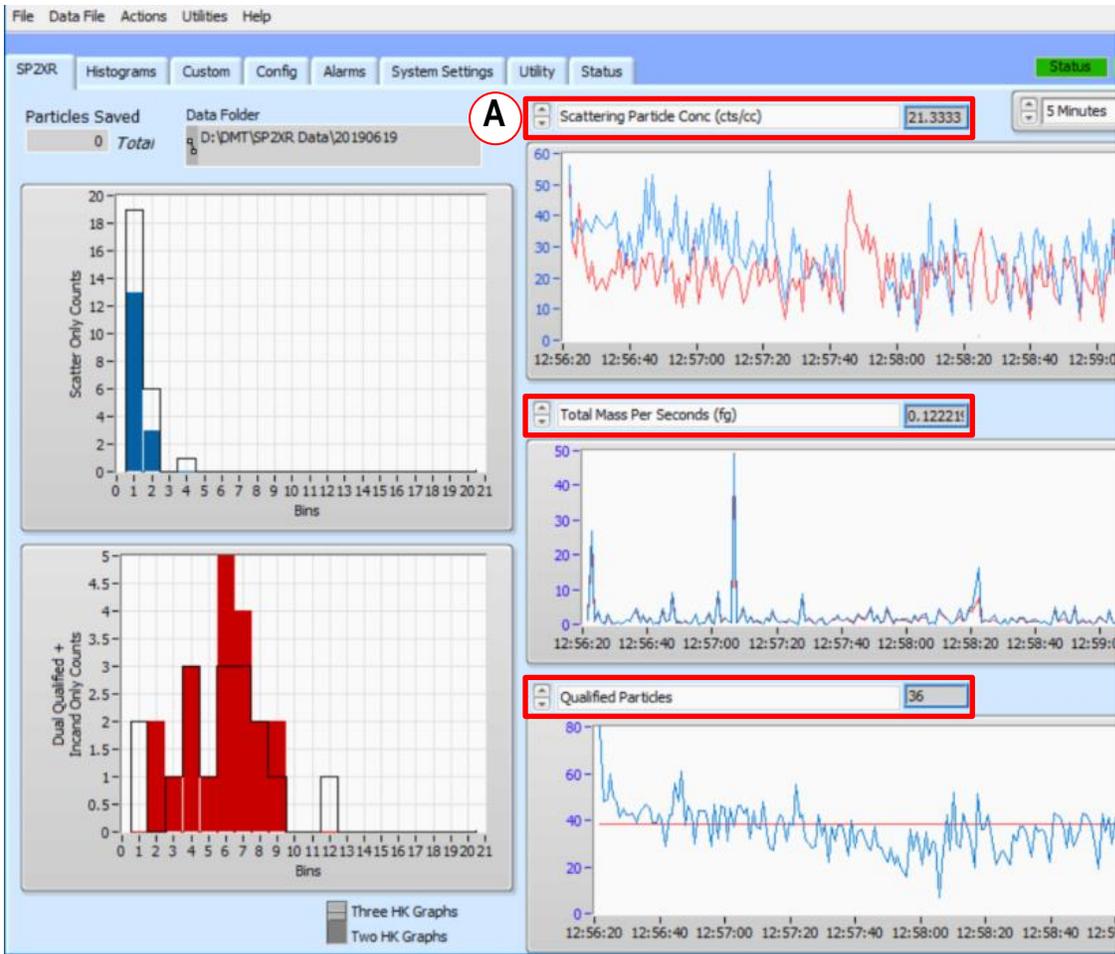


Figure 9: Choosing parameters

By default, the x and y axis of the plots will auto scale as data is collected.

Figure 10 shows the **File** dropdown menu. It is used to save a Configuration file, restart the program, save the current screen as a .jpg, or exit the program. This is the preferred way to close the program as the configurations and files will be saved properly.

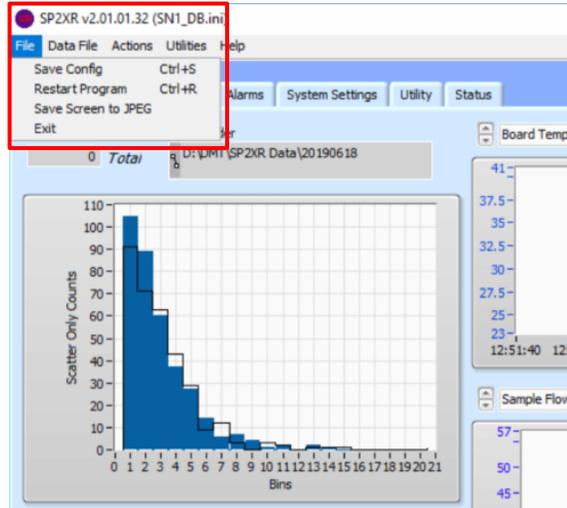


Figure 10: File tab

To start recording data, choose the **Data File** dropdown menu and **Start Recording** (see Figure 11). The **Recording/Not Recording** button in the status bar shows whether or not data is being written to a file. The data file path will be shown in the **Data Folder** box on the upper left of the SP2-XR tab.

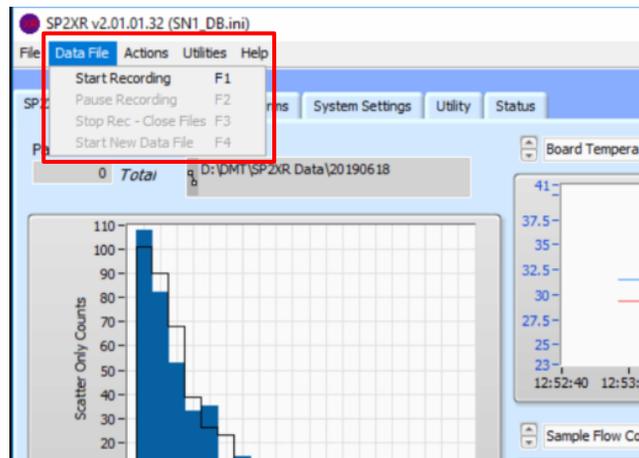


Figure 11: Data File tab

1.14 SP2-XR Main Screen

The following section details the SP2-XR main screen (Figure 12).

- Box **(A)** shows the data file path, as well as the number of particles saved to the file.
- Box **(B)** shows the housekeeping time series plots. The time series displayed is configurable at points **(1)**. The middle plot can be hidden or shown by using the toggle **(2)**.
- The Pause Display toggle **(C)** will pause the data visualization display for closer inspection of a particular data event or to save a screen capture of the event.

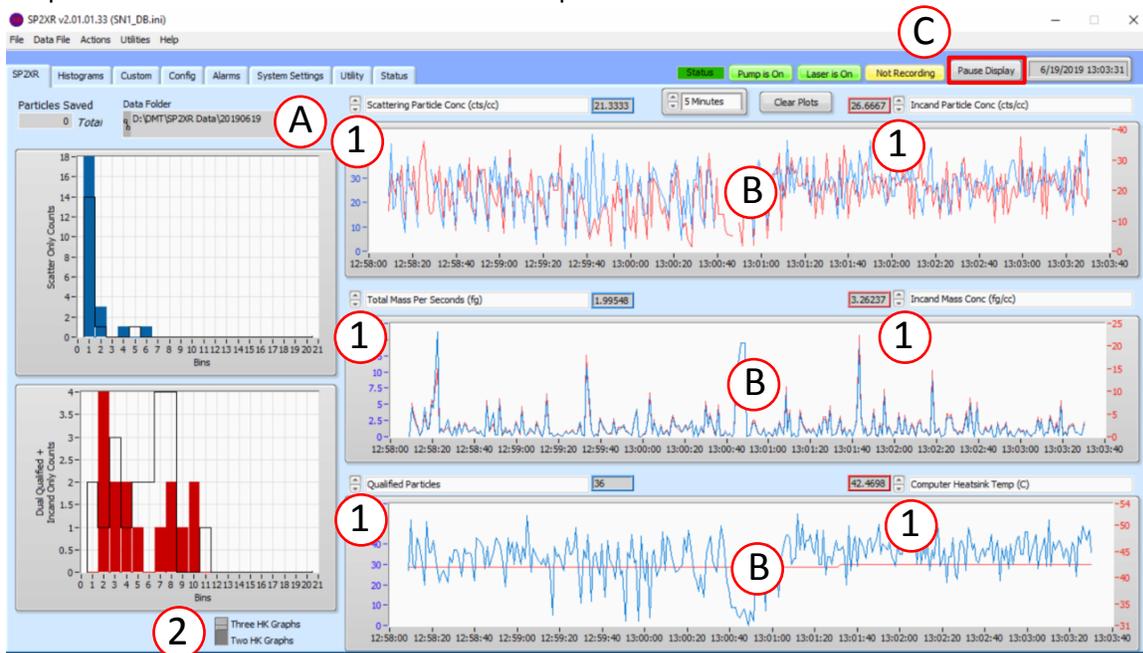


Figure 12: SP2-XR Main Screen

1.15 Histograms Tab



Figure 13: Histograms window: Scatter (blue) and Incandescent (red)

The Histograms tab (Figure 13) shows plots of particle diameter versus scattering counts and particle mass versus incandescence counts. These numbers are obtained from threshold tables. The total number of qualified **total particles per sample period** are recorded in the top right field (A). Histogram parameters:

- **Norm:** This button will normalize the histogram display.
- **X Mode:** This setting allows the user to change the x-axis labels between numbered size “bins” and the actual measurements.
- **Graph:** This setting allows the user to change the y-axis labels between “counts” or concentration in particles per cubic centimeter.
- **Cumulative:** This button is used to accumulate multiple sample periods in the histogram. The number of samples accumulated is set in the “# Samples” box.
- **# Samples:** This is the location for the user to select the number of sample periods to be accumulated when “Cumulative” mode is active.
- **Cursors:** There is a cursor on each plot that can be dragged to get the exact x and y coordinates of a specific bar’s peak. The coordinates are displayed in the cursor box.
- **Auto Scale:** By default, the x and y axis of the plots will auto scale as data is collected. The user can turn the auto scale off/on by right clicking on the axis and clicking the “Auto Scale X/Y” option. Once the auto scale is turned off, the user can adjust minimum and maximum values of the graph by clicking on the labels and entering the desired value.

1.16 Config Tab

The **Config** tab (Figure 14) contains settings that are part of the .ini file and are only editable if the administrator software password is entered. Upon opening the window, all data input locations will be greyed out. If any changes are made in the config tab, the .ini file must be saved or a new one created for changes to take effect.

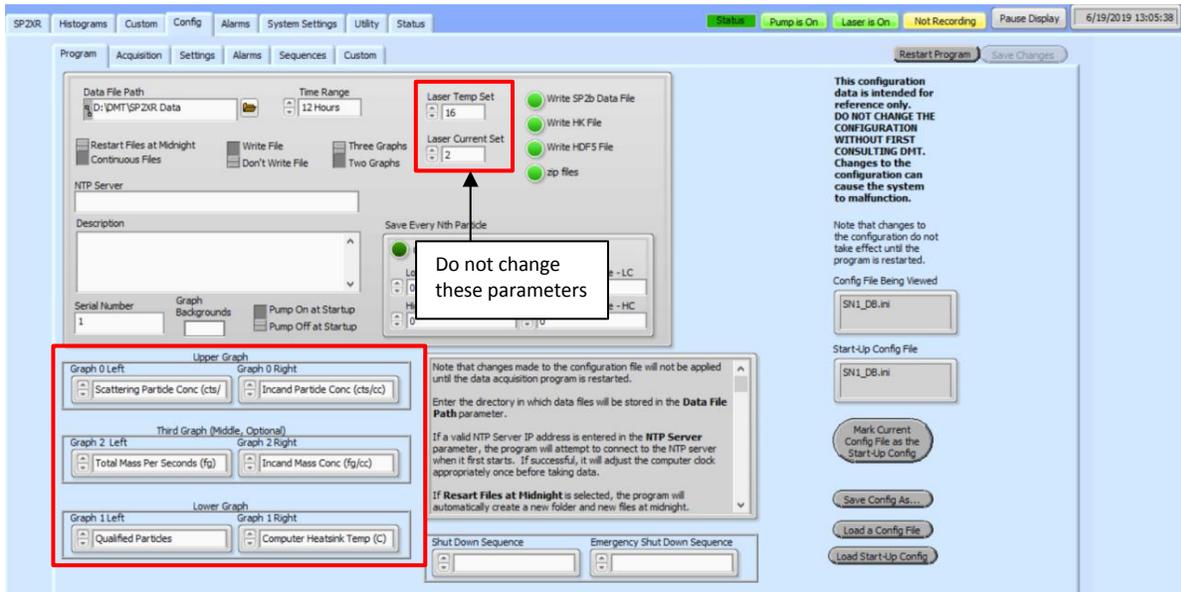


Figure 14: Config / Programs tab

The Program tab has default parameters that are set up for instrument operation.

- **Restart Program/Save Changes:** These buttons are used to save changes to the configuration file being viewed and restart the program so changes can take effect. When the program is restarted, new data files must be started and all housekeeping plots will reset.
- **Data file Path:** The SP2-XR software is stored on the C: drive. Any files saved to the C: drive will be deleted upon instrument shut down. Data should be stored on the D: drive or an external drive.
- **Time Range:** Changes the default length of time displayed on the housekeeping plots.
- **Restarted files at Midnight/Continuous files:** Toggle to either record one continuous file set, or start a new folder and file at 12:00AM.
- **Write File/Don't Write File:** If Write File is selected the unit will start recording housekeeping files automatically when powered on. The sample pump and laser will not start automatically.
- **Three Graphs/Two Graphs:** Toggle the default number of housekeeping plots in the SP2XR tab. The box below allows the user to set the default parameters displayed on each plot.
- **NTP Server:** If a valid server address is entered in the field, the program will attempt to connect to the NTP server when it first starts. If successful, it will adjust the computer clock appropriately before taking data.

- **Save Every Nth Particle:** If the size of the recorded data files is a concern, and there is not a need to see every packet of particle data, this parameter can be set to read and record only the Nth particle data.
- **The Description Box:** Allows the user to save additional information about the configuration files or any notes helpful to operation.
- **The Parameters:** Laser Temp Set and Laser Current Set are operationally critical defaults and should not be changed without consulting Droplet Management Technologies prior to making those changes.
- **Graph Backgrounds:** Allows the user to change the default background color of the time-series plots.
- **The Data File Type:** The data file types can be selected by clicking the green indicator lights next to the file type. The maximum number of particles per **.HDF5** can be entered above.
- **(Emergency) Shut Down Sequence:** Allows the user to define a sequence to follow upon shut down or in case of emergency shut down.
- **Config File Information:**
 - The file being **Viewed** is the file last read from/written to
 - The **Start-Up** file is the config loaded upon instrument start up
 - **Mark Current Config File** button allows the user to make the current config the default config.
 - The buttons below allow the user to save the config as a new file or load a config file

Config / Acquisition Tab

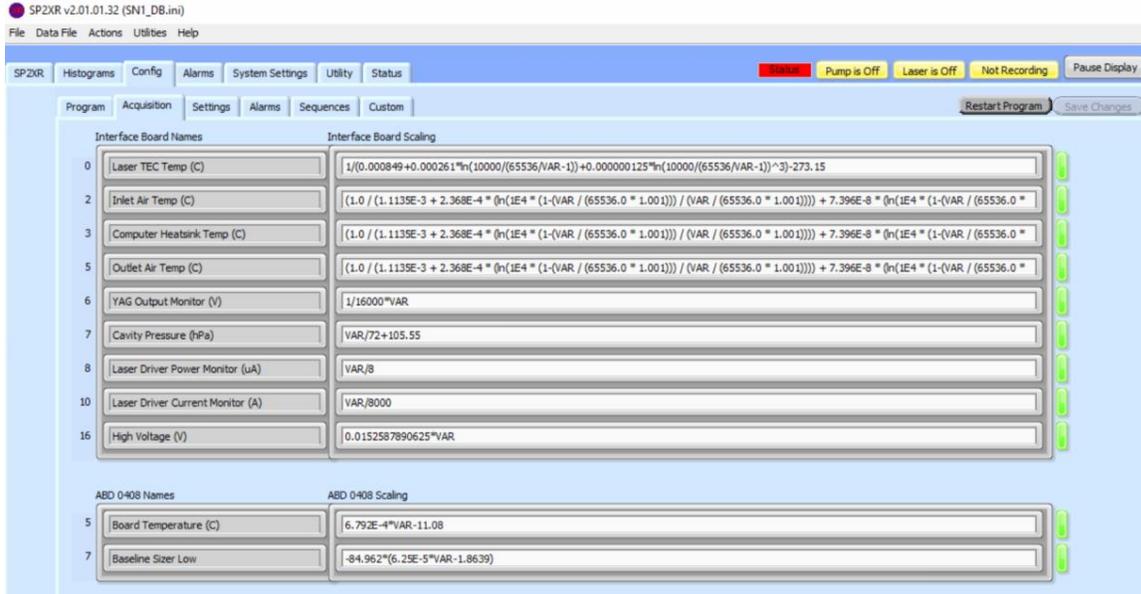


Figure 15: Config / Acquisition tab

The **Acquisition** tab is shown in Figure 15. This tab contains equations for scaling A/D counts to housekeeping parameters. **These values should not be changed unless directed by DMT.**

Config / Settings Tab

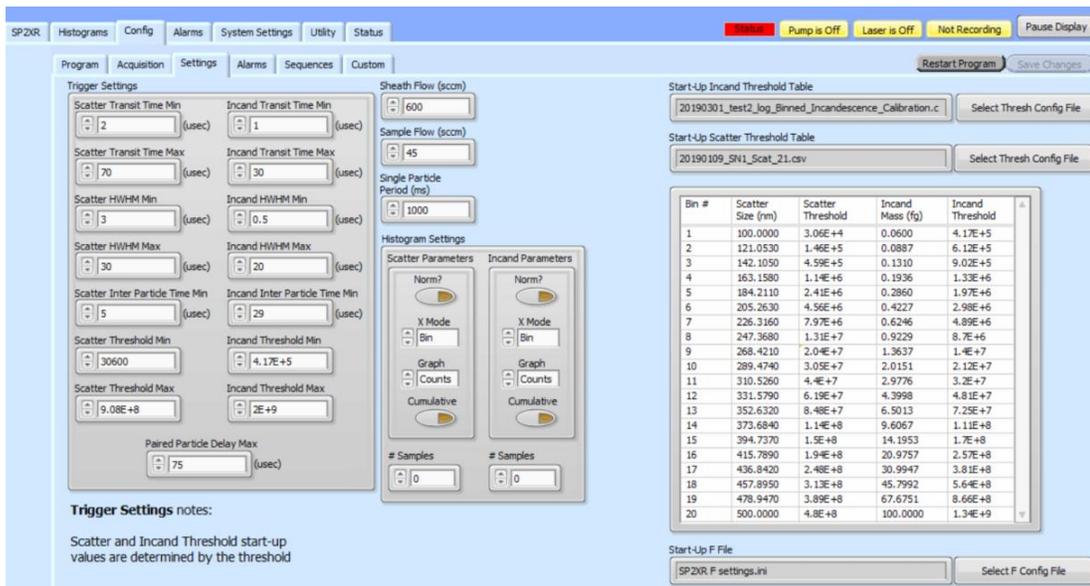


Figure 16: Config / Settings tab

The **Settings** Tab (Figure 16) allows the user to build default parameters and save them in the .ini file. Changing the values here will not be implemented until the **Save Changes** button is pressed and the program is restarted.

- **Trigger Settings** are the same as described in **Appendix C**.
- **Sheath and Sample Flows** can be configured here.
- **Polling Interval** sets the time interval for the Housekeeping (HK) file and the PBP recording. For most applications 1000 Milliseconds is recommended.
- **Histogram Settings** are the same as described in the **Histogram Tab**.
- **Threshold Tables** contain the scattering and incandescence count thresholds for correctly sizing particles. These are generated at DMT and are instrument specific.

Config / Alarms Tab

Alarms allow the user to monitor any of the SP2-XR housekeeping parameters and set an action or series of actions if certain criteria are met.

- **Name** is used for the alarm name. This name is useful for clarity to the operator as well as the reference name for commands.
- **Channel** determines which of the data channels is used for the alarm comparison.
- **Condition** selects which logical check is applied to the selected channel: <, <=, =, > (not equal), >= or >.
- **Threshold** defines the value that the channel will be compared to when determining if a condition is true or not.

- **Hysteresis** allows the alarm to be configured such that small amounts of noise near the threshold value will not continually trigger the alarm.
- **Action** defines what action will be taken when the alarm transitions from false to true. In addition to this action the transition will also be noted in the log file. When an alarm transitions from true to false, the transition is logged but no other action is taken.

Note: Most of the actions are not inherently bi-directional. That is, when an alarm goes from true to false, the opposite action is not executed, e.g. “Turn Laser Off Alarm” will not turn the laser back on when the alarm becomes false. Actions will not always use all of the listed parameters.

- **Min Time** specifies the minimum amount of time in seconds that the alarm condition must meet before the alarm is set to true. Set this to 0 to have an alarm work as soon as the condition is detected. If Min Time is set to a larger value, short excursions past the alarm condition will not cause the action to be executed.

Note: when an alarm condition is met but the minimum time has not yet elapsed, the alarm goes into a warning state, indicated by a Yellow alarm color.

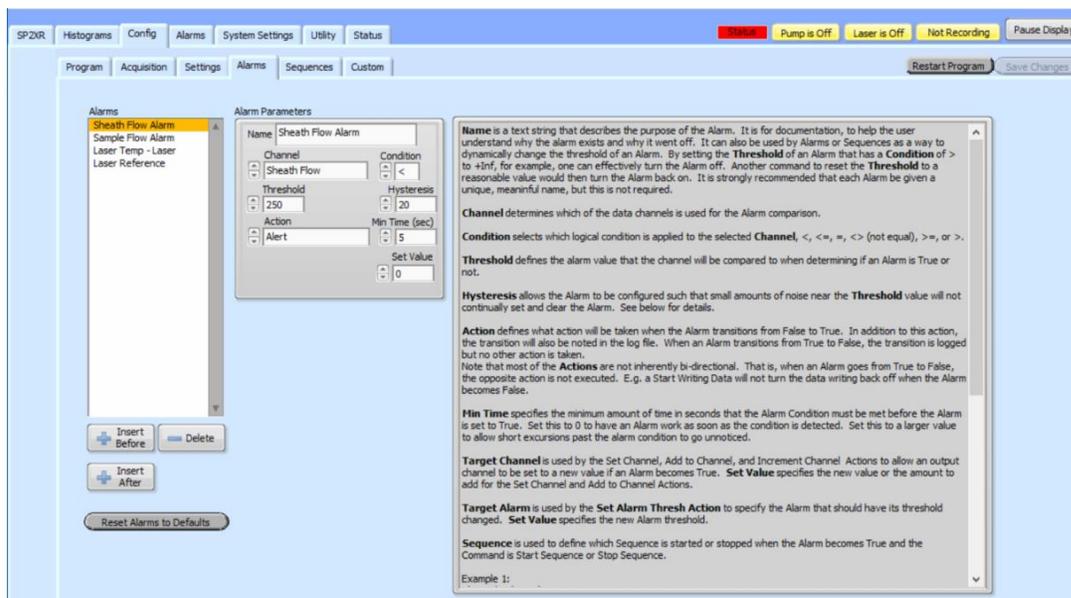


Figure 17: Config / Alarms tab

Config / Sequences Tab

The **Config / Sequences** tab allows the user to configure sequences.

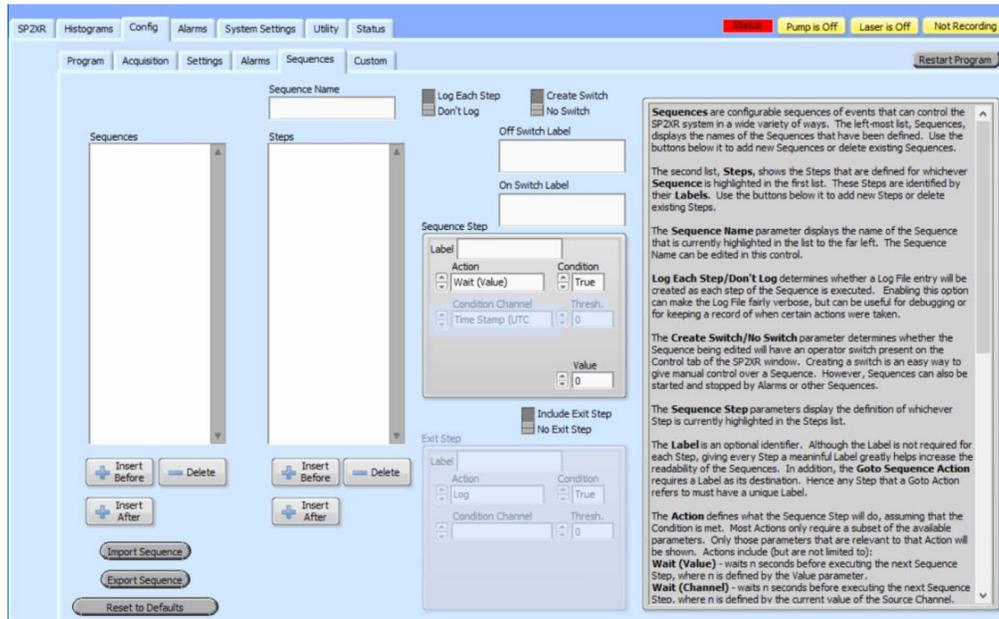


Figure 18: Config / Sequences tab

- **Sequences Box:** Displays all sequences.
- **Import/Export Sequence:** Saves the current sequence to a .seq file or allows the user to load a .seq file.
- **Steps:** Displays all steps in the selected sequence.
- **Log Each Step/Don't Log:** Allows the user to select whether each step of the sequence will create a log file entry as executed. This option creates large log files but adds a lot of detail.
- **Create Switch/No Switch:** Allows the user to create an operator switch on the SP2XR system settings tab.
- **Sequence Step Box:** This box allows you to configure the specific step of the sequence including logical condition and action.
- **Include Exit Step:** allows one to save the currently-highlighted Sequence in a small .seq file.
- **Exit Step Box:** Allows the user to configure the settings of the exit step.

Config / Custom Tab

The **Config / Custom** tab (Figure 19) allows the user to configure any of the data display parameters for the Custom tab.

- **Display Tab** shows or hides the **Custom** tab from the SP2XR interface. If the custom tab cannot be seen upon start-up, check here.
- **Display Sets** is a list of the display sets that have been defined.
- **Set Name** is a set of parameters that define how the custom display will appear. Click on the display set to edit its properties.
- **Insert before/Insert after** can be used to add new Display Sets relative to the location of the highlighted one
- **Delete** will remove the highlighted Display set.
- **Display Set Name** is used to label the Display Set that is currently being edited.
- **Graph 1 Plots** and **Graph 2 plots** allows the selection of up to seven channels to display. The Y-axis (left or right) for each plot can be individually selected.



Figure 19: Config / Custom tab

1.17 Alarms Tab

The **Alarms** tab (Figure 20) allows the user to configure or set alarms that correspond to data display parameters for the numeric inputs. Changes here will take effect immediately but will not be saved in the config file unless the “Save Changes” button in the upper right-hand corner is pressed. The software should be restarted with the “Restart Program” button after saving changes.

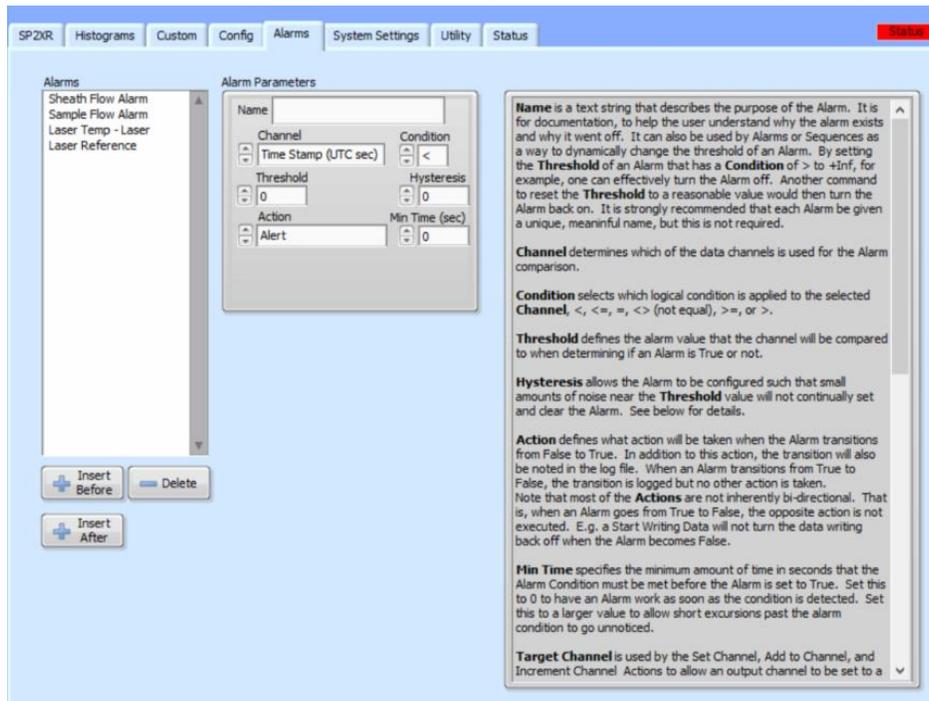


Figure 20: Alarms tab

Examples of how to set parameters for Alarms

Example 1:

Name: Auto Data Record

Channel: Elapsed time

Condition: >

Threshold: 60

Hysteresis: 0

Action: Start writing data

Min Time: 0

Set Value: 0

Sequence: near.

Target Channel: near.

This alarm causes the program to begin writing data to a file after the program has run for 60 seconds.

Example 2:

Name: Laser Overheat

Channel: Laser Temp (V)

Condition: >=

Threshold: 40

Hysteresis: 1

Action: Set channel

Min Time: 5

Set Value: 0

Sequence: near.

Target Channel: Laser Power Switch

This alarm will cause the program to turn off the laser if the Laser Temp becomes greater or equal to 40 for more than 5 seconds. This alarm will not become false until the laser temp falls below 39. If it is desired that the laser come back on automatically at that time, it would be necessary to define another alarm using the < condition and the Set Channel Action.

Example 3:

Name: Alarm Alert

Channel: Error

Condition: <>

Threshold: 0

Hysteresis: 0

Action: Alert

Min Time: 0

Set Value: 0

Sequence: near.

Target Channel: near.

This default alarm causes an alarm to be true whenever an error is logged. This ensures that the Alarm Status indicator at the top of the main program display turns red each time an error occurs. This alerts the user to the error condition even when the program is not displaying the status tab.

Example 4:

Name: Reduce Laser Cur

Channel: YAG Crystal Temp

Condition: >

Threshold: 35

Hysteresis: 0

Action: Set Channel

Min Time: 60

Set Value: 2000

Sequence: near.

Target Channel: MonPumpLaser

This alarm reduces the laser current to 2000 if the YAG Crystal Temp rises above 35°C for more than one minute.

Timers: Timers are virtual channels within the SP2-XR system used to count time. Any number of Timer channels can be defined. The only parameter for a Timer channel is its name. Each Timer starts with a value of 0 when the SP2-XR program starts and counts up in units of seconds. A Timer can be set to any value using the Set Channel button on the Control tab, or using a sequence, Alarm, or CCL action. When set to a new value, it will start counting up from there immediately. Most often, Timers will be created so that sequences can act according to time elapsed from specific events.

1.18 System Settings tab

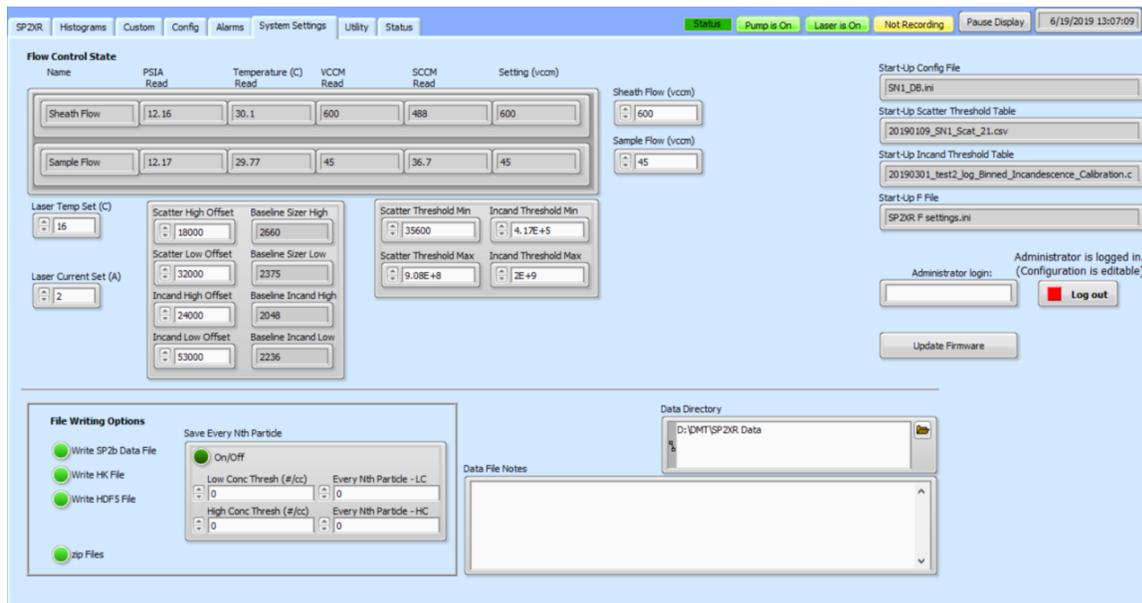


Figure 21: System Settings tab

The **System Settings** tab (Figure 21) provides a summary of experiment settings, and allows the user to adjust instrument controls

- **Flow Control State:** Displays all flow settings and allows the user to configure Sheath and Sample Flow, respectively.
- **File writing options, locations and data file notes input:** Allows the user to select the type of file, maximum size, and file location.
- **Sequence viewing and toggle on/off:** Allows the user to see all sequences on the SP2-XR and turn each on or off.
- **Start-up Config, Threshold tables, and F files:** Shows the user all the default settings files that will be loaded upon instrument start up.
- **Administrator login:** Allows the user to input the administrator password and edit configuration settings.

1.19 Utility Window

The **Utility window** has functions and windows for viewing data and logs. To open a utility, select it from the **Utilities** dropdown menu.

Utility – Data Reader

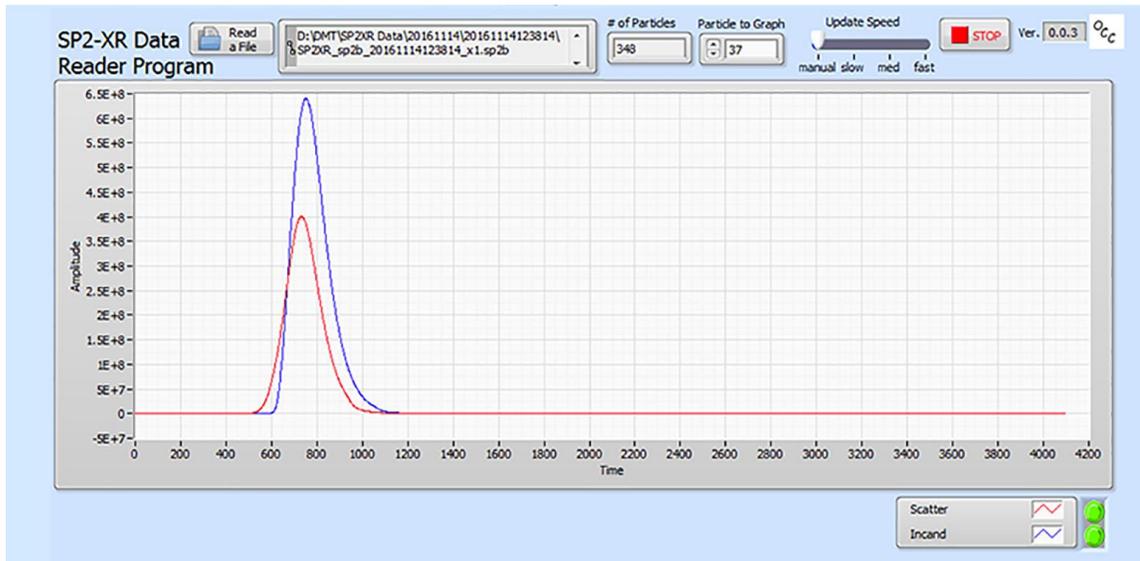


Figure 22: Utility – Data Reader

The data reader allows the user to load and read a file from a previously written experiment.

Utility – Log reader

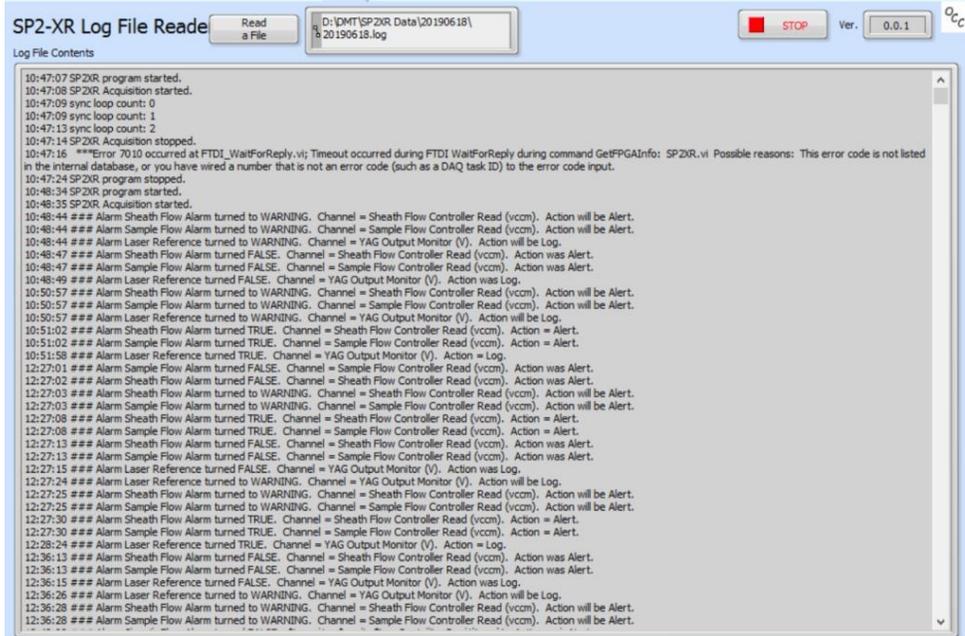


Figure 23: Utility Log Reader

The Log Reader allows the user to load a log file to find out more about the status of the SP2XR throughout the experiment.

1.20 Status Window

The screenshot displays the 'Status' tab of the SP2XR software. At the top, there are status indicators: 'Status' (red), 'Pump is On' (green), 'Laser is Off' (yellow), 'Not Recording' (grey), and 'Pause Display' (grey). The date and time are shown as 6/18/2019 14:11:11.

The main area is divided into several sections:

- Alarms Table:**

Alarm Name	Status	True Time	Ch Value	Threshold
Sheath Flow Alarm	False	Inf	600 <	250
Sample Flow Alarm	False	Inf	45 <	20
Laser Temp - Laser	False	Inf	16.283 >	35
Laser Reference	Warning	14:10:31	0.024 <	2.25
- System Information:**
 - SP2XR Version: 2.01.01.32
 - Serial Number: 1
 - Description:
 - FPGA FW Version: 34
- Data Folder:** D:\DMT\SP2XR Data\20190618
- Data File:** (Empty)
- Configuration File:** SN1_DB.ini
- Last 20 Logs:**
 - 14:11:10 Scatter Hi Baseline outside of calibrated limits
 - 14:11:10 Laser Driver Pwr Mon outside of calibrated limits
 - 14:11:09 YAG Power Monitor outside of calibrated limits
 - 14:11:09 Scatter Hi Baseline outside of calibrated limits
 - 14:11:09 Laser Driver Pwr Mon outside of calibrated limits
 - 14:11:09 YAG Power Monitor outside of calibrated limits
 - 14:11:09 Scatter Hi Baseline outside of calibrated limits
- Calibration Alarms (Red Box A):**
 - Laser Driver Pwr Mon outside of calibrated limits
 - Scatter Hi Baseline outside of calibrated limits
- Parameters Table:**

Sheath Flow Controller Pressure (psia)	12.23
Sheath Flow Controller Temperature (C)	29.87
Sample Flow Controller Read (vccm)	45
Sample Flow Controller Read (sccm)	36.9
Sample Flow Controller Pressure (psia)	12.21
Sample Flow Controller Temperature (C)	29.82
Laser TEC Temp (C)	16.283
Inlet Air Temp (C)	-68.343
Computer Heatsink Temp (C)	42.025
Outlet Air Temp (C)	28.52
YAG Output Monitor (V)	0.024
Cavity Pressure (hPa)	598.217
Laser Driver Power Monitor (uA)	48
Laser Driver Current Monitor (A)	0.178
High Voltage (V)	1.953
Purge Flow Monitor (sccm)	33.422
Board Temperature (C)	32.548
Baseline Size Low	0
Baseline Size High	1.455E+4
Baseline Incand Low	2.186E+4
Baseline Incand High	2.911E+4
Bandwidth Size Low	6.55E+4
Bandwidth Size High	48
Bandwidth Incand Low	0
Bandwidth Incand High	12

At the bottom, there is a 'Log This Message' button, a 'Message' input field, and an 'Insert Time Stamp' button. The bottom right corner shows the date and time: 04172019 12:18.

Figure 24: Status tab

The Status window (Figure 24) provides information on the status of any alarms on the instrument as well as a list of housekeeping parameters and their current values. The left side of the tab contains the current data folder, in YYYYMMDD form, as well as the data (if recording) and configuration file names. The bottom of the window contains the last 20 logs for quick checking of problems, as well as a location to log and timestamp a custom message. If a calibration alarm (A) shows a parameter is outside of calibrated limits during operation, the instrument must be sent to DMT for service.

Laser Beam Profiler Software

The SP2-XR contains an internal camera that is permanently mounted and that can be used to view the laser beam profile. The profile can be used as a reference to the laser beam health and alignment to determine if maintenance or service may be required. For the camera to operate the laser power monitor circuit board must first be removed from the laser cavity. The application software can then be started and the beam profile can be viewed.

1.21 Camera Preparation

To view the laser beam profile with the camera the laser power monitor must first be removed. This procedure is illustrated in the following steps.



Figure 25: SP2-XR front panel screws

1. Remove the front panel from the instrument, there are 11 screws on the front panel. Remove with a #1 Phillips head screw driver (Figure 25).

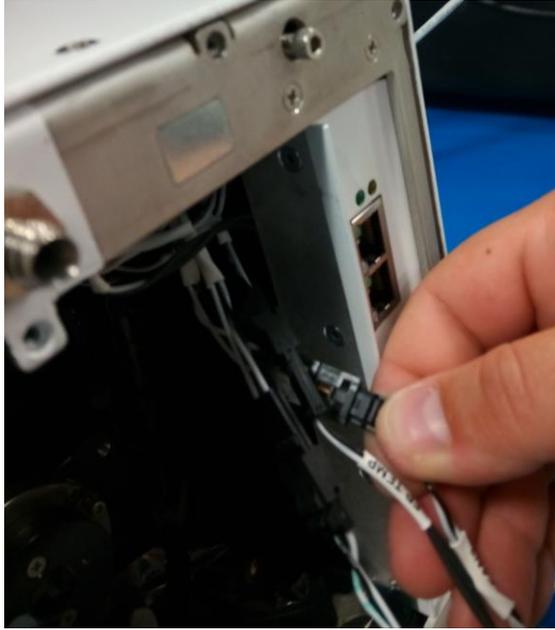


Figure 26: Front panel connections

2. Tilt the front panel away from the instrument. Locate and disconnect the connections for the front panel fan and temperature sensor (Figure 26).

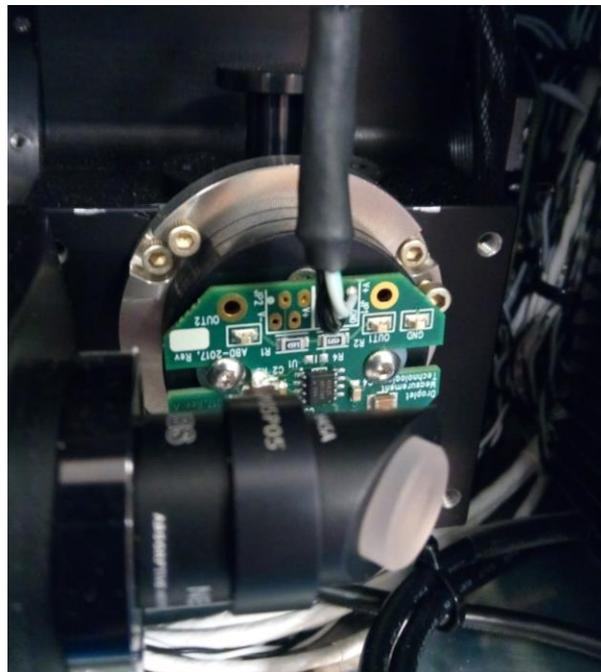


Figure 27: Laser power monitor board

3. The front panel can be placed to the side. Locate the laser power monitor circuit board (Figure 27).

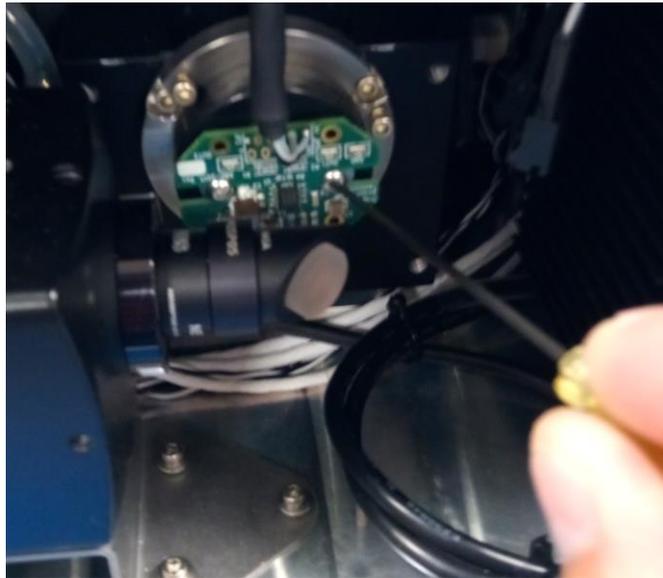


Figure 28: Laser power board removal

4. With a 1/16" hex driver, remove one of the screws from the laser power monitor. The second screw only needs to be loosened, not fully removed (Figure 28).

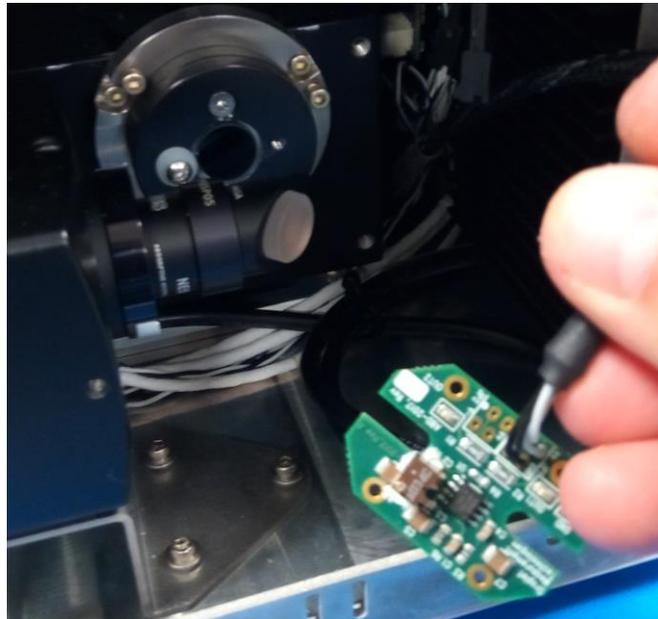


Figure 29: Laser power board removed

5. Now the laser power monitor can be removed from laser cavity. It is recommended that the power monitor board be kept in an electronics ESD bag to prevent short circuiting since it will

still be supplied power. Place the power monitor inside the instrument such that it is not between the camera and laser viewing area (Figure 29).



Figure 30: Front panel connections 2

6. Connect the front panel fan and temperature sensor connections and install the front cover (Figure 30).

1.22 Running the software

The following instructions will enable the user to view the laser beam profile with the instruments provided third party software. For further information on the software see the manual that was provided with the instrument.



Figure 31: vBeam application

1. When the instrument is running, navigate to the desktop screen. Double-click on the icon labeled “vBeam” (Figure 31).

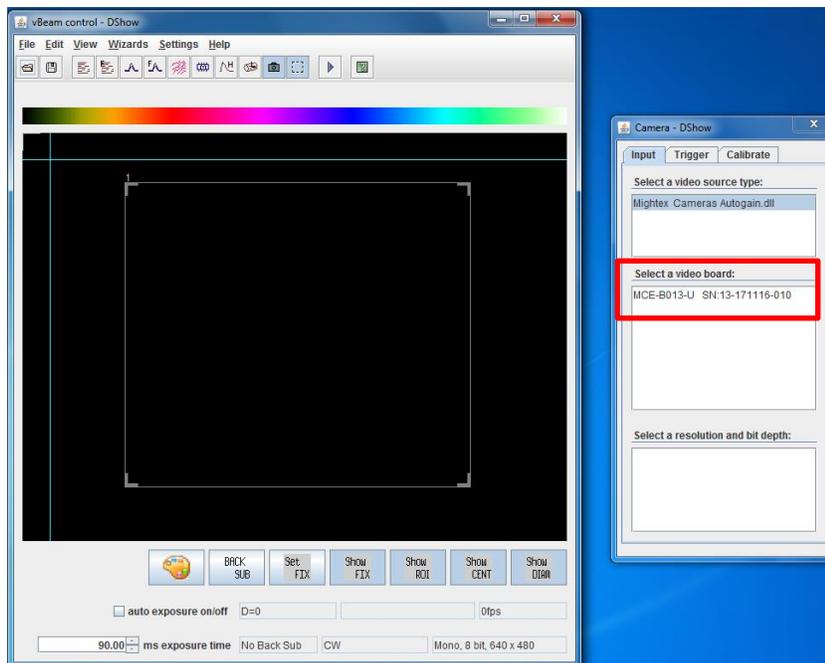


Figure 32: Video board selection

- When the application starts there will be two windows labeled “vBeam control – Dshow” and “Camera – Dshow”. Under the “Camera – Dshow” window, the middle box labeled “Select a video board” there will be a part number and serial number for the camera similar to “MCE-B013-U SN:XX-XXXXXX-XXX”. Click on the part number (Figure 32).

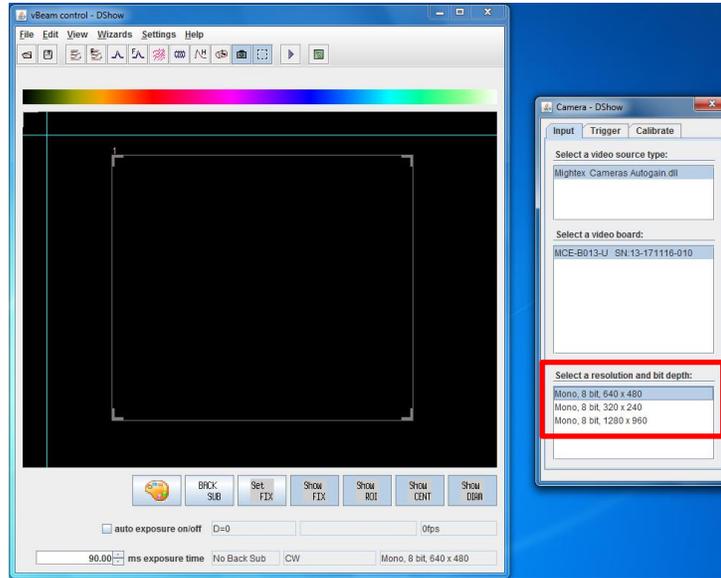


Figure 33: Resolution and bit depth selection

- After clicking the part number, the software will generate options under the bottom box labeled “Select a resolution and bit depth”. Click on the desired resolution (Figure 33).

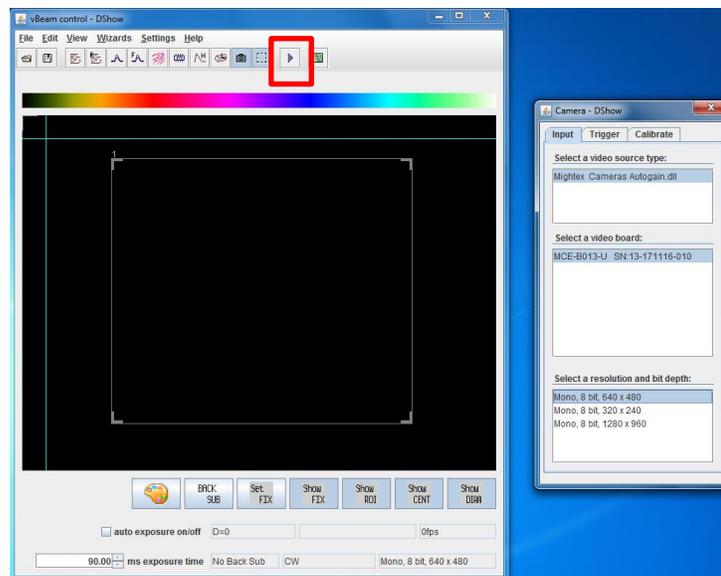


Figure 34: vBeam play button

4. Now the software is ready. Navigate back to the “vBeam control – Dshow” window. On the top part of the window, right of center click the play button to start the camera (Figure 34).

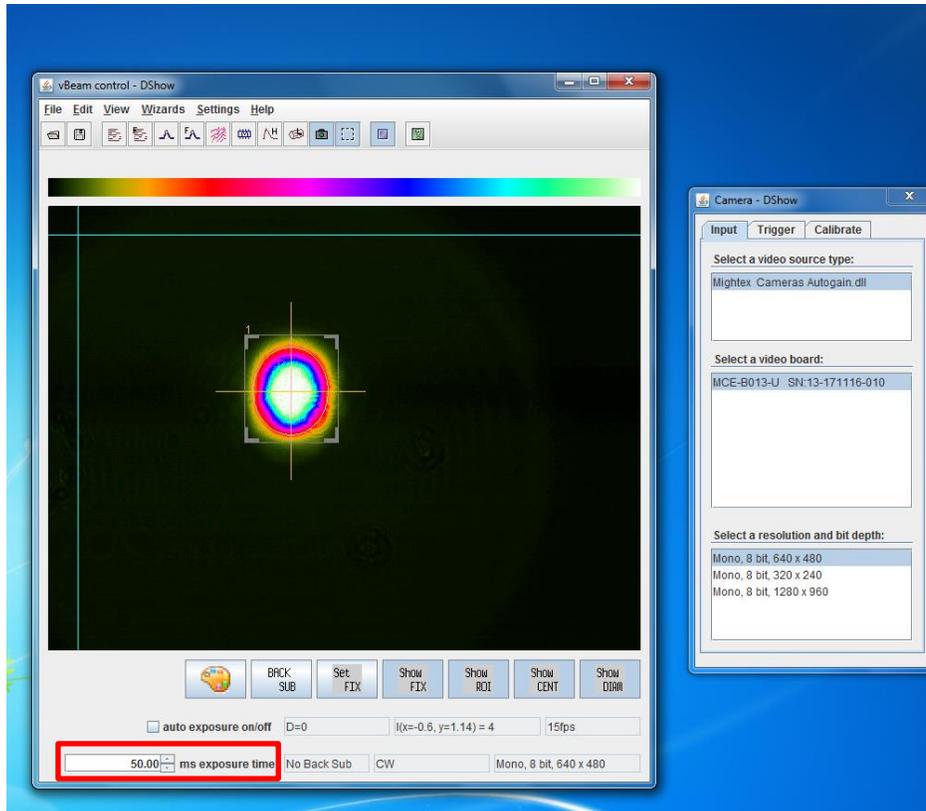


Figure 35: vBeam exposure time

5. The default exposure time is 90.00ms. This will need adjusted, change to 50.00ms first. Then adjust as necessary for the desired representation of the beam. (The laser must be enabled from the SP2-XR software for viewing, see section 4.2.)

Laser Safety Interlocks

The SP2-XR features two types of laser safety interlocks that operate in series. The first (Figure 36) is a cabinet laser safety interlock that disables the laser if the cover or face plate of the unit is removed. Be careful to make sure the interlock is not intentionally or accidentally pressed down if the cover has been removed from the unit.



Figure 36: Cabinet Interlock Switch

The second safety interlock comes internally in the form of a key. Figure 37 shows the key in the locked position (laser disabled). In this position, the key can be removed to prevent accidental activation of the laser.

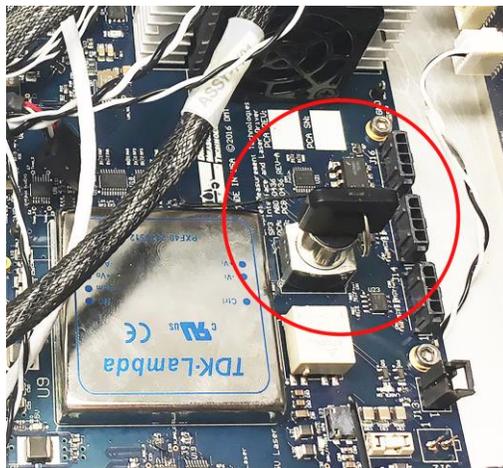


Figure 37: SP2-XR Key in the locked (laser off) position

CAUTION: If the laser turns off because an interlock switch was disengaged, the laser will automatically turn on again when the interlock is re-engaged. The laser can also be turned off from the software interface by clicking on the **Actions** Tab on the main screen navigation bar, or **F8** as a keyboard shortcut.

Routine Maintenance

It is recommended at least once per month, or before an experiment, to perform a particle zero count check. Attach the filter included with shipment to the inlet. After a few minutes the instrument should record an occasional particle, but effectively the particle concentration measurement should be zero. If not, contact DMT for support. If threshold settings for either channel need to be adjusted, refer to the calibration report received with the unit to verify threshold changes will not negatively affect desired particle measurements.

1.23 Cleaning the Laser Optics

The optics used in the SP2-XR have reflectivity of 99.97% or better, and it is very difficult to clean them without causing damage or contamination. DMT recommends consultation with our support teams to determine if the user should attempt to clean the optics on site.

In the event that the user desires to clean the optics without sending to DMT, carefully perform the following steps:

1. Locate the cleaning port for the mirror optic at the front-end, and back-end of the optical block (Figure 38a). Generally, contamination occurs at the mirror end; start cleaning here. For access, remove the two lock-down screws near the cleaning port (Figure 38b), then remove the cleaning port.

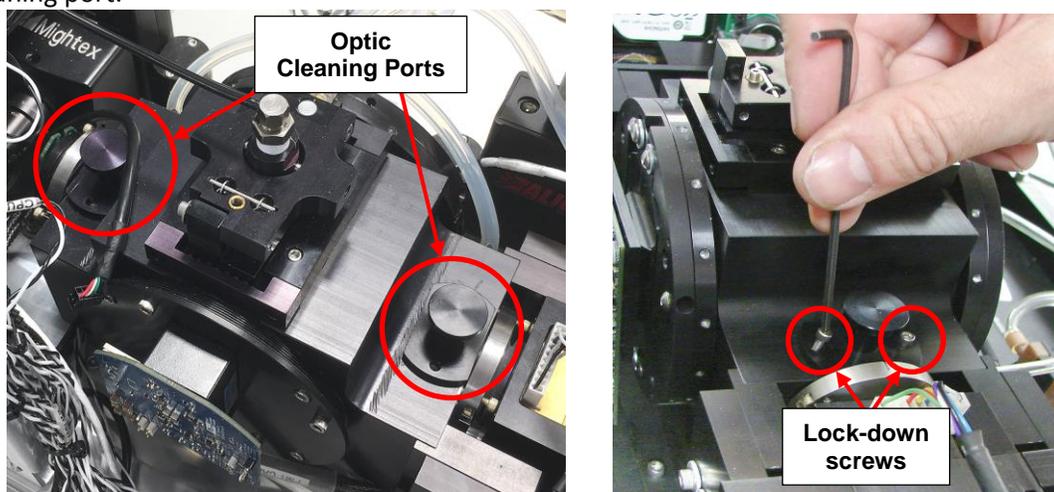


Figure 38: Cleaning port access to optics

2. Using an optical grade cotton tipped applicator with a one to two drops of spectra-photo grade acetone, clean the optic (Figure 39). A single gentle swipe in one direction across the middle portion of the optic works best. **DO NOT** use a scrubbing or circular motion, as this tends to spread any contamination. Usually 2-3 cleaning swipes using fresh acetone and a fresh cotton swab for each swipe is adequate.

NOTE: Avoid hitting the side of the cleaning port with the optical grade cotton tipped applicator, as grease from the O-ring can get on the applicator and smear the optics.



Figure 39: Cleaning the Optics

3. Replace the port, lift the rear interlock, and observe the laser power for one minute. Check to see if the **Reference** has returned to approximately to **2.5 V**. If the power is still low, press the rear interlock (the laser interlock) down to OFF and repeat steps 1-2 of the procedure. It may take numerous attempts to return the laser to normal power.
4. Reinstall cleaning port and replace the lock-down screws.
5. If laser reference power is still low, repeat the cleaning procedure outlined in steps 1-2 for the optic at the back end of the optical block. This is the crystal/laser end. Make sure the Laser is OFF, and be gentle, as the crystal end is delicate and scratches easily.

NOTE: Only clean the crystal end when all other cleaning efforts have been exhausted.

Troubleshooting

<i>Problem</i>	<i>Possible Cause</i>	<i>Solutions</i>
Instrument does not start when turned on.	No power to instrument.	Verify power source. Check fuse drawer on rear panel.
Large burst of high-concentration aerosol particles have contaminated the instrument and the laser power has dropped significantly.	Rapid over-pressurization of the chamber.	IMMEDIATELY turn off the laser. If possible, put a filter on the front of the instrument, and allow to purge for 30-60 minutes. After this time turn the laser on and observe the laser power. If it is nearly to the level before the contamination, allow the SP2-XR to operate. If not, purge for additional time. Contact DMT if the laser power does not recover.
The instrument has been started, but no particles are seen on the display.	Laser off or no sample flow.	Check that the laser has not shut off. Check that the sample flow is positive. Check the laser interlocks are engaged (i.e., depressed).
YAG Output Monitor reference voltage low OR Scattering particles under sizing	Contaminated Optics	Optics cleaning, see section 7.
Laser is overheating	Lack of airflow	Verify there is sufficient room for ventilation of the case fans (front panel) and laser cooling fan (underneath).

Additional Questions

Our goal is for you to be successful on your campaigns and science applications with this product and for Droplet Measurement Technologies to be your Global Choice for Atmospheric & Environmental Measurement Solutions and your Trusted Partner for Scientific Exploration.

Should you have any additional questions or comments, please contact us via telephone at +1 (303) 440-5576, or email at customer-contact@dropletmeasurement.com.

To learn more about what is new at Droplet Measurement Technologies, please visit our website at <http://www.dropletmeasurement.com>.

Appendix A: Expanded Theory of Operation

Design

The Single Particle Soot Photometer (SP2-XR) utilizes the high optical power intracavity Nd:YAG laser. Light-absorbing particles, mainly refractory black carbon (rBC), absorb energy and are heated to the point of incandescence. The energy emitted in this incandescence is measured, and a quantitative determination of the rBC mass of the particle is made. This mass measurement is independent of the particle mixing state, and hence the SP2-XR is a reliable measure of the black carbon mass concentration. Since the SP2-XR detects single particles, the SP2-XR also measures the black carbon mass concentration.

All particles scatter light, regardless of whether or not they incandesce. A scattering detector is included in the SP2-XR, which detects single particle scattering at 1064 nm. The scattering detector can be used to detect non-BC-containing aerosol number and optical particle size.

Processing Electronics

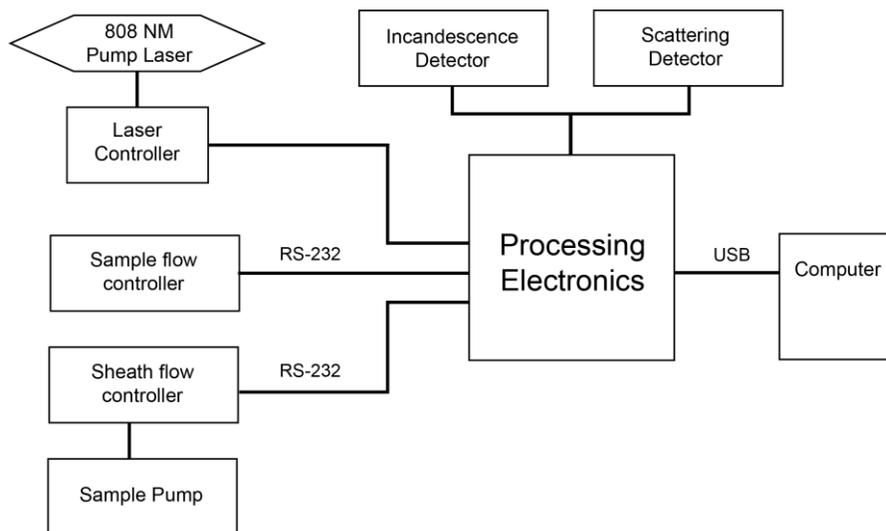


Figure 40: SP2-XR Processing electronics

Flow System

The SP2-XR uses a recirculating sheath flow air system. Figure 41 details the flow system.

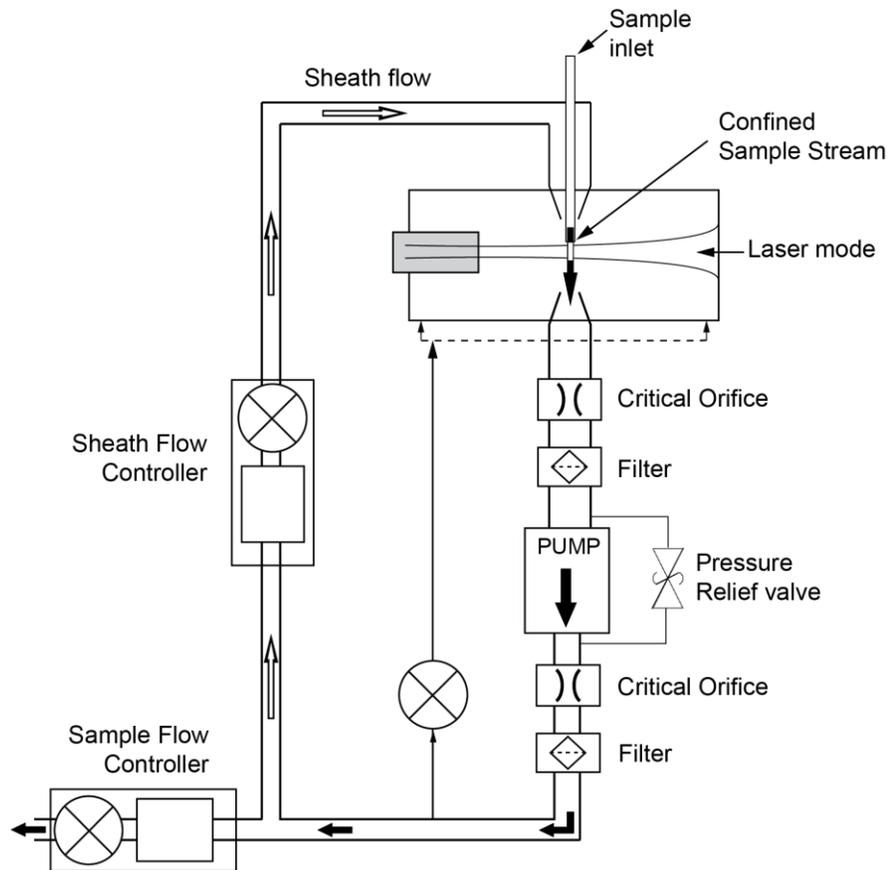


Figure 41: SP2-XR Aerosol Flow

The flow rate of air being pulled into the inlet is controlled by the sample flow controller. Deviations between the sample flow and output flow could indicate there are leaks in the plumbing.

Laser Characteristics

The heart of the SP2-XR is the Nd:YAG laser. This will be referred to in the following discussion simply as the YAG laser. Figure 43 shows a diagram of the laser and the main optical components. The laser cavity consists of a gain medium, the YAG crystal, and the output coupler. The particles from the aerosol jet enter the path of the laser beam at the center of the cavity. The mirrors are coated to have a reflectivity of 99.97% or better at the 1064-nm wavelength of the YAG laser. In a standard laser, the power that escapes through one of the laser mirrors is used as the laser source; in the SP2-XR application, the goal is to contain the power within the cavity between the mirrors (open-cavity laser) and utilize it directly. The power in the cavity is nominally 1 MW per cm². The YAG laser operates continuously and is not pulsed. The gain medium is optically pumped with a free space

diode laser at 808nm. The 808 nm leakage power that is available external to the cavity from, the pump laser, is approximately 50-100 mW. This power is monitored by the YAG power monitor and is displayed on the data system in relative numbers. A lens focuses the pump light on to the YAG crystal gain medium. The laser beam is Gaussian in shape, nominally 230 microns width at 90% power level. The YAG laser is central to the system. The two detectors are oriented in the plane of the SP2-XR optical diagram as shown in (Figure 42). The aerosol jet is perpendicular to the plane of the SP2-XR optical diagram and sends the particles across the laser beam.

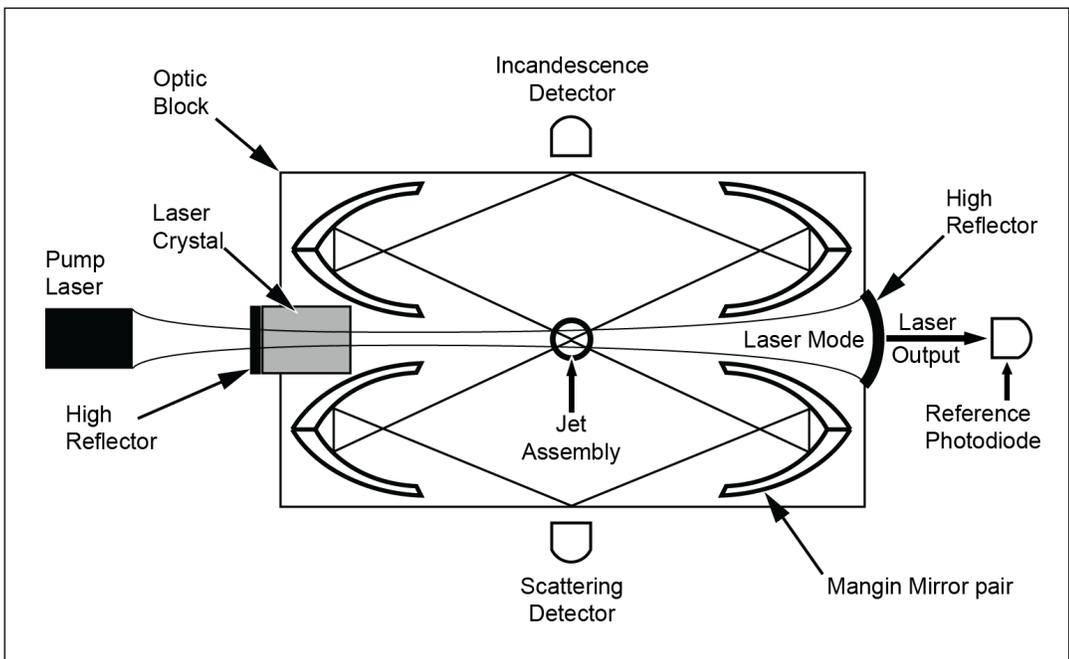


Figure 42: SP2-XR Optical Diagram

Optical Detectors

The SP2-XR uses two different types of detectors. The scattering channel uses an avalanche Photodiode (APD) that is optically filtered to only allow 1064 nm radiation. This will measure the scattering signal from all particles; those that scatter light only, and those that both scatter and incandesce. The incandescence channel uses a photomultiplier tube (PMT) that measures the incandescence signal in the visible region. This channel is optically filtered to pass broadband light, nominally from 400-750nm.

Appendix B: Warranty and Contact Information

The seller warrants that the equipment supplied will be free from defects in material and workmanship for a period of twelve (12) months from the confirmed date of purchase of the original buyer.

The equipment owner will pay for shipping to DMT, while DMT will pay for the return shipping expense.

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

Service procedures and repairs are warranted for 90 days.

Droplet Measurement Technologies, LLC can be contacted at the following address:

Droplet Measurement Technologies, LLC
2400 Trade Centre Avenue
Longmont, Colorado USA 80503
Telephone: +1 (303) 440-5576
Fax: +1 (303) 440-1965
www.dropletmeasurement.com

Appendix C: Particle Size / Shape determination

Particle Trace Schematic

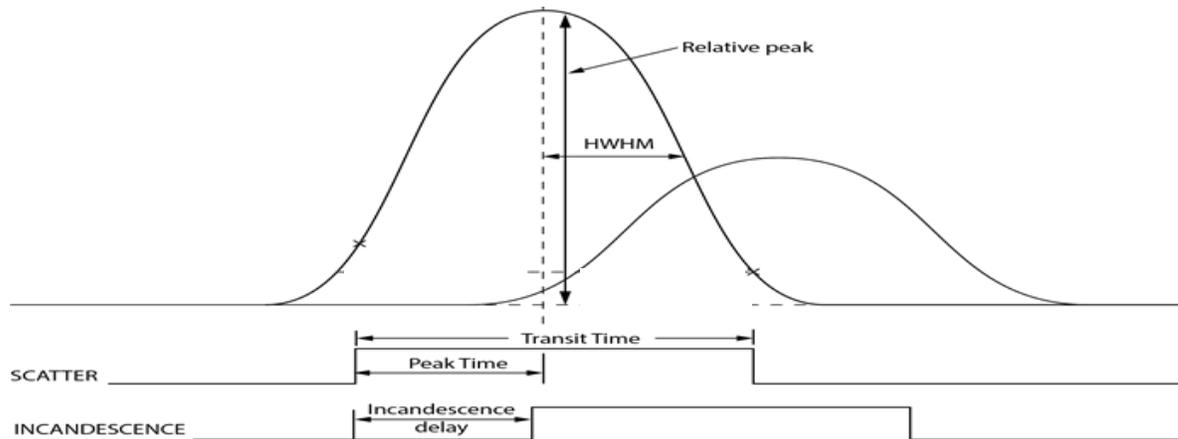


Figure 43: SP2-XR Particle trace schematic

Particle Parameter Settings:

- Transit Time Min: Minimum transit time for a particle, this is set to reject very short electronic or optical noise spikes.
- Transit Time Max: Maximum transit time for a particle. This allows the rejection of floater particles, which typically have a longer transit time.
- HWHM Time Min: Minimum particle width, allows rejection of electronic noise.
- HWHM Time Max: Maximum particle width, allows rejection of floater particles.
- Interparticle Time Min: Sets a minimum time between any two particles, typically set at 0.
- Threshold: Minimum A/D counts needed for a particle to be qualified. Increasing this value will reduce the smallest particles which can be measured; but will eliminate the potential of qualifying noise particles.
- Paired Particle Delay Max: Sets the maximum amount of time between a scattering particle and an incandescence particle for the firmware to qualify them as a single particle event. This is based on threshold crossings and is the maximum absolute value of incandescence delay.

NOTE: All time values are in microseconds (μs).

Appendix D: Particle by Particle data files

PBP Data file descriptions

The PBP data file heading SP2XR_PbP_YYYYMMDDHHMMSS_xXXXX.csv, contains the individual particle data. This can be opened with any program working on a .csv file.

The following listing gives the description for each of the columns:

Column Heading	Item Description
Time Stamp (sec)	Unix Epoch time (Converted to local)
UTC Offset	UTC offset for local time in hours.
Scatter relPeak	The A/D counts for the peak height for scattering particles
Scatter Transit Time	Time when scattering particle crosses the leading threshold until it crosses the falling threshold, microseconds
Scatter Peak Time	Time when scattering signal crosses, the threshold until peak height in microseconds
Scatter HWHM	Half width at half maximum for the scattering peak, microseconds
Scatter Size (nm)	Scatter particle size in nanometers based on the scattering threshold table
Incand relPeak	The A/D counts for the peak height for incandescent particles
Incand Transit Time	Time when incandescent particle crosses the leading threshold until it crosses the falling threshold, microseconds
Incand Peak Time	Time when incandescent particle crosses the leading threshold until peak maximum, microseconds
Incand HWHM	Half width at half maximum for the incandescent peak, microseconds
Incand Delay	Time between when the scattering peak and the incandescence peak cross the threshold for each particle microseconds
Incand Mass (fg)	Incandescence particle mass in femtograms based on the incandescence threshold table

Flag* - Dual Qualified	Both a scattering and incandescing signal were detected during the particle capture period, indicating that they were from the same particle
Flag* - Scatter Detected	A scattering signal was detected during the particle capture period
Flag* - Incand Detected	An incandescence signal was detected during the particle capture period
Flag* - Scatter Rejected	A scattering signal was detected during the particle capture period but was rejected by the firmware
Flag* - Incand Rejected	An incandescence signal was detected during the particle capture period but was rejected by the firmware
LV Time Stamp (UTC sec)	Number of seconds since January, 1, 1904 midnight UTC/GMT.

*These flags are binary values, a value of 1 indicates the condition was present, and value of 0 indicates the condition was not present.

Appendix E: Housekeeping data files

Housekeeping (HK) Data file description (parameters)

The HK data file heading SP2XR_hk_YYYYMMDDHHMMSS_xXXXX.csv, contains the one second average of the set points, housekeeping values and the binned particle data. This can be opened with any program working on a .csv file.

The following listing gives the description for each of the parameters:

Parameter	Parameter Description
Time Stamp (sec)	Unix Epoch time (Converted to local)
UTC Offset	UTC offset for local time in hours.
Incandescence Particle Conc (cts/cc)	Concentration of all particles showing an incandescent signal, with or without a scattering signal
Scattering Particle Conc (cts/cc)	Concentration of particles showing only a scattering signal, particles which also show incandescence are not counted
Incandescence Mass Conc (cts/cc)	Number of incandescent particles multiplied with the size information to give mass loading
Total Mass Per Seconds (fg)	Combined mass of all incandescence particles each second
Scatter Bin 1-N (N=number of scatter bins)	Number of particles in scattering bin 1 through bin N. Number of bins is dictated by the threshold table.
Incand-Bin 1-M (M=number of incand bins)	Number of particles in Incandescence bin 1 through bin M. Number of bins is dictated by the threshold table.
Qualified Particles	Total number of qualified particles each second
# PbP Records	Total number of PbP records correlating to each second of the HK file. (This may vary from the qualified particles number due to particles that are not dual qualified but are detected in the same particle capture period that are written as one record but qualified individually.)
Dual Qualified Scatter and incandescence Particles	Number of particles qualified for both scatter and incandescence
Qualified Scatter Only Particles	Number of particles qualified for scattering only
Qualified incandescence Only Particles	Number of particles qualified for incandescence only
Sheath Flow Controller Read (vccm)	(Volume) Flow reading from the sheath flow controller
Sheath-Flow Controller Read (sccm)	(Mass) Flow reading from the sheath flow controller
Sheath Flow Controller Pressure (psia)	Pressure reading in the sheath flow controller
Sheath Flow Controller Temperature (C)	Temperature reading on the sheath flow controller
Sample Flow Controller Read (vccm)	(Volume) Flow reading from the sample flow controller

Sample Flow Controller Read (sccm)	(Mass) Flow reading from the sample flow controllers
Sample Flow Controller Pressure (psia)	Pressure reading from the sample flow controller
Sample Flow Controller Temperature (C)	Temperature reading of the sample flow controller
Laser TEC Temp (C)	Pump laser internal temperature
Inlet Air Temp (C)	Air temperature at the inlet to the case
Computer Heatsink Temp (C)	Computer heat sink temperature
Laser Heatsink Temp (C)	Pump laser heat sink temperature
Outlet Air Temp (C)	Air temperature at the outlet to the case
YAG Output Monitor (V)	Power monitor at the output of the YAG laser
Cavity Pressure	Air pressure in cavity (Mbar)
Laser Driver Power Monitor (uA)	Internal diode to the pump laser optical power
Laser Driver Current Monitor (A)	Current supplied to the pump laser
High Voltage (V)	APD High voltage Bias
Purge Flow Monitor (sccm)	Purge flow measurement in standard cm ³ /m
Board Temperature (C)	Control board temperature
Baseline Sizer Low	Scattering detector high gain baseline (A/D counts)
Baseline Sizer High	Scattering detector low gain baseline (A/D counts)
Baseline Incandescence Low	Incandescence detector low gain baseline (A/D counts)
Baseline Incandescence High	Incandescence detector high gain baseline (A/D counts)
Bandwidth Sizer Low	Scattering low gain channel baseline noise
Bandwidth Sizer High	Scattering high gain channel baseline noise
Bandwidth Incandescence Low	Incandescence low gain channel baseline noise
Bandwidth Incandescence High	Incandescence high gain channel baseline noise
LV Time Stamp (UTC sec)	Number of seconds since January, 1, 1904 midnight UTC/GMT.

Appendix F: Single Particle Trace Files

Single particle trace (sp2b) Data file description (parameters)

The sp2b data file heading SP2XR_hk_YYYYMMDDHHMMSS_xXXXX.sp2b, contains the raw binary sets of data records with one record per particle event.

The following listing gives the structure of each record:

Field	Data Type	Description
Data	2-D array of 32-bit integers (I32)	Data for Scatter and Incandescence traces.
Reserved	Unsigned 16-bit number (U16)	Reserved
Time Stamp	Single Precision Real	Packet UTC Time Stamp
Reserved	Single Precision Real	Reserved
Reserved	Single Precision Real	Reserved
Reserved	Single Precision Real	Reserved
Reserved	Single Precision Real	Reserved
Reserved	Single Precision Real	Reserved
Reserved	Single Precision Real	Reserved
Reserved	Double Precision Real	Reserved
Reserved	Double Precision Real	Reserved
Reserved	1D array of Single Precision Real	Reserved

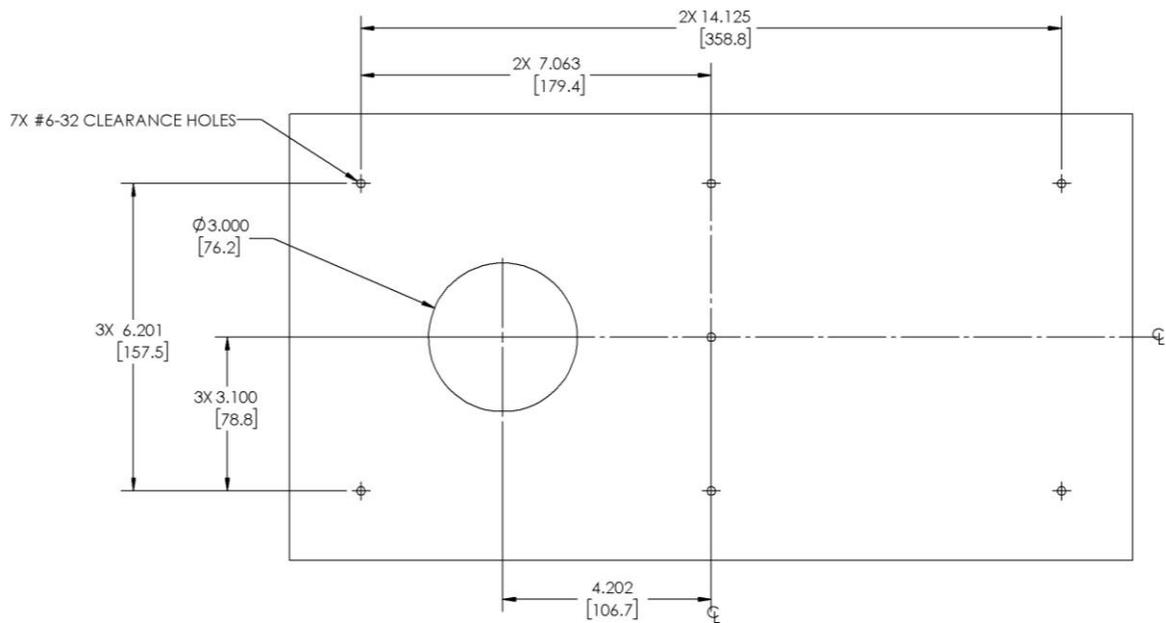
Appendix G: Mounting Information

Requirements for Custom Mounting Solutions

The SP2-XR may be mounted in on an aircraft rack as long as the laser cooling fan on the underneath side of the instrument has sufficient clearance to draw air for proper laser operation.

In addition, there are five #6-32 socket head cap screws securing rubber feet to the bottom of the instrument. These must first be removed, and the 5 locations may be used for custom mounting solutions.

Two mounting options are available for mounting that will maintain sufficient airflow for the laser cooling fan. The first option is to stand the instrument off the mounting surface. There shall be at least 0.5" (12.7mm) of standoff height between the bottom of the instrument and the mounting surface. The second option is to remove a hole from the mounting surface that the laser cool fan can draw air through. See Figure 45 below for dimensions.



NOTES:

1. MAKE SURE FAN IS OVER 3.0 INCH HOLE.
2. MOUNTING HOLES OF INSTRUMENT BASEPLATE ARE AT A DEPTH OF .16 INCHES (4.0mm).

Figure 44: SP2-XR Mounting Hole Dimensions