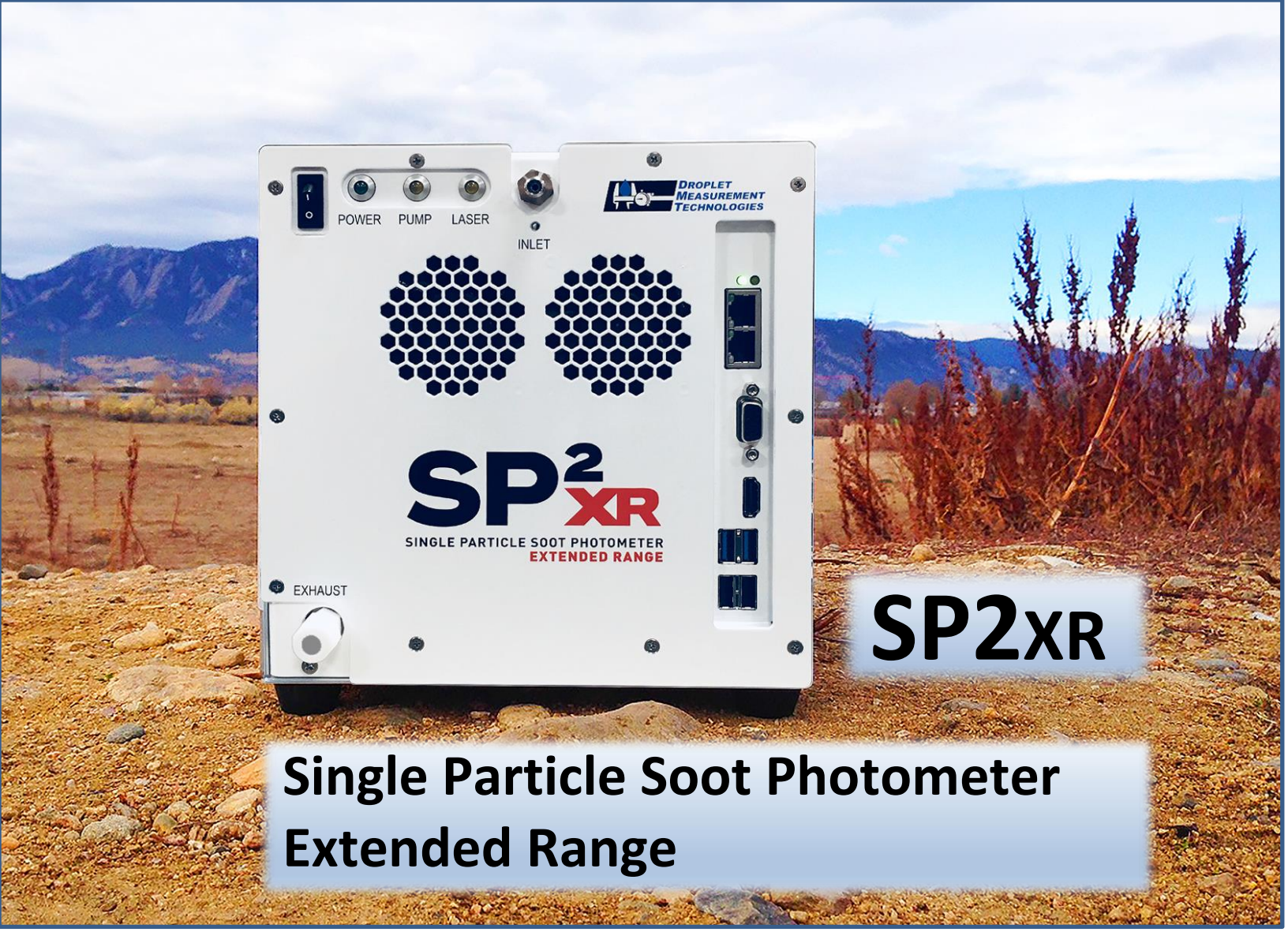


Operator Manual

DROPLET MEASUREMENT TECHNOLOGIES

2400 Trade Centre Avenue
Longmont, CO 80503 USA

DOC-0425 Revision A

CONTENTS

Figures

1.0 Specifications

1.1 General Specifications

Measured Parameters	• Single-particle laser incandescence • Single-particle light scattering
Auxiliary Parameters	• Air, Computer, and laser temperature, cavity and flow controller pressure, sample and sheath flow.
Derived Parameters	• BC mass distribution as function of particle diameter • Particle number distribution as a function of particle size
Maximum Data Acquisition Rate	• 25,000 particles/second • 10% coincidence at 3000 Particles/second
Particle Size Range Encompasses the accumulation mode of most particles, i.e. range where most mass is found.	• Scattering signal: 100 – 500 nm diameter (this range encompasses the accumulation mode of most particles, i.e. range where most mass is found) • Incandescent signal: depends on particle density, 50nm – 800 nm mass-equivalent diameter assuming a black carbon density of 1.8 g/cm^3
Sample Aerosol Medium	• Air, 0°C to 40°C (32° - 104°F)

Lasers The pump laser can be controlled with the SP2-XR software.	• Nd:YAG Laser: 1064 nm, up to 1 MW/cm^2 intracavity circulating power • Pump Laser: 808 nm, 3 W
Sample Flow	30 – 120 Standard cm^3/minute
Flow Control	ALICAT Electronic flow control with a laminar flow element (LFE) and a solenoid valve
Pump	Single-head diaphragm pump in box
Weekly Routine Maintenance:	• Conducting 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 DMT 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.

Rear Panel (power connection)	Power connection – DC input, 18-36VDC (24V nominal) *Power surge protection is highly recommended
Front Panel Display and 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.
Computer System	Intel i7-6600U CPU 8 GB RAM 128 GB mSATA SSHD
Software	• SP2-XR Executable program in LabVIEW
Data Storage Capacity Depends on the number of particles.	At a standard concentration of 1,000 #/cm^3 and a standard flow rate of 100 volumetric cm^3/minute, the SP2-XR computer has the capacity to store 56 hours of continuous data.
Backup Battery Capacity	10.24Wh (This battery pack should not be replaced or modified in any way.)

1.2 Electrical Specifications

Voltage:	SP2-XR: 18-36VDC, (24V Nominal)
Power Consumption:	25 W maximum / 80 W typical

1.3 Physical Specifications

Weight:	13 Kg (28.5lbs) for SP2-XR Instrument
Dimensions:	SP2-XR: 41 cm W x 41 cm H x 82 cm L (Actual) Not including inlet hardware and fuses.
Shipping Container:	Durable Pelican Case ATA Transit Case that conforms to the Air Transport Association's Specification 300 Category 1 standards
Other:	Suitable for airborne operation mounted in the aircraft cabin

1.4 Operating Limits

Altitude:	0-20,000 ft.

2.0 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.

All DMT product names and the Droplet Measurement Technologies Logo are trademarks of Droplet Measurement Technologies, LLC.

All other brand and product names are trademarks, or registered trademarks, of their respective owners.

Software License

DMT licenses SP2-XR software only upon the condition that you accept all of the terms contained in this license agreement.

This software is provided by DMT "as is" and any express or implied warranties, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose are disclaimed. Under no circumstances and under no legal theory, whether in tort, contract, or otherwise, shall DMT or its developers be liable for any direct, indirect, incidental, special, exemplary, or consequential damages (including damages for work stoppage; computer failure or malfunction; loss of goodwill; loss of use, data or profits; or for any and all other damages and losses). Some states do not allow the limitation or exclusion of implied warranties and you may be entitled to additional rights in those states.

Warranty

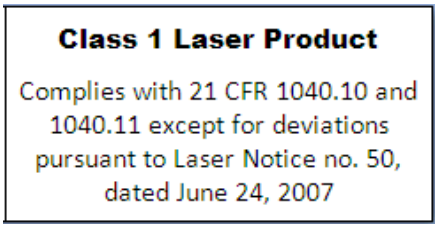
The seller warrants that the equipment supplied will be free from defects in material and workmanship for a period of eighteen months from date of shipment or 12 months from the date of either installation or first use whichever comes first. When returning the equipment to DMT for warranty or service procedures, the equipment owner will pay for shipping to DMT, while DMT will pay the return shipping expense. Consumable components, such as tubing, filters, pump diaphragms, and Nafion humidifiers and dehumidifiers are not covered by this warranty.

2.1 Safety Information

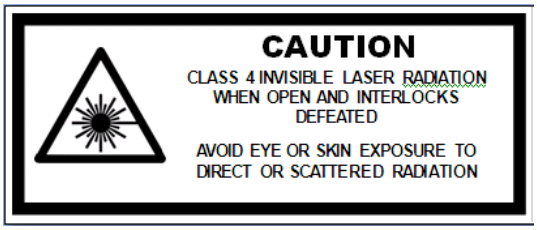
Laser Safety

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.

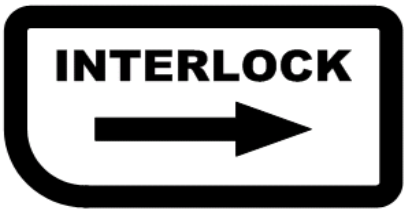
CAUTION – Use of controls, adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure. Strict observance of the following Warning labels is advised.



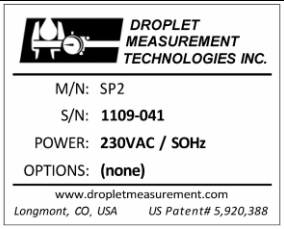
Back panel of the SP2-XR



Exterior of the laser frame:



Interlock switches:



Back panel of the SP2-XR

2.2 Interface Features

The SP2-XR input and output features are shown in (Figure 1) below

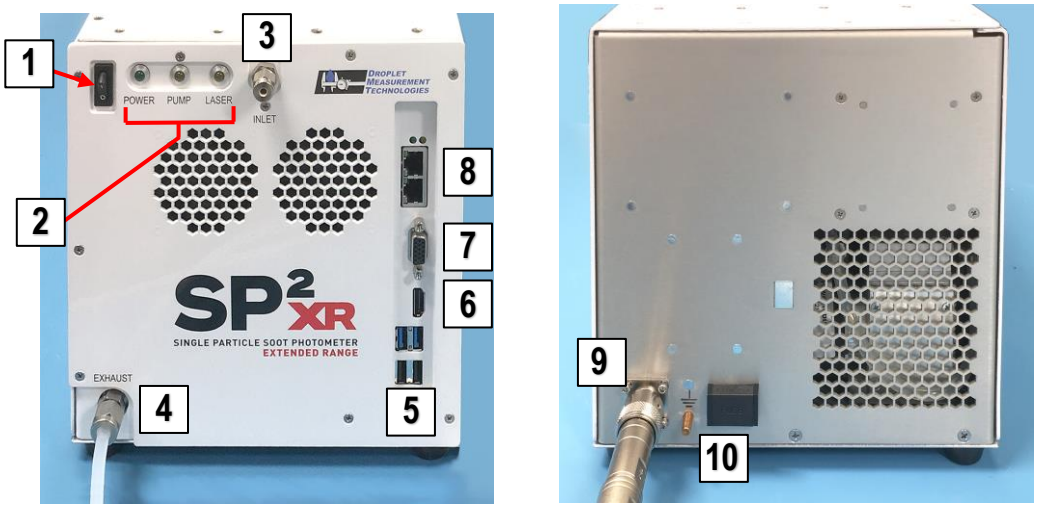


Figure 1: Front and Rear view of the SP2-XR

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	9	DC input 24 VDC power connection
5	USB 2.0 ports (Mouse) and other	10	Optional Ground /Fuse drawer

3.0 Introduction

The SP2-XR directly measures the black carbon, known as soot, in individual aerosol particles. Its high sensitivity, fast response, and specificity to elemental carbon make it the premier instrument for the following tasks:

- Characterizing pollution sources
- Characterizing black carbon soot in snow, ice, or water
- Calibrating Aethalometers
- Documenting thin, atmospheric layers of contamination

The SP2-XR utilizes the same intracavity incandescence technology as the SP2, with an optical system that is based on the DMT UHSAS integrated optical block. The SP2-XR uses one scattering and one incandescence detector. The particle peak processing is done in the instrument firmware and software which provides data without the need for two pass processing.

The Single Particle Soot Photometer (SP2-XR) utilizes the high optical power *intra*-cavity Nd:YAG laser. Light-absorbing particles, mainly black or elemental carbon, absorb energy and are heated to the point of incandescence. The energy emitted in this incandescence is measured, and a quantitative determination of the 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, the SP2-XR also measures the black carbon mass concentration

4.0 Unpacking and Setup

4.1 Unpacking

The SP2-XR will be shipped in 1 case. It is 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.

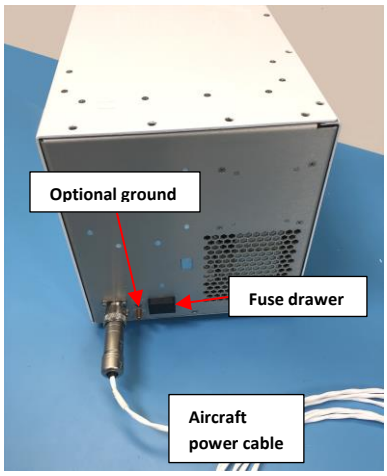
The shipment also includes:

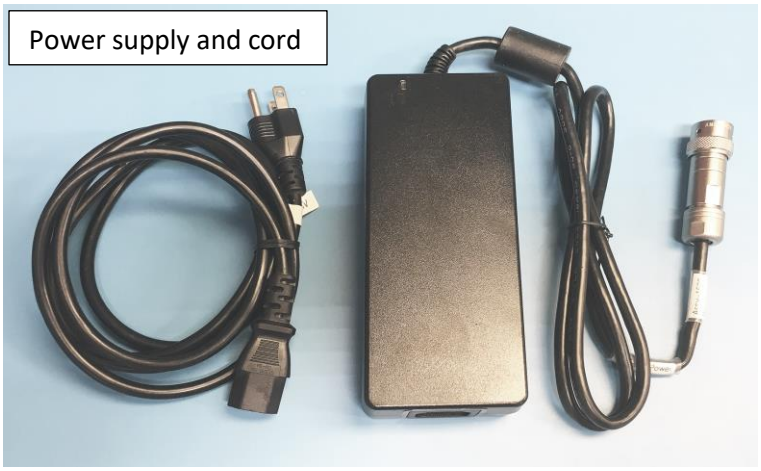
- Beam Scan Camera
- Calibration
- Toolkit
- Alignment Tools

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

4.2 Set Up

1. Connect the SP2-XR power cable. Either remote power, or the provided power supply (Figure 2b.)





2. If using the provided power supply, plug in the SP2-XR power supply using the appropriate region adapter. The optional ground is generally used to protect the instrument in an airplane.
3. If there is a plug on the inlet tube, be sure to remove it before powering up the instrument.

NOTE: The SP2-XR computer is intended primarily 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.

4.3 Steps for Powering-up the System

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

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

2.) If the unit does not power up check the fuse drawer on the rear panel.

3.) Start the SP2-XR software by double-clicking the SP2-XR icon on desktop.

4.) In the software, go to the **Actions** tab **(A)** in the upper left-hand corner of the screen.

5.) Toggle on the pump. You should hear the pump activate. **Once** the pump has started, it is safe to toggle the **Laser on (B)** from the **Actions tab** or (F7) (Figure 2).

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.

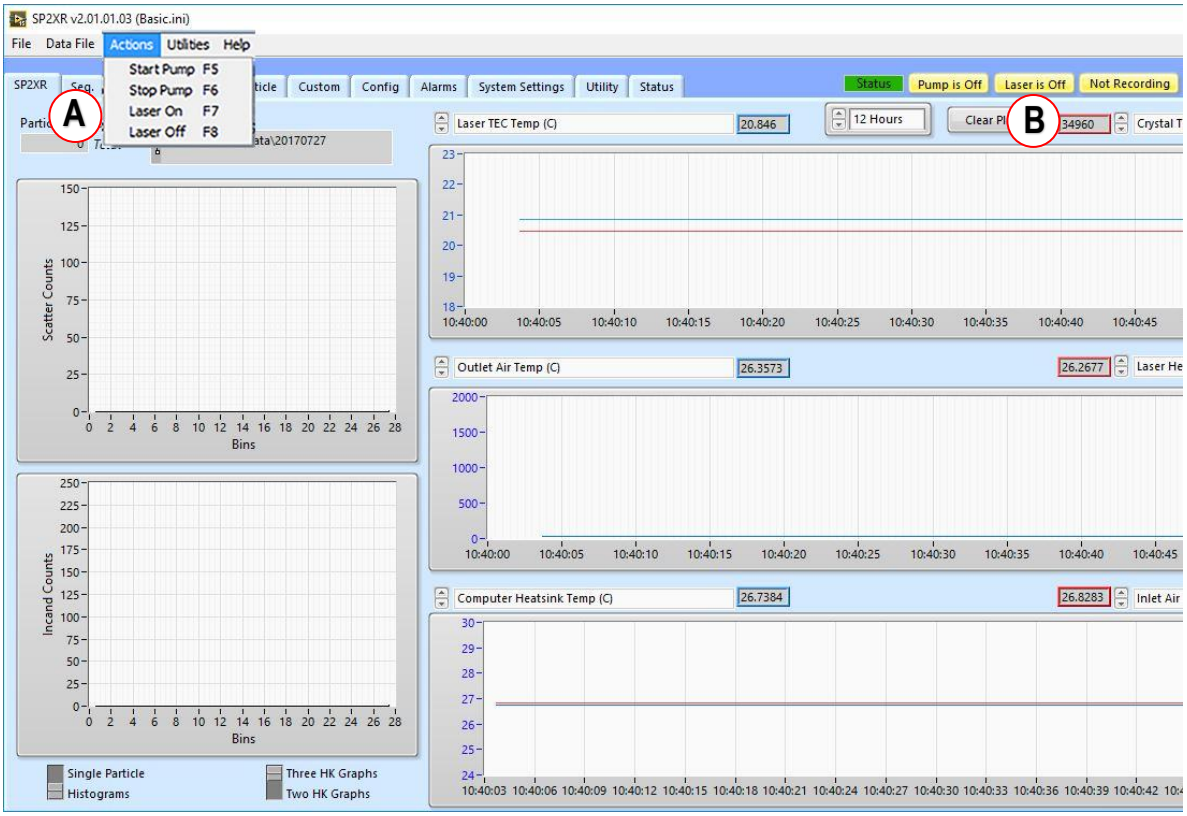


Figure 2: Start the Pump and Laser

4.4 Powering the System Down

To turn off the SP2-XR, follow the instructions below:

1.) On the SP2-XR software's **Actions** tab (Figure 2), set the **Laser Power Switch** to Off.

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

2.) In the **Actions** tab **(A)** (Figure 2), turn off the **Pump** switch to the SP2-XR.

3.) Shut down the SP2-XR software by selecting **File > Exit.**

4.) Turn off the SP2-XR instrument using the **System Power** switch located on the left front corner of the unit.

5.0 SP2-XR Software

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

- The basic software for control of the instrument, setting instrument flows, visualization of the operation and recording of the data is not password protected.
- In the System Settings tab, there is the administrator login window.
- Entering the second level password, gives access to the acquisition settings in the single particle 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.

The programs are loaded on the C: drive of the SP2-XR as well as a copy which is provided on the memory stick that ships with the unit.

5.1 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.
- . RAW – Raw data in A/D counts, with no conversion factors applied.
- . 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 are captured.
- Threshold data files – Relates the A/D particle signal counts to the particle size. These tables are developed by the SP2-XR calibration program.

5.2 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 all recorded parameters. Each of the tabs will bring up a new screen allowing for instrument control or display of parameters.

- To start, make sure that the correct **Config** file is chosen **(A)** (Figure 5). Go to the **Config** tab and **Program** Sub-tab (Figure 12) and check the Config file being viewed window. After setting up the correct **Config** file, navigate to the main SP2-XR screen initiate the start-up procedure for the Pump and laser.
- Check the status area in the upper right **(B)** (Figure 3) to make sure the Pump and laser are on and running.

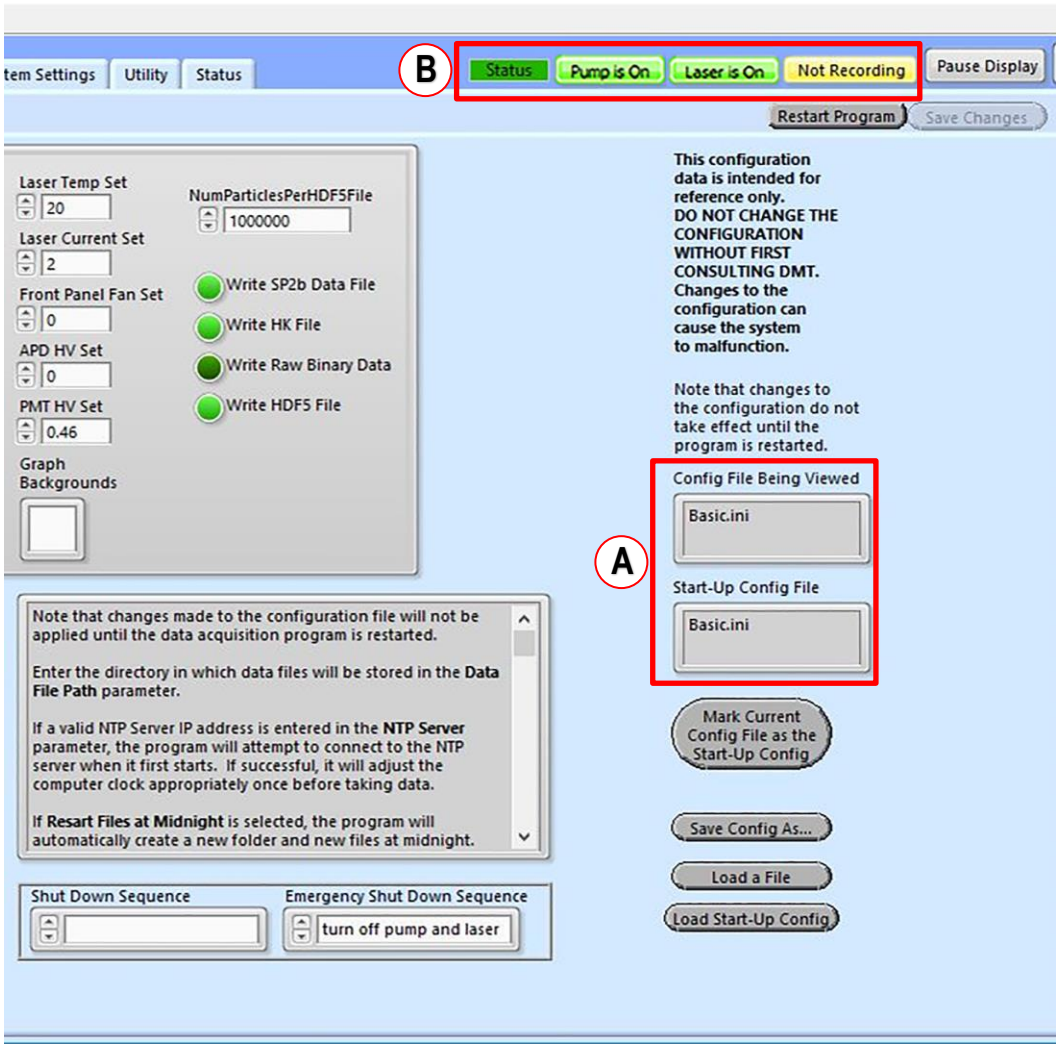


Figure 3: Choose the correct Config file

After finding the Main SP2-XR tab, choose the parameter **(A) "Sample Flow Controller Read"**, and set the flow **(B)** to approximately **60 sccm**. Check that the flow is stable (Figure 4). Other parameters can be chosen by scrolling through the up and down arrows to the left of the displayed parameters or by clicking in the fields highlighted in (Figure 4) a drop-down menu will appear, and a parameter can be chosen from the list. A full description of these parameters can be found in Appendix D **"Housekeeping Data files".**

Figure 4: Choosing parameters

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 axis and entering the desired value.

(Figure 5) shows the **File** tab **(A)**. It is used to save a Configuration file, save the current screen as a .jpg, or Exit the program. This is the preferred way to close the program as the configurations and configuration files will be saved properly.

To start recording data, choose the **Data File** Pull-down menu **(B)** (Figure 6) and **Start Recording** (F1). Check the status at the top right of the main program window, the **Recording / Not Recording** button shows when data is being written to a file. The data file name and location will be shown in the **Data File Path** box (Figure 7) on the upper left of the single particle SP2-XR screen.

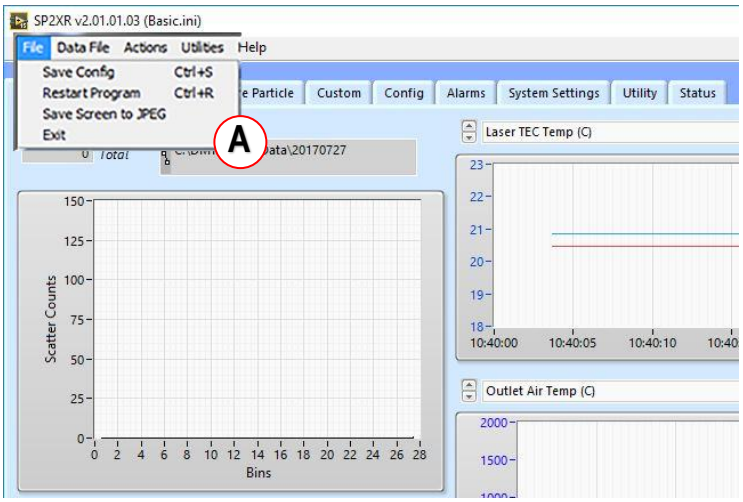


Figure 5: File tab

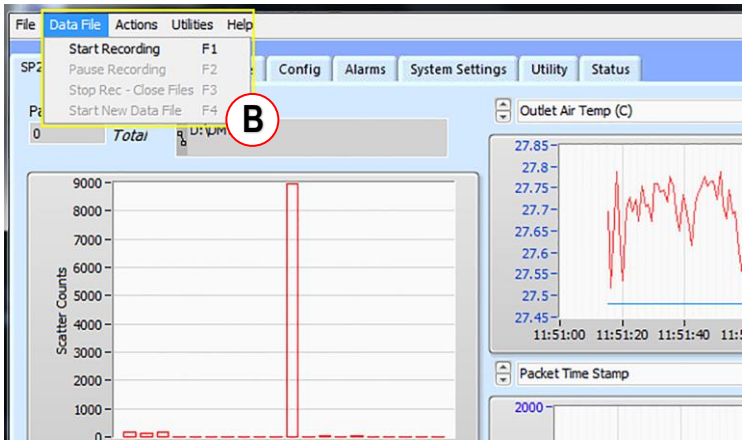


Figure 6: Data File tab

5.3 SP2-XR Main Screen

The following section details the SP2-XR main screen (Figure 7).

- The windows in the upper left (A) show the folder location and the data file name, as well as the number of particles saved to the file.
- All of the parameters that are saved to the housekeeping data file can be viewed in the time series windows (B).
- The default parameters are set in the Config and Program Tab, but these can be changed in real-time by scrolling with the arrows or clicking in the legend window and activating the drop-down menu. The time duration of the window can be set by the scroll/dropdown menu.
- The windows on the left of the tab (C) can be configured to show the histogram of the particle size distribution, matching the Histogram tab, or the single particle signal trace, identical to the Single Particle tab.
- The Pause Display toggle (D) will pause the data visualization display for closer inspection of a particular data event, or to save a screen capture of the event.

Figure 7: Verifying particle response

5.4 Sequence Tab

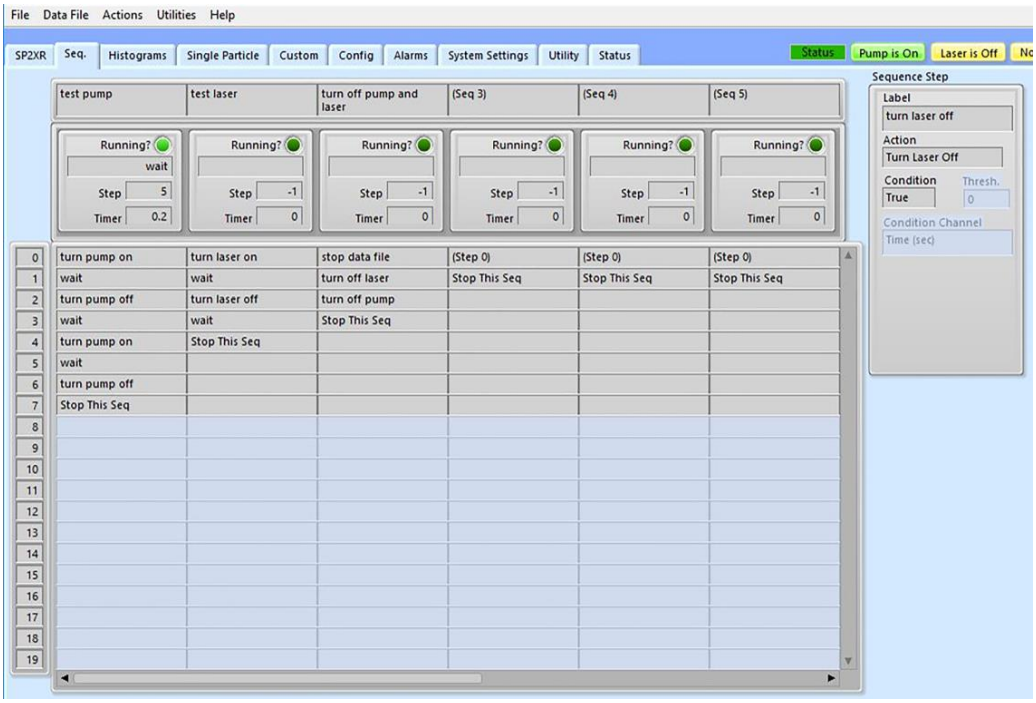


Figure 8:Sequence tab

The **Sequence** Tab (Figure 8) is a quick reference to all of the Sequences available. It shows which ones are running, and which state they are in. Specific sequences can be turned on and off by pressing the “Running” button.

5.5 Histograms Tab

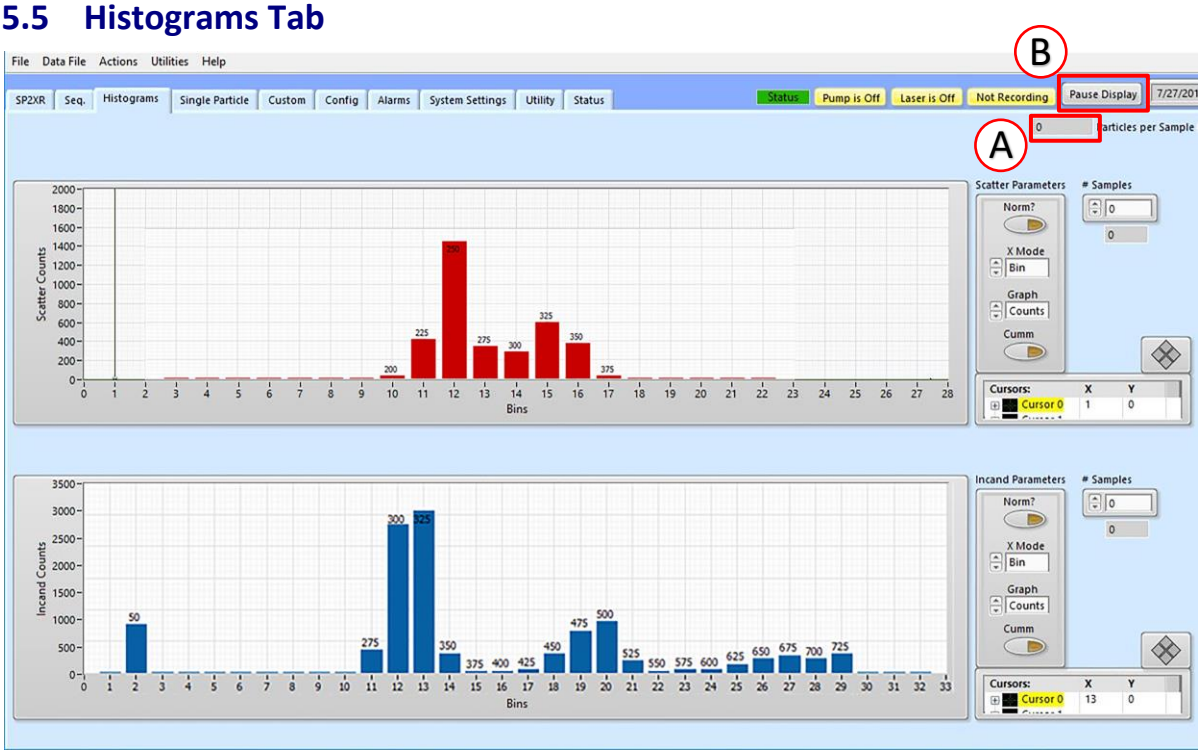


Figure 9: Histograms window: Scatter (Red) and Incandescent (blue)

Particle size histograms (Figure 9) detail the particle size histograms showing scatter (red) and incandescence (blue) as developed from the threshold tables. The data is given in counts on the Y axis. The **particles per sample period** are recorded in the top right field **(A)**. The **Pause Display** toggle **(B)** will pause the data visualization display for closer inspection of a particular data event, or to save a screen capture of the event.

5.6 Single Particle Tab

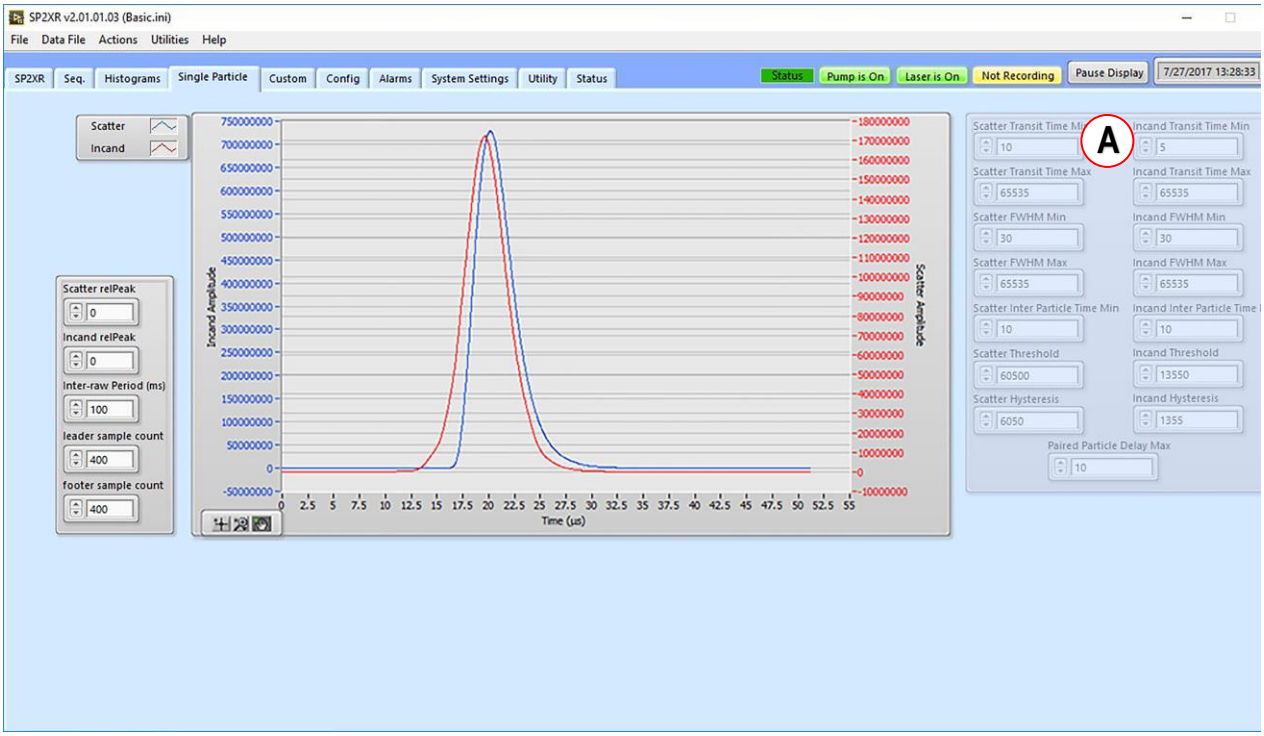


Figure 10: Single particle window

The Single Particle Tab (Figure 10) shows the full digitized signal traces as recorded by the respective detectors.

- The data can be saved in the SP2b data file format if this option is selected for writing in the Config Programs tabs.
- The acquisition parameters shown on the right of the screen **(A)** can be accessed by entering the second level password. Any changes made here will immediately change the instrument parameters but will not be saved in the .ini file when the SP2-XR program is closed. See Appendix A for a schematic of particle traces and how these parameters are applied.

5.7 Custom tab

(Figure 11) shows The **Custom** tab (Figure 13) has two Custom data displays **(A) (B)**. Each of the charts provided, are user configurable and can display up to 8 channels on two y axis'.

Figure 11: Custom tab

5.8 Config Tab

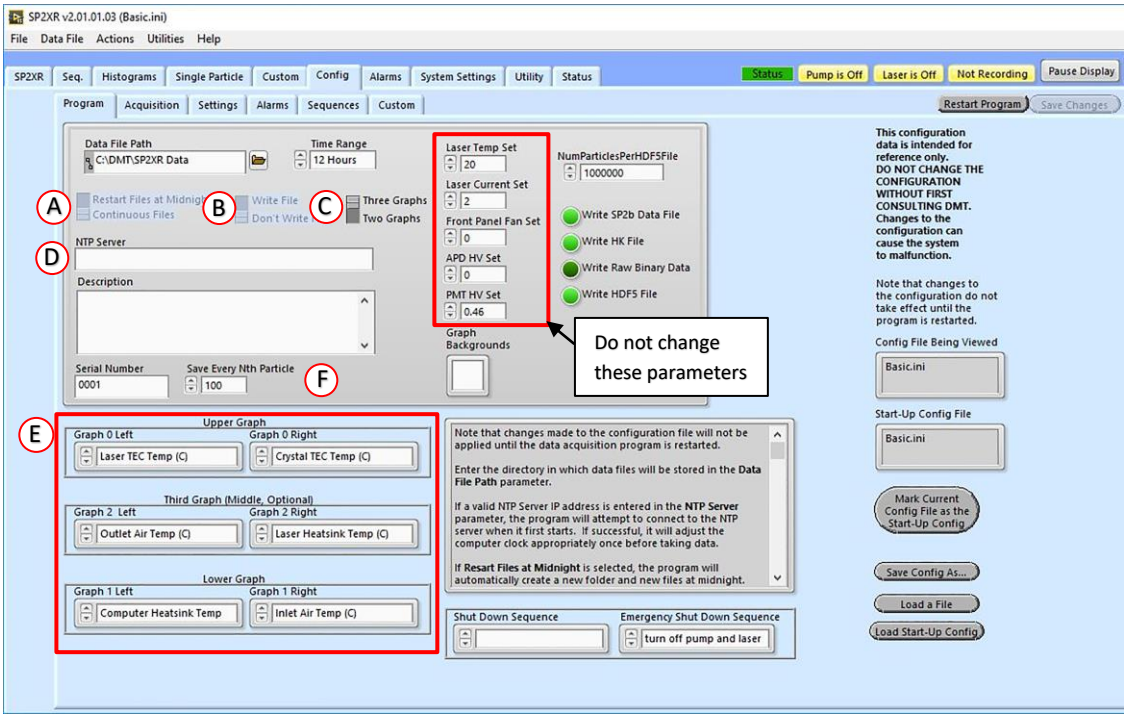


Figure 12: Config / Programs tab

The **Config** tab (Figure 12) and the four sub tabs and all parameters in the config tab are part of the .ini file and are only editable if the second level software password is entered.

Following any changes to the .ini parameters, the .ini file must be saved as either the existing file or one with a new name. The Program tab has default parameters that are setup for much of the instrument operation.

- **Data file Path (A)**: The SP2-XR software is stored on the C: drive which if write-protected, any files saved to the C: drive will be deleted when the instrument is shut down. Data can be stored on the D: drive or an external drive.
- **Restart files at Midnight/Continuous files**: Will restart with new settings at either midnight or immediately.
- **Write File/Don't Write File (B)**: If Write file is selected, when the unit is powered on, it will start recording housekeeping files automatically. The sample pump and laser will not come on automatically.
- **NTP Server:** If a valid server address is entered in the field **(D)**, the program will attempt to connect to the NPT server when it first starts. If successful, it will adjust the computer clock appropriately once before taking data.
- **Three Graphs/Two Graphs (C)**: Two or Three-time series graphs can be shown. A series of different Graphs can be shown by selecting them in the lower windows **(E).**
- **Reset to defaults:** This button will reset the .ini file to the factory default values. Should the .ini file become corrupted, this method should get the user back to an operational state.

- **The parameters:** Laser Temp Set, Laser Current Set, Crystal Temp Set (not active), APD HV set, and PMT HV Set, are operationally critical defaults and should not be changed without consulting Droplet Management Technologies prior to making those changes.
- **Save Every Nth Particle (F)**: 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.

5.8.1 Config / Acquisition Tab

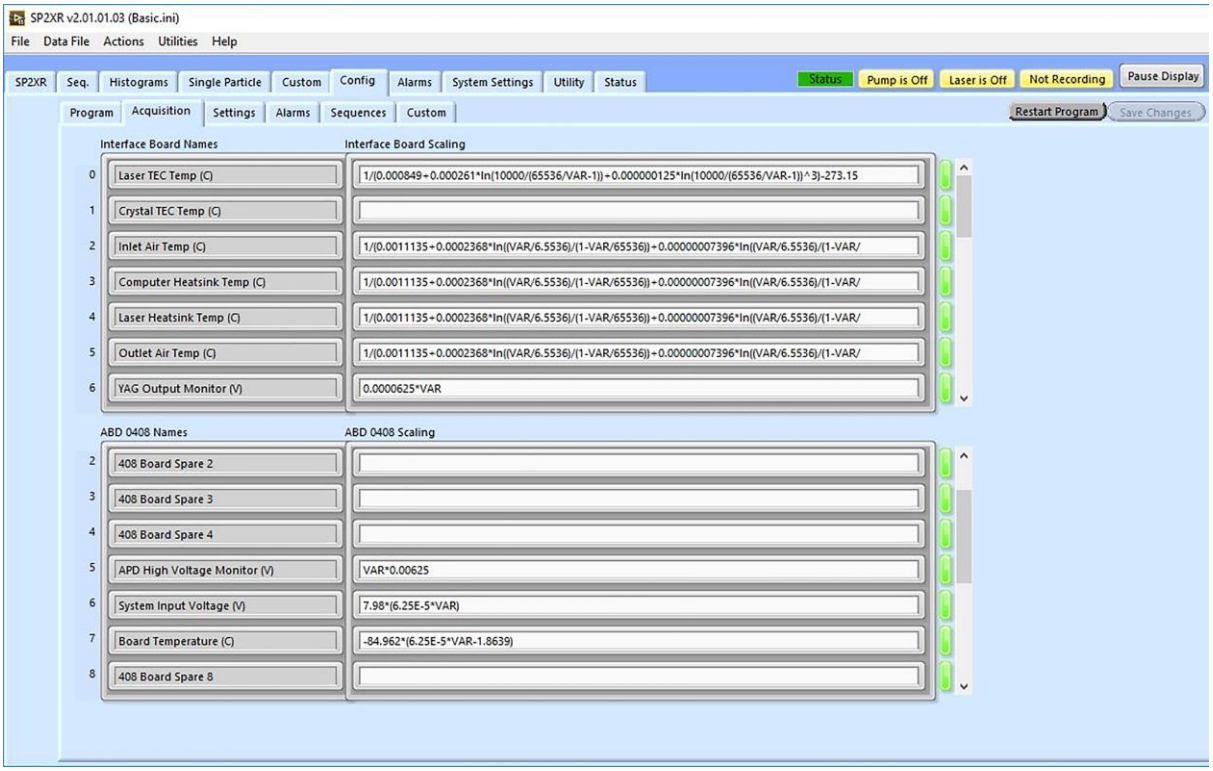


Figure 13: Config / Acquisition tab

The **Acquisition** tab is detailed in (Figure 13). On the left side are the parameters used in scaling the A/D channels from the Interface Board and the control board. These values should not be changed unless directed by DMT. The right-hand side of the screen shows the selected threshold tables and the A/D values with the corresponding particle size bins.

5.8.2 Config / Settings Tab

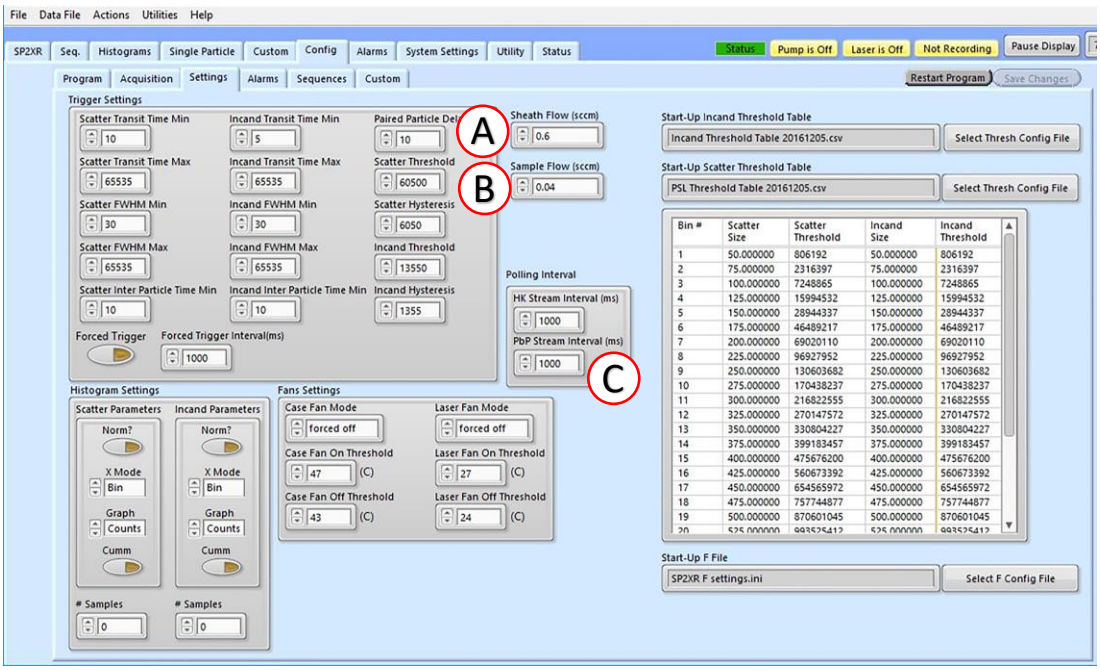


Figure 14: Config / Settings

The **Settings** Tab (Figure 14) allows the user to build default parameters and save them in the .ini file. It contains the same parameters shown in the single particle tab, (Figure 11). Changing the values here will not be implemented until the file is saved and the program has been reloaded.

- Sheath flow: **(A)**Sets the default sheath flow in sccm
- Sample flow: **(B)**Sets the default sample flow in sccm
- Polling interval: **(C)**This sets the time for the Housekeeping (HK) file and the PBP recording. For most applications 1000 Milliseconds is recommended

5.8.3 Config / Alarms Tab

Configuring the Alarms (Figure 15) allows the user to monitor any of the parameters in the SP2-XR housekeeping 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, so that the operator knows the purpose of the alarm. It is also used programmatically to refer to the alarm so that its threshold can be changed by a sequence, CCL command, or another alarm.
- **Channel** determines which of the housekeeping data channels is used for the alarm.
- Condition selects which logical condition is applied to the selected channel: <, <=, =,<>(not equal), >= or >.
- **Threshold** defines the value that the channel will be compared to when determining if an alarm is true or not.
- **Hysteresis** allows the alarm to be configured such that small amounts of noise near the threshold value will not continually set and clear the alarm. For the < and <= commands, once

the alarm has been triggered, the value of the channel must go above [Threshold + Hysteresis] before the alarm can turn off. For the > and >= commands, Hysteresis is ignored.

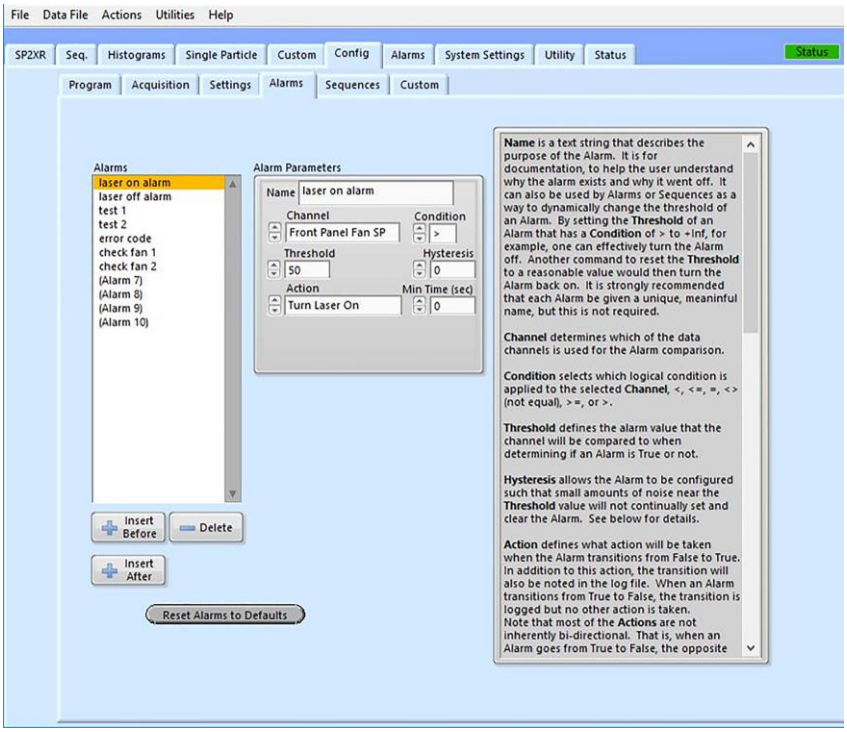


Figure 15: Config / Alarms

- **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. For a complete list of actions, See Appendix D.

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. An example of this would be: “Turn Laser Off Alarm” will not turn the laser back on when the alarm becomes false.
Note: 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.

- **Set Value and Target Channel** are used by the "Set Channel" and "Add to Channel" actions to allow an output channel to be set to a new value if an alarm becomes true. Target channel is also used by the "Set Ch to Manual" and "Set Ch to Control" actions.
- **Sequence** is used by the "Start Sequence" and "Stop Sequence" actions. This parameter specifies which sequence should be started or stopped when the alarm becomes true.
- **Target Alarm** is used by the "Set Alarm Thresh Action" action to change the threshold of an alarm to the value specified by the "Set Value" parameter.

5.8.4 Config / Sequences

Configuring the Alarms (Figure 16) allows the user to monitor any of the parameters in the SP2-XR housekeeping 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, so that the operator knows the purpose of the alarm. It is also used programmatically to refer to the alarm so that its threshold can be changed by a sequence, CCL command, or another alarm.

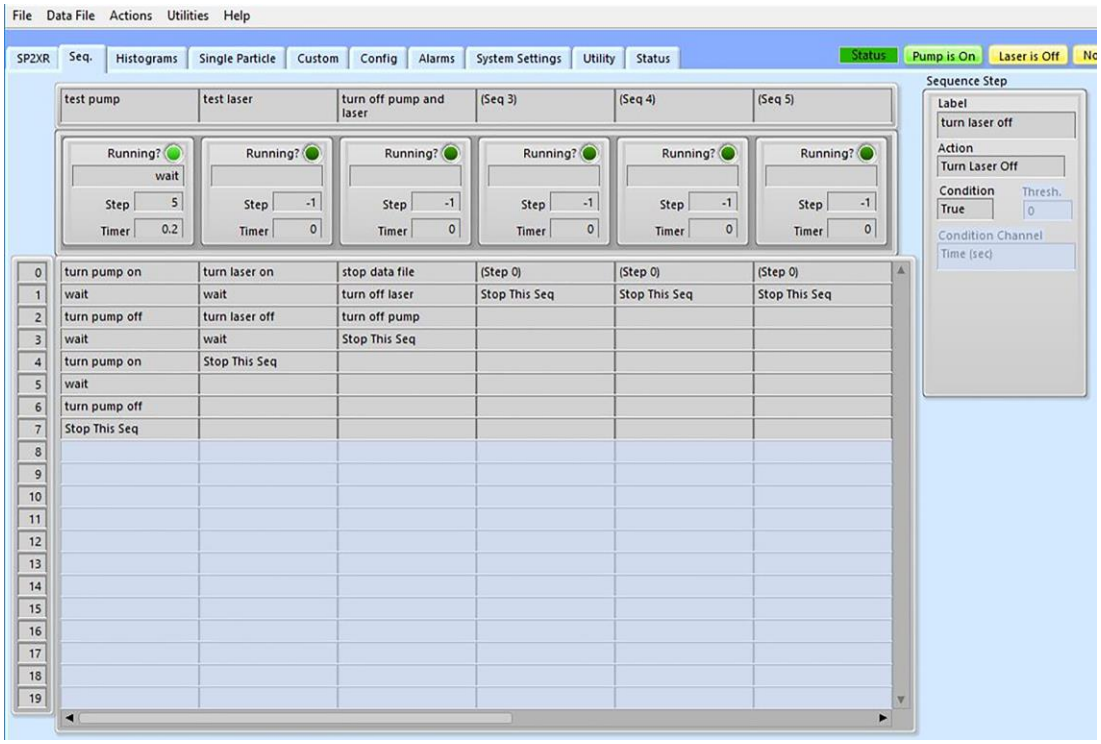


Figure 16: Config / Sequences tab

5.8.5 Config / Custom

The **Config / Custom** tab (Figure 17) allows the user to configure or set any of the data display parameters for the two data displays on the Custom tab (section 4.7).

Display indicates if the custom tab will be displayed in the SP2-XR program.

Display Sets is a list of all the display sets that have been defined. The custom display tab can be configured to show an arbitrary number of custom displays.

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 and **Insert after** can be used to label the Display Set that is currently being edited.

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.

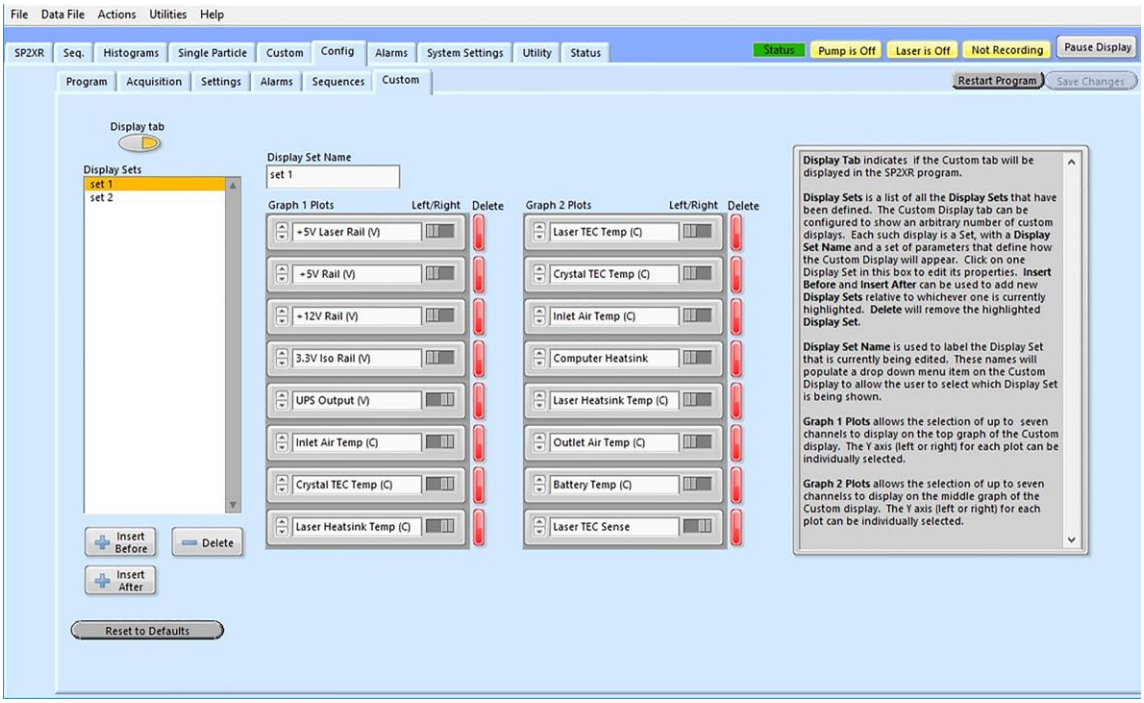


Figure 17: Config / Custom tab

5.9 Alarms Window

The **Alarms** tab (Figure 18) allows the user to configure or set that correspond to data display parameters for the numeric inputs (See section 5.9.1).

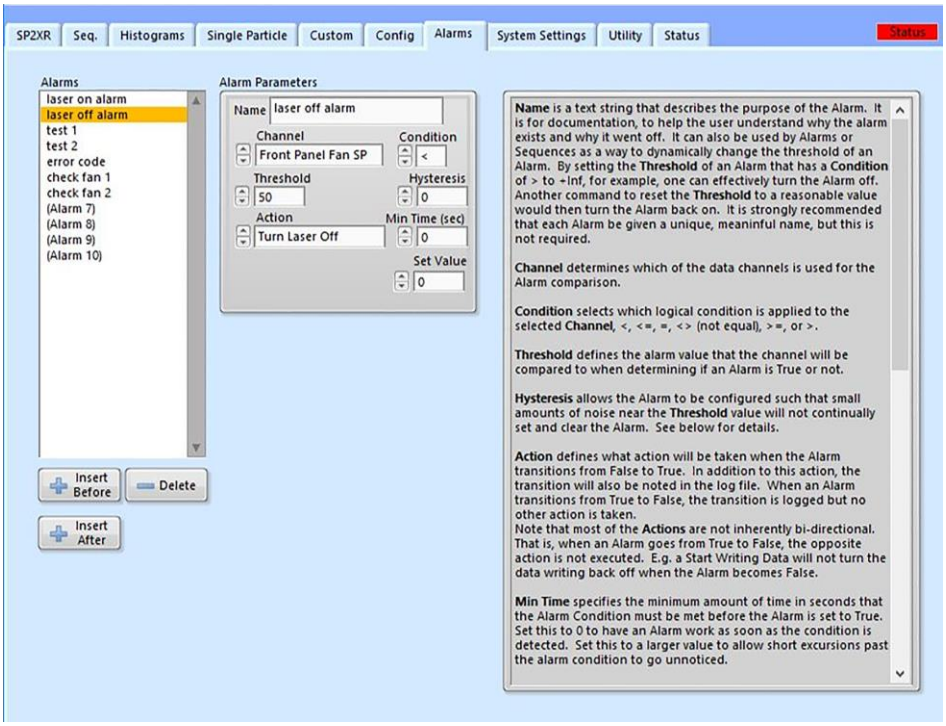


Figure 18: Alarms tab

- The "**Alarm Parameters"** field is also used by several other actions to specify the numeric value that the action uses. See the description field on the right of the window for detailed descriptions of each function.

5.9.1 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: Mon PumpLaser
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.

5.10 System Settings tab

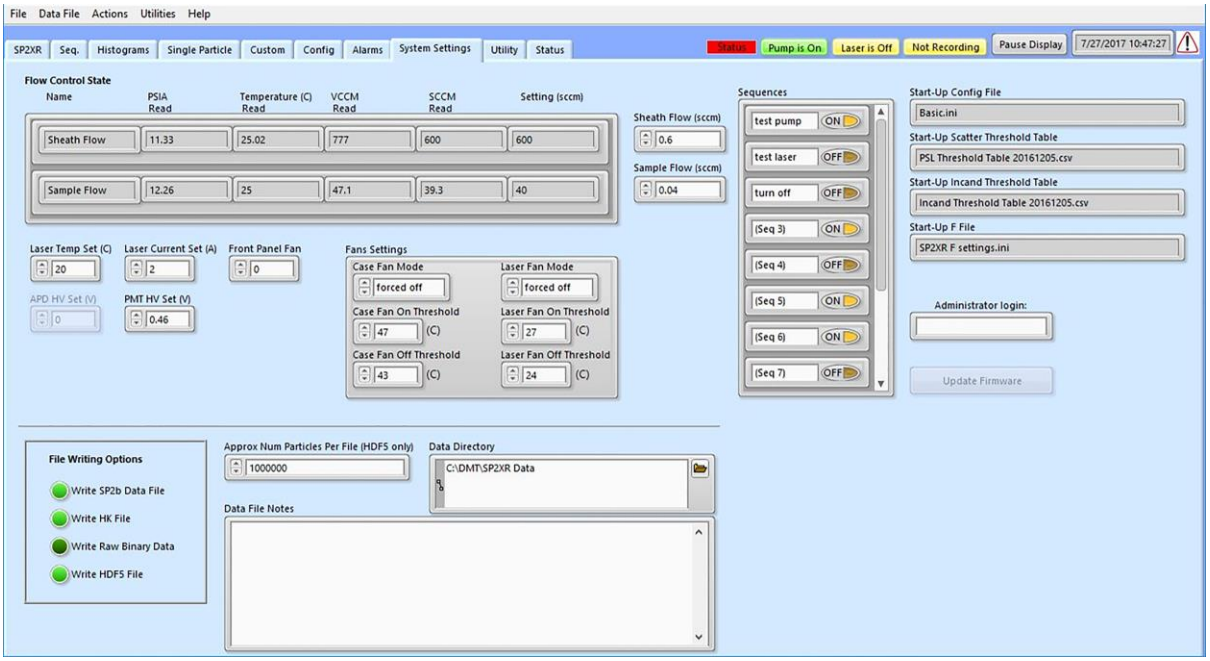


Figure 19: System Settings tab

The **System Settings** tab (Figure 19) is a good overview of settings for the current experiment. Most adjustments and/or settings are made here to control the experiment and data collection.

- **Flow Control, laser and fan settings**
- **File writing options, locations and data file notes input.**
- **Sequence viewing and toggle on/off**
- **Start-up Config, Threshold tables, and F files**
- **Administrator login**

5.11 Utility Window

The **Utility window** (Figure 20) has functions and windows for viewing data and logs.

5.11.1 Utility – Data Reader

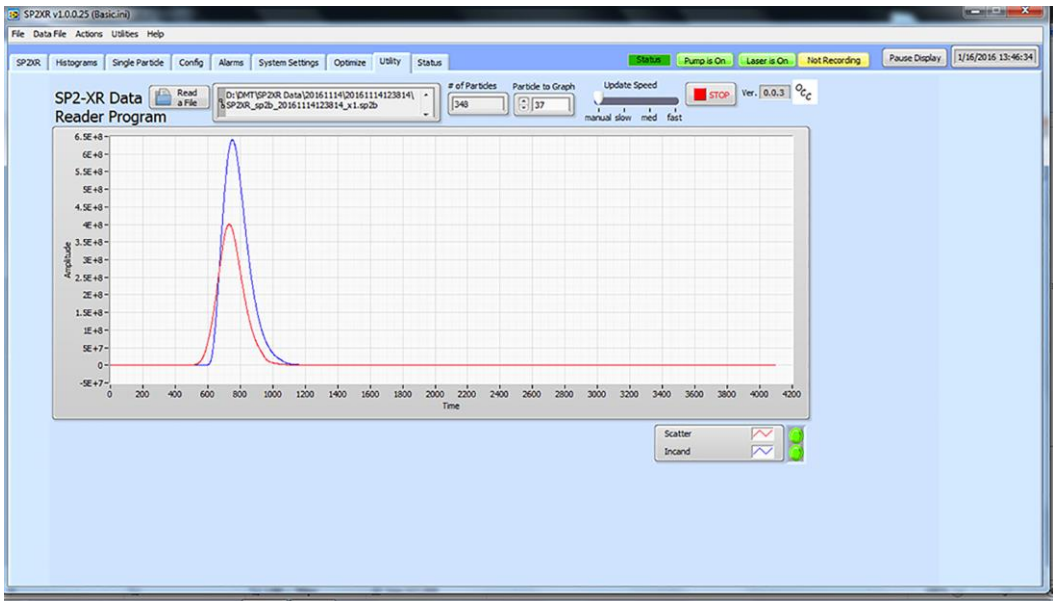


Figure 20: Utility – Data Reader

5.11.2 Utility – Log reader

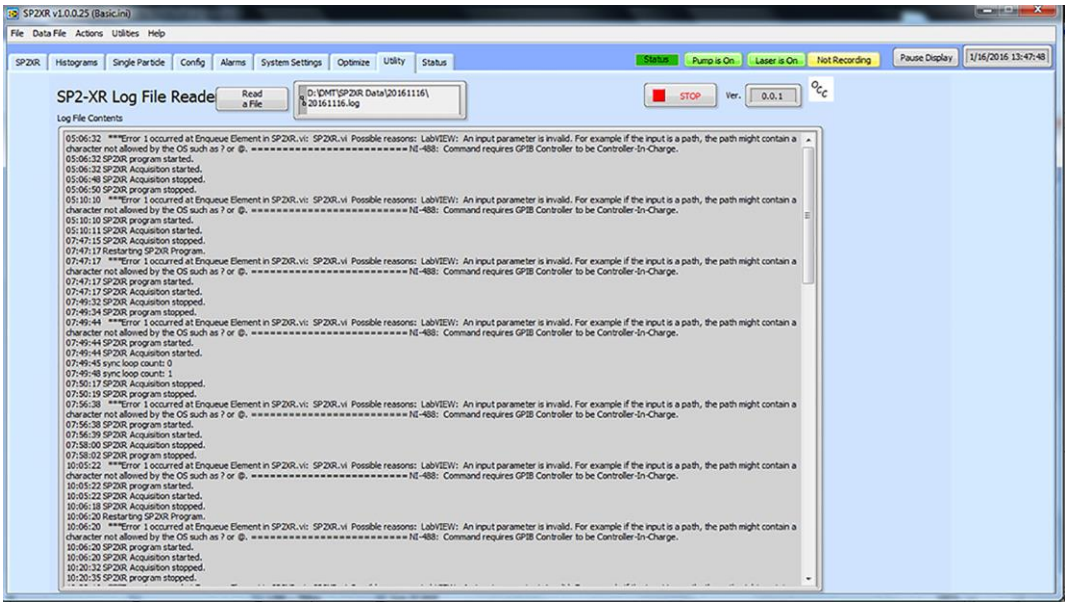


Figure 21: Utility Log Reader

5.12 Status Window

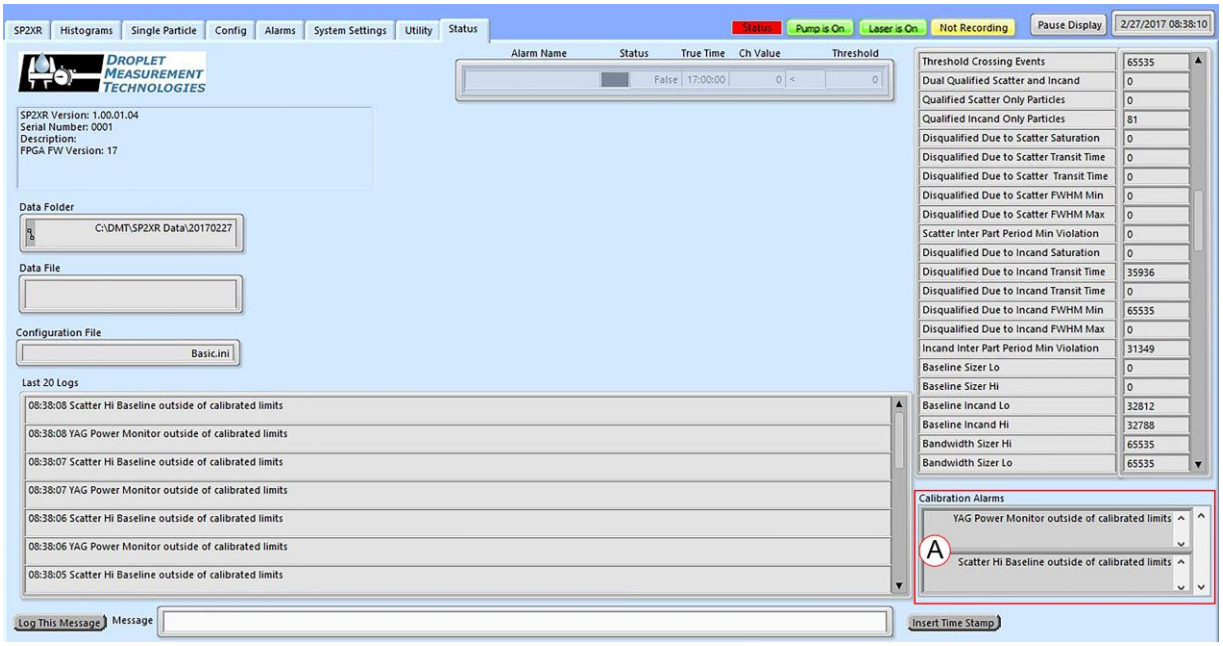


Figure 22: Status tab

The Status window (Figure 22) provides information for housekeeping parameters and alarm information on the right side of the tab, and a log window on the left side which can aid in identifying or solving any errors in data collection and software. Calibration alarms are logged in the lower right (A). When status is red and alarm notes show that unit has exceeded its calibration limits, please call DMT for further instruction.

6.0 Laser Safety Interlocks

The SP2-XR features two types of laser safety interlocks that operate in series. The first, (Figure 23: Cabinet Interlock Switch) is a cabinet laser safety interlock that disables the laser if the cover of the unit is removed. Be careful to make sure the interlock is not intentionally or accidentally engaged or pressed down if the cover has been removed from the unit.

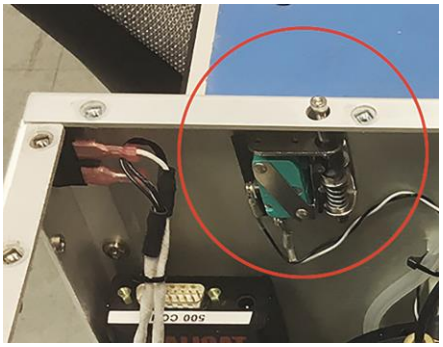


Figure 23: Cabinet Interlock Switch

There is a secondary fail-safe for disable/enable laser power, that is located internally in the form of a key that can be turned to the locked or unlocked position. (Figure 24: SP2-XR Key in the locked (laser off) position). In this position, the key can be removed to prevent accidental activation of the laser.

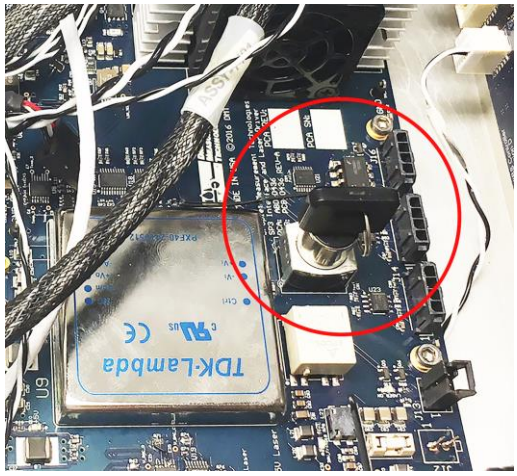


Figure 24: SP2-XR Key in the locked (laser off) position

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.

7.0 Routine Maintenance

It is recommended that at least once per month, or before an experiment, a particle zero count check is executed. This is done by attaching the filter included with the shipment to the SP2-XR 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 first, to verify threshold changes will not negatively affect desired particle measurements.

7.1 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 damaging or further contaminating the optics. If the laser power drops and it cannot be recovered by a minor alignment, and other parameters such as the pump laser power are verified, it is worth trying to clean the optics to recover laser power. Most likely the contamination will be on the surface of the coupler. This should be cleaned first. A full alignment of the system will be required to replace the coupler and get the YAG laser operational if a basic cleaning is not effective.
Carefully perform the following instructions for cleaning the optics:

1) Locate the cleaning port for the mirror optic at the front-end, and back-end of the optical block (Figure 25a). Generally, contamination occurs at the mirror end. Start cleaning with this optic. For access, remove the two lock-down screws near the cleaning port (Figure 25b), then remove the cleaning port.

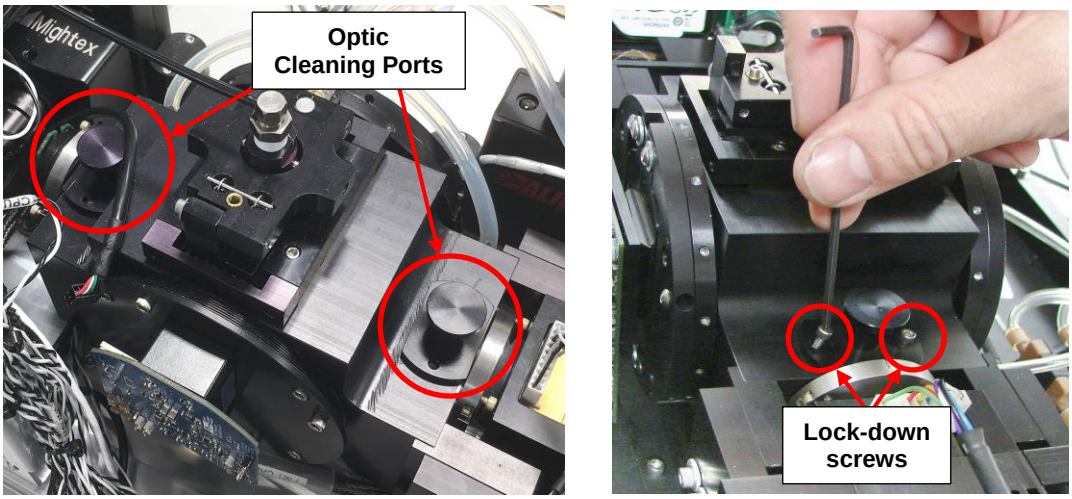


Figure 25: Cleaning port access to optics

2) Using a cotton swab with a one to two drops of spectra-photo grade acetone, clean the optic (Figure 26: Cleaning the Optics). 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 Q-tip, as grease from the O-ring can get on the Q-tip and smear the optics.

Figure 26: 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.

8.0 Troubleshooting

Problem		***Possible Cause***		***Solutions***
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).

Appendix A: Theory of Operation

Design

The single-particle The Single Particle Soot Photometer (SP2-XR) utilizes the high optical power *intra*-cavity Nd:YAG laser. Light-absorbing particles, mainly black or elemental carbon, absorb energy and are heated to the point of incandescence. The energy emitted in this incandescence is measured, and a quantitative determination of the 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, the SP2-XR also measures the black carbon mass concentration.

All particles scatter light, regardless of whether or not they absorb light. 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

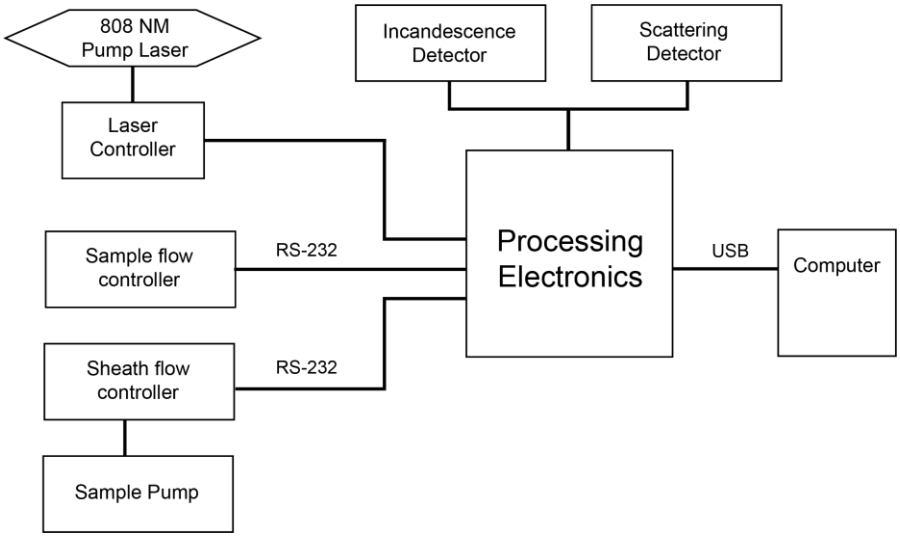


Figure 27: SP2-XR Processing electronics

Flow System

The SP2-XR uses a recirculating sheath flow air system. Figure 3 details the flow system.

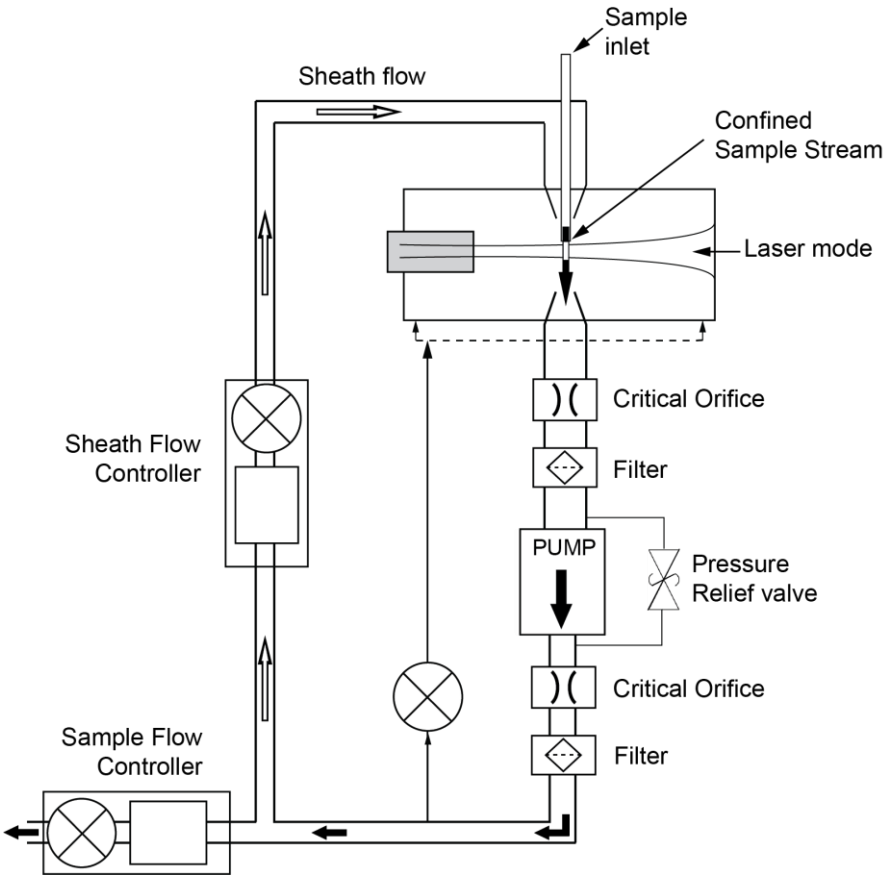


Figure 28: SP2-XR Aerosol Flow

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 2 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 approximately 1 Mw per cm^2. The YAG laser

operates continuously and is not pulsed. The gain medium is optically pumped with a free space diode laser at 808nm. The 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 29). The aerosol jet is perpendicular to the plane of the SP2-XR optical diagram and sends the particles across the laser beam.

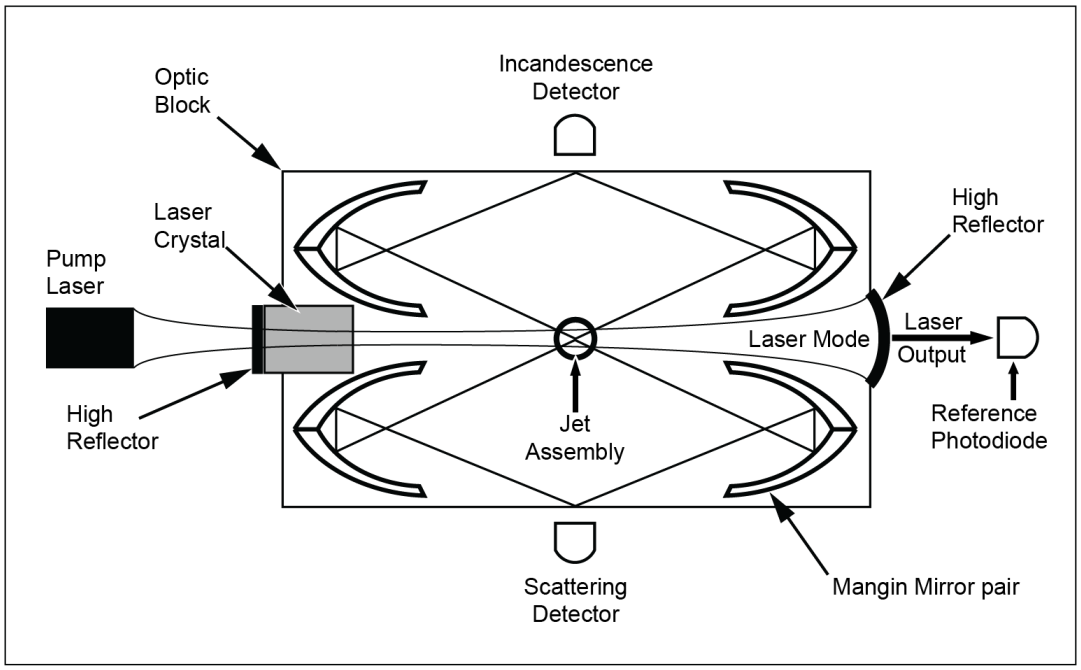


Figure 29: SP2-XR Optical Diagram

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 light to pass through. This channel will measure the scattering signal from all particles, both those that scatter light, and those that scatter both One detector is optically filtered to pass only the 1064 nm radiation. This will measure the scattering signal from all particles, both 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: Particle Size / Shape determination

Particle Trace Schematic

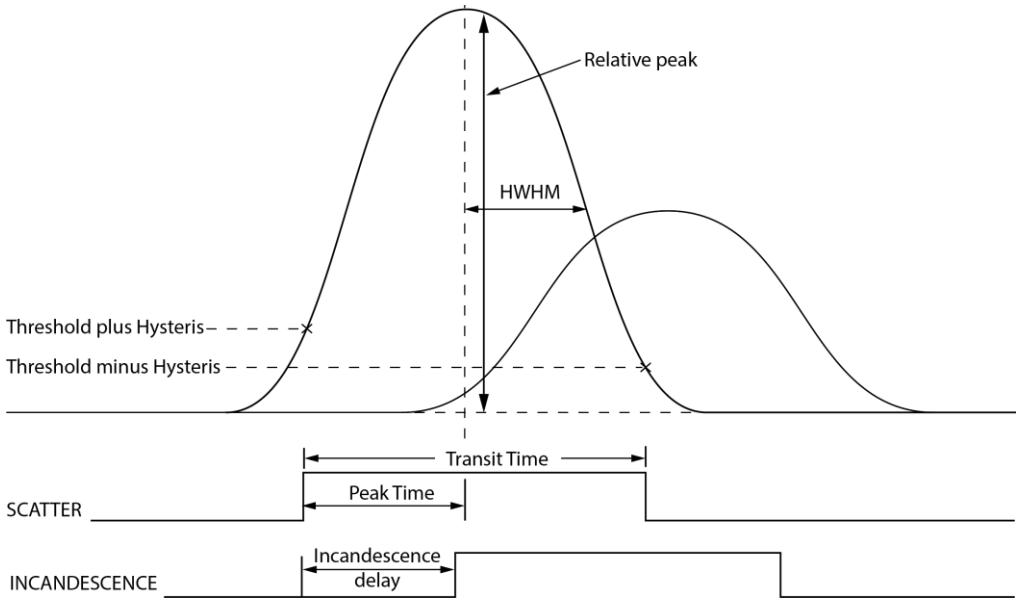


Figure 30: SP2-XR Particle trace schematic

- XXXXX Transit Time Min: Minimum transit time for a particle, this is set to reject very short electronic or optical noise spikes.
- XXXXX Transit Time Max: Maximum transit time for a particle. This allows the rejection of floater particles which typically have a longer transit time.
- XXXXX FWHM Time Min: Minimum particle width, allows rejection of electronic noise.
- XXXXX FWHM Time Max: Maximum particle width, allows rejection of floater particles.
- XXXXX Interparticle Time Min: Sets a minimum time between scattering and incandescence particles, typically set at 0.
- XXXXX Threshold: Minimum A/D counts, with +/- hysteresis 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.
- XXXXX Hysteresis: Sets the hysteresis around a particle event for it to be qualified. A small amount of hysteresis is desired to minimize the chance of electronic noise being qualified.
- 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 clock counts of 25ns.

Appendix C: Particle by Particle data files

PBP Data file descriptions

The PBP data file heading SP2_XR_PBBYYYYMMDDHHMMSS_xX.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 (sec)	This is the time stamp for the PBP particle packet. This is seconds after midnight, windows time.
Packet Time Stamp	Time stamp in seconds from when the instrument was started
Flag	PBP Flag error
Dropped Records	Count of Records dropped since last packet
Record Count	Number of particles in the packet
Record Size	Count of bytes per record
Particle Time Stamp	Time stamp in seconds of the individual particle
Particle Flags	1 if qualified for scattering particle, 2 if qualified for incandescent particle.
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, clock counts
Scatter Peak Time	Time when scattering signal crosses, the threshold until peak height in clock counts
Scatter FWHM	Actually, HWHM for the width of the scattering peak, clock counts
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, clock counts
Incand Peak Time	Time when incandescent particle crosses the leading threshold until peak maximum, clock counts
Incand FWHM	HWHM for the width of the incandescent peak, clock counts

Incand Delay	Time between when the scattering peak and the incandescence peak cross the threshold for each particle
Reserved	Future use
	All clock counts are 25 ns.

Appendix D: Housekeeping data files

Housekeeping (HK) Data file description (parameters)

The HK data file heading SP2_XR_hk_YYYYMMDDHHMMSS_xX.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	Seconds after midnight, windows time
Time (sec)	
Time Stamp	
Elapsed Time	
Error Code	
Packet Time Stamp	
Laser TEC Temp (C)	Pump laser internal temperature
Crystal TEC Temp (C)	Not implemented
Inlet Air Temp (C)	Air temperature at the inlet to the case
Computer Heatsink Temp (C)	Pump laser heat sink temperature
Laser Heatsink Temp (C)	Computer 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 Limit Monitor (A)	Current limit set for the pump laser
Laser Driver Current Monitor (A)	Current supplied to the pump laser
Laser TEC Sense	Driving current to the Laser TEC
Laser Over Temp (On/Off)	True or High if laser over temp is observed
+5V Laser Rail (V)	Absolute pressure in the cell

+5V Rail (V)	5 Volt Interface Board Rail
+12V Rail (V)	12 Volt Interface Board Rail
High Voltage (V)	APD High voltage Bias
Battery Temp (C)	Temperature of Backup Battery
UPS Output (V)	UPS Controller Voltage output
12V Iso Rail (V)P	Interface Board Isolated 12V Rail
5V Iso Rail (V)	Interface Board Isolated 5V Rail
3.3V Iso Rail (V)	Interface Board Isolated 3.3V Rail
Spare 22	Spare
Spare 23	Spare
408 Board Spare 0	Spare
408 Board Spare 1	Spare
408 Board Spare 2	Spare
408 Board Spare 3	Spare
408 Board Spare 4	Spare
408 Board Spare 5	Spare
System Input Voltage (V)	Input voltage applied to the SP2-XR
Board Temperature (C)	Electronics board temperature
408 Board Spare 8	Spare
408 Board Spare 9	Spare
408 Board Spare 10	Spare
408 Board Spare 11	Spare
408 Board Spare 12	Spare
408 Board Spare 13	Spare
408 Board Spare 14	Spare
408 Board Spare 15	Spare
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
Fan1 (RPM)	FAN 1 RPM
Fan 2 (RPM)	FAN 2 RPM
Fan 3 (RPM)	FAN3 RPM
Spare Tach	Reserved /unused
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

Qualified incandescence Only Particles	Number of particles qualified for incandescence
Disqualified Due to Scatter Saturation	Number of particles disqualified due to saturation of the scattering signal (oversize particles)
Disqualified Due to Scatter Transit Time Min	Number of particles disqualified due to below allowed transit time. Probably noise not real particles
Disqualified Due to Scatter Transit Time Max	Number of particles disqualified due to above transit time. Probably floater particles
Disqualified Due to Scatter FWHM Min	Number of particles disqualified due to shorter signal than FWHM limit. Probably noise spike
Disqualified Due to Scatter FWHM Max	Number of particles disqualified due to longer signal than FWHM limit. Probably floater particles.
Scatter Inter Part Period Min Violation	# of particles violating the minimum amount of time between scattering particles.
Disqualified Due to incandescence Saturation	Number of particles disqualified due to saturation of the incandescence signal (oversize particles)
Disqualified Due to incandescence Transit Time Min	Number of particles disqualified due to below allowed transit time. Probably noise not real particles
Disqualified Due to incandescence Transit Time Max	Number of particles disqualified due to above transit time. Probably floater particles
Disqualified Due to incandescence FWHM Min	Number of particles disqualified due to shorter signal than FWHM limit. Probably noise spike
Disqualified Due to incandescence FWHM Max	Number of particles disqualified due to longer signal than FWHM limit. Probably floater particles.
incandescence Inter Part Period Min Violation	Number of particles violating the minimum amount of time between Incand particles.
Baseline Sizer Lo	Scattering detector high gain baseline (A/D counts)
Baseline Sizer Hi	Scattering detector low gain baseline (A/D counts)
Baseline incandescence Lo	incandescence detector low gain baseline (A/D counts)
Baseline incandescence Hi	incandescence detector high gain baseline (A/D counts)
Bandwidth Sizer Hi	Scattering Hi Gain Channel Baseline Noise
Bandwidth Sizer Lo	Scattering Low Gain Channel Baseline Noise
Bandwidth incandescence Lo	Incand Low Gain Channel Baseline Noise
Bandwidth incandescence Hi	Incand - Hi Gain Channel Baseline Noise
ABD-0408 HK ADCs min	Flag for channel being under threshold
ABD-0436 HK ADCs min	Flag for channel being under threshold
ABD-0408 HKADCs max	Flag for channel being over threshold
ABD-0436 HKADCs max	Flag for channel being over threshold
incandescence Particle Conc (cts/cc)	Concentration of particles showing an incandescent signal

Scattering Particle Conc (cts/cc)	Concentration of particles showing only a scattering signal, particles which show incandescence also are not counted
incandescence Mass Conc (cts/cc)	Number of incandescent particles multiplied with the size information to give mass loading
Scattering Mass Conc (cts/cc)	number of scattering particles multiplied with the size information to give mass loading
Sheath Flow SP	Sheath flow set point
Sample Flow SP	Sample flow set point
Laser Temp SP	Set point for pump laser temperature
Laser Current SP	Set point for pump laser current
Spare 4 SP	Reserved unused
Spare 5 SP	Reserved unused
PMT HV SP	Set point for high voltage on incandescence photomultiplier
PbP Packet Time	Timestamped PbP packet
Scatter Bin 1-27 Incand-Bin 1-27	Number of particles in scattering bin 1-27 Number of particles in Incandescence bin 1-27