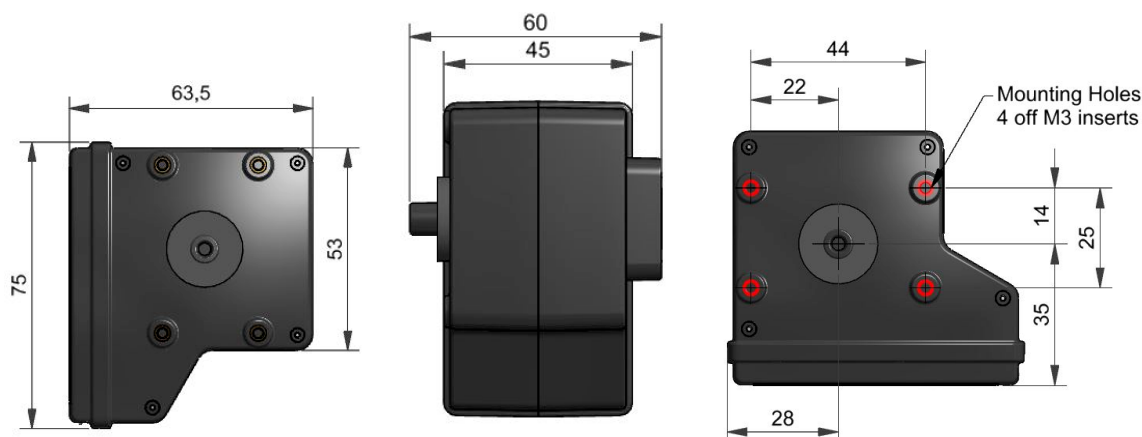The purpose of this manual is to explain how to set up, install and use the Alphasense Optical Particle Counter OPC-N2 for measuring PM_1, $PM_{2.5}$ and PM_{10}, as well as measuring particle size distributions in real time.

1 OPC-N2 Specification

All dimensions in millimetres (± 0.15 mm)

MEASUREMENT		
Particle range (μm)	Spherical equivalent size (based on RI of 1.5)	0.38 to 17
Size categorisation (standard)	Number of software bins	16
Sampling interval (seconds)	Histogram period	1.4 to 10
Total Flow rate (typical)	L/ min	1.2
Sample flow rate (typical)	mL/ min	220
Max particle count rate	Particles/ second	10,000
Coincidence probability	% at 10^6 particles/ L	0.84

POWER		
Measurement mode	mA (typical)	175
Non-measurement mode	mA (typical) Laser at minimum power; fan off	95
Transient power on start-up	mW for 1 ms	<5000
Voltage range	V DC	4.8 to 5.2

KEY SPECIFICATIONS		
Digital Interface		SPI (Mode 1), USB 2.0
Data storage	micro SD	16 GB
USB VID		Ox04D8
USB PID		OxF3D5
Laser classification	as enclosed housing	Class 1
Temperature range	°C	-20 to 50
Humidity range	% rh (continuous)	0 to 95 (non-condensing)
Weight	g	< 105

Table 1 Power and environmental performance limits

2   How it Works

Like conventional optical particle counters, the OPC-N2 measures the light scattered by individual particles carried in a sample air stream through a laser beam. These measurements are used to determine the particle size (related to the intensity of light scattered via a calibration based on Mie scattering theory) and particle number concentration. Particle mass loadings- PM_1 $PM_{2.5}$ or PM_{10}, are then calculated from the particle size spectra and concentration data, assuming a particle density and refractive index (RI). Default settings are: density 1.65 g/ml, RI 1.5+i0). Respiratory profiles are included in the PM calculations.

Most conventional OPCs employ a narrow inlet to physically constrain the airborne particles to pass through a uniform central part of the illuminating laser beam and ensure accurate sizing. Such instruments incorporate both an air-pump sufficiently powerful to draw the sample aerosol through the narrow inlet tube and a particle filter upstream of the pump to avoid pump contamination and ultimate blockage. The result is an OPC with high current consumption and a regular maintenance requirement to replace the pump protection filter (frequent in dirty atmospheres).

The Alphasense OPC-N2 uses a different approach: we removed the pump and replaceable particle filter. Instead, the patented OPC-N2 uses an elliptical mirror and dual-element photodetector to create a 'virtual sensing zone' in free space at the centre of an open scattering chamber.

The OPC-N2 classifies each particle size, at rates up to ~10,000 particle per second, recording the particle size to one of 16 "bins" covering the size range from 0.38 to 17 µm. The resulting particle size histograms can be evaluated over user-defined sampling times from 1 to 10 second duration. This histogram data and air temperature are transmitted via an SPI interface to a host computer. The patented OPC-N2 design results in virtually all sampled airborne particles passing straight through the sensor without being deposited, allowing the OPC-N2 to operate for very long periods (>1 year) without the requirement for regular maintenance or cleaning.

Consistent with most commercial Optical Particle Counters (OPCs), all particles, regardless of shape are assumed to be spherical and are therefore assigned a 'spherical equivalent size'. This size is related to the measurement of light scattered by the particle as defined by Mie theory, an exact theory to predict scattering by spheres of known size and refractive index (RI). The OPC-N2 is calibrated using Polystyrene Spherical Latex Particles of a known diameter and known RI. Correction factors can be applied for errors resulting from particles of different density.

3   PM measurements

The particle size histogram data recorded by the OPC-N2 sensor can be used to calculate the mass of airborne particles per unit volume of air, normally expressed as µg/m^3.
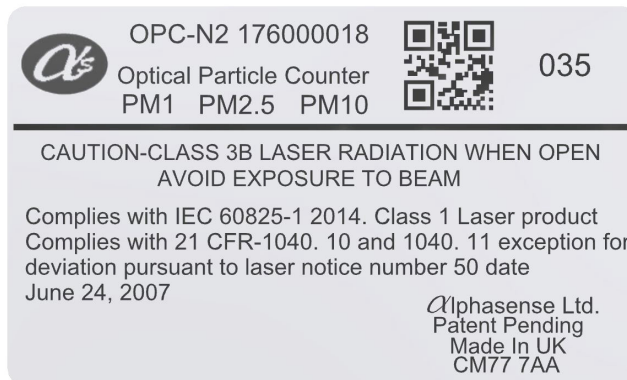
The accepted international standard definitions of particle mass loadings in the air are PM_1, $PM_{2.5}$ and PM_{10}. These definitions relate to the mass and size of particles that would be inhaled by a typical adult. So, for example, $PM_{2.5}$ is defined as *'particles which pass through a size-selective inlet with a 50% efficiency cut-off at 2.5 µm aerodynamic diameter'*. The 50% cut-off indicates that a proportion of particles of larger than 2.5 µm will be included in $PM_{2.5}$, the proportion decreasing with increasing particle size, in this case out to approximately 10 µm particles.

The OPC-N2 calculates the respective PM values according to the method defined by European Standard EN 481. Conversion from the 'optical size' of each particle as recorded by the OPC-N2 and the mass of that particle requires knowledge of both particle density and its RI at the wavelength of the illuminating laser beam, 658 nm. The latter is required because both the intensity and angular distribution of scattered light from the particle are dependent on RI. The OPC-N2 assumes an average RI value of 1.5 + i0. For particle density, the OPC-N2 allows a different value to be set for each size bin. The default setting for each size bin is a Particle Density value of 1.65 g/ml, a figure that equates to a typical value found in many environments. However, where it is known that different size fractions in the ambient aerosol have different densities (for example, the smallest clay particles may have a higher density than larger aggregates of the same particles) different Particle Density values may be set for different bins to achieve a more accurate determination of PM. Contact Alphasense for instructions to modify the particle bin density. The OPC-N2 also has a Sample Volume Weighting factor for each size bin that is applied to the total mass of particles in that bin. The default values are those defined by European Standard EN 481 for PM_1, $PM_{2.5}$ and PM_{10}.

Notes
- The OPC-N2 calculations of particle mass assume a negligible contribution from particles below approximately 0.38 µm, the lower limit of particle detection of the OPC-N2 sensor.
- The EN 481 standard definition for PM_{10} extends to particle sizes beyond the upper measurable size limit of the OPC-N2. In some cases, this can result in the reported PM_{10} value being underestimated by up to ~10%.

4   Health and Safety

OPC-N2 176000018
Optical Particle Counter
PM1   PM2.5   PM10   035

CAUTION-CLASS 3B LASER RADIATION WHEN OPEN
AVOID EXPOSURE TO BEAM

Complies with IEC 60825-1 2014. Class 1 Laser product
Complies with 21 CFR-1040. 10 and 1040. 11 exception for
deviation pursuant to laser notice number 50 date
June 24, 2007

*α*lphasense Ltd.
Patent Pending
Made In UK
CM77 7AA

The OPC-N2 uses an embedded diode laser light source that operates at typically 5-8 mW (max. 25mW) at a wavelength of 658 nm. The OPC-N2 is a Class 1 laser product, since the user does not have access to the laser source. The OPC-N2 is designed for OEM use, normally mounted in a secondary housing. The user must not open or adjust any parts of the OPC-N2. It is the user's responsibility to ensure that the unit is used safely and complies with any local regulations.

> **DO NOT** remove the external housing: this not only ensures the required airflow but also protects the user from laser light. Removal of the casing may expose the user to Class 3B laser radiation. You must avoid exposure to the laser beam. Do not use if the outer casing is damaged- return to Alphasense. Removal of the external housing exposes the OPC circuitry which contains components that are sensitive to damage by static discharge.

5   Connecting power and taking readings

The OPC-N2 is shipped pre-calibrated. There are no user serviceable parts. Power and data communications are provided via the SPI socket. Firmware uploading and SD card downloading are via the micro-USB socket. Use of the SD card will require internal firmware updating if the firmware version is prior to version 0015d.

Connection to the OPC-N2 for real-time data transfer can be made via the SPI direct to your own circuit's internal bus using your own-provided SPI interface. The micro-USB socket can be used for updating the internal firmware and downloading the SD card measured data. See page 15 for further firmware information.

When first using this OPC, we recommend that you use the SPI adapter. You can then view the data options along with the data resolution and range when the OPC-N2 is connected to your PC, that has the Alphasense-supplied software installed. Apple compatible software is not yet available. Pin assignments for the SPI adapter are shown in Table 2 below. The green LED shows that power is supplied to the OPC-N2 and the red LED flashes when the PC and OPC-N2 are communicating.

The OPC-N2 requires a 4.8 to 5.2 Volt DC supply with minimum noise. On-board regulators supply power to the laser and fan. Required current is 175 mA when operating/ measuring and 95 mA when the fan is disabled and laser is operating at its lowest power setting. There is a very short one amp current surge at switch-on.

SPI Connection
When connecting direct to your own SPI connector, the SPI pinouts are:

Pin	Function
1	Vcc
2	SCK
3	SDO
4	SDI
5	/SS
6	GND

Table 2. SPI pin assignments

Use the micro-USB socket to either download the SD data card or to reprogram the OPC-N2, using programs supplied by Alphasense. You cannot download real time data via this socket.

6   Sampling the environment

The sample air flow rate through the unit is determined by both the fan speed and any obstruction that affects the inlet or outflow of the OPC. Because of this, tubing, valves, baffles or obstructions that will restrict air flow into or out of the OPC should be avoided. However, because fan speed can vary and external factors such as wind direction in the vicinity of the OPC may affect the sample flow rate through the OPC, such variations are monitored and corrected dynamically by the OPC so that the particle concentrations and derived PM values are unaffected by flow variations.

Alphasense recommends that the OPC-N2 inlet is exposed directly to the target sample volume and the fan exhaust blowing into an unconstrained space. The OPC-N2 can be positioned in any orientation but if the inlet is pointing upwards, care should be taken to avoid very large droplets or grit from entering the unit due to gravity.

7   Software installation

The examples below are for installation using Microsoft Windows XP and Microsoft Windows 7. Please contact Alphasense directly if you are using Windows 8. It is recommended that the Windows PC is running .NET version 3.5 or above.
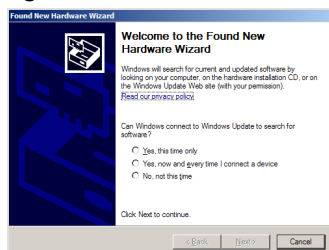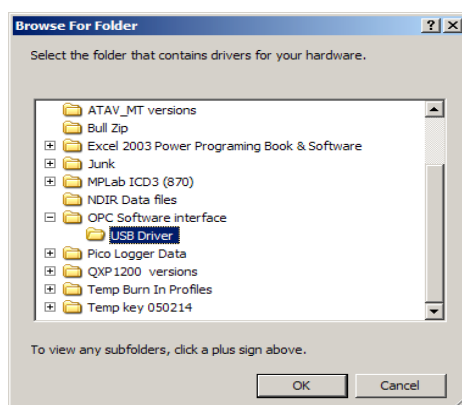

Installing the device driver (Windows XP)

Copy the folder "OPC Interface Software" to the PC desktop. Connect the USB interface lead to the PC. If the USB interface lead (USB to SPI converter) is connected to the PC for the first time, Windows will need a device driver and this will start the "Found New Hardware" wizard.

Select the "Yes, this time only" option and click next.
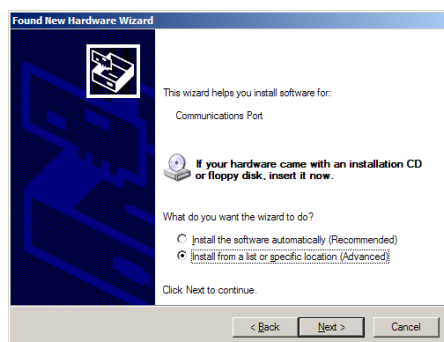
The following window will give you an option as to whether to use a CD to install the device driver or to use another location. Select "Install from a list or a specific location (Advanced)".
Navigate to the OPC folder containing the folder named "USB Driver", this contains the driver file *devtech2.inf* which Windows needs to drive the OPC device.

Click OK to allow Windows to locate and install the device driver. This process is automatic but you will be prompted by the form below to confirm the installation.
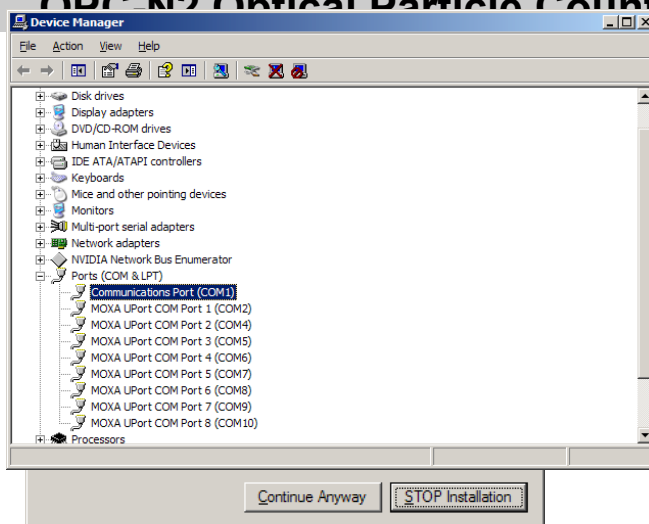
Click "Continue Anyway" to finish the installation.

Once the device driver is installed correctly, the OPC device should appear in the Device Manager window as a "Communication Port" with an assigned COM port number. Make a note of this assigned port number, as you will need it when starting the software.

The Driver installation is now complete.

Installing the device driver (Windows 7)

Copy the folder "OPC Interface Software" to the PC desktop. Connect the USB interface lead to the PC. If the USB interface lead (USB to SPI converter) is connected to the PC for the first time Windows will need a device driver.

Open the system properties and locate the device manager.
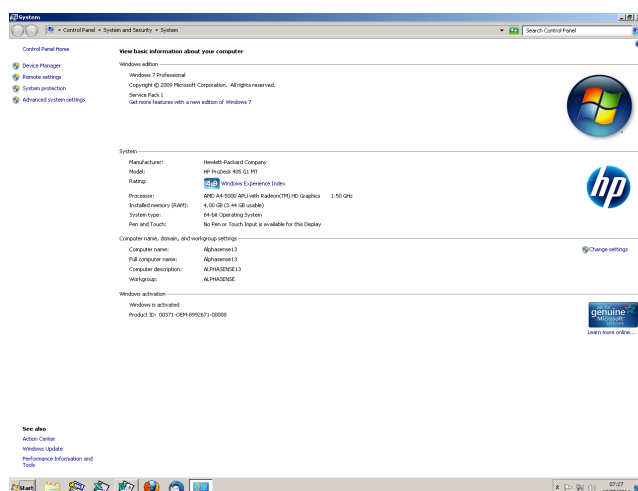
Windows 7 will show the new device as "USB-ISS" with a yellow exclamation mark indicating a driver problem.
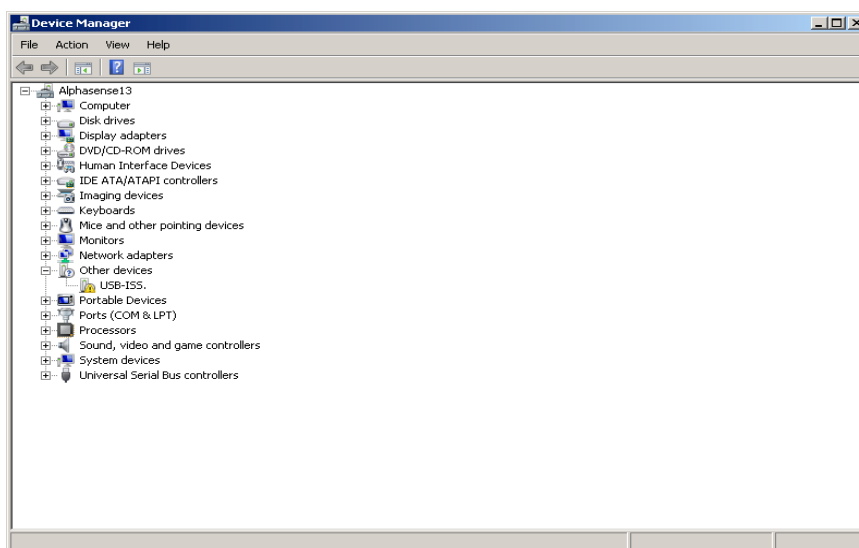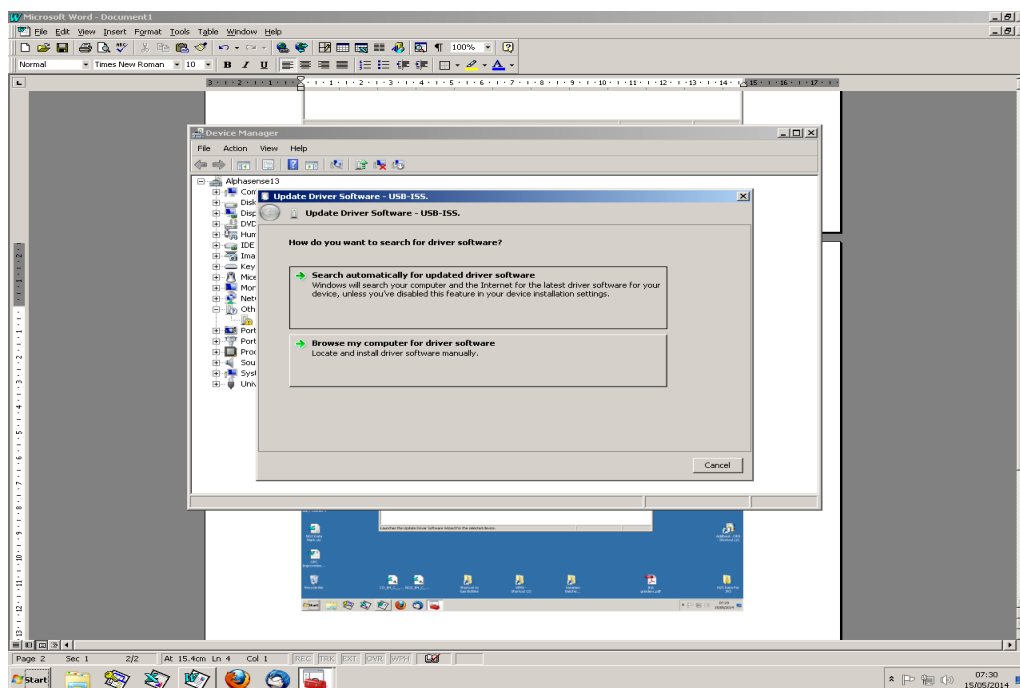

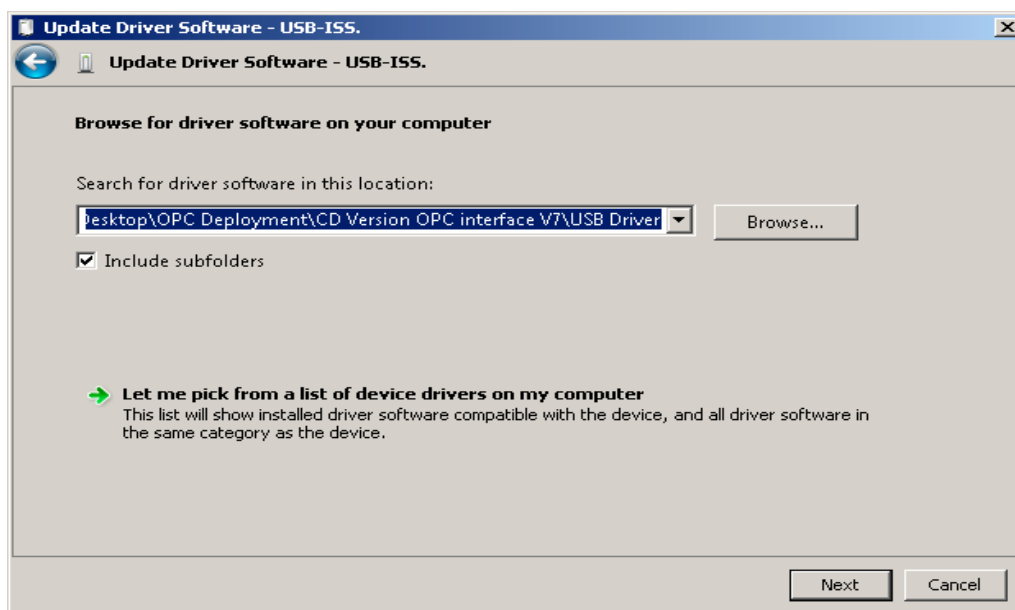Right click the icon and select "Update Driver Software…
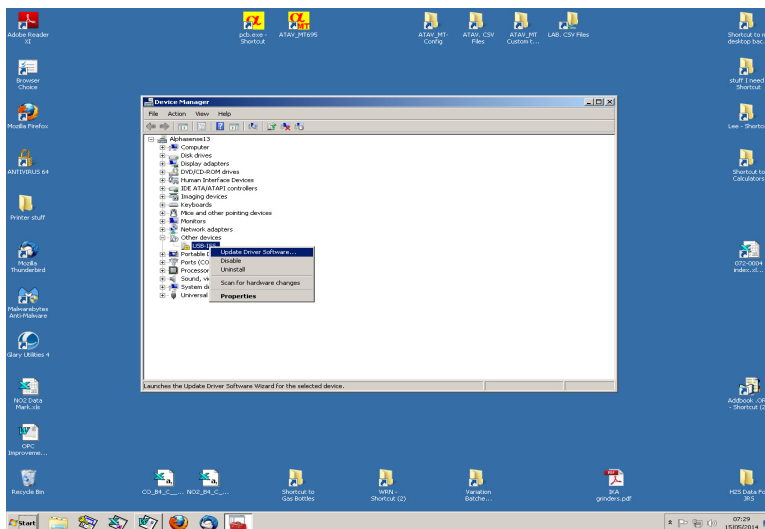
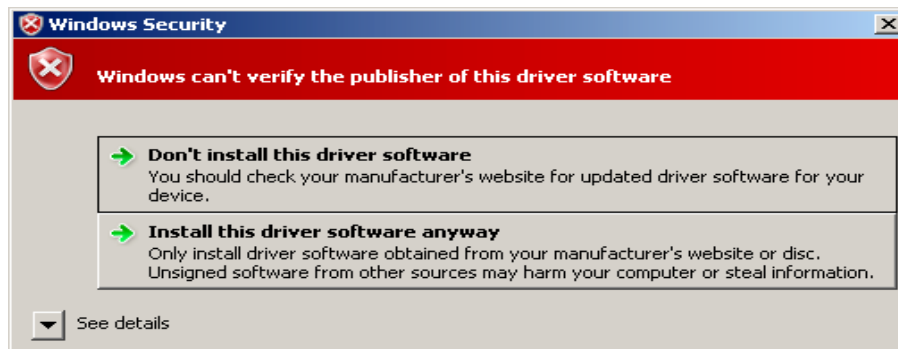Select the "Browse my computer for driver software" option.

Navigate to the folder "OPC Interface Software" copied to your desktop and locate the folder named "USB Driver", Click Next.
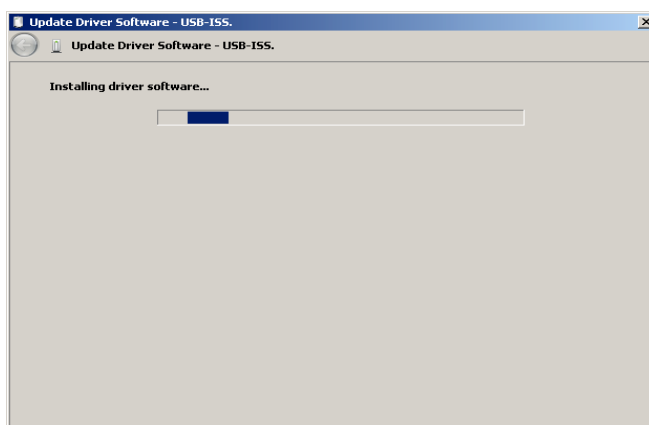
Windows 7 will then issue a security warning. This is due to a licence issue and not a concern to the operating system. Select the "Install this driver software anyway" option.

Windows will then install the driver files for the device.

Once the device driver software has been installed the form below will be displayed. Make a note of the allocated COM port number (COM4 in the example below)
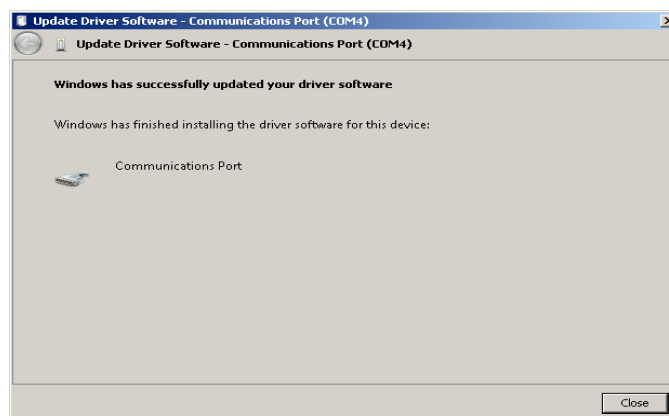
Incorrect installation of the device driver

If the device driver is installed incorrectly the Device Manager will indicate this with a yellow exclamation mark symbol shown below.
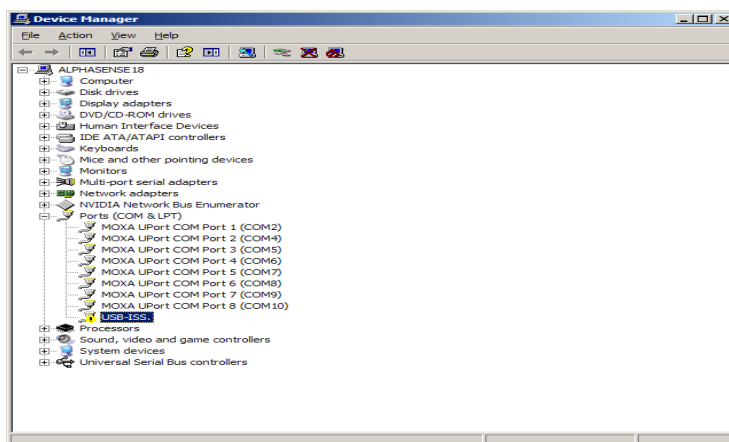
If this should happen remove the USB lead and uninstall the device by right clicking the symbol and selecting "Uninstall". Return to the beginning of the "Installing the device driver" (Windows XP or Windows 7) section.

There is no uninstall function for the software interface. The interface is stored as a set of files in a single folder (to be kept intact) and will run as a normal Windows application. The entire folder can be deleted when redundant.

## Connecting the device and running the software

Connect the USB-SPI interface lead and OPC device to the PC. If you are prompted for device drivers refer to the previous section of the user manual. Double click the OPC-N2.exe icon to start the software application. When the application is first started the main form will be in "start-up mode" as shown in section 8.

Run the software as with previous versions and connect to the OPC-N2 by choosing the virtual COM port it is assigned to. Some text should appear in the software's main text box indicating some details of the OPC on successful connection. At this stage the OPC is on, but the laser is running at reduced power. Press Ctrl+R to read out all the configuration variables stored the OPC. See page 15 for more information on firmware variables.

8   Data Display Screens

Default start-up screen

Select the allocated COM port: A list of COM ports available on the PC/Laptop is displayed in the drop-down menu at the bottom-left of the screen. Be sure to select the correct port number; the software will not respond unless the port with the attached OPC-N2 device is selected.
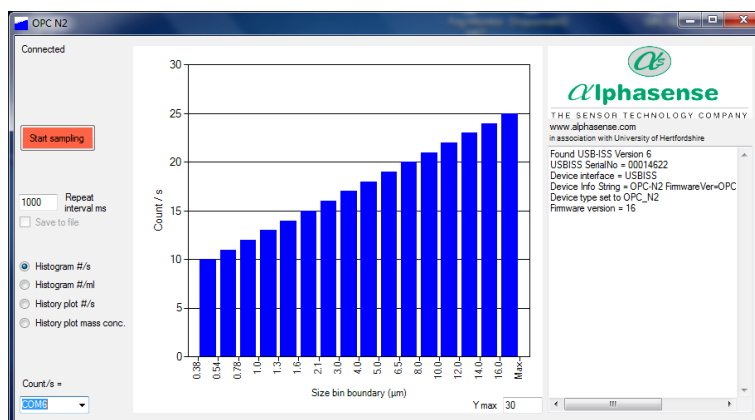
- If particle density of ambient particles is known to be different from the default setting (1.65 g/ml), please contact Alphasense for details on how to change this value.

- **Device information** (Right hand side text window): This shows hardware serial number and firmware versions currently installed on the OPC-N2.

- **Start sampling**: Starts data collection with the fan and laser running continuously. The button will then show 'Stop sampling' to allow termination of the sampling process.

- **Repeat interval ms**: Sets the duration (in milliseconds) over which a particle size histogram is acquired. The default is 1,000 ms. We recommend a maximum of 10,000 ms to avoid the risk of an individual size bin becoming full (65,536 counts). Longer intervals can be set in very clean environments.

- **Y max**: This sets the maximum y-axis value of the histogram screen display. **Note**: If the displayed data reaches the top of the display, enter a larger Y max value.

- Histogram y-axis **'Counts/ s':** This displays the recorded counts per second in each size bin, regardless of the setting of the 'Repeat interval ms'. For example, if a 10,000 ms sampling interval is set, the 'Counts/ s' figure will represent the average counts per second over that period.

## Histogram Counts/s vs Particle Size display mode

When the **Start sampling** button is pressed, the OPC-N2 will first ask if the data are to be saved. Once answered, it will begin to display particle size histogram data and if selected, store data to a file.
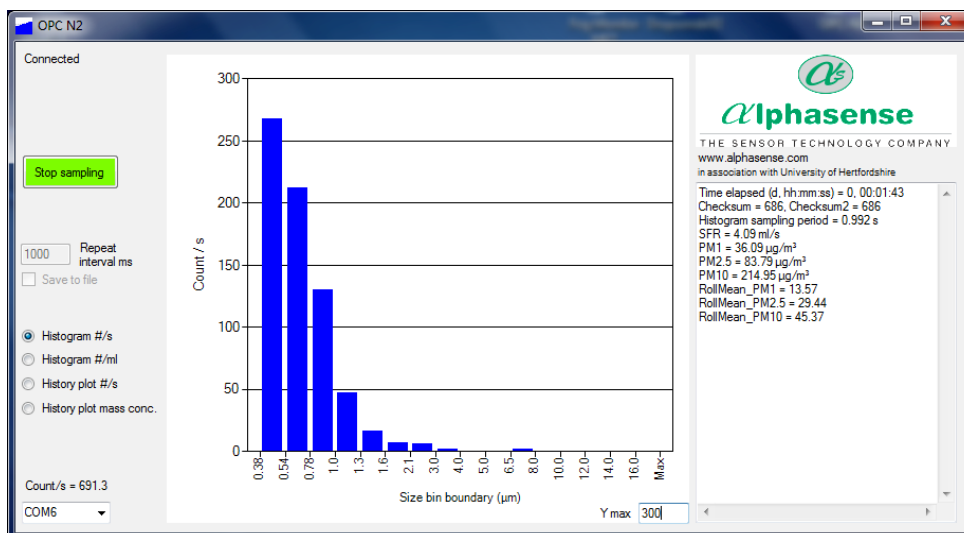
- Data relating to each acquired histogram, including PM values, is given in the right-hand window of the display. The RollMean_PM10, etc., are the current rolling mean values for PM evaluated over the previous 5 minutes or to the beginning of sampling if that is less time.

  - The total particle count rate per second across all size bins (Counts/ s) is given in the bottom-left of the screen.

Histogram Number Concentration vs Particle Size display mode

Click the 'Histogram #/ml' button on the left-hand side of the screen to show the recorded data in particle number concentration (particles per millilitre of sampled air) format, as below:
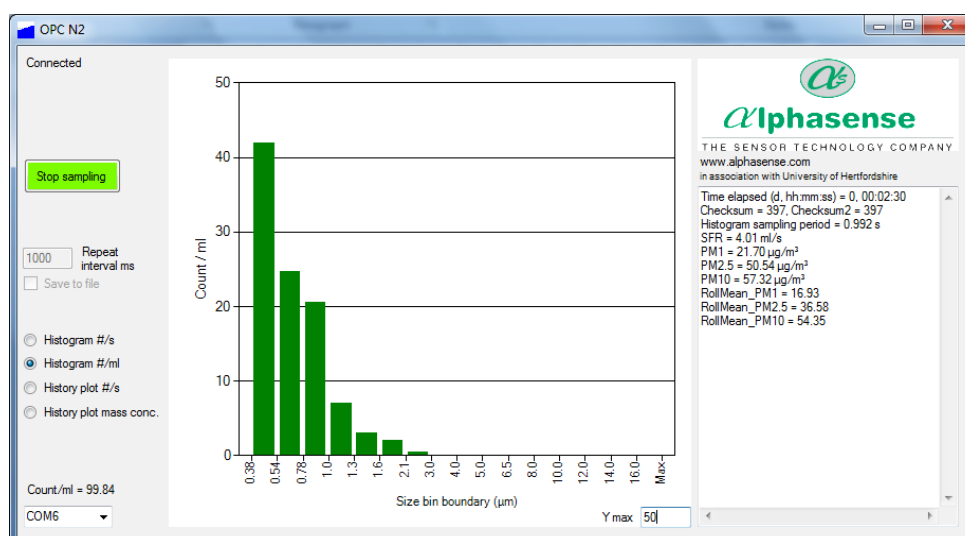
History Plot of Counts/s display mode

Click the 'Histogram plot #/s' button on the left-hand side of the screen to show a temporal record of the particle count rate since the start of the sampling session. The plot scale will automatically change to show longer recording time periods and/or increasing Counts/ s.
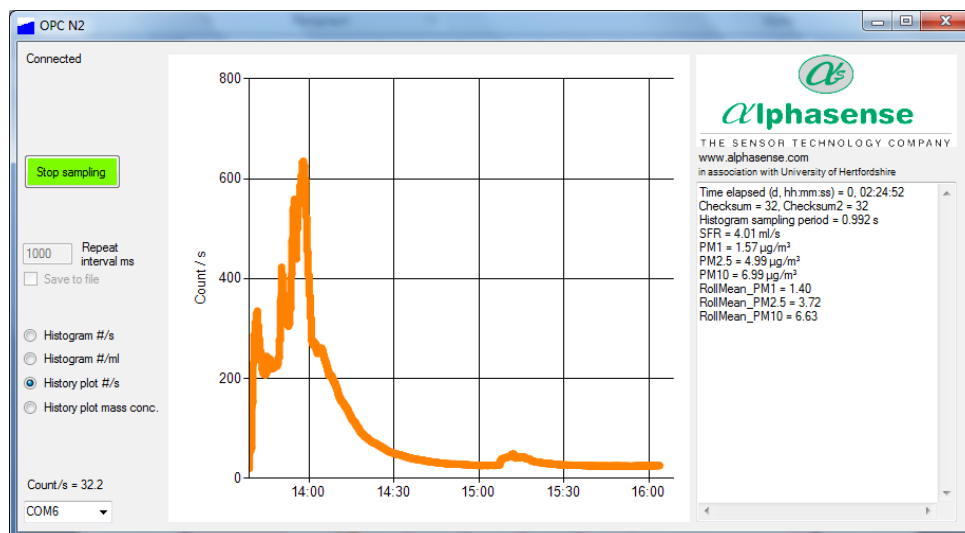
History Plot of Mass Concentration display mode

Click the 'Histogram plot mass conc.' button on the left-hand side of the screen to show a temporal record of PM_1, $PM_{2.5}$ and PM_{10} values (in µg/m^3) since the start of the sampling session. The plot scale will automatically change to show longer recording time periods and/or increasing PM values.
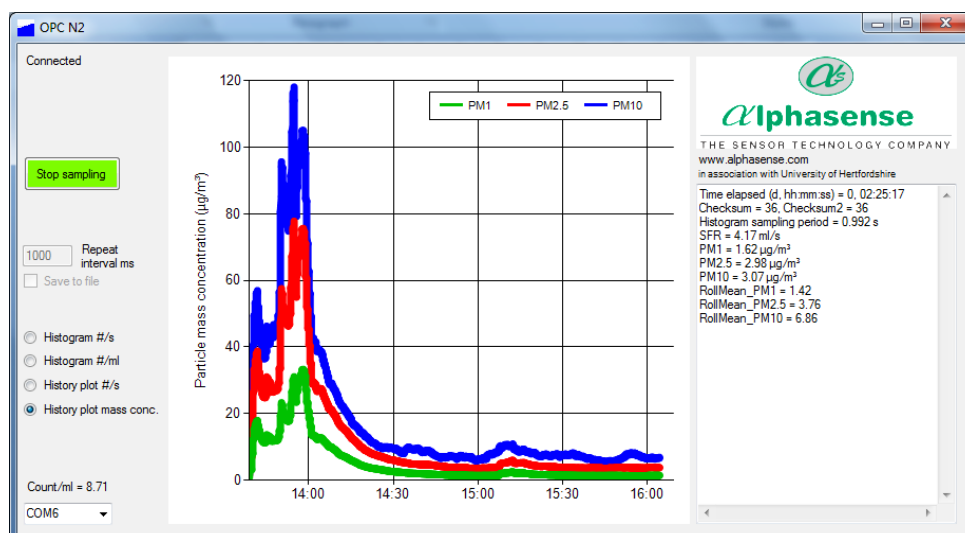
Data relating to each acquired histogram, including PM values, is given in the right-hand window of the display.

9 Other Software Functions

Shutting down the software

It is recommended that the software application be closed before removing the USB to SPI interface to avoid USB communication errors.

Log file

The application will also create a log file from all of the output bins into a single .CSV file. You will be asked if you require a log file after selecting the "start" button. If you select "yes" you will be prompted for a file name and location to store the file. An example of the log file is included in the deployment package.

Firmware information

The information window on the right of the main form shows the firmware version installed as the software first loads up. The OPC-N2 also has the ability install firmware upgrades via the USB port. This is achieved using a Bootloader tool, contact Alphasense to obtain access to the Bootloader tool User Manual. To check to see if your device can upgrade firmware via the USB port, check the information string printed as the device is first connected. To upgrade firmware via USB you need to have firmware version 0015d or above.

Example: "OPC-N2 FirmwareVer=OPC-015d…………………………..BD"

As the firmware first loads it follows the procedure below:
Check for SD memory card. All versions of the OPC-N2 will come with a 16GB micro SD card fitted. This card is internal and is not accessible from outside the case, please note it may not be fitted on early release OPC-N2 or OPC-N1.
1. If a SD card is found, the OPC will check for a USB connection. The OPC-N2 comes equipped with a micro USB port.
2. If a USB connection is found the device will switch to "USB mode". This makes the OPC-N2 behave like an external storage device (pen-drive) until the USB is disconnected.
3. If a USB connection is not found then it will check for the SPI master connection (SCLK). The OPC will wait up to 60 seconds for an SPI connection to be established.
4. If an SPI connection is not found the OPC-N2 will switch to "SD card mode", This will create a new file on the SD card (.csv format) and continue to log data. A new data file will be created every 24 hrs. When in SD card mode the SPI is still active, if SPI command "SPIShutDownDAC" (0x03) is sent, the OPC will close the current SD card log file and exit SD card mode.

More firmware commands (via software)

There are four commands that can be used edit factory settings through the OPC software:
1. Ctrl + R: Read and display all configuration variables. This will display the variables available to the user for edit. The data is displayed in the information window to the right of the software window.
2. Ctrl + W: Write all values to configuration memory. This command will write the current configuration values to volatile memory, this means that the user can run the OPC with their desired configuration but the changes will be reset once the power is disconnected.
3. Ctrl + S: Save all values to configuration memory. This command will write the current configuration values to non-volatile memory, this means that the user can permanently save their configuration values.
4. Ctrl + B: Enter Bootloader mode. This allows the OPC to interact with the Bootloader application so that new firmware can be installed via USB port.

10   OPC-N2 Factory settings

The OPC firmware retains the factory settings and calibrations.
These settings should not be modified as this will affect the OPC calibration and its accuracy.
If you wish to modify any of these settings, then contact Alphasense at (+44) 1376 556700.

The following parameters are factory set and stored in the firmware:

Bin boundaries	The upper and lower particle size limits defining each of the 16 size bins.
Bin particle volumes (um3)	The volume ascribed to each particle in that bin in firmware.
Bin particle volumes by software (um3)	The volume ascribed to each particle in that bin in software (parameter present to confirm firmware values, which should be the same).
Bin particle densities (g/ml)	The density ascribed to each particle in that bin. The default setting is 1.65 g/ml for all bins.
Bin sample volume weightings	Correction for size dependent sampling efficiency. Normally set to 1.0.
Gain scaling coefficient	A global factor to normalise between units. Normally 1.0.
Laser digital pot setting	A parameter to determine laser beam power.
Fan digital pot setting	A parameter to determine fan speed.

NOTE: Changing either the fan speed or laser power will change calibration and the OPC-N2 will require recalibration. When the OPC-N2 is not sampling, both the laser and fan are switched automatically to low-power settings.

End of User Manual