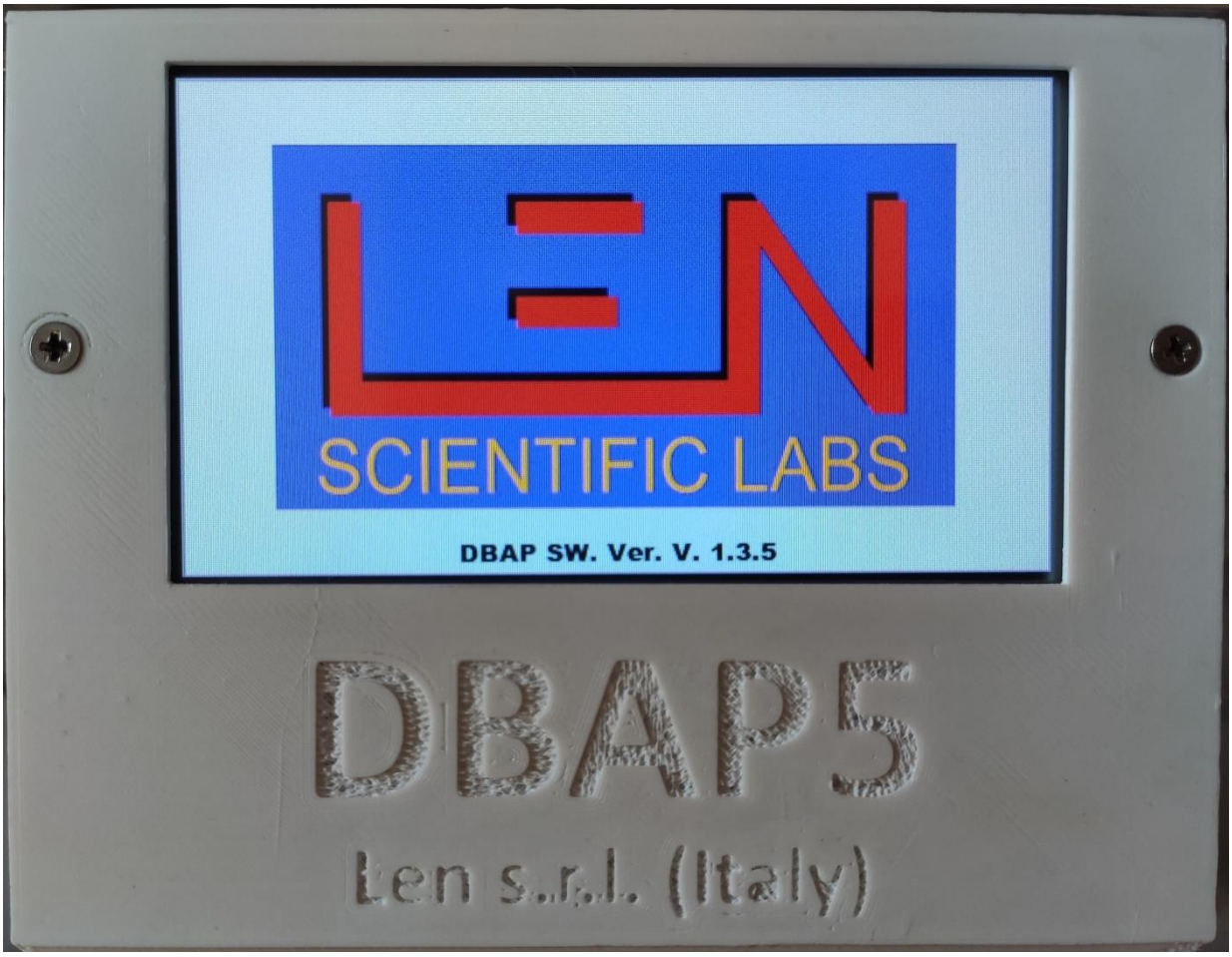
# DBAP5

**Manual version 1.16-EN**
**Firmware 1.5.2 or higher**

# 5 Wavelengths Dual Beam Absorption Photometer

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# 1. Scientific reasons

Atmospheric aerosol, both of natural and anthropogenic origin, regulates the earth global temperature by acting as a forcing on the radiative balance due to its optical properties, i.e., the ability to absorb and diffuse sunlight.
The absorption of solar radiation act as a regulator of the global terrestrial temperature, in fact the heating to the atmosphere and the cooling to the Earth surface caused by this absorption are hypothesized to have significant climate impacts[1], therefore reliable observations of the aerosol absorption coefficients (Kab) are crucial to quantify the radiative forcing of the climate, and so aerosol absorption measurement are recommended for all station in the GAW network.
From the absorption coefficients it is possible to retrieve the equivalent black carbon (EBC) concentration, using the adequate value of Mass Absorption Coefficient (MAC) in **Eq. 1**

$$EBC = \frac{K_{ab}^{\lambda}}{MAC^{\lambda}}$$

**Eq. 1**

EBC can have effect not only on air quality but also on human health, as highlighted by the WMO report[2].

A key factor in better understanding of the aerosol composition is the spectral dependency of absorption coefficient given by the Angstrom Absorption Exponent (AAE) defined as **Eq. 2**

$$\boldsymbol{K_{ab}^{\lambda} \propto \lambda^{-AAE}}$$

**Eq. 2**

The values of AAE between 870 nm and 420 nm, calculated from **Eq. 3** as

$$\boldsymbol{AAE_{420-870} = \left(\frac{ln\left(K_{ab}^{870}/K_{ab}^{420}\right)}{ln(870/420)}\right)}$$

**Eq. 3**

[1] *Particulate absorption of solar radiation: anthropogenic vs. dust. C. Wang et al 2009 Atmos. Chem. Phys.*
[2] *Health effects of black carbon 2012 World Health Organization.*

This is widely used to characterize the particle composition, as reported in[3] where AERONET AOD dataset has been investigated. From this work, Figure shows that different AAE values are related to different aerosol composition.

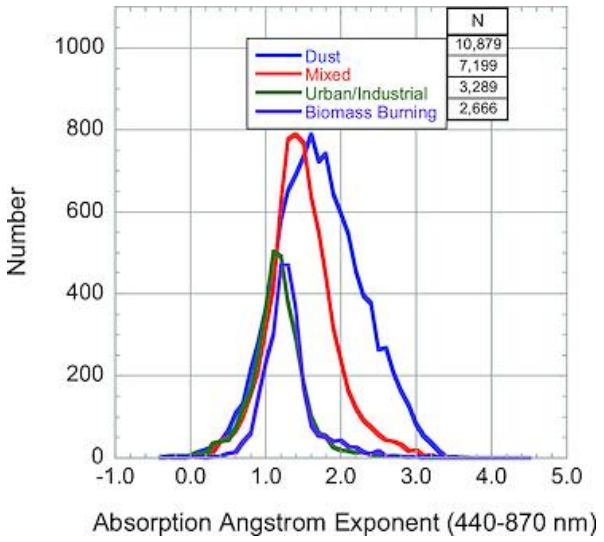


**Figure 1**

[3] *Analysis of AERONET aerosol absorption properties and classifications representative of aerosol source regions. D. M. Gilles et al. 2012 J. Geophys. Res.*

## 2. Instrument description

**Figure 2**

**Figure 3**

1 *Air inlet*
2 *Air outlet*
3 *Power plug and switch*
4 *Ethernet plug RJ45*
5 *Female RS232 db9 port*
6 *USB port*
7 *Cooling fan*
8 *LCD screen with touch screen*
9 *Filter tape*
10 *Measurement chamber*
11 *Plexiglas cover lock*

## 2.1. Pneumatic circuit

**Figure 4** shows the pneumatic circuit of the DBAP5. Air flow entering the measuring chamber (1), after the measuring channel the flow is measured through the Venturi tube (2). The flow then enters the reference channel. Any possible flow fluctuation due to the pump (5) is attenuated by an expansion lung (4). The air flow is then evacuated through the instrument outlet.

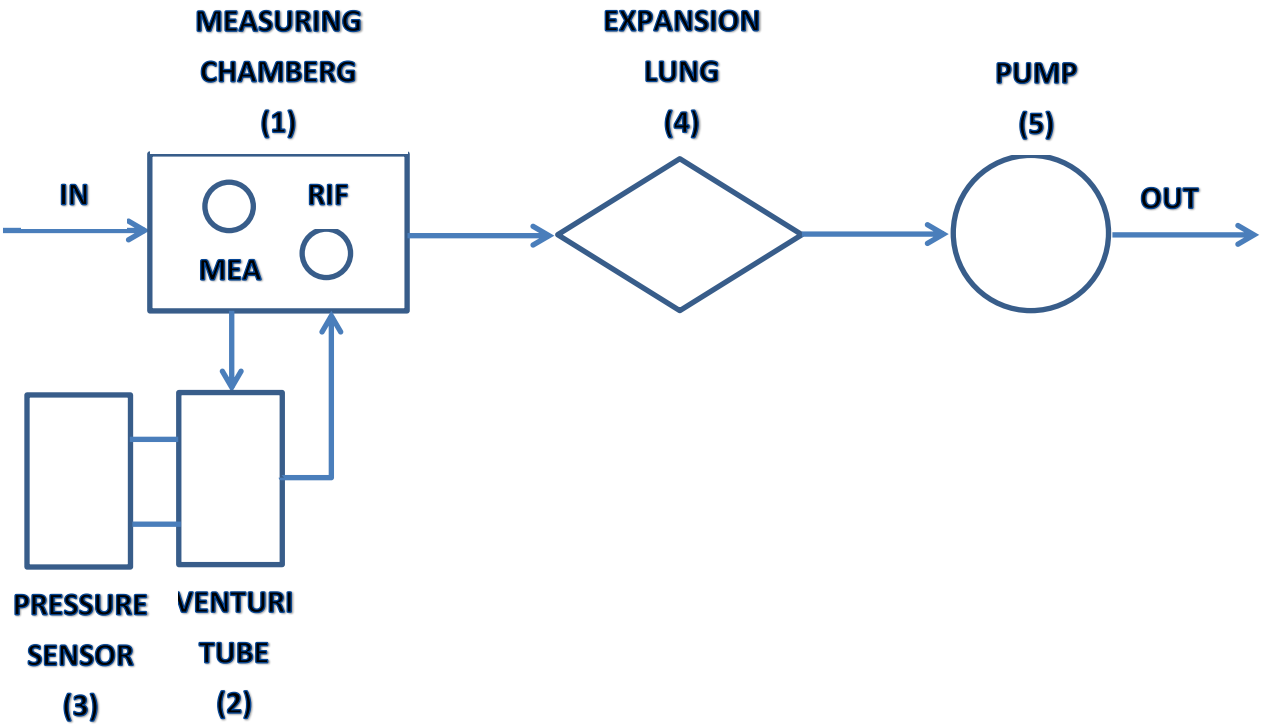


**Figure 4**

Air flow in the Venturi tube is measured using **Eq. 4**

$$Q = a + b\sqrt{dP * 100}$$

**Eq. 4**

In which Q is the air flow in l/min and dP is the Venturi tube's differential pressure. The factor 100 is necessary to convert dP from millibar (unit used by instrument) to Pascal.

Coefficients *a* and *b* mainly depend on the geometric characteristics of the tube.
In DBAP5 they are set following a factory calibration, however they can be changed following a further calibration performed by user[4].

Sampled air relative humidity (RH) is measured between the inlet and the measurement chamber, while sampled air temperature is measured inside the Venturi tube. Both air RH and temperature offset can be adjusted by user. Atmospheric pressure is also recorded.

## 2.2. Measurement chamber

The measuring chamber (**Figure 5**), designed according to dual beam technology, has two distinct cells (reference and measurement) in which the light generated by the LED is conveyed using an optical fiber. This technique, ensuring a continuous comparison with the uncontaminated filter during the measurement, cuts any errors due to possible changes in the optical properties of the filter due, for example, to changes in humidity and temperature. The light intensity is in fact measured downstream of the filter in both cells, supplying the transmittance at each instant of time and for each wavelength, the variation of which over time supplies the absorption coefficient (paragraph **3**).

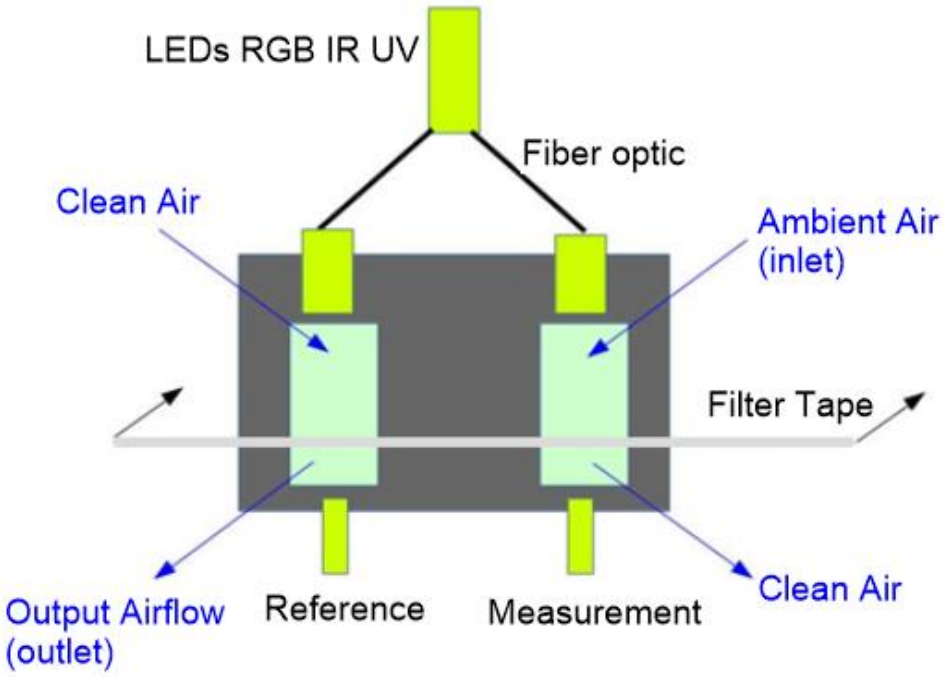


**Figure 5**

[4] See paragraph 5.3 for parameters setting

Ambient air enters the upper part of the measuring cell, passes through the filter, depositing the particulate load on it, and exits the lower part of the cell.

After passing through the filter, the air is free of aerosols and enters the reference cell from above.

The developed measuring chamber ensures that the filter is subjected to the same pressures to minimize the possible difference in the optical path of the light inside the filter due to different deformations of the filter itself.

## 2.3. LED

Light sources are at the following wavelength:

- IR: 870 nm
- RED: 634 nm
- GREEN: 522 nm
- BLUE: 465 nm
- UV: 420 nm

## 2.4. Touch screen

The instrument display is a touch screen that allow the user to perform basic operation on the instrument and control the measured data. The use of touch screen is described in paragraph **4**.

## 2.5. Filter Tape

The filter tape used for the measurement is made of fiberglass (GF 10 width 40 mm, retention degree 99.98%). To keep measure efficiency, the filter must be advanced when particles load became too intensive, thus the advancement is driven by transmittance value, as described in paragraph **3.2**, that can be set by the user.
For the filter replacement procedure, refer to paragraph **6**.

# 3. Measurement principle

The method for finding the absorption coefficient for each wavelength, and then the equivalent black carbon, is based on the measurement of the change in filter transmittance as particulate matter accumulates on it.

Using the 'dual beam' technology (paragraph **2**) the transmittance (τ ) is defined for each wavelength as the ratio between the light intensity measured in the measuring cell ($I_M$) and in the reference cell ($I_R$), transmittance which is normalized to 1 in the first measurement cycle (t = 0).

$$\tau^{\lambda}(t) = \frac{I_m^{\lambda}(t)/I_r^{\lambda}(t)}{I_m^{\lambda}(t=0)/I_r^{\lambda}(t=0)}$$

**Eq. 5**

the attenuation coefficient for each wavelength (Katt) in unit of in $m^{-1}$ is calculated from the filter transmittance variation over a time interval following **Eq. 6**

$$K_{att}^{\lambda}(t) = \frac{A}{Qdt} ln\left(\frac{\tau^{\lambda}(t-dt)}{\tau^{\lambda}(t)}\right)$$

**Eq. 6**

In which A is the area of the filter where particles are collected (spot area) in $m^3$, Q is the air flow passing through the filter in $m^3/s$ and dt the time interval in seconds between the two measurements, which is set to 60 s.
The absorption coefficients are then calculated from the attenuation coefficients taking in account of two effects on the aerosol optical properties due to the filter media, using the correction factor **Eq. 7**

$$F(\tau) = \frac{1}{C(a + b\tau)}$$

**Eq. 7**

where the coefficient C depends mainly on the type of filter and considers the increase in absorption due to multiple scattering within the filter fiber.
F(t) depends linearly on the transmittance and describe the shadow effect that leads to an underestimation of absorption due to the growth of the particulate load on the filter itself.

In **Eq. 7** C, a and b can be set by the user, and by default they are set as:

- a = 0.531
- b = 0.610
- C = 2.3+0.0003λ[nm]

the absorption coefficients ($K_{ab}^{\lambda}$) are therefore calculated as:

$$K_{ab}^{\lambda} = K_{att}^{\lambda} F(\tau)$$

**Eq. 8**

The Equivalent Black Carbon (EBC) is derived from the absorption coefficients using **Eq. 1**.
DBAP5 gives the value of EBC calculated at 870 nm (IR), using a MAC of 6.17e-6, value that can be set by the user following the scientific upgrade. The DBAP5 also allows the user the possibility to set a MAC value for each wavelength to get EBC for all the 5 colours.

$$BC = \frac{K_{ab}^{\lambda=870}}{MAC^{\lambda=870}} \ [\mu g/m3]$$

**Eq. 9**

To minimize measurement noise, especially in clean environment, the user can decide to receive the absorption coefficient as simple moving average (SMA) over a time (P) of a maximum of 10 minutes.

$$K_{ab}^{\lambda} = \sum_{i=-P}^{i=0} K_{ab}^{\lambda}(i)$$

**Eq. 10**

where i=0 represent the last received data.

## 3.1. Measurement cycle

After closing the measurement chamber, the pump is turned on and the dark current noise is measured with LED off. The background noise thus obtained will be subtracted from the next light intensity measurements. This phase has a total duration of 5 second, as 1 seconds are used for each color.

Subsequently all five transmittances are normalized to 1. This phase has a total duration of 60 seconds, as 12 seconds are used for normalization for each color.

After these first two phases, the real measurement cycle begins: transmittance (**Eq. 5**) is measured every second for each wavelength and integrated over a minute to perform the calculation of the absorption coefficient in $m^{-1}$ (**Eq. 8**) and of the equivalent black carbon in $\mu g/m^3$ (**Eq. 9**).

After P minutes (chosen SMA interval) the first value of the absorption coefficients and EBC is supplied for each of the 5 wavelengths, values that are updated every minute.

## 3.2. Filter tape advancement

As the amount of absorbing matter collected on the filter reaches a critical value, the light intensity variation becomes very weak leading big uncertainty in the measure. Thus, the filter tape is advanced when the transmittance values reaches the value set in the configuration for each color, default values are 0.6 for UV, other colors set to 0.0 (disabled) .

When this transmittance threshold is reached the measure is stopped, the pump gets turned off and the measurement chamber lifts its upper part to let the filter tape pass inside. After the filter is in the new position the measurement chamber closes and the measure starts again.
The user can in any case change the default transmittance values. In the case of limits set to multiple colors, the first threshold reached will shift the filter.

# 4. Local control (touch screen)

After the instrument has been turned on, it is able to receive remote commands (RS22, telnet), and after touching the screen the instrument can receive local commands, following the menu shown in **Figure 6**. The last button (DOWNLOAD MEASURE TO USB STICK) appears only if a USB stick is inserted in the instrument.

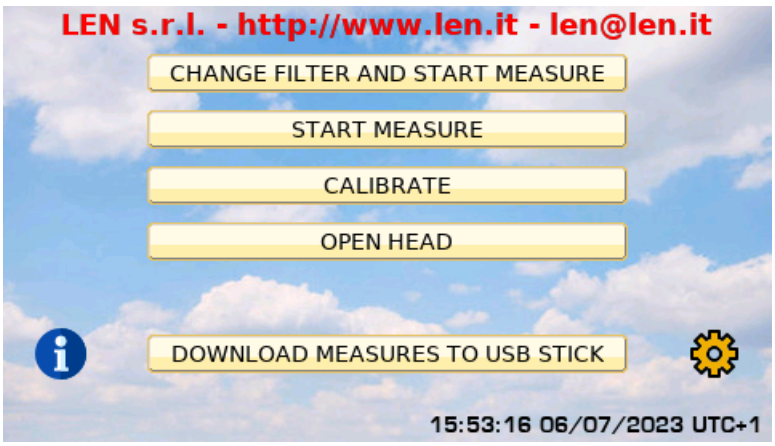


**Figure 6**

Choosing the maintenance icon on the bottom-right corner of the screen it is possible to change language (Italian, English or French) used on the touch screen.
The icon information shows a new screen with some of the configuration of the instrument, as shown in **Figure 7**

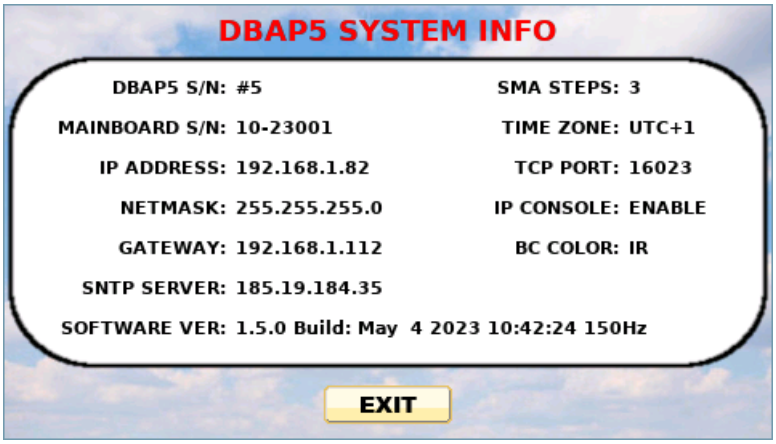


**Figure 7**

## 4.1. Measurement options

In the main menu (**Figure 6**) the top first two options ("CHANGE FILTER AND START MEASURES" and "START MEASURES") activate the measures.

By choosing the first choice the filter tape will advance and the measurement cycle start, and by choosing the second choice the measurement cycle will start without changing the filter position.

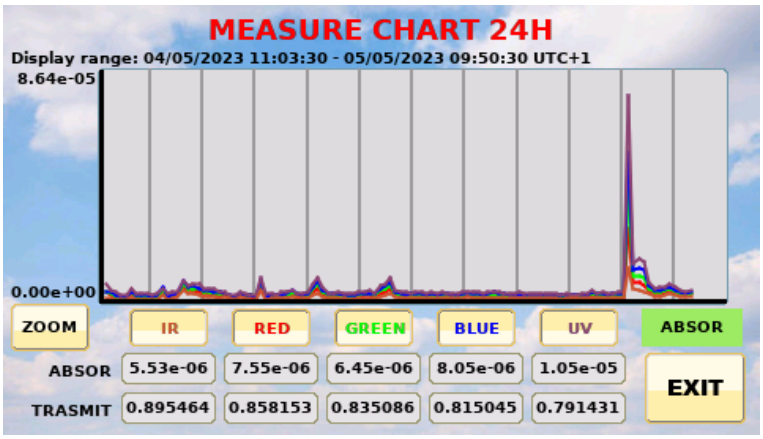


**Figure 8**

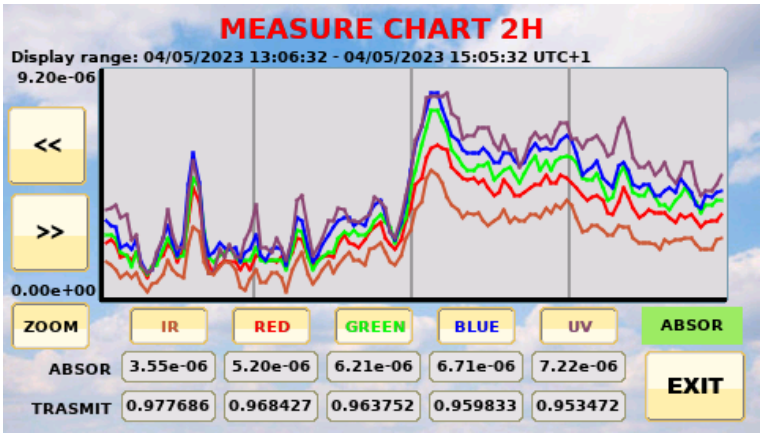


**Figure 9**

During measurement operations, the display will show the time series of the absorption coefficients measured for all wavelengths during the time interval showed at the top of the screen (Range display time). The vertical grid shows 2-hour intervals (or 30 minutes in case of activated zoom). The last measured values of absorption coefficient (in $m^{-1}$) and transmittance are reported, for each wavelength, in the boxes at the bottom of the screen. By clicking on the options that show the name of the colours, you can choose whether to display the absorption coefficient measured at the relative

wavelength. 1 to 5 curves can be displayed at the same time. However, at least one time series is always displayed.

The ZOOM button allows the last 2 hours of measurement to be displayed on the screen instead of the last 24 hours and vice versa. If zoom is enabled the [<<] navigation button displayed to the right of the chart ordinate moves the zoom time window one hour back and the [>>] button one hour forward.

The EXIT button can be used to stop the measurement.

The green bottom on the bottom right allows to switch between graphical visualization of absorption coefficients (ABSOR **Figure 8** and **Figure 9**), Angstrom Absorption Exponent (AAE **Figure 10**), transmittances (TRANSMIT **Figure 11**) and a screen reporting numerical values (VALUES **Figure 12**), equivalent black carbon (BC **Figure 13**).

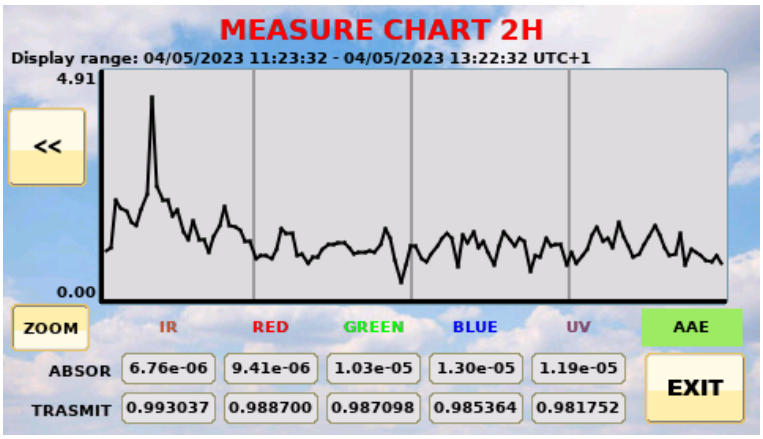


**Figure 10**

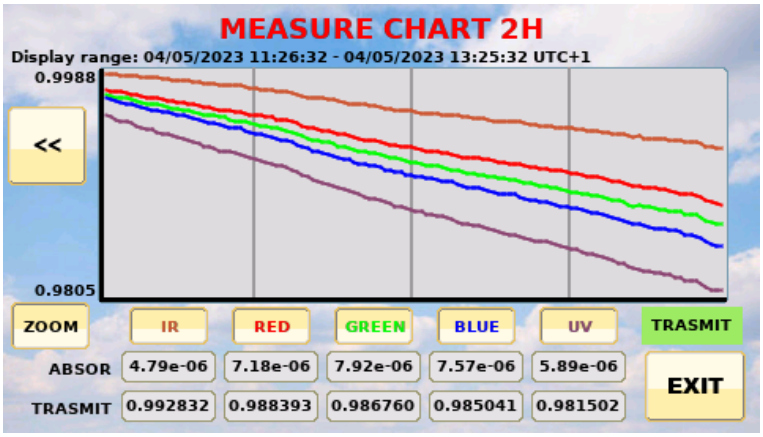


**Figure 11**

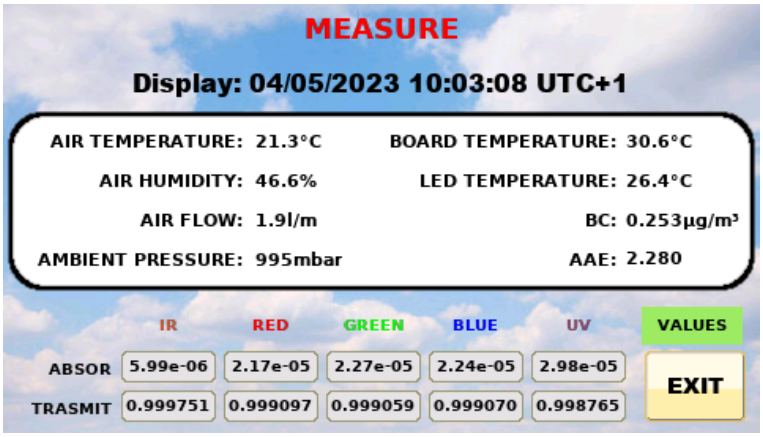


**Figure 12**

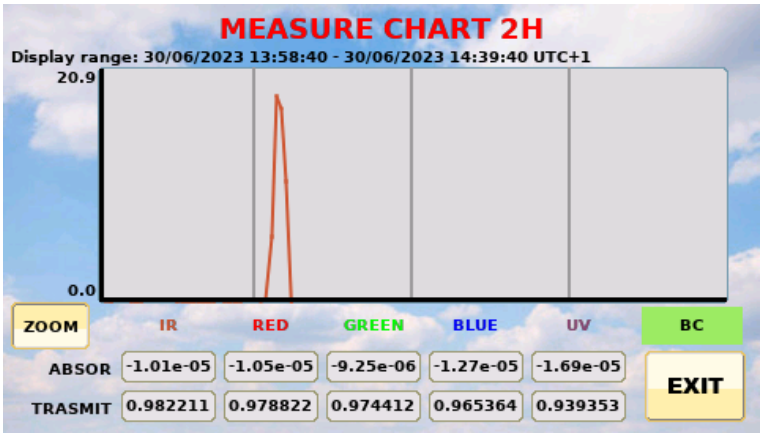


**Figure 13**

## 4.2. Calibrate

The CALIBRATE button put the instrument in the calibration mode, the mode that is mainly used by the manufacturer. In this mode, the screen will display the signal received by the two detectors of the measurement chamber (MEASURE and REFERENCE) together with the related transmittance to check the signal stability (**Figure 14**).

The screen shows the result of the signal in the selected wavelength, choosing NO LIGHT the LED will be turned off and the dark current measurement is performed.

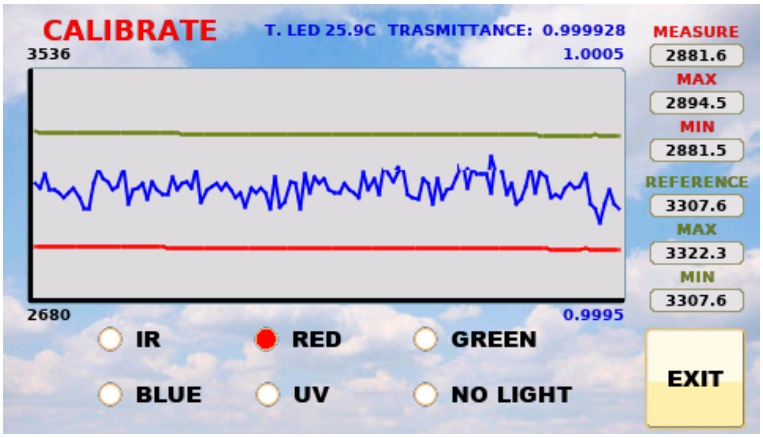


**Figure 14**

## 4.3. Open head

The OPEN HEAD button forces the measurement chamber to open, and the screen of **Figure 15** to appear on the display. From this new menu, it's possible to advance the filter (by choosing FORWARD REEL), increase the opening of the chamber (OPEN HEAD) or close the measurement chamber (CLOSE HEAD).

**Figure 15**

## 4.4. Download measure to USB stick

This choice appears only if a USB mass storage is plugged in the USB port of the DBAP and measure is not active. Choosing this option, a new screen (**Figure 16**) allows to decide the period of data that must discharged.

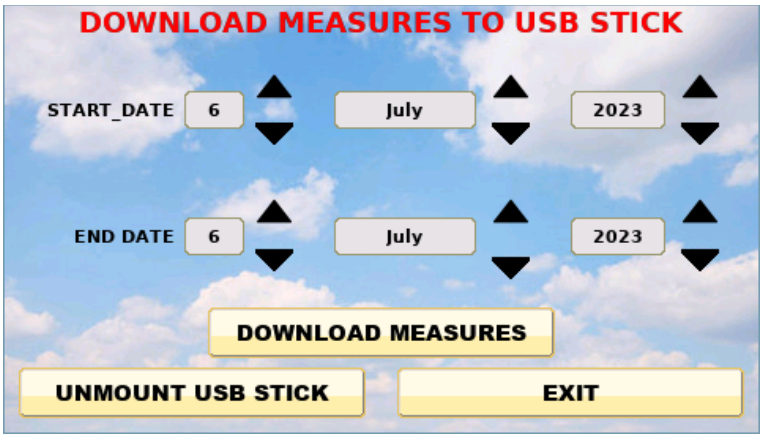


**Figure 16**

**Note:** to save data to USB measurement must stopped!

# 5. Remote control

Using the communication protocol via RS232 or telnet allows the user to gain greater control of the instrument. The RS232 port has the following parameters: 57600, 8, N, 1. The telnet uses port 16023 as the default port, but it can be changed with the CHANGE_PORT command.
Network settings: must be provided by the user exclusively via the serial link (command: CHANGE_IP and CHANGE_GATEWAY, paragraph **0**).

To visualize on a computer terminal all possible commands type "?" .

| Command | Description |
|---|---|
| **?** | *Show Help Menu* |
| **ADMIN** | *Switch to admin menu. Reserved for the producer – need a password.* |
| **CHANGE_FILTER** | *Change filter* |
| **CHANGE_GATEWAY** | *Change IP gateway (CHANGE_GATEWAY IPSUB1.IPSUB2.IPSUB3.IPSUB4)* |
| **CHANGE_IP** | *Change IP address and netmask (CHANGE_IP IPSUB1.IPSUB2.IPSUB3.IPSUB4 NETSUB1.NETSUB2.NETSUB3.NETSUB4)* |
| **CHANGE_PORT** | *Change TCP remote console port (CHANGE_PORT NUM_PORT)* |
| **CHANGE_SNTP_SERVER** | *Change SNTP IP SERVER (CHANGE_SNTP_SERVER IPSUB1.IPSUB2.IPSUB3.IPSUB4). With no arguments disabled SNTP* |
| **CLOSE_HEAD** | *Close head* |
| **CLOSE_REMOTE_SESSION** | *Close remote session (console telnet)* |
| **DATE** | *Display date and time* |
| **DELETE_ALL_MEASURES** | *Delete all measures* |
| **DELETE_DATE_MEASURES** | *Delete all measures of that day (DELETE_DATE_MEASURES DD/MM/YYYY)* |
| **DELETE_LOGS** | *Delete all logs* |
| **DISABLE_FLUXMETER** | *Disable the fluxmeter The flow is fixed to user default* |
| **DISABLE_PUMP** | *Disable the pump in the measure. The flow is fixed to user default* |
| **DISABLE_REMOTE_CONSOLE** | *Disable remote console* |
| **ENABLE_FLUXMETER** | *Enable the fluxmeter.* |
| **ENABLE_PUMP** | *Enable the pump in the measure.* |
| **ENABLE_REMOTE_CONSOLE** | *Enable remote console* |
| **FORWARD_REEL** | *Forward reel* |
| **GET_DATE_MEASURES** | *Print measures of date (GET_DATE_MEASURES DD/MM/YYYY [hh:mm]).* |
| **GET_DATE_RANGE_MEASURES** | *Print measures date range (GET_DATE_MEASURES DD/MM/YYYY DD/MM/YYYY).* |
| **GET_HEADER_MEASURE** | *Print header measures.* |
| **GET_LAST_MEASURES** | *Print last measures (Max. 1 day). Without argument show only last* |
| **LED_BLUE** | *Switch on blue led* |
| **LED_GREEN** | *Switch on green led* |
| **LED_IR** | *Switch on IR led* |
| **LED_NONE** | *Switch off all led* |

| Command | Description |
|---|---|
| **LED_RED** | *Switch on red led* |
| **LED_UV** | *Switch on UV led* |
| **OPEN_HEAD** | *Open head* |
| **READ_AIR_HUMI** | *Read air humidity* |
| **READ_AIR_TEMP** | *Read flux temperature* |
| **READ_ENVIRO_PRESSURE** | *Read environmental pressure* |
| **READ_FLUX_L_MINUTE** | *Read flux l/min* |
| **READ_FLUX_PRESSURE** | *Read flux pressure* |
| **READ_INT_TEMP** | *Read internal temperature* |
| **READ_LED_TEMP** | *Read led temperature* |
| **SET_AIR_HUMI_OFFSET** | *Set air humidity offset (range -10 to +10)* |
| **SET_AIR_TEMP_OFFSET** | *Set air temperature offset (range -10 to +10)* |
| **SET_BC_CONSTANT** | *Set constant to calculate black carbon (syntax SET_BC_CONSTANT <COLOR> value)* |
| **SET_DATE** | *Set date and time (hh:mm:ss DD/MM/YYYY)* |
| **SET_DEFAULT_FLUX** | *Set default flux for no pump or no fluxmeter* |
| **SET_FACTORY_CONFIG** | *Set factory configuration and restart* |
| **SET_FILTER_CORRECTION_CONST** | *Set filter correction const (syntax SET_FILTER_CORRECTION_CONST <COLOR> <CONST_A> <CONST_B> <CONST_C>)* |
| **SET_FLOW_CONST_A** | *Set flow const A* |
| **SET_FLOW_CONST_B** | *Set flow const B* |
| **SET_LEVELS_FILTER_CHANGE** | *Transmittance level filter change for colors. (IR_TR RED_TR GREEN_TR BLUE_TR UV_TR)* |
| **SET_SMA_STEPS** | *Set Simple Moving Average steps. 1 to 10 measures* |
| **SET_SPOT_AREA** | *Set spot area* |
| **SET_TIME_ZONE** | *Set UTC time zone* |
| **SHOW_CONFIG** | *Show configuration parameters* |
| **SHOW_DATE_MEASURES** | *Show date measure present on sd (optional parameters DATE NUM_DATE_MEASURES).* |
| **SHOW_LOG_GEN** | *Show generic logs. (Optional argument last number of logs).* |
| **SHOW_LOG_SYS** | *Show system logs. (Optional argument last number of logs).* |
| **SHOW_STATUS** | *Show DBAP status* |
| **SHOW_VER** | *Show software version* |
| **SPD** | *Set pump duty cycle* |
| **START_CALIBRATION** | *Measure and reference every second update* |
| **START_MEASURE** | *Start measure. Option PUMP enable at once the pump* |
| **START_PUMP** | *Start pump* |
| **START_STREAMING** | *Start streaming measure* |
| **STOP_CALIBRATION** | *Stop calibration* |
| **STOP_MEASURE** | *Stop measure (switch off clock, led and pump)* |
| **STOP_PUMP** | *Stop pump* |
| **STOP_STREAMING** | *Stop streaming measure* |

Commands are not case sensitive, and they must be followed by the \n\r characters.

DBAP5 commands can be divided in Action, Write and Read commands. Action commands are used for activating some operation, Write commands for parameters setting and Read commands to receive information and data for the instrument.

## 5.1. Read Command

| Command | |
|---|---|
| **?** | *Show Help Menu* |
| **DATE** | *Show instrument date and time* |
| **GET_DATE_MEASURES** | *Download data of the given day starting from the given time (time is optional), data format is reported in appendix A.* |
| **GET_DATE_RANGE_MEASURES** | *Download all data in the given dates range (GET_DATE_MEASURES DD/MM/YYYY DD/MM/YYYY).* |
| **GET_HEADER_MEASURE** | *Download the header as reported in Appendix A.* |
| **GET_LAST_MEASURES** | *Show last measurement data, it can be given with an integer (n) less than 1440 as argument to get last n measurement data, in is missing only the last measure is downloaded. Data format is reported in appendix A.* |
| **READ_AIR_HUMI** | *Show the air sampled air temperature [%].* |
| **READ_AIR_TEMP** | *Show the temperature [Celsius degrees] inside the Venturi tube.* |
| **READ_ENVIRO_PRESSURE** | *Show enviroment pressure [mbar].* |
| **READ_FLUX_L_MINUTE** | *Show flow [l/min].* |
| **READ_FLUX_PRESSURE** | *Show the differential pressure [mbar] in the Venturi tube.* |
| **READ_INT_TEMP** | *Show the internal temperature [Celsius degrees].* |
| **READ_LED_TEMP** | *Show led temperature [Celsius degrees].* |
| **SHOW_CONFIG** | *Show the parameter setting on the instrument.* |
| **SHOW_DATE_MEASURES** | *Show the date of the measures saved in the instrument memory, if used with argument it will show the date starting from the given date.* |
| **SHOW_LOG_GEN** | *Shows the instruments generic logs (maximum last 1000 events).* |
| **SHOW_LOG_SYS** | *Shows the instruments system logs (maximum last 1000 events).* |
| **SHOW_STATUS** | *Shows instrument status and errors.* |
| **SHOW_VER** | *Shows the firmware and bootloader version.* |
| **START_STREAMING** | *Start data streaming over RS232 or telnet. Data format is reported in appendix A* |
| **STOP_STREAMING** | *Stop data streaming* |

## 5.2. Write command (parameter setting)

| Command | Description |
|---|---|
| **CHANGE_GATEWAY** | ***Only over RS232***<br>*Set the IP gateway.* |
| **CHANGE_IP** | ***Only over RS232***<br>*Set IP and netmask.* |
| **CHANGE_PORT** | *Set the TCP port for the communication over telnet.* |
| **CHANGE_SNTP_SERVER** | *Set the NTP server for time synchronization.*<br>*Used without parameter will disable the time synchronization.* |
| **SET_AIR_HUMI_OFFSET** | *Set the offset for the air humidity sensor by adding the given value.* |
| **SET_AIR_TEMP_OFFSET** | *Set the offset for the air temperature sensor by adding the given value.* |
| **SET_BC_CONSTANT** | *Set the color and the related MAE of* **Eq. 8** *to calculate the EBC.* |
| **SET_DATE** | *Set instrument date and time.* |
| **SET_DEFAULT_FLUX** | *Set the fictitious flux value for operations without active pump.* |
| **SET_FACTORY_CONFIG** | *Set instrument factory configuration (appendix B).* |
| **SET_FILTER_CORRECTION_CONST** | *Set the coefficient for the filter correction function* **Eq. 7**. |
| **SET_FLOW_CONST_A** | *Set coefficients a for the air flow calibration* **Eq. 4** . |
| **SET_FLOW_CONST_B** | *Set coefficients b for the air flow calibration* **Eq. 4** . |
| **SET_LEVELS_FILTER_CHANGE** | *Set the transmittance threshold for advancing the filter tape (paragraph* ***3.2****). Setting the value to 0 will disable the tape movement for the related colour.* |
| **SET_SMA_STEPS** | *Set the number of measures to use for the SMA calculation (****Eq. 10****).* |
| **SET_SPOT_AREA** | *Set the filter spot area (****Eq. 6****) in* $m^2$. |
| **SET_TIME_ZONE** | *Set time zone* |
| **SPD** | *Set the pump duty cycle to change the instrument flow.* |

## 5.3. Action command

| Command | Description |
|---|---|
| **CHANGE_FILTER** | *Open the measuring chamber, filter advancement and close the measuring chamber. Command can only be run when the measurement is not active, after this action measure does not start automatically.* |
| **CLOSE_HEAD** | *Close measurement chamber.* |
| **DELETE_ALL_MEASURES** | *Delete all the measures stored in the SD card.* |
| **DELETE_DATE_MEASURES** | *Delete the measures of the given day stored in the SD card.* |
| **DELETE_LOGS** | *Remove all system logs.* |
| **DISABLE_FLUXMETER** | *Disable the reading of the fluxmeter, to use only if the fluxmeter is broken and an external fluxmeter is used. Data are given with a default flux and must be corrected during post-analysis.* |
| **DISABLE_PUMP** | *This command allows to perform measures without flow (pump off). Data are then given with a default flow . Used mainly for electronic noise check. Command can only be run when the measurement is not active, after this action measure does not start automatically.* |
| **DISABLE_REMOTE_CONSOLE** | *Disable the telnet communication.* |
| **ENABLE_FLUXMETER** | *Enable the reading of the fluxmeter (default condition).* |
| **ENABLE_PUMP** | *Enable pump, to use after the disabled pump command to return in normal operation mode. Command can only be run when the measurement is not active, after this action measure does not start automatically.* |
| **ENABLE_REMOTE_CONSOLE** | *Enable the telnet communication.* |
| **FORWARD_REEL** | *Advancing the filter. This command can be executed only when the measurement chamber is open.* |
| **LED_BLUE** | *Activate only blue led. To be used in calibration mode.* |
| **LED_GREEN** | *Activate only green led. To be used in calibration mode.* |
| **LED_IR** | *Activate only ir led. To be used in calibration mode.* |
| **LED_NONE** | *None of the LED is active. To be used in calibration mode for dark current.* |
| **LED_RED** | *Activate only red led. To be used in calibration mode.* |
| **LED_UV** | *Activate only uv led. To be used in calibration mode.* |
| **OPEN_HEAD** | *Open the measurement chamber. Command can only be run when the measurement is not active.* |
| **START_CALIBRATION** | *Put the instrument in calibration mode. Command can only be run when the measurement is not active.* |
| **START_MEASURE** | *Start measures.* |
| **START_PUMP** | *Activate the pump.* |
| **STOP_CALIBRATION** | *Stop the calibration mode.* |
| **STOP_MEASURE** | *Stop the measure* |
| **STOP_PUMP** | *Stop the pump* |

## 5.4. Other commands

| Command | Description |
|---|---|
| **ADMIN** | *Enable the administration mode. Reserved for the producer – need a password.* |
| **EXIT** | ***Only over TCP/IP.***<br>*Disable remote console (telnet).* |

# 6. Changing the tape filter

1. Stop measures
2. Open head
3. Open the Plexiglas cover
4. Advance the remaining filter by manually running the right knob
5. When the filter is completely removed, unscrew the right knob and remove the used tape filter from the support
6. Place the right knob back on the support
7. Unscrew the left knob and insert the new filter tape on the support
8. Block the filter screwing back the knob, insert the filter tape from the left side of the control camera and pass it through, then stop it. Use the adhesive tape on the right support
9. Close the Plexiglas cover
10. Close head
11. Advance the filter (forward_reel) to check if the operation was successful

**Figure 3** shows the correct position of the tape filter inside the instrument.

# APPENDICE A: data format

In the following table is reported the data format obtained in streaming or by using GET_DATE_MEASURES, GET_DATE_RANGE_MEASURES and GET_LAST_MEASURES commands.

| *Parameter* | *header* | *Unit* | *Parameter* | *header* | *Unit* |
|---|---|---|---|---|---|
| Date | DATE | yyyy-mm-dd | UV transmittance | TRANS_UV | |
| Time | TIME | HH:MM:SS | IR absorption coefficient | KABS_IR | $m^{-1}$ |
| Decimal day (0 = 1st January) | NUMERIC_DAY | days | RED absorption coefficient | KABS_RED | $m^{-1}$ |
| Venturi tube differential pressure | FLUX_PRESS | mbar | GREEN absorption coefficient | KABS_GREEN | $m^{-1}$ |
| Flow | FLUX_L/M | l/min | BLUE absorption coefficient | KABS_BLUE | $m^{-1}$ |
| LED temperature | LED_TEMP | °C | UV absorption coefficient | KABS_UV | $m^{-1}$ |
| Air temperature (in Venturi tube) | AIR_TEMP | °C | Equivalent Black carbon IR | BC_USER | $\mu g/m^3$ |
| Main-Board temperature | INT_TEMP | °C | Ambient pressure | ENVIRO_PRESS | hPa |
| IR transmittance | TRANS_IR | | Flags | FLAGS | hex |
| RED transmittance | TRANS_RED | | AAE 870-420 | AAE | |
| GREEN transmittance | TRANS_GREEN | | RH | AIR_HUMI | % |
| BLUE transmittance | TRANS_BLUE | | Time Zone | TIME_ZONE | |
| | | | SMA | SMA | minutes |

# APPENDIX B: Flags

The last field in the data (Flags) is an hexadecimal number that report system status.
The table below shows the value of the flags and their meaning.

| *Flag* | *Meaning* |
|---|---|
| 1 | Cooler fan active |
| 2 | Pump disabled. |
| 4 | Start of new measure |

In case more flag are detected together they are added in the flags. For example, flag 3 is the sum of flag 1 and 2, that means that the cooler fan is active and there is a pump disabled.

# APPENDIX C: Electrical and mechanical specification

| Electrical | | |
|---|---|---|
| *Power supply* | *220 Vac* | *Max 0.5A* |
| *Power consumption* | | *36 Watt* |
| *Mains filter* | *Arctronics AR3 series* | |
| *Protection* | *2 x fuse (5x20)* | *2A* |
| *Power plug* | *IEC* | |
| *Ethernet* | *RJ45* | *10-100 Mbps* |
| *RS232* | *DB9 (3 pin)* | *57.600 Kbps* |

| Mechanical | | |
|---|---|---|
| *Dimension* | *19" x 6 Unit* | *Max 460 x 300 x 270 mm* |
| *Weight* | *11 Kg* | |
| *Tape filter* | *width 40 mm* | *type GF10* |
| *Air Inlet* | *D= 6 mm* | |
| *Air outlet* | *D= 6 mm* | |
| *Air flow (adjustable)* | *1 – 2.5 l/min* | |
| *Working temperature* | *10-30 C°* | |

# APPENDIX D: Normative

The instrument is harmonized with the following standards:

- CE, UL60950-1, EN60950-1
- CEI EN 61010-1
- 2006/95/EC
- 2004/108/CE
- 1990-03-05/4690 /art 3 22012008/37

Intended use: Laboratory equipment for environmental monitoring.

# APPENDIX E: Poster PM2022

## Deve opment of a new photometer for measuring the absorption coefficient at 5 different wave ength Dua Beam Absorption Photometer 5 (DBAP5), description and first comparisons

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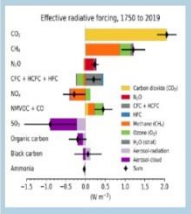
[3] Istituto di Scienze Polari , Consiglio Nazionale delle Ricerche, Bologna

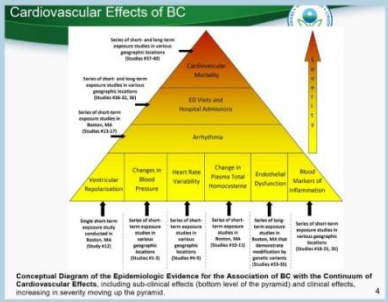
### Motivation




Black Carbon (BC) is the main absorbing component of atmospheric aerosol. Generated by the incomplete combustion of fuels, biomass burning, internal combustion engines (especially diesel), and industrial processes, it has a lifetime in the atmosphere of days to weeks.

By strongly absorbing solar radiation and reducing albedo, when deposited on snow and ice, BC has a warming effect on climate [1], the quantification of which is still uncertain.

Moreover, epidemiological studies provide evidence of the association of cardiopulmonary morbidity and mortality with exposure to black carbon.

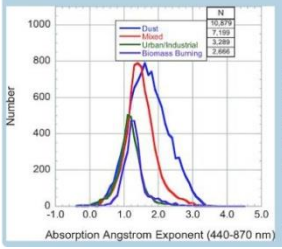



**Conceptual Diagram of the Epidemiologic Evidence for the Association of BC with the Continuum of Cardiovascular Effects**, including sub-clinical effects (bottom level of the pyramid) and clinical effects, increasing in severity moving up the pyramid. 4

These features have made BC an important pollutant to monitor, understand, and manage despite not currently having direct legal limits imposed in Europe and elsewhere (Reche et al., 2011; European Environment Agency, 2016).

#### Absorption coefficient Spectra Dependence (AAE)

Black carbon is not the only absorbing component of atmospheric aerosol, dust and organic compounds also absorb the radiation but with a different spectral dependence of the absorption coefficient, quantified by the Absorption Angstrom Exponent (AAE).

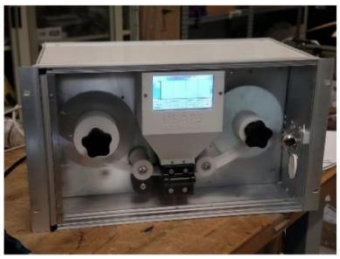



This is thus a key parameter to evaluate aerosol composition and sources.

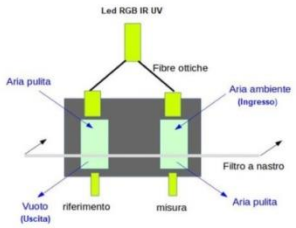
D. M. Gilles et al. 2012

### DBAP5 description

The most popular method for measuring BC concentration and spectrally resolved aerosol absorption coefficient is the filter-based absorption photometer. Particles are collected on filter and as the particle load increase, the light passing though the filter decrease. DBAP5 is a 5 wavelength (from 420 to 870 nm, filter-based photometer based on the dual beam technology (Dual Beam Absorption Photometer).



Measuring the variation in filter light transmission at increasing particle load it evaluate the attenuation coefficients, then converted in the absorption coefficient by applying the appropriate filter correction equations.




Dua Beam chamber

Equivalent Black Carbon concentration can be then derived using the appropriate Mass Absorption Coefficients. The dual beam technology is a technique that simultaneously compare the absorption of the particulate matter with the absorption on the white filter, providing more precise measurement especially in low concentration site.

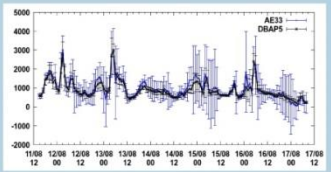
**Technica Specification**

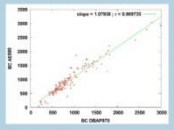
| | |
|---|---|
| LED | 870,634,522,465,420 nm |
| Air flow | 1-5 l/m |
| Filter tape | Glass fiber GF-10 w=40mm |
| communication | RS232, telnet |

### Instrumental intercomparison

Urban site Bo ogna with an AE33 (spring 2021)

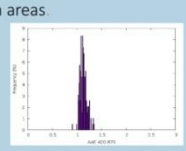
The BC [ng/cm3] DBAP5 has been evaluated from absorption coefficient at 870 nm



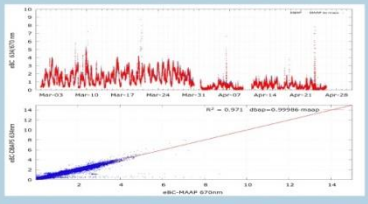
One hour averaged data has been used to compare DABP5 and AE33 measures. Correlation is very good, Comparing the SD, the DBAP5's SD is generally lower than AE33's, indicating less noise in the DBAP5 measurements in Urban areas

During this period AAE has been evaluated from DBAP5 data, results agree with [3], showing typical values of urban sites



Rura site San Pietro Capofiume, with a MAAP, Spring 2022

The BC for DBAP5 has been evaluated comparing it with BC measured using a Multi Angle Absorption Photometer.



One-minute data have been compared for two months. The results show a powerful agreement between two instrumental setup.

1) Reche. C. et al.: New considerations for PM, Black Carbon and Atmos. Meas. Tech.
2) European Environment Agency: Black carbon: Better monitoring needed to assess health and climate change impacts
3) An analysis of AERONET aerosol absorption properties and classifications representative of aerosol source regions. D. M. Gilles et al. 2012 J. Geophys. Res.
4) S. K. Grange et al.: Evaluation of EBC source apportionment using observations from Switzerland 1885 particle number concentration for air quality monitoring across different European cities