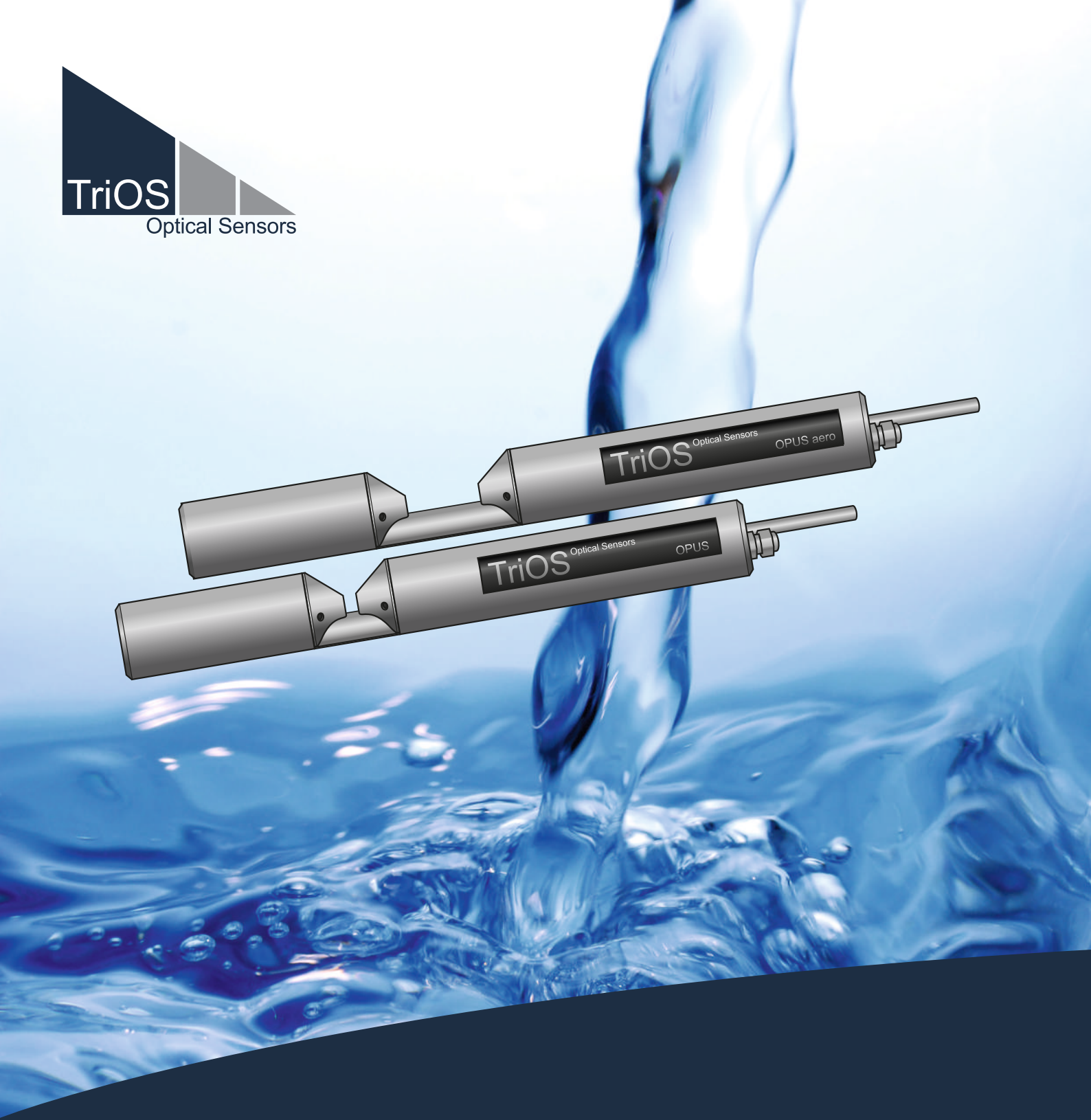
TriOS
Optical Sensors



OPUS

OPERATING INSTRUCTIONS

Table of contents

1 General information

1.1 Introduction

Welcome to TriOS. We are pleased that you have chosen our OPUS submersible sensor.

OPUS is a spectral probe for the online measurement of nitrogen and carbon compounds. By analyzing a complete spectrum, OPUS is able to provide reliable readings for N-NO_3, N-NO_2, organics (COD_{eq}, BOD_{eq}, DOC_{eq}, TOC_{eq}) and a range of other parameters.

OPUS aero is a variant of OPUS for the online measurement of nitrate and nitrite in waste water aeration tanks. By analyzing a complete spectrum, OPUS aero is able to provide reliable measurement values for either NO_3-N only or NO_3-N and NO_2-N, depending on the calibration.

OPUS is equipped with the TriOS G2 interface and thus allows simple and fast sensor configuration using a web browser. Integration into existing process control systems and external Data loggers is easy to implement. Mobile applications can also be realized with the battery pack available as an accessory. Using WLAN, a laptop, tablet or smartphone can then simply be used for control without the need to install special application software or an app.

In this manual you will find all the information about OPUS that you need for Commissioning. Technical specifications, detection limits and dimensions can be found in chapter 7.

Please note that the user is responsible for complying with regional and national regulations for the installation of electronic devices. Any damage caused by incorrect use or unprofessional installation is not covered by the warranty.

All sensors and accessories supplied by TriOS Mess- und Datentechnik GmbH must be installed and operated in accordance with TriOS Mess- und Datentechnik GmbH specifications. All parts have been designed and tested according to international standards for electronic instruments. The device complies with international standards for electromagnetic compatibility. Please use only original TriOS accessories and cables to ensure smooth and professional use of the devices.

Read this manual carefully before using the device and keep it for future reference. Before using the sensor, make sure that you have read and understood the safety precautions described below. Always ensure that the sensor is operated correctly. The safety precautions described on the following pages are intended to ensure problem-free and correct operation of the device and the associated accessories and to prevent you, other persons or devices from being harmed.

NOTICE

If translations differ from the original German text, the German version is binding.

Software updates

This manual refers to software version 1.3 and higher. Updates include bug fixes and new functions and options. Devices with older software versions may not have all the functions described here.

Copyright notice

1.2 Health and safety instructions

This manual contains important information on health and safety regulations. This information is marked in accordance with the international specifications of ANSI Z535.6 (“Product safety information in product manuals, instructions and other collateral materials”) and must be followed. The following categories are distinguished:

⚠ DANGER

Danger / Will cause serious injury or death

⚠ WARNING

Warnings / May cause serious injury or death

⚠ CAUTION

Caution / May cause moderate injury

NOTICE

May lead to material damage

Tip / Useful information

Electromagnetic waves

Devices that emit strong electromagnetic waves can influence the measurement data or cause the sensor to malfunction. Avoid operating the following devices in the same room as the TriOS sensor: cell phones, cordless phones, transceivers or other electrical devices that generate electromagnetic waves.

⚠ CAUTION

Never look directly into the light source without suitable UV protection! The UV light can irreversibly damage your eyes.

Reagents

Follow the manufacturer's safety and operating instructions when using reagents. Observe the applicable Ordinance on Hazardous Substances for Reagents (GefStoffV)!

Biological safety

Liquid waste may be biologically hazardous. You should therefore always wear gloves when handling such materials. Observe the currently valid Biological Substances Ordinance (BioStoffV)!

Waste

When handling liquid waste, the regulations for water pollution, drainage and waste disposal must be observed.

1.3 Warnings

- This sensor has been developed for use in industry and science. It should only be used to measure aqueous solutions such as process waste water, river water or seawater.

> ***NOTICE***
>
> **Stainless steel sensors are not made for use in seawater or high chloride concentrations (corrosion). Only sensors made of titanium can be used here.**

- Sensors made of stainless steel must be cleaned immediately after contact with salt water or other corrosion-causing substances (e.g. acids, alkalis, chlorine-based compounds). The material resistance should be tested for each application.
- The sensor has seals made of NBR (acrylonitrile butadiene rubber). Sealing rings made of other materials may be used on individual request. Before operation, ensure that the measuring medium does not damage the seals.
- Do not cut, damage or modify the cable. Ensure that there are no heavy objects on the cable and that the cable does not kink. Ensure that the cable does not run close to hot surfaces.
- If the sensor cable is damaged, it must be replaced with an original part by TriOS Mess- und Datentechnik GmbH customer support.
- Do not place any unsuitable objects within the optical path while the measurement process is running, as this may cause damage to the sensor or falsified measurement results.
- Stop operation of the sensor if excessive heat is generated (i.e. more than lukewarm). Switch off the sensor immediately and disconnect the cable from the power supply. Please contact your dealer or TriOS Technical support.
- Never attempt to disassemble or modify any part of the sensor unless specifically described in this manual. Inspections, modifications and repairs may only be carried out by the device dealer or by TriOS authorized and qualified specialists.
- Devices from TriOS Mess- und Datentechnik GmbH comply with the highest safety standards. Repairs to the devices (which include the replacement of the connecting cable) must be carried out by TriOS Mess- und Datentechnik GmbH or an authorized TriOS workshop. Incorrect, improper repairs can lead to accidents and injuries.

> ***NOTICE***
>
> **TriOS does not guarantee the plausibility of the measured values. The user is always responsible for monitoring and interpreting the measured values.**

1.4 User and operating requirements

The spectrally resolving photometer OPUS was developed for use in industry and science. The target group for operating the OPUS is technically experienced specialist personnel in companies, sewage treatment plants, waterworks and institutes. The application often requires the handling of hazardous substances. We assume that the operating personnel are familiar with the handling of hazardous substances due to their professional training and experience. In particular, the operating personnel must be able to correctly understand and implement the safety markings and safety instructions on the packaging and in the package inserts of the test kits.

1.5 Intended use

The intended use of the OPUS is exclusively to carry out photometric measurements as described in this manual. In this respect, the photometer is a submersible sensor that is used under water or with flow-through cells. Please observe the technical data of the accessories. Any other use is considered improper.

The sensor may only be used to measure the absorption or transmission of aqueous liquids, such as process waste water, municipal waste water, surface water and groundwater. The use of other media can damage the sensor. To use the OPUS in media other than those specified here, please contact TriOS Mess- und Datentechnik GmbH Technical Support (support@trios.de).

NOTICE

Avoid any contact with the glass parts in the optical path, as these can become scratched or dirty. As a result, the functionality of the device is no longer guaranteed.

According to current scientific knowledge, the device is safe to use if it is handled in accordance with the instructions in these Operating instructions.

NOTICE

Damage caused by improper use is excluded from the warranty.

1.6 Disposal instructions

At the end of its service life or useful life, the device and its accessories can be returned to the manufacturer (see address below) for disposal in an environmentally friendly manner. Proof of prior professional decontamination must be provided in the form of a certificate. Please contact us before returning the device for further details.

Address of the manufacturer:

TriOS Mess- und Datentechnik GmbH
Bürgermeister-Brötje-Str. 25
26180 Rastede
Rastede, Germany
Phone: +49 (0) 4402 69670 - 0
Fax: +49 (0) 4402 69670 - 20

1.7 Certificates and approvals

The product meets all requirements of the harmonized European standards. It therefore fulfills the legal requirements of the EU directives. TriOS Mess- und Datentechnik GmbH confirms the successful testing of the product by affixing the CE mark (see appendix).

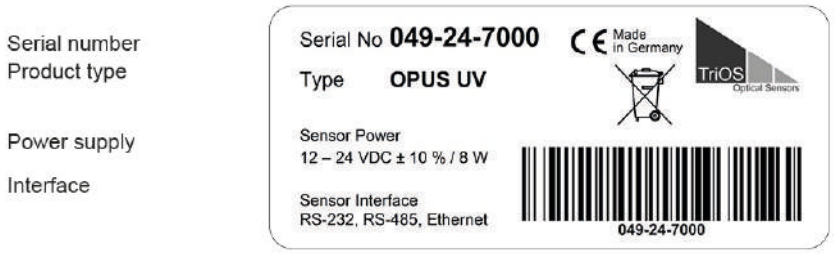
2 Introduction

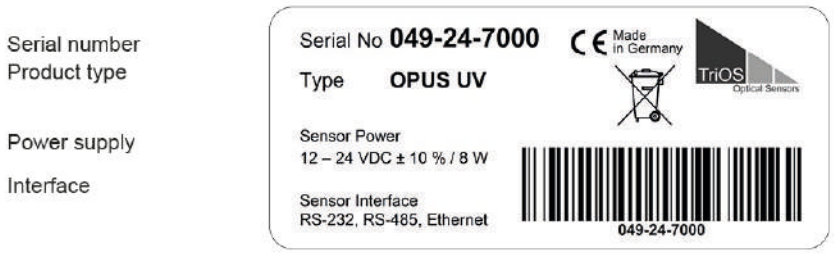
OPUS is an intelligent measuring instrument that can be operated without additional hardware. The following chapters explain the correct operation of the OPUS sensor with all its functions and setting options.

2.1 Product identification

All TriOS Mess- und Datentechnik GmbH products are provided with a product label that clearly shows the product designation.

There is also a type plate on the sensor with the following information, which you can use to clearly identify the product:





The type plate also contains the product barcode, the TriOS Optical Sensors logo and the CE quality mark.

Please note that the specifications given here are for illustrative purposes only and may vary depending on the product version.

2.2 Scope of delivery

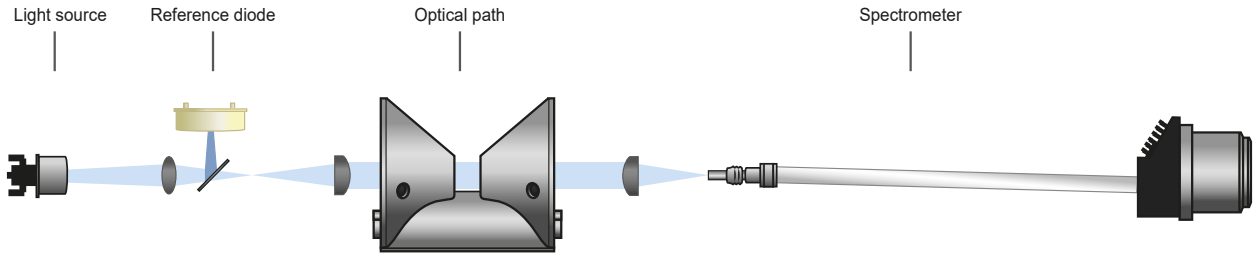
The delivery includes the following components:

1. Sensor
2. Operating instructions
3. Accessories (if applicable)

Keep the original packaging of the device for possible return for maintenance or repair purposes.

2.3 Measuring principle and structure

For optimal use of the sensor, it is essential to know and understand the idea and theory on which the sensor is based. The following is a thorough overview of the measuring principle, the optical arrangement and the subsequent calculation.



Essentially, the photometer consists of four parts: a defined light source, a lens system, the optical path through the medium and a spectrometer. The arrangement of these parts is shown schematically in the figure above.

A xenon flash lamp is used as a broadband light source in the OPUS.

The light passes through the medium in the optical path and is partially absorbed by the medium. The spectrometer records the remaining light with spectral resolution and determines its intensity I at different wavelengths over a defined wavelength range.

The light attenuation when passing through a measurement medium is compared with the light attenuation caused by ultrapure water. The measurement in ultrapure water provides the so-called base intensity I_0.

According to equation 1 and equation 2, the sensor determines the transmission T and the absorption coefficient A for individual wavelengths over the defined wavelength range.

Equation 1: Calculation of the transmission

$$T = \frac{I}{I_0}$$

Equation 2: Calculation of the absorption coefficient

$$A = -\log_{10} T$$

with

T Transmission in %
I Current light intensity
I_0 Basic light intensity for ultrapure water
A Absorbance in AU (AU = absorbance unit)

The integrated analysis software can be used to calculate concentration equivalents from the absorption with the corresponding concentrations.

2.3.1 Spectral analysis

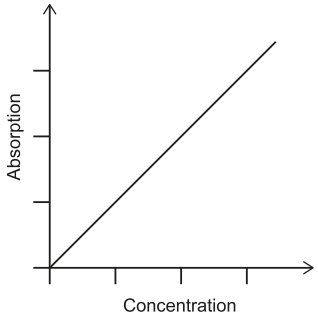
Absorption spectrum

The basis of every LSA (linear spectral analysis) is the measurement of absorption. The sensor emits a beam of light that crosses the optical path and its intensity is then measured again. If the medium being measured is ultrapure water, almost no light is absorbed. In an application, however, the measuring medium is often cloudy, so that not all of the light rays pass through and some of the emitted light is absorbed by the water or measuring medium.

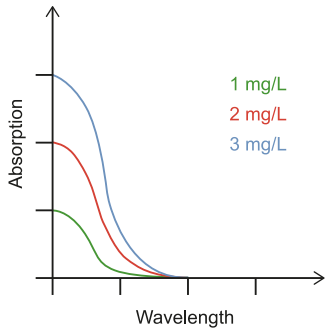
In the OPUS, the light emitted by the light source is first measured by a reference diode. After it has passed through the optical path and thus the measuring medium, where it is partially absorbed, it is measured by the spectrometer. See also chapter “Measuring principle and set-up”.

Lambert-Beer's law

The absorption of light is linear to the concentration of the measured parameter. The basis for this is Lambert-Beer's law.



Beer-Lambert-Law

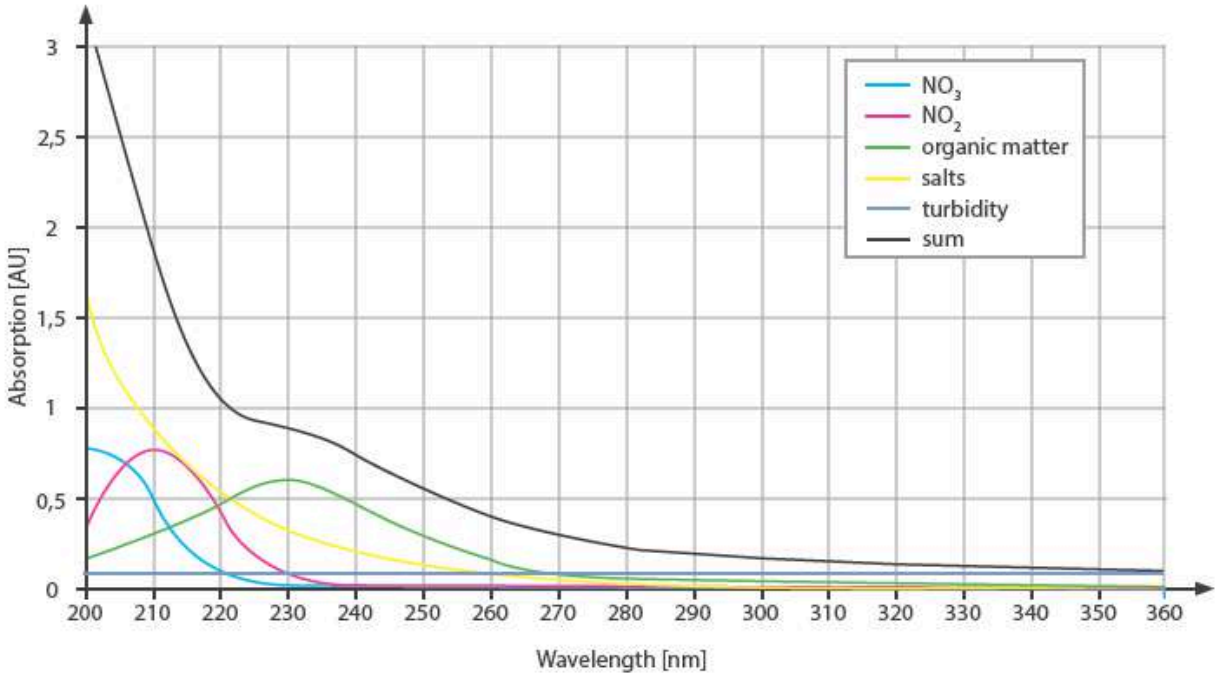


Example nitrate concentration

Linear spectral analysis OPUS

Spectral analysis (LSA) on OPUS works with the complete absorption spectra from 200 to 360 nm. The absorption spectra of the substances known and expected for the respective application are stored as an analysis group (LSA group / parameter set) on the sensor as a calibration.

Typical absorption spectrum



The LSA calculates a combination of the stored absorption spectra of the LSA group whose result best matches the measured absorption spectrum of the medium. The analysis then simultaneously calculates the substance concentrations required to reproduce the measured absorption spectrum of the medium.

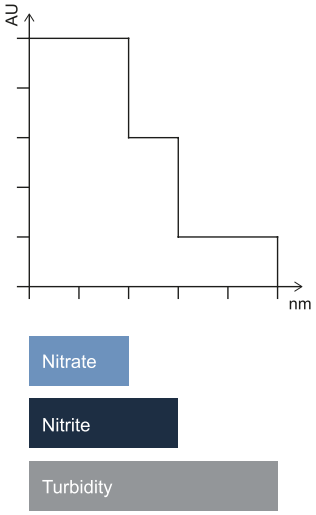
The sum of all spectral deviations between the absorption spectrum of the medium and the reconstructed absorption spectrum of the LSA results in the fit error in the stored data.

Fit error

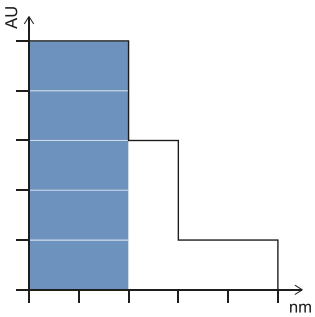
It can be seen in the figure above that nitrate, for example, has its maximum at 200 nm and nitrite at 210 nm. Each of the measurable parameters has such a characteristic spectrum, which can be used to detect the concentration and occurrence. In contrast to many other devices, OPUS does not measure the content of a parameter at predefined points, but includes the entire area in the calculation.

Schematic representation of fit error

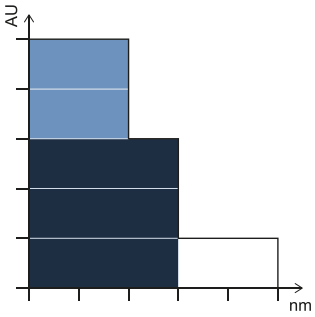
On the right is a simplified representation of a measurement spectrum.
The three colored rectangles represent different substances, such as nitrate, nitrite and turbidity.
An attempt is now made to fill the measurement spectrum with plausible values in order to obtain an approximation of the curve.
There are various possibilities here.



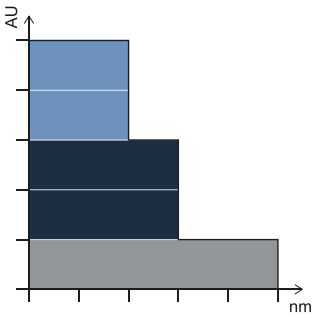
Variant 1 would be, for example: Nitrate = 5
This variant does not include any other control parameters. The resulting unassigned areas are called fit errors.
In this case: Fit error = 5



Variant 2:
1 control parameter
Nitrate = 2
Nitrite = 3
Fit error = 2

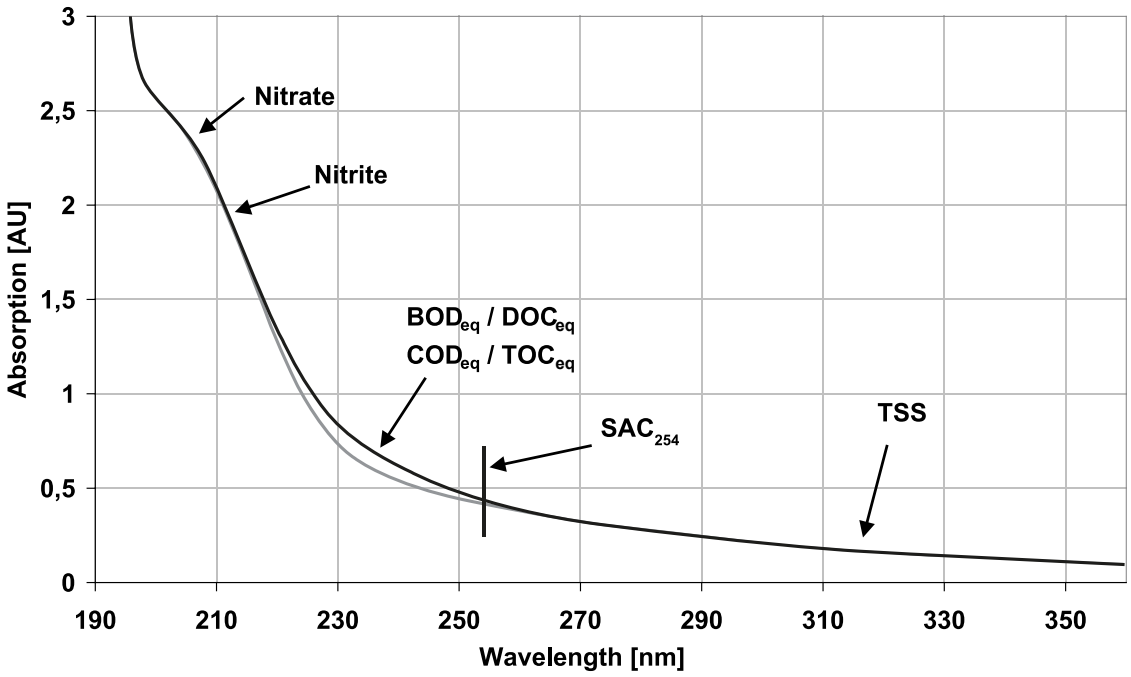


Variant 3:
2 control parameters
Nitrate = 2
Nitrite = 2
Turbidity = 1
Fit error = 0



The combination with the lowest fit error is searched for. This results in the composition of the measurement parameters. The diagram illustrates why a consideration of the entire measuring range provides considerably more accurate results than a point-by-point consideration of the curve at the wavelengths characteristic of the parameter.

Absorption spectrum of waste water with/without $_{CODeq}$



The significant ranges of the parameters are named in the spectra shown.

2.3.2 Parameters

Substances with a specific absorption spectrum, such as nitrate and nitrite, can be used directly as an element of the LSA group.

For sum parameters such as COD, BOD, TOC and DOC, theoretical absorption spectra are stored, which TriOS has been able to determine as typical from many years of experience. A spectral analysis based on UV absorption can only use the UV light absorbing components of these parameters. For this reason, OPUS only uses equivalents and the parameters are given the suffix “eq”: COD$_{eq}$, BOD$_{eq}$, TOC$_{eq}$ and DOC$_{eq}$.

The LSA group also contains correction spectra that take into account the effects of turbidity, for example.

As the entire absorption spectrum is recorded, parameters such as the SAC$_{254}$ (spectral absorption coefficient at 254 nm) can also be calculated.

2.4 Browser

The photometer is equipped with a web interface that can be used to configure and calibrate the sensor. To access the web interface, you need the G2 InterfaceBox and an Ethernet-enabled device with a web browser, such as a notebook.

Open one of the following URLs in your web browser (depending on the structure of the network):

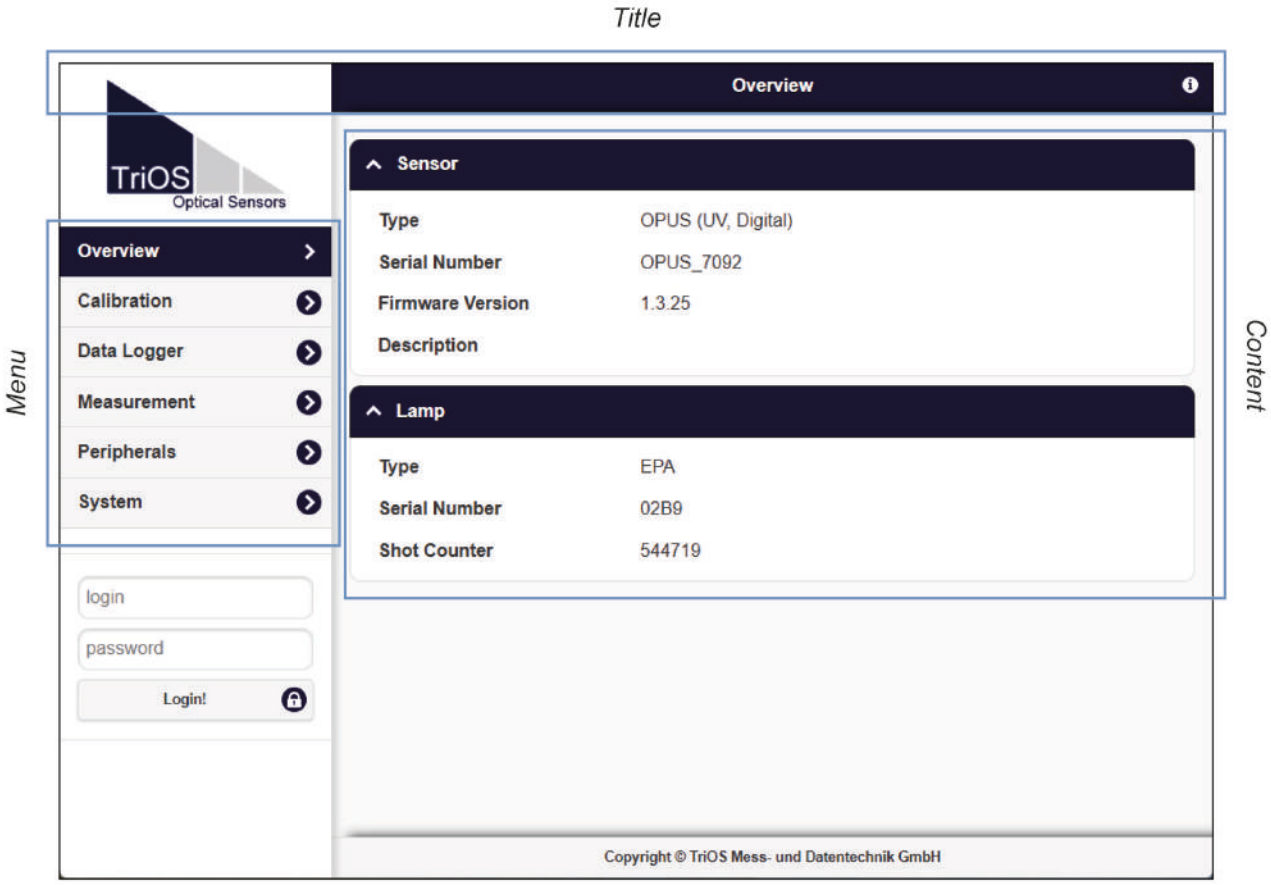
http://opus_7XXX/ (7XXX is the serial number) or

http://192.168.77.1/

http://opus/ or

Up to version 1.3.x, automatic measurements are suspended if an Ethernet-enabled device is connected. As soon as the sensor is disconnected from your device again, the measurements are continued at the set interval if the timer for automatic measurements is activated.

The web interface is divided into three areas (see illustration):



Three areas: Title at the top, Menu on the left and Content in the middle.

The name of the current page is displayed in the title. To the right is the info button. This shows the contact details of the relevant TriOS authorized dealer and TriOS Mess- und Datentechnik GmbH.

The individual pages are listed in the menu on the left. The name of the current page is highlighted in blue.

Below the menu is the login area, which certified TriOS service technicians can use to authenticate themselves. In most cases, problems can be solved here on site.

The menu is used to navigate the web interface. Each line is a link to a different page with correspondingly different setting options. The link that refers to the page currently displayed is always highlighted in the menu. Special, selected content and functions are reserved exclusively for TriOS Mess- und Datentechnik GmbH Technical support staff. Authentication is required for this content, so it is not accessible to everyone.

The “Content” area displays the relevant information and setting options. Content that requires authentication is deactivated (“grayed out”) if authentication fails or is not possible due to a lack of corresponding information.

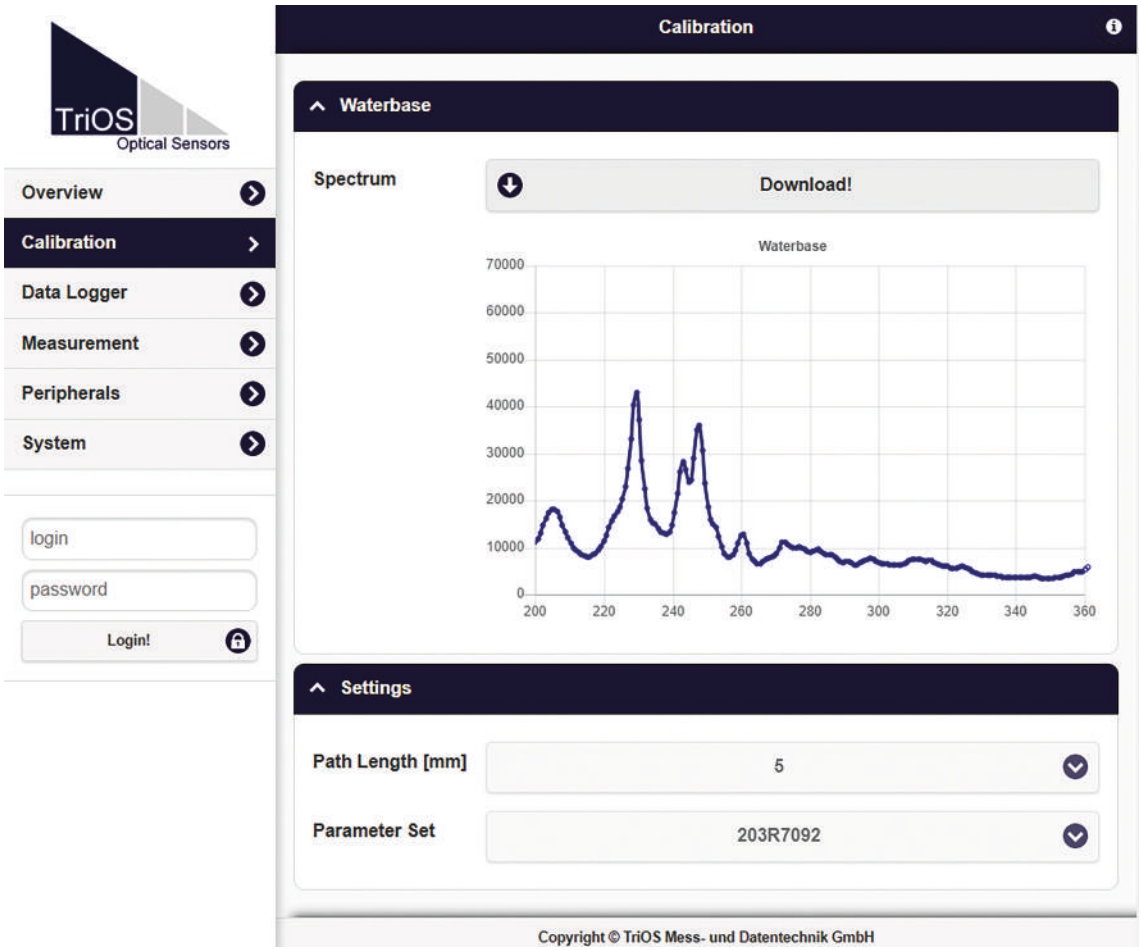
If settings have been made, they must be saved using the " Save" button. Otherwise the settings will be lost.

Overview

Basic information about the sensor is summarized on the overview page (“Overview”, see above). This includes the device type and serial number of the sensor as well as the version number of the installed firmware. The type of lamp module with serial number is also listed, as well as the number of measurements that have been carried out by this lamp module.

Calibration

The lamp spectrum I_0 is displayed on the “Calibration” page under “Waterbase”. The set optical path in millimetres and the selected parameter set (LSA group) are displayed under “Settings”.

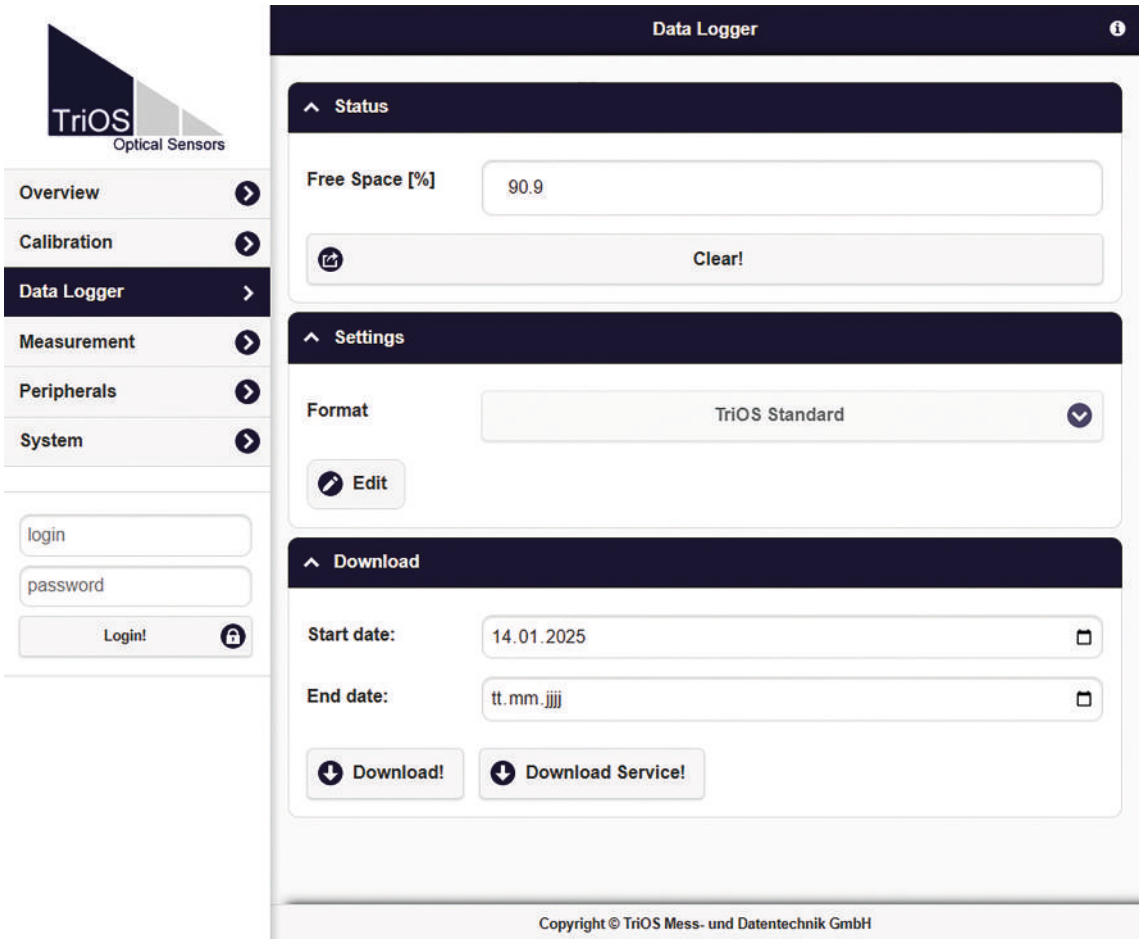


Data logger

OPUS is equipped with a simple Data logger function that allows approx. 42,000 measurements to be stored. This allows the OPUS to operate almost completely autonomously over a very long period of time. However, a sufficient power supply must be ensured.

The Data logger function is controlled via the “Data Logger” page, which is shown in the following illustration.

The measurement interval is set to 2 minutes at the factory so that the Data logger records the measurements for approx. 1400 hours (58 days). If the memory is full, only the last recorded measurement data is saved and old data is overwritten.



Status

The “Status” area shows what percentage of the memory is still free.

The “Clear” button is used to format the memory and delete all data. For security reasons, only confirm the security prompt.

After confirming the security prompt, the memory on the measuring device, and therefore all data, is irrevocably deleted.

Settings

The data format in which the data is saved can be selected here. Two options are available: “TriOS Standard” and “CSV” (Comma Separated Values).

TriOS Standard" is configured by default. In this case, parameters such as substance concentrations, sum parameters and absorbance values are saved in CSV and spectra in TriOS DAT format. Only in this form can TriOS customer support offer assistance with more in-depth problems.

Alternatively, all data can be saved in CSV format. This data can be read and processed by the most common spreadsheet programs.

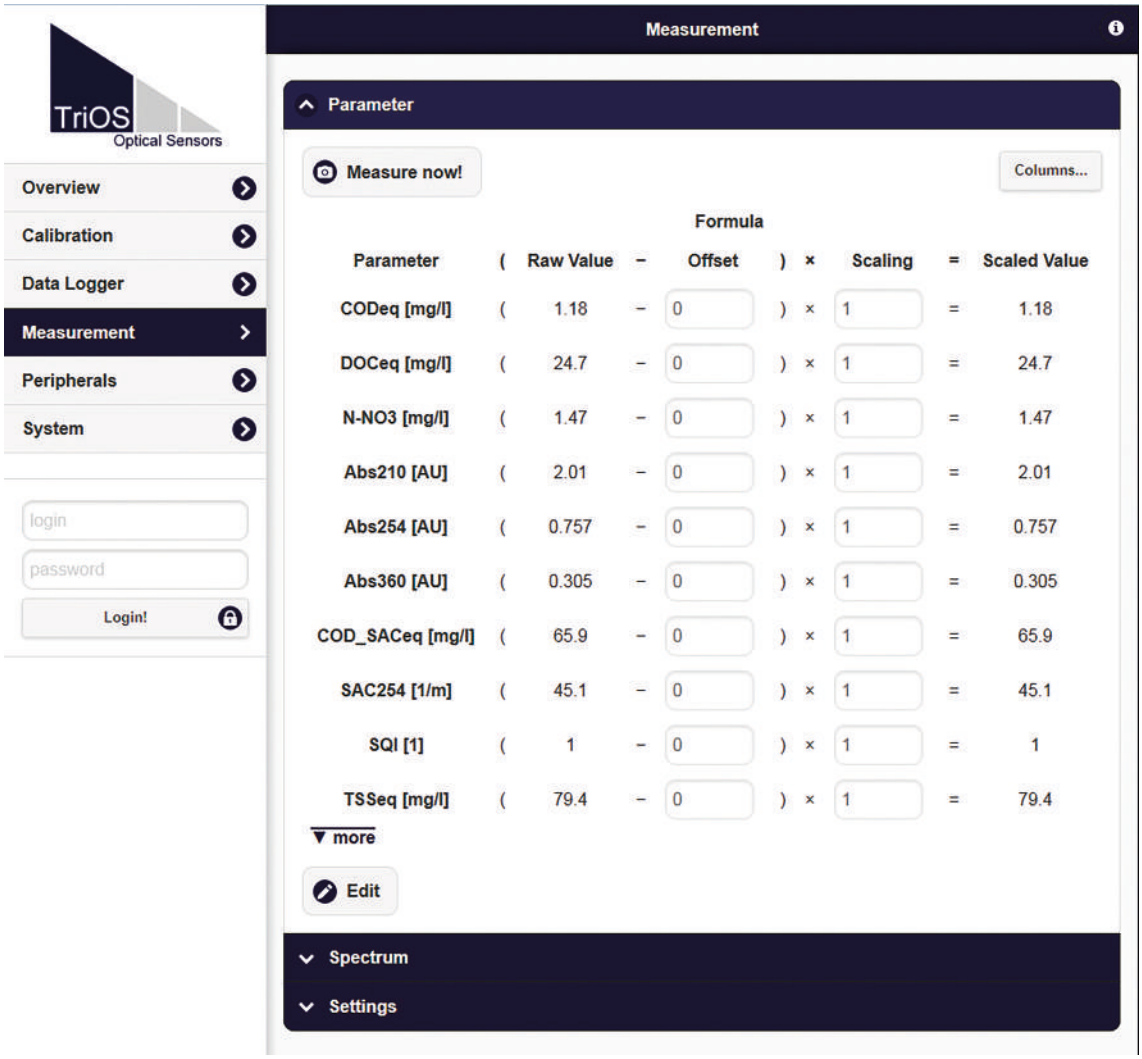
Download

The previously saved data can be retrieved using the “Download” button.

As the memory may contain a lot of data, the download may take a long time. It is therefore always advisable to specify a time range for the download and to download the data in several packages.

Measurement

The “Measurement” page shows the results of the last measurement carried out, as well as the settings for the interval for automatic measurements.



Parameters

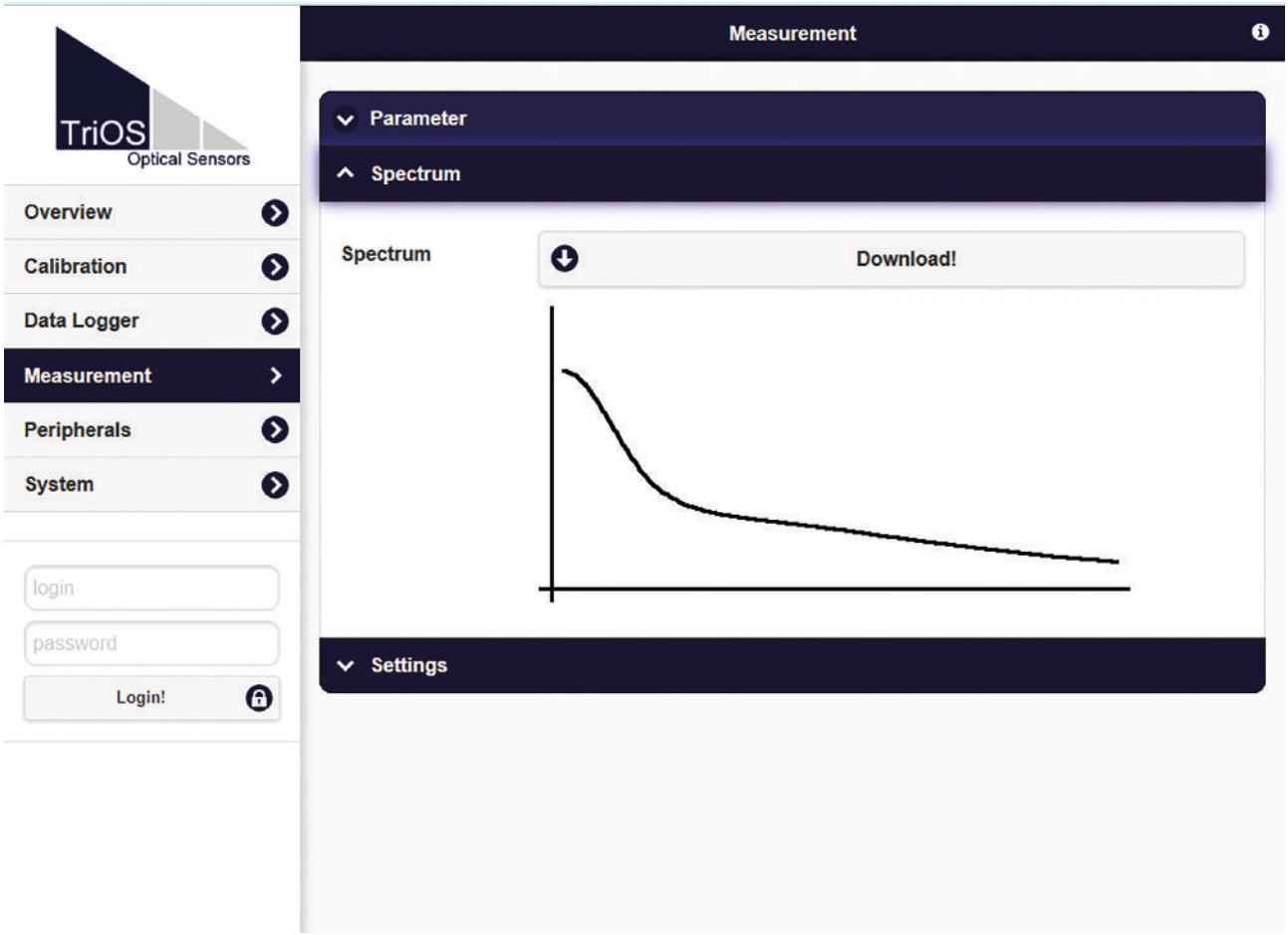
The results calculated during the last measurement are displayed under “Parameters”. It is also possible on this page to scale the measured values to the desired parameter using entries for “Offset” and “Scaling”. A new measurement can be triggered at any time. To do this, click on the “Measure Now!” button. A new measurement is then carried out with the saved settings.

The example view shows the values of the following parameters:

- COD_{eq}- calculated with spectral analysis (LSA) in mg/L
- DOC_{eq} - calculated with spectral analysis (LSA) in mg/L
- $N\text{-}NO_{3-}$ calculated with spectral analysis (LSA) in mg/L
- Abs_{210} - Test parameter in absorption units AU
- Abs_{254} - Test parameter in absorption units AU
- Abs_{360} - Test parameter in absorption units AU
- $COD\text{-}SAC_{eq}$- COD derived from $_{SAC254}$ in mg/L
- SAC_{254}- in 1/m
- SQI - Sensor Quality Index
- TSS_{eq} - derived from Abs_{360} in mg/L

Spectrum

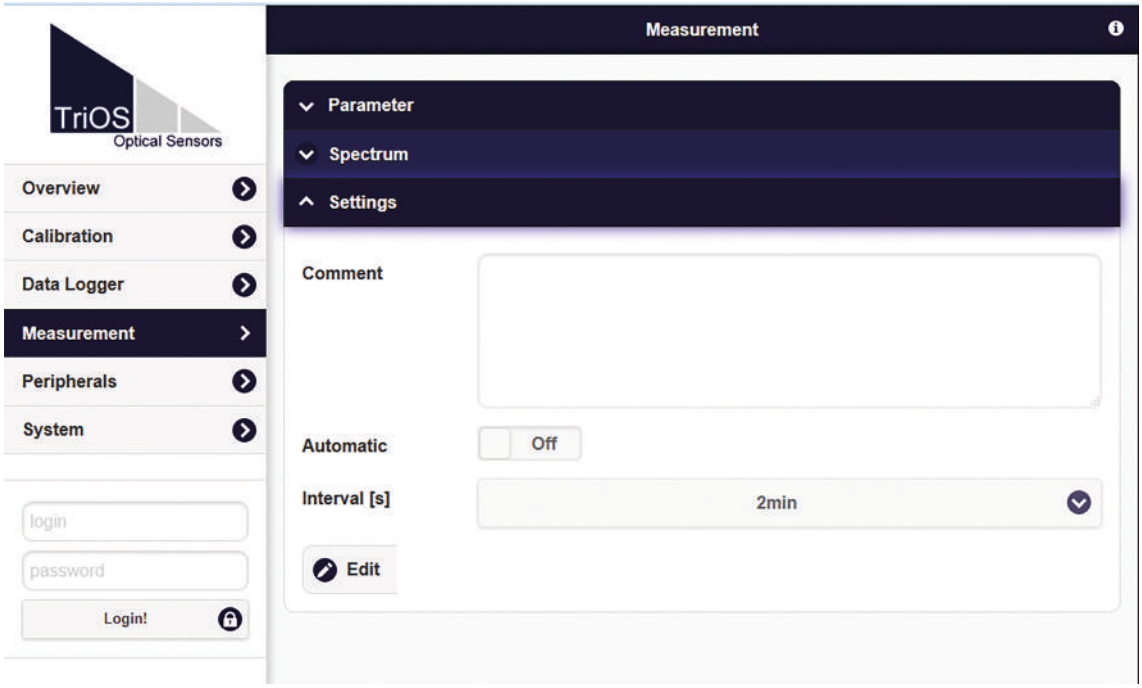
The currently measured absorption spectrum is displayed in the “Spectrum” sub-item. By pressing the “Download” button, this spectrum is downloaded to the computer as a CSV file.



Settings

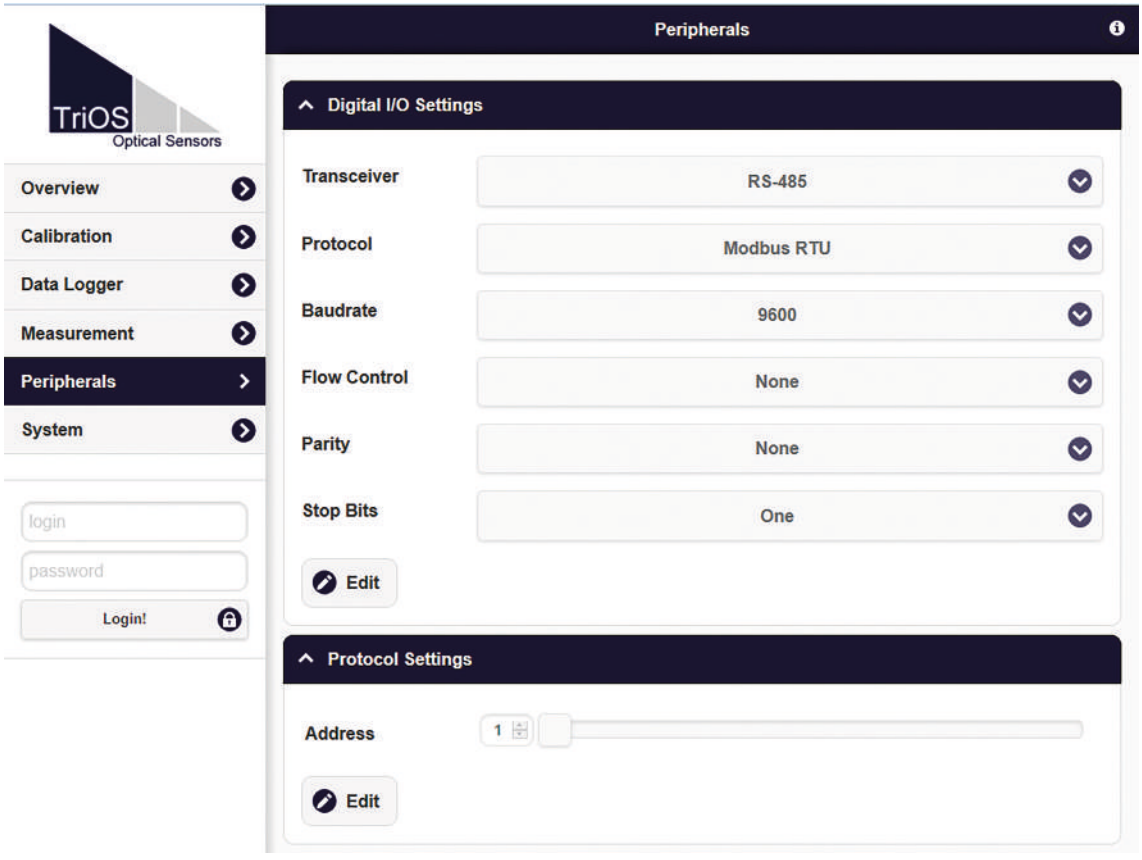
In the “Settings” sub-item, settings for the automatic measurement can be made after pressing the “Edit” button.

- Comments can be added in the “Comment” field, which are then linked to the measured values and spectra
- Automatic measurements can be activated
- An interval for the automatic measurements can be defined



Peripherals

In the “Peripherals” submenu, the interface can be configured, a protocol selected and the Modbus address changed after pressing the “Edit” button.

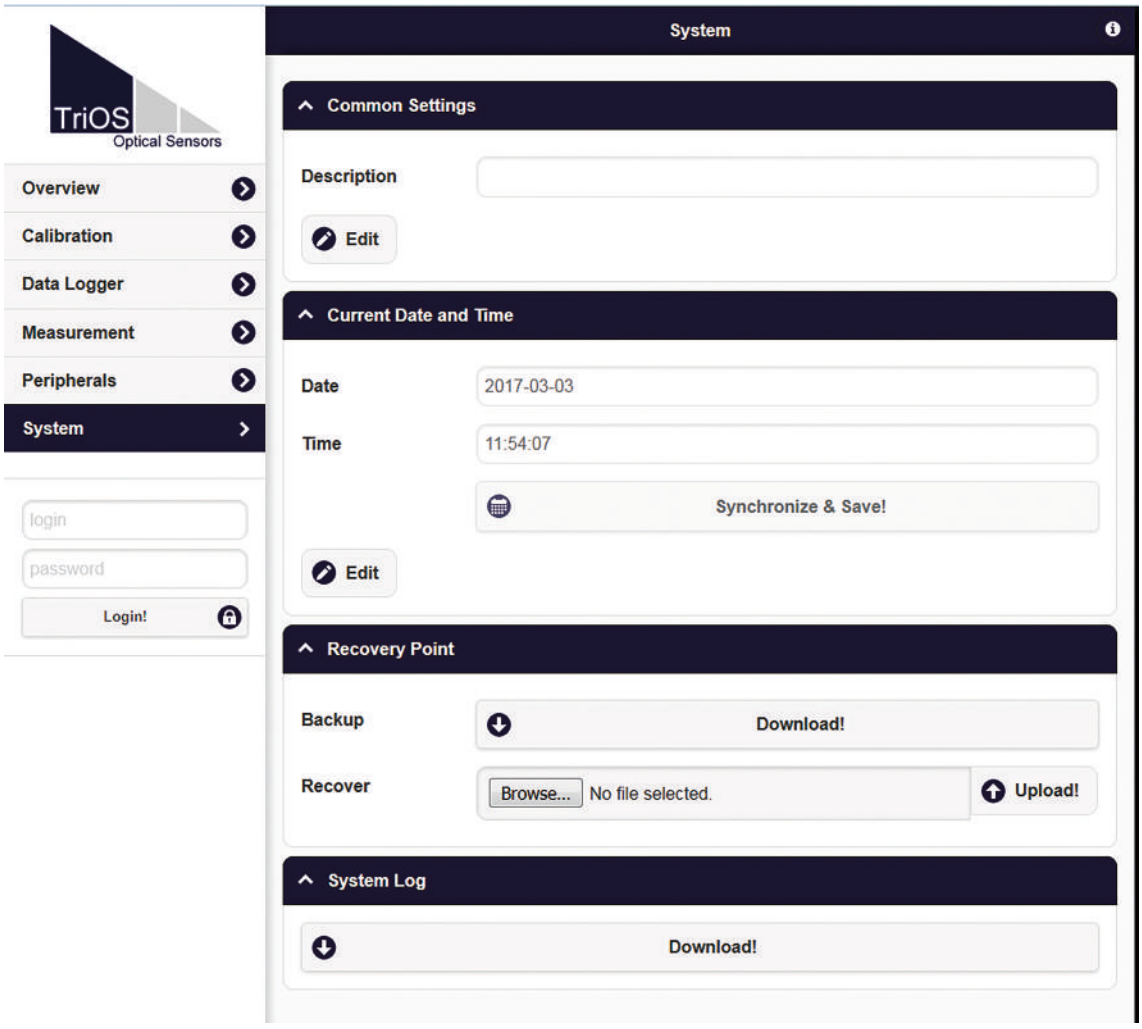


The factory settings are:

Hardware mode:	RS-485
Protocol:	Modbus RTU
Baud rate:	9600
Flow control:	None
Parity:	None
Data bits:	8
Stop bits:	1

System

The “System” page is used to manage the sensor. Tasks on this page include uploading a calibration file and downloading the current calibration as a restore point.



General settings

After pressing the “Edit” button, a comment such as a name or the location of the sensor can be entered here. This comment then appears on the “Overview” page below the firmware version.

Current date and time

The date and time of the sensor are set here or the date and time are transferred from the PC (“Synchronize & Save”).

Restore point

To download the current calibration from the sensor and save it on a PC or other medium, press the “Download” button. This calibration file (config.ini) must be saved and stored safely.

If a previously downloaded calibration or a calibration file created by the TriOS Mess- und Datentechnik GmbH service department is to be uploaded to the OPUS, this can be done using the “Upload” function. See also chapter 6.3.1.

System log

It is useful to make this file available to TriOS Technical support for error analysis. Any failures and errors are saved here internally and with a date stamp.

2.5 Login

To use the service function, you need a login and a password. You will receive this when you attend a TriOS training course.

3 Commissioning

This chapter deals with the Commissioning of the sensor. Pay particular attention to this section and follow the safety precautions to protect the sensor from damage and yourself from injury.

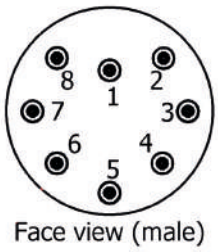
Before putting the sensor into operation, make sure that it is securely fastened and that all connections are made correctly.

3.1 Electrical installation

OPUS is supplied with either a fixed cable or a SubConn 8pin connector.

3.1.1 SubConn-8pin connector

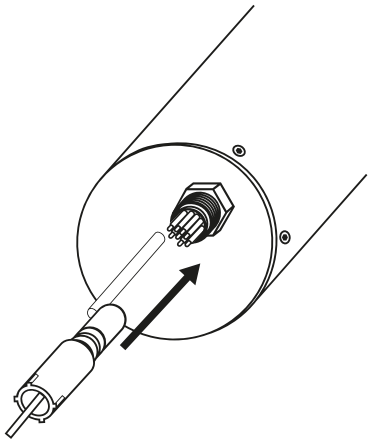
Plug the connector end of the connection cable onto the connector plug by aligning the pins with the slots on the cable.



Face view (male)

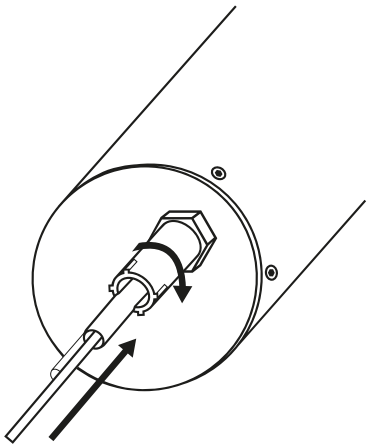
1. Ground (Power + Ser. Schnittstelle)
2. RS-232 RX / RS-485 A (commands)
3. RS-232 TX / RS-485 B (data)
4. Power (12...24 VDC)
5. ETH_RX-
6. ETH_TX-
7. ETH_RX+
8. ETH_TX+

step 1



Plug the connector end of the connection cable onto the connector plug by aligning the pins with the slots on the cable.

step 2

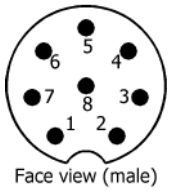


In the next step, turn the locking sleeve clockwise to secure the plug end to the bulkhead connector.

NOTICE

Do not bend the connection back and forth when inserting or removing it. Insert the connector straight and use the locking sleeve to tighten the pin contact.

3.1.2 Fixed cable with M12 industrial plug



1. RS-232 RX / RS-485 A (commands)
2. RS-232 TX / RS-485 B (data)
3. ETH_RX-
4. ETH_RX+
5. ETH_TX-
6. ETH_TX+
7. ground (power + ser. interface)
8. power (12...24 VDC)

NOTICE

Ensure that the polarity of the operating voltage is correct, otherwise the sensor may be damaged.

3.2 Interfaces

3.2.1 Serial interface

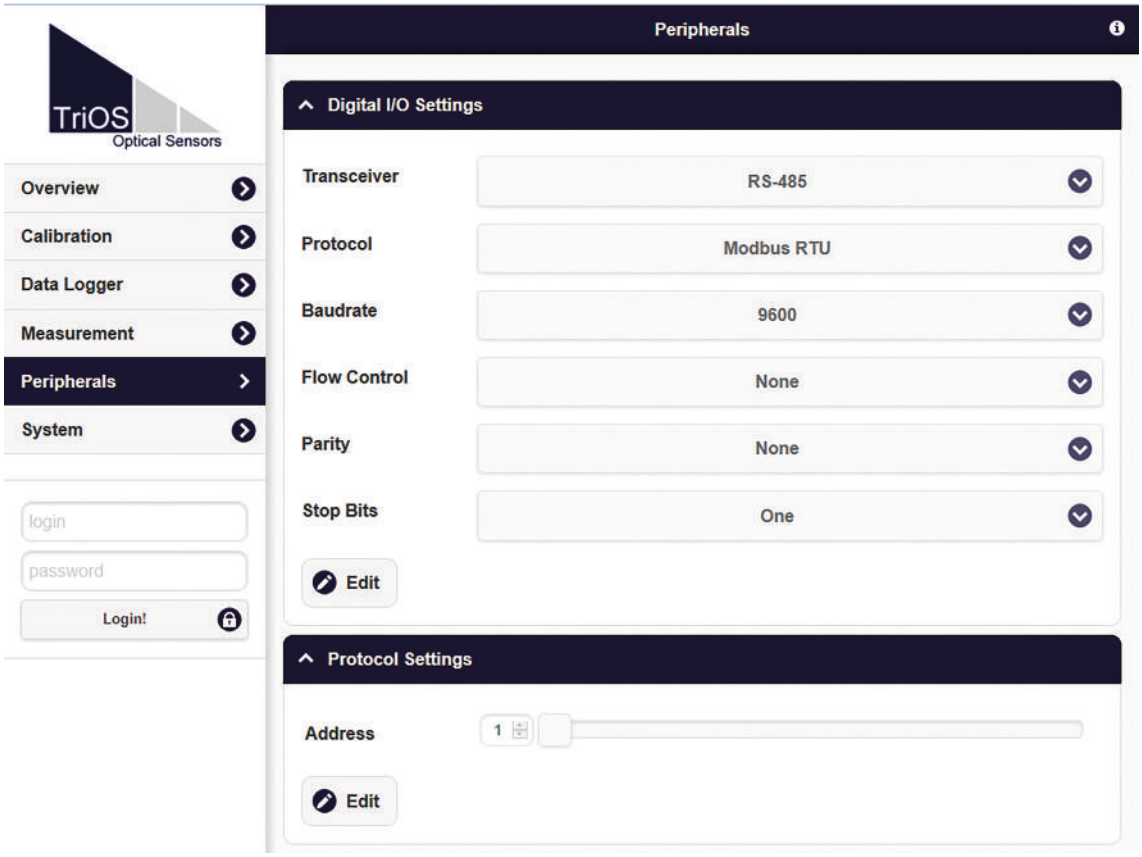
OPUS provides two lines for digital serial communication with a control device. It is equipped with a configurable digital serial interface. The RS-232 (also EIA 232) and RS-485 (also EIA 485) standards are supported and can be switched between via the web interface.

The RS-232 and RS-485 digital interfaces are voltage interfaces. With RS-232, voltages from -15 V to +15 V are possible, with RS-485 from -5 V to +5 V, with respect to ground.

With RS-232, data is transmitted on one line in each direction, with the RX line being used for communication from control device to sensor and the TX line from sensor to control device.

RS-485 uses a differential signal, whereby the sign-negated potential of the A line is applied to the B line. The decisive factor is the difference A-B, which makes the transmission as robust as possible against interference signals.

The digital interface can be configured in the OPUS web interface on the “Peripherals” page. The following setting options are available, as shown in the following illustration:



Transmitting and receiving device

The electrical connection standard can be selected here.

- RS-232
- RS-485 (factory setting)

Protocol

Specifies the data protocol to be used:

- Modbus RTU (factory setting)
- IEEE 488.2 (SCPI)
- ASCII Output

A detailed description of the Modbus RTU protocol for OPUS can be found in the appendix.

Baud rate

Specifies the transmission speed. The following options are available:

- 1200
- 2400
- 4800
- 9600 **Standard setting for all TriOS controllers**
- 19200
- 38400
- 57600

NOTICE

If there are difficulties with communication, you should try to reduce the baud rate.

Flow control

Activates flow control at software level (XON/XOFF). The default setting is “none”.

NOTICE

If the Modbus RTU protocol is used, “None” must be selected here.

Parity

Activates the parity check during data transmission. Possible options are:

- None (deactivated)
- Even
- Odd

Stop bits

Defines the number of stop bits. Possible options are:

- One (default)
- Two

NOTICE

For various Modbus devices, it may be necessary to set “Two” here if no parity check is to take place.

The factory settings are:

- Hardware mode:	RS-485
- Protocol:	Modbus RTU
- Baud rate:	9600
- Flow control:	None
- Parity:	None
- Data bits:	8
- Stop bits:	1

Settings for the active protocol can be made in the “Protocol Settings” section.

- The following properties are also available in the Modbus RTU protocol:
  - Address: This is the slave address for Modbus communication. It identifies the sensor in the bus system and must be unique. The default for OPUS is 1 (0x01).

3.2.2 Network

The IEEE 802.3 10BASE-T compliant Ethernet interface is used as the universal interface for the new Tri-OS G2 sensors. This makes it possible to establish a connection to a single sensor or even set up a complex sensor network.

NOTICE

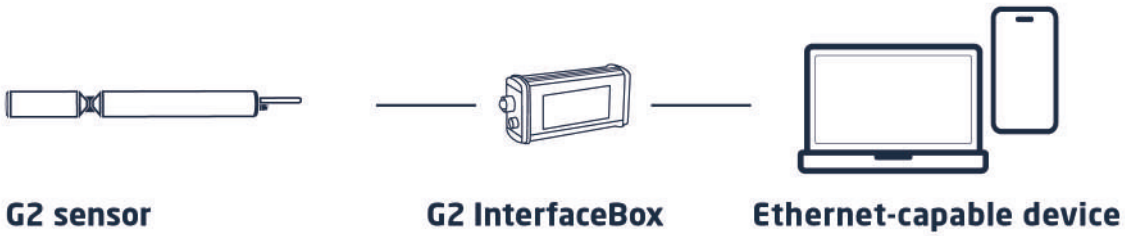
If the DHCP server of the OPUS is active, it has the static IP address 192.168.77.1.

This address cannot be changed!

Network with a single G2 sensor

The easiest way to establish a connection with the OPUS is with the G2 InterfaceBox. It is used both to establish the connection and to supply power to the sensor and can be used universally for all TriOS G2 sensors.

The following illustration shows a connection setup to a single sensor:



The TriOS G2 InterfaceBox translates the 8-pin M12 sensor connector to the standard connections for the power supply (2.1 mm barrel connector) and for network access (RJ-45 socket).

G2 InterfaceBox

There are three connections on the housing of the G2 InterfaceBox:

1. Power supply 12 or 24 VDC; 2.1 mm barrel connector
2. Sensor connection 8-pin M12
3. Ethernet connection RJ-45 socket

Proceed as follows to connect the sensor to an Ethernet-capable device using the G2 InterfaceBox:

1. Make sure that the Ethernet adapter of your device is configured to automatically obtain the network settings (IP address and DNS server).
2. Insert the M12 plug at the end of the sensor cable into the M12 socket (2) of the G2 InterfaceBox and close the screw cap.
3. Connect the 24 VDC power supply unit to the G2 InterfaceBox to supply the sensor with power.
4. Wait at least 3 seconds before finally connecting the LAN cable to your Ethernet-enabled device and the G2 InterfaceBox.

The web interface can now be accessed with any browser via the URL

http://opus/ or

http://opus_7XXX/ (7XXX is the serial number) or

http://192.168.77.1/.

If the web interface cannot be called up, make sure that the LAN cable has been connected after the sensor has been supplied with power and try all three URL options.

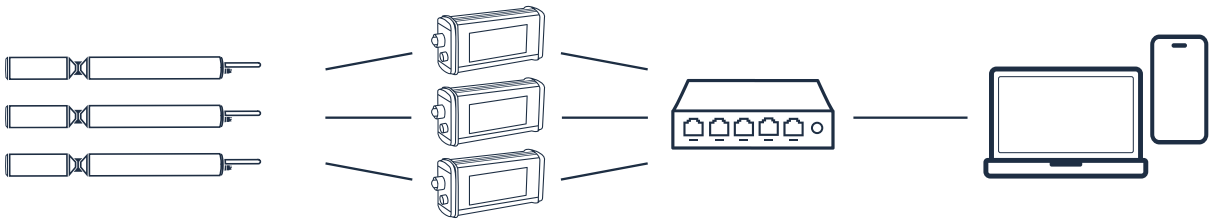
If an Ethernet-enabled device is connected, the automatic measurements of the OPUS are suspended. As soon as the LAN connection between the sensor and the Ethernet-enabled device is disconnected, the measurements are resumed at the set interval, provided the timer is activated.

Network with multiple G2 sensors

Using an Ethernet switch or hub or standard router, it is possible to connect several sensors in a complex network and use them simultaneously. In the sensor network, each sensor requires its own G2 InterfaceBox for the power supply.

Like every G2 sensor, OPUS supplies a simple DHCP server and a simple DNS server, which are configured exclusively for the direct individual connection - as described in the previous section. For a complex sensor network, it is necessary for these servers to be provided by the user. The OPUS recognizes them automatically and then switches off the internal servers. Ask your network administrator for advice on how this can best be implemented in your case.

The following illustrations show examples of different ways of setting up a sensor network.



G2 sensors

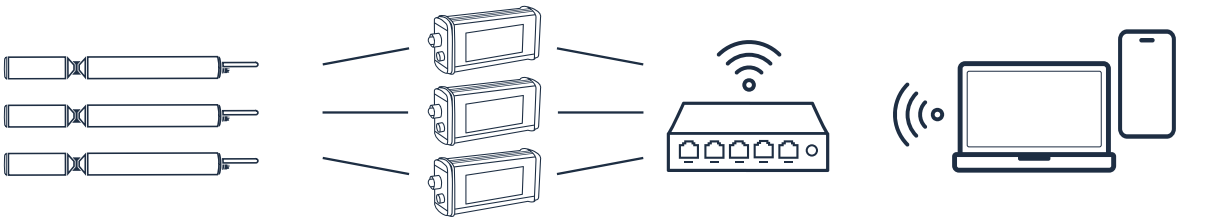
G2 InterfaceBox

a) Ethernet switch / hub

b) Router with DHCP server

a) Ethernet-capable device with DHCP server

b) Ethernet-capable device



G2 sensors

G2 InterfaceBox

a) Access point
b) Wireless router with DHCP server

a) Wi-Fi-capable device with DHCP server
b) Wi-Fi-capable device

OPUS can only be used from one Ethernet-capable device at a time.

If several sensors are used in a network, the web interface can be accessed via the host name http://opus_7XXX/ (7XXX is the serial number) or via the IP. Ask your network administrator for advice.

NOTICE

Damage caused by improper use is excluded from the warranty!

4 Application

OPUS (aero) can be operated with all TriOS controllers. Instructions for correct installation can be found in the controller manual.

NOTICE

Never transport the sensor just hanging on the cable.

4.1 Normal operation

4.1.1 Immersion mode

For immersion operation, the sensor can be completely or partially immersed in the water/measuring medium. For a correct measurement, the measuring window must be completely submerged and free of air bubbles. Use the mounting rod with a shackle and a stainless steel chain or steel wire to suspend the device in the medium. Do not carry or pull the sensor by the sensor cable.

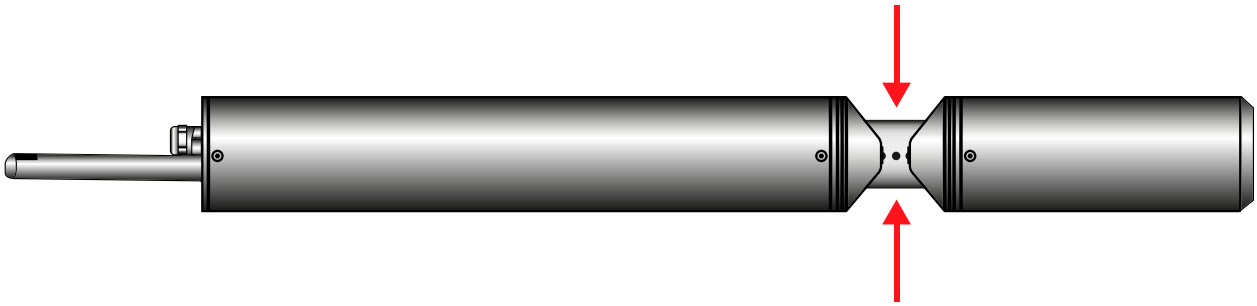
The sensor can also be fastened with suitable hydraulic clamps as shown in the illustration below. Make sure to use suitable clamps with an inner diameter of 48 mm (not for the deep-sea version). To protect the housing tube from excessive punctual pressure, mount the clamps close to the device covers. Suitable clamps can be obtained from TriOS.

OPUS fastening in clamps

OPUS on the shackle

The sensor should be installed at right angles to the direction of flow. This minimizes deposits on the windows and optimally supports the function of the nano coating.

Direction of flow



When immersing the sensor, make sure that there are no air bubbles in front of the sensor windows. If there are air bubbles in front of the window, shake the sensor carefully until the bubbles are removed.

4.1.2 Cleaning system

OPUS (aero) and all other sensors from TriOS Mess- und Datentechnik GmbH are equipped with an innovative anti-fouling technology to prevent contamination and dirt on the optical window: nano-coated windows in combination with a compressed air cleaning system.

Nano-coating

All TriOS optical windows are treated with a nano coating.

Windows with nano coating

Windows without nano coating

The wettability of the surface on the coated glass is significantly lower. This effect is achieved by the nano-coated surface of the glass, to which no dirt adheres. In combination with compressed-air cleaning, the windows are kept clean over long periods of time, reducing the amount of cleaning required.

Compressed-air cleaning

OPUS can be modified with the optional compressed air cleaning head. The head has an air outlet directly on the pane of the device and a hose fitting for connecting compressed air.
TriOS controllers have valves on which fixed flushing intervals can be set under software control. Compressed air between 3 and 6 bar must be provided for this.

NOTICE

The optimum pressure for compressed-air cleaning is between 3 and 6 bar. The total length of the hose should not exceed 25 meters. Suitable hoses are available from Trios (polyurethane, 6 mm outer diameter, 4 mm inner diameter)

To connect the hose, simply push the hose into the appropriate connection. To disconnect it again, push the blue locking ring towards the connection and pull the hose out. If necessary, secure the hose to the appliance and the cable with cable ties to prevent the compressed air hose from hitting uncontrollably.

NOTICE

The pressure must not exceed 7 bar! Valve damage could occur!

Compressed air flushing can affect the measurement results. Therefore, the flushing intervals should be sensibly controlled.

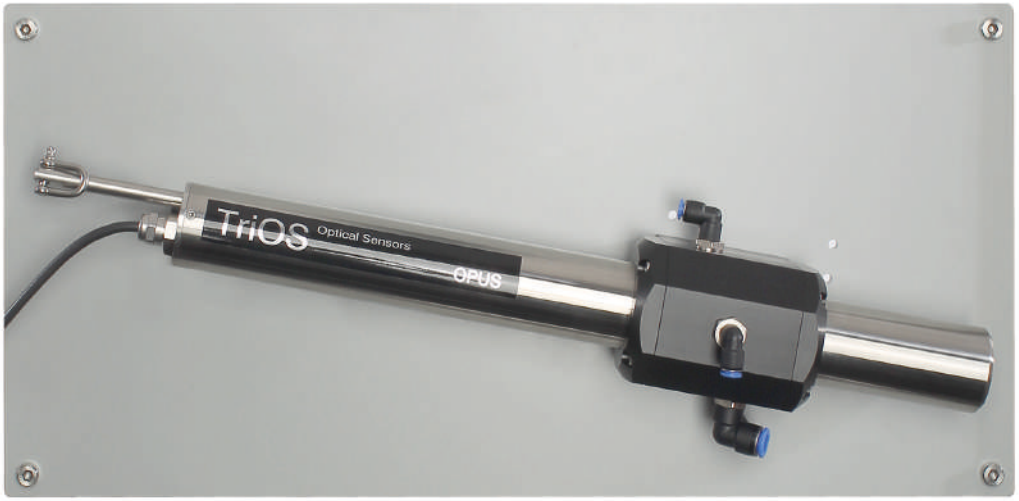
4.1.3 Float

The float is the ideal solution for applications with fluctuating water levels.

4.2 Bypass installation

With the optional FlowCell (flow cell), OPUS can be installed as a bypass. Together with the flow cell, a panel is available on which OPUS and the flow cell can be easily mounted at an optimum angle.

OPUS bypass installation on panel



NOTICE

The maximum pressure in the flow cell must not exceed 1 bar. Make sure that the sensor is installed in the correct position to ensure a free flow of water.

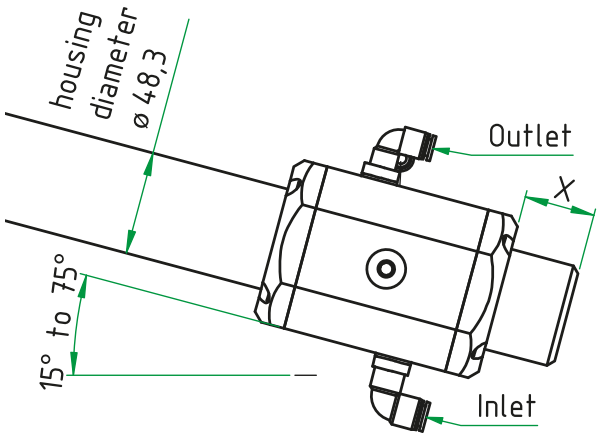
The FlowCell has three hose connections. The inlet has an 8 mm hose connection and is located on the right-hand side of the flow cell. On the left side of the cell is a 6 mm drain hose connection.

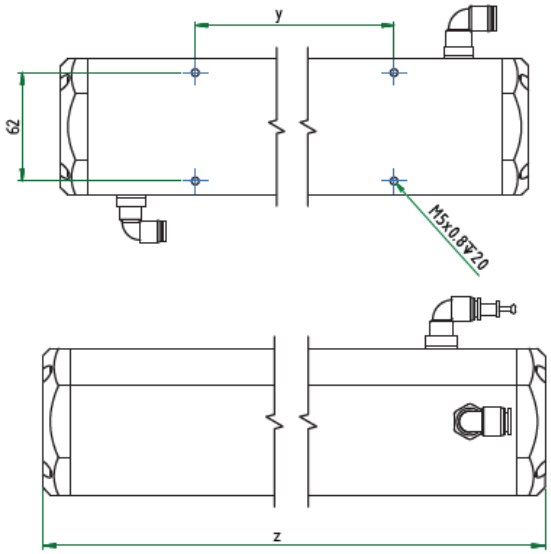
Finally, there is a third hose connection at the top of the cell that can be used for cleaning with liquids. If this inlet is not used, it should be closed with a plug.

FlowCell dimensions by path length

As OPUS can be purchased in different path lengths, the dimensions of the corresponding flow cell vary accordingly as described in the following table:

Path length [mm]	x [mm]	y [mm]	z [mm]
up to 10	99,5	62	108
20 / 50	98,5	96	150





The hoses are installed by applying slight pressure to the hose connectors. To remove the hoses again, press on the locking ring on the hose connector and carefully pull on the hose.

NOTICE

The flow cell cannot be combined with compressed air cleaning.

Installing the sensor in the FlowCell

To install the OPUS in the flow cell, please proceed as follows:

1. Remove the two end caps and the two sealing rings by loosening the eight screws.
2. Slide the OPUS into the flow cell and secure it in the correct position. All openings must be free so that the flowing liquid can flow directly through the optical path. The back of the OPUS should point towards the underside of the flow cell. The screw heads on the tube ends should disappear completely into the flow cell so that the OPUS is centered in the flow cell.
3. Slide one sealing ring each over the OPUS into the grooves provided in the flow cell. Before final assembly, check the sealing rings for damage and use new ones if necessary. The sealing rings (48 x 5 mm NBR) are available as spare parts from TriOS Mess- und Datentechnik GmbH.
4. When the position of the sensor is correct, install the two end caps and secure them again with the eight screws.

The flow cell and the OPUS should be installed at an angle of between 15° and 75° to the horizontal so that neither air bubbles nor sinking dirt particles interfere with the measurement. After installation, check for leaks and a free flow of water.

4.3 Pipe installation

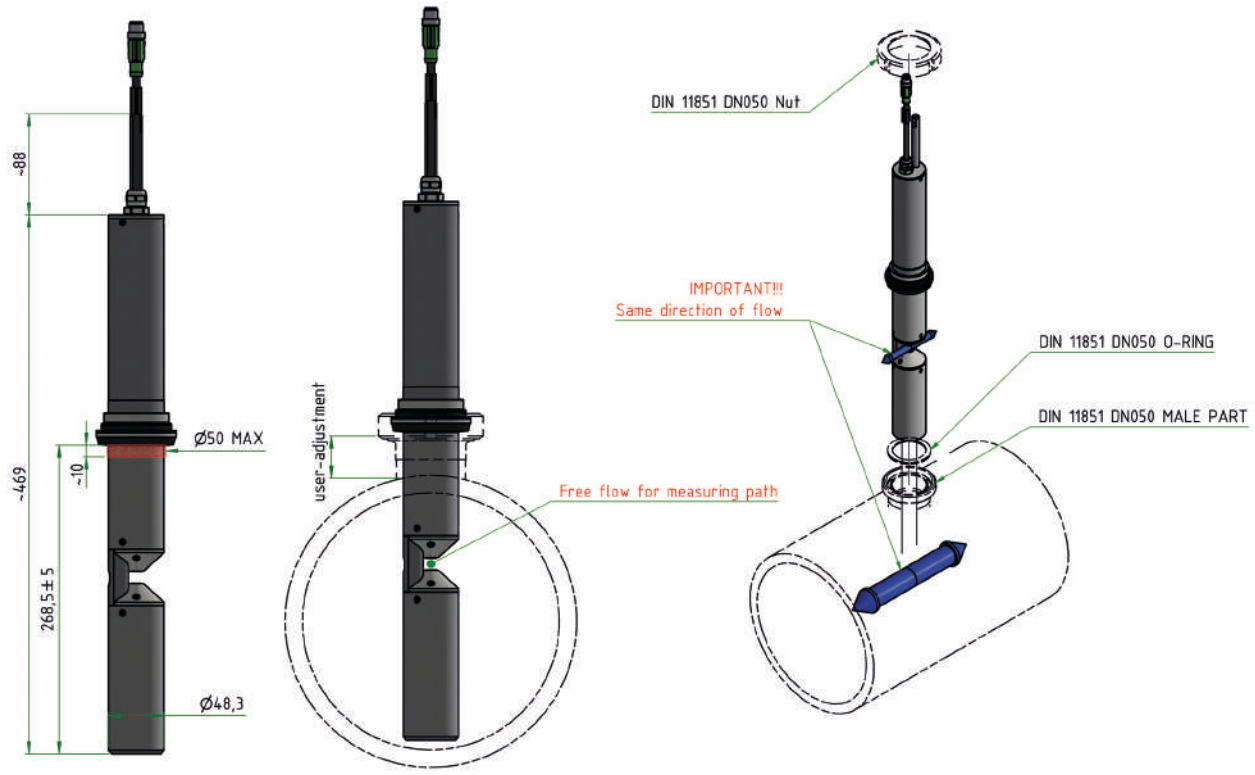
OPUS can be mounted directly into the pipe (either with the special flange version of the sensor or customer installations on site). In case of a grounded pipe, no additional grounding of the sensor housing is required as long as no insulation is mounted between the pipe and the sensor. Two of the available TriOS flange solutions are shown in the illustrations below (with and without compressed air purge possible).

The maximum pressure must not exceed 5 bar.

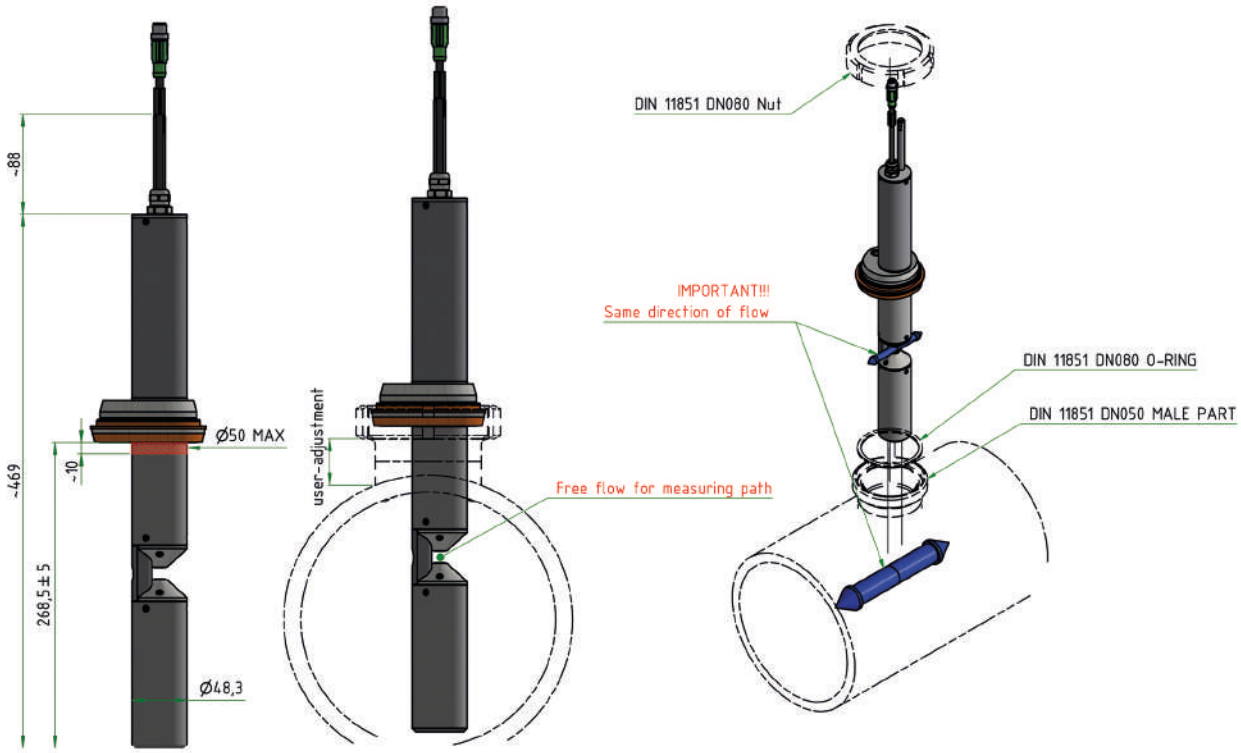
Groove nut, gasket and weld-on socket are not offered by TriOS.

Use suitable material alloys. The sensor housing is designed for installation on the pipe connection in accordance with DIN 11851.

Pipe connection DN50 to DIN 11851 without compressed air connection



Pipe connection DN80 to DIN 11851 with compressed air connection



5 Calibration

5.1 Manufacturer calibration

All TriOS sensors are supplied calibrated. The calibration of the OPUS is stored in the sensor, i.e. all output values are calibrated values. See also chapter 2.3.

The calibration(LSA group) must match the application of the OPUS. The composition of the UV light absorbing substances in the different waters must match the calibration and be able to be represented by the LSA group. For example, a seawater application requires an LSA group that contains the absorption spectrum of sea salt. Drinking water contains different substances than waste water.

5.1.1 SQI (Spectral Quality Index)

The SQI is generally between 0 and 1 and is a percentage for assessing the measurement quality. 1 corresponds to 100 % and is perfect, 0 corresponds to 0 % and is poor. Below 50 %, the measurement is classified as unusable (red). Between 50 % and 80 %, the measurement may still be OK (yellow), depending on the requirements and application. Between 80 % and 100 %, everything is OK (green) and can be used. The controllers react accordingly with color changes to the SQI of the sensor.

The SQI is based on the fit error of the LSA (linear spectral analysis). See also section 2.3.1 Spectral analysis.

Fit error

The fit error of the LSA is the sum of all deviations between the measured absorption spectrum and the spectrum calculated from the parameter spectra. The fit error varies depending on the application and the number of parameters. Therefore, the SQI must be adapted to the application in order to be effective.

To prevent false alarms, the threshold value for the SQI is set by default when the OPUS is delivered so that the measurements are always evaluated at 100%.

Application-specific threshold value

The application-specific threshold value for the SQI can be calculated with at least 100 absorption spectra from the application. This must in turn be imported into the OPUS so that the SQI reports red, yellow, green for “bad spectra” or atypical spectra and the processes can be controlled with the SQI.

If the threshold value is left at the default value, it is always green, as the original setting has not been changed, except for spectra that are actually unusable.

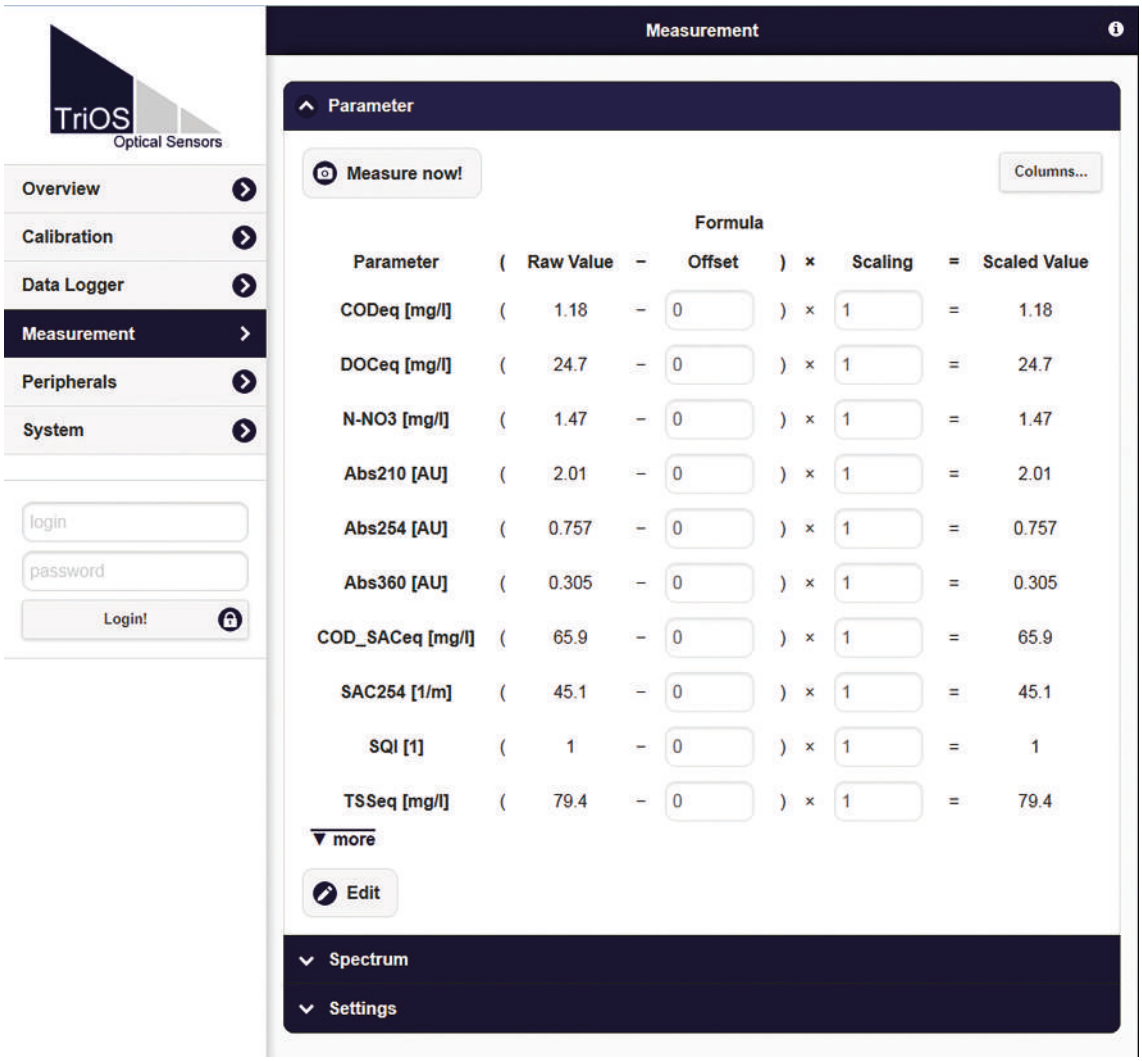
If the water composition fluctuates greatly, for example due to different industrial processes, the SQI can become unreliable - especially if not all parameters have been recorded correctly.

Heavy contamination in the water can also have a negative impact on the SQI. In this case, however, the cause usually lies in the sensor contamination and not in the ingredients of the water.

5.2 Customer calibration

The sensor can be adapted to laboratory analyses and local conditions using scaling factors. This is set either in the controller or directly in the sensor's browser. To do this, open the “Measurement” submenu in the browser. The customer calibration or local calibration works in addition to the manufacturer calibration, whose values are not changed by the customer calibration.

Theoretical absorption spectra are stored for sum parameters such as COD_{eq}, BOD_{eq}, TOC_{eq} and DOC_{eq}. Of these parameters, a spectral analysis based on UV absorption can only use the UV light-absorbing components, which are contained in the medium to varying degrees depending on local conditions. For this reason, a customer-specific calibration must typically be carried out for these sum parameters.



In the “Measurement” menu item in the “Parameters” sub-item, individual measurements can be triggered using the “Measure now!” button. button and all available parameters can be scaled after pressing the “Edit” button.

The formula on which the calculation of the scaled measured value with scaling factor and offset is based is shown in the top line.

(Raw Value - Offset) · Scaling = Scaled Value

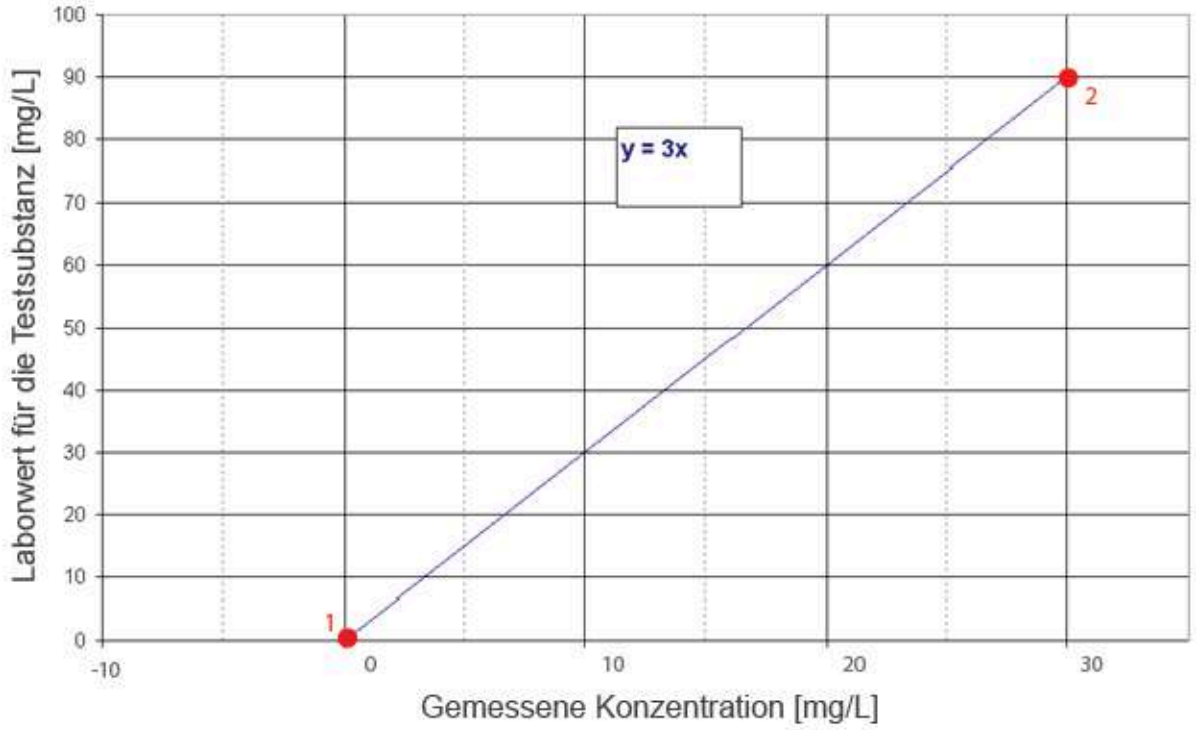
(Measured value - axis shift) · Scaling factor = scaled measured value)

The customer calibration serves as a fine adjustment of the sensor to special media and supplements the manufacturer calibration.

The local calibration is adjusted using a linear equation. Normally, only the scaling factor is required for this.

At least one data point consisting of laboratory value and sensor value is required for local calibration.

1. *Offset = 0* is assumed
2. Create a diagram as shown below and connect the two data points with a straight line. The gradient of the straight line is the scaling factor.



3. The scaling factor can be calculated using the following equation:

$$\text{Scaling factor} = \frac{\text{Laboratory value}}{\text{Measured value}}$$

This means for the example in the figure above:

$$\text{Scaling factor} = \frac{90\ \text{mg/L}}{30\ \text{mg/L}} = 3$$

4. If several laboratory values are available, all laboratory values should be entered in the graph. In this case, offset = 0 should also be assumed. The gradient of the straight line is the scaling factor.

All TriOS controllers have the option of setting scaling factors and offset values for measurement parameters.

Please refer to the relevant manual.

Make absolutely sure that no double scaling is carried out on the sensor: For example, directly in the G2 sensor menu on the one hand and via the TriOS controller on the other!

The customer calibration serves as a fine adjustment of the sensor to special media and is not intended to replace the manufacturer calibration.

NOTICE

Measuring ranges and detection limits of the scaled parameters depend on the scaling factor!

5.3 Measurement properties

Ideally, the optical path of the OPUS is selected so that the absorption at 210 nm (Abs210) is not greater than 2.5 AU and the absorption at 360 nm (Abs360) is not greater than 0.5 AU.

If the absorption at 210 nm exceeds 3 AU or at 360 nm exceeds 0.8 AU, the measured values may deviate significantly or can no longer be calculated (output: NaN)

The path length must be selected according to the absorption level of the medium.

Limit values for absorption at 210 nm and 360 nm

Abs210	0,2...2,5	2,5...3	≥ 3
Abs360	≤ 0,5	0,5...0,8	≥ 0,8

5.3.1 Nitrate and nitrite

The absorption spectra of nitrate and nitrite are very similar. To ensure that nitrite can be measured as well as nitrate, the absorbances at 210 and 360 nm must remain within the specified limits. This can also be ensured if the concentrations of nitrate and turbidity (see section 5.3.2) remain within the intended limits.

Path (mm)	Parameters	$N\text{-}NO_3$ $N\text{-}NO_2$	NO_3 NO_2
0,3	Nitrate	2.4...120 mg/L	11...530 mg/L
	Nitrite	4.4..220 mg/L	14.4...730 mg/L
1	Nitrate	0.7...36 mg/L	3.2...160 mg/L
	Nitrite	1.3...67 mg/L	4.3...220 mg/L
2	Nitrate	0.35...18 mg/L	1.6...80 mg/L
	Nitrite	0.65...33.5 mg/L	2.15...110 mg/L
5	Nitrate	0.14...7.2 mg/L	0.64...32 mg/L
	Nitrite	0.26...13.4 mg/L	0.86...44 mg/L
10	Nitrate	0.07...3.6 mg/L	0.32...16 mg/L
	Nitrite	0.13...6.7 mg/L	0.43...22 mg/L
50	Nitrate	0.014...0.72 mg/L	0.064...3.2 mg/L
	Nitrite	0.014...0.72 mg/L	0.086...4.4 mg/L

Absorption limit values

Abs210	0,2...2,5	2,5...3	≥ 3

5.3.2 Seawater, brackish water

Up to 1 g/l sea salt (1 PSU) in natural waters at 10 mm path the disturbances are still negligible.

Limit values for sea salt

Path [mm]	Sea salt [g/L]
0,3	33
1	10
2	5
5	2
10	1
50	0,2

5.3.3 Turbidity

There are correlations between turbidity and absorption, although these are highly dependent on the size and type of particles.

Up to 200 NTU turbidity at 10 mm path, the interferences should still be negligible.

The absorption at 360 nm should remain below 0.5 AU. If it is above 0.8 AU at 360 nm, the measured values can deviate significantly or can no longer be calculated (NaN).

Path (mm)		
0,3	Turbidity	6600 NTU
	DOC_{eq}	3000 mg/L
	TSS_{eq}	5000 mg/L
1	Turbidity	2000 NTU
	DOC_{eq}	900 mg/L
	TSS_{eq}	1500 mg/L
2	Turbidity	1000 NTU
	DOC_{eq}	450 mg/L
	TSS_{eq}	750 mg/L
5	Turbidity	400 NTU
	DOC_{eq}	180 mg/L
	TSS_{eq}	300 mg/L
10	Turbidity	200 NTU
	DOC_{eq}	90 mg/L
	TSS_{eq}	150 mg/L
50	Turbidity	40 NTU
	DOC_{eq}	18 mg/L
	TSS_{eq}	30 mg/L

Turbidity essentially acts as an offset. Therefore, the limit values for Abs360 should be observed (see 5.3).

Turbidity limits

Abs360	≤ 0,5	0,5...0,8	≥ 0,8

5.3.4 Unknown substances

Substances that absorb UV light but are not included in the LSA group (calibration) can significantly interfere with the measurement result. Under certain circumstances, measured values can no longer be calculated (NAN or permanently zero).

If this is the case, contact TriOS Technical support (see also Chap. 6.3.2).

6 Malfunction and maintenance

To ensure error-free and reliable measurement, the device should be checked and maintained at regular intervals. To do this, the sensor must first be cleaned.

6.1 Cleaning and care

Deposits (fouling) and dirt depend on the medium and the duration of exposure to the medium. Therefore, the degree of soiling depends on the application. For this reason, it is not possible to give a general answer as to how often the sensor needs to be cleaned.

Normally the system is kept clean by the nano-coated window and additionally by the air purification system. If the soiling is too severe, the following instructions should be followed.

NOTICE

Damage caused by improper cleaning is not covered by the warranty!

6.1.1 Cleaning the housing

⚠ CAUTION

Please wear protective goggles and gloves when cleaning the sensor. CAUTION - especially if acids or similar are used for cleaning.

To loosen solid dirt, we recommend soaking the sensor in a rinsing solution for a few hours. Exposed plug connections should be avoided during cleaning so that they do not come into contact with water. When cleaning, please always ensure that the locking cap of the connector is firmly closed. Please inform yourself thoroughly about the risks and safety of the cleaning solution used.

If the sensor is very dirty, additional cleaning with a sponge may be necessary. You should exercise extreme caution to avoid scratching the glass of the optical path.

In case of calcification, a 10% citric acid solution or acetic acid solution can be used for cleaning.

Brownish dirt or spots may be contamination from iron or manganese oxides. In this case, a 5% oxalic acid solution or 10% ascorbic acid solution can be used to clean the sensor. Please note that the sensor should only come into contact with the acids briefly and then be rinsed thoroughly with water.

NOTICE

Under no circumstances should the sensor be cleaned with hydrochloric acid. Even very low concentrations can damage stainless steel components. In addition, TriOS Mess- und Datentechnik GmbH warns against the use of other strong acids, even if the sensor has a titanium housing.



6.1.2 Cleaning the measurement window

You can clean the window with a lint-free cloth, a clean paper towel or a special optical paper from TriOS Mess- und Datentechnik GmbH with a few drops of acetone. Make sure that you do not touch the window surface with your fingers!

To make cleaning the optical windows easier, TriOS Mess- und Datentechnik GmbH offers a cleaning set with acetone and special optical cleaning paper.

NOTICE

Do not use harsh cleaning solutions, spatulas, sandpaper or cleaning agents containing abrasive substances to remove stubborn dirt.


6.2 Maintenance and inspection

NOTICE

Avoid any contact with the glass parts in the optical path, as these can become scratched or dirty. As a result, the functionality of the device is no longer guaranteed.

6.2.1 Checking the zero value

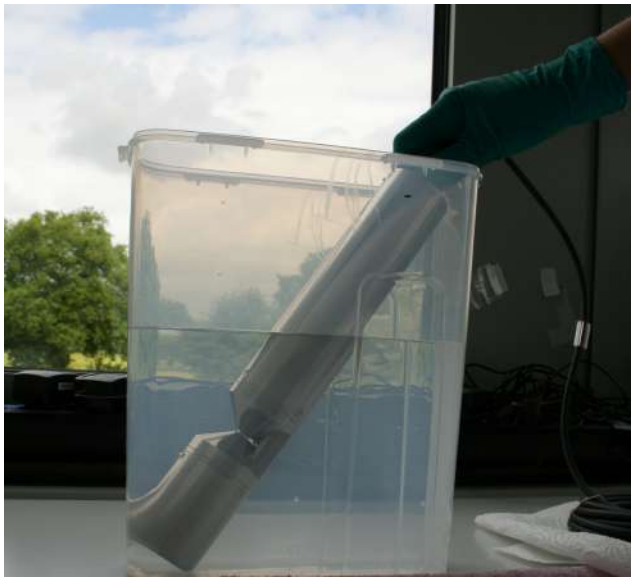
Prepare the sensor for the zero value check as described in the previous chapter.

We recommend using the TriOS VALtub to check the zero value, as this seals the optical path optimally and enables a quick zero value check. Make sure that the O-ring of the VALtub is positioned exactly on the seals of the sensor.

Sample tray

Sensor in VALtub

Alternatively, another vessel suitable for immersion can be used. The optical path must always be completely immersed in the water during the measurement.



The zero valueof the OPUS is checked via the web interface. To access the web interface, you need the G2 InterfaceBox and an Ethernet-capable device with a web browser, such as a notebook.

The sensor is prepared as follows before the zero value test:

Clean the sensor as described in chapter 6.1.1 Housing cleaning. At the end of cleaning, rinse it carefully with deionized water. Dry the sensor with a paper towel. Wipe the sensor with a little acetone on a kitchen towel to remove grease residues.

⚠ CAUTION

Always wear suitable gloves and safety goggles to protect yourself!

Clean the windows of the sensor with special optical paper or a soft, lint-free cloth and a little acetone according to the instructions for cleaning the measuring window.

Important: Then polish the windows with a dry, soft cloth or special optical paper to remove any thin film that may appear while cleaning the windows.

Provide a suitable measuring vessel filled with ultrapure water. The measuring vessel should be carefully cleaned with detergent solution before use and then rinsed with ultrapure water.

Immerse the sensor in the vessel sufficiently filled with ultrapure water so that the measuring windows are completely covered with water. Wait 10 - 15 minutes. During this time, hidden dirt can be removed from the sensor.

Remove the probe from the water and rinse it with ultrapure water. Fill the container with fresh ultrapure water and immerse the sensor again. Lift the probe and move it slightly in the water to remove any air bubbles and air pockets. You can now check the zero value via the web interface.

If possible, the sensor should be in an inclined position in the measuring vessel or in a horizontal position in the VALtub in order to avoid an accumulation of very fine, barely visible air bubbles at the upper measuring window. When using a stationary measuring cylinder in which the sensor is positioned vertically, particular attention should be paid to air bubbles in the optical path.

Ensure sufficient stability!

If possible, carry out the zero value testat an ambient temperature of 20 °C. The temperature of the ultrapure water should also be 20 °C.

General notes

- Do not touch the part of the sensor that is immersed in the ultrapure water with your hands unless you are wearing gloves during the sensor test.
- Be sure to use ultrapure water (ultra pure, resistance of 18.2 MΩcm).
- If impurities appear in the water during the test, it must be replaced!
- Make sure that there are no air bubbles in front of the measuring windows.

It is recommended to carry out at least 5 individual measurements under “Measurement” before the test in order to bring the sensor up to operating temperature.

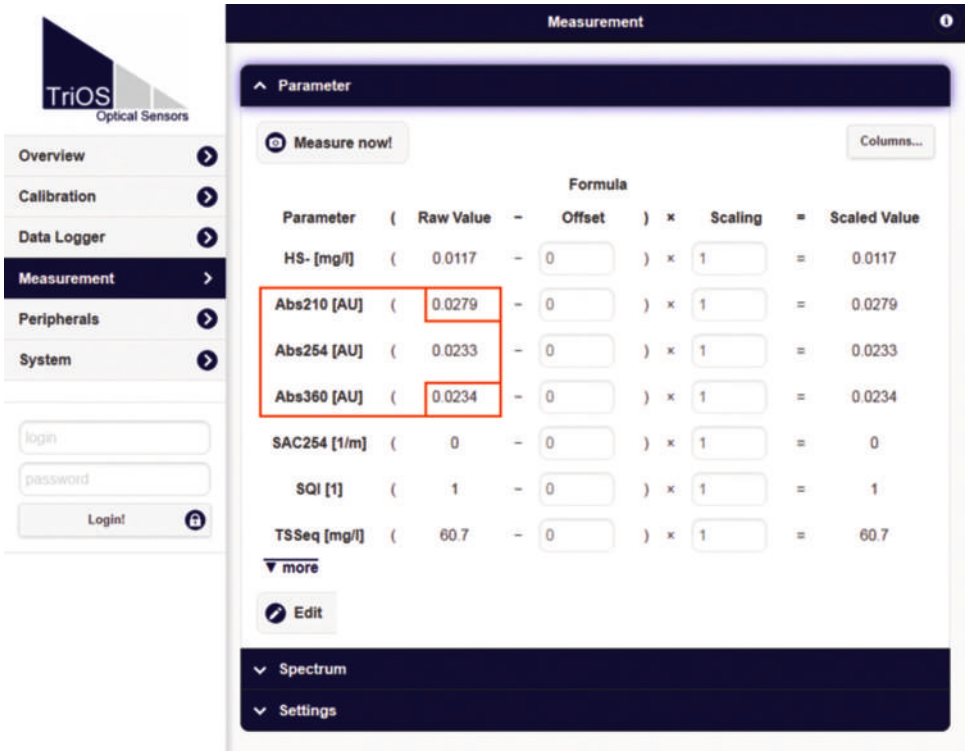
NOTICE

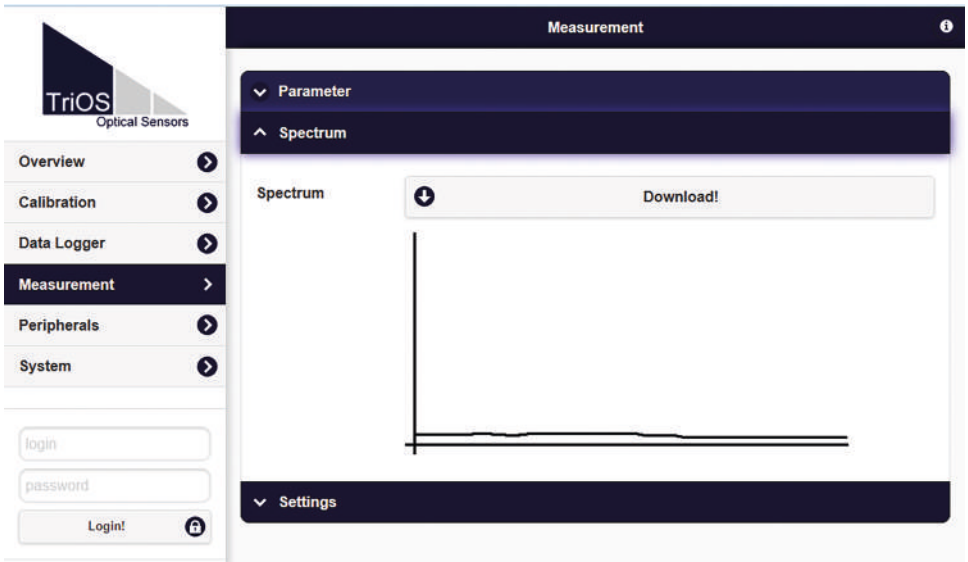
Damage caused by improper cleaning is not covered by the warranty!

Limit values for deciding whether a new zero line must be drawn:

- 0.1 AU at 360 nm
- 0.2 AU at 210 nm

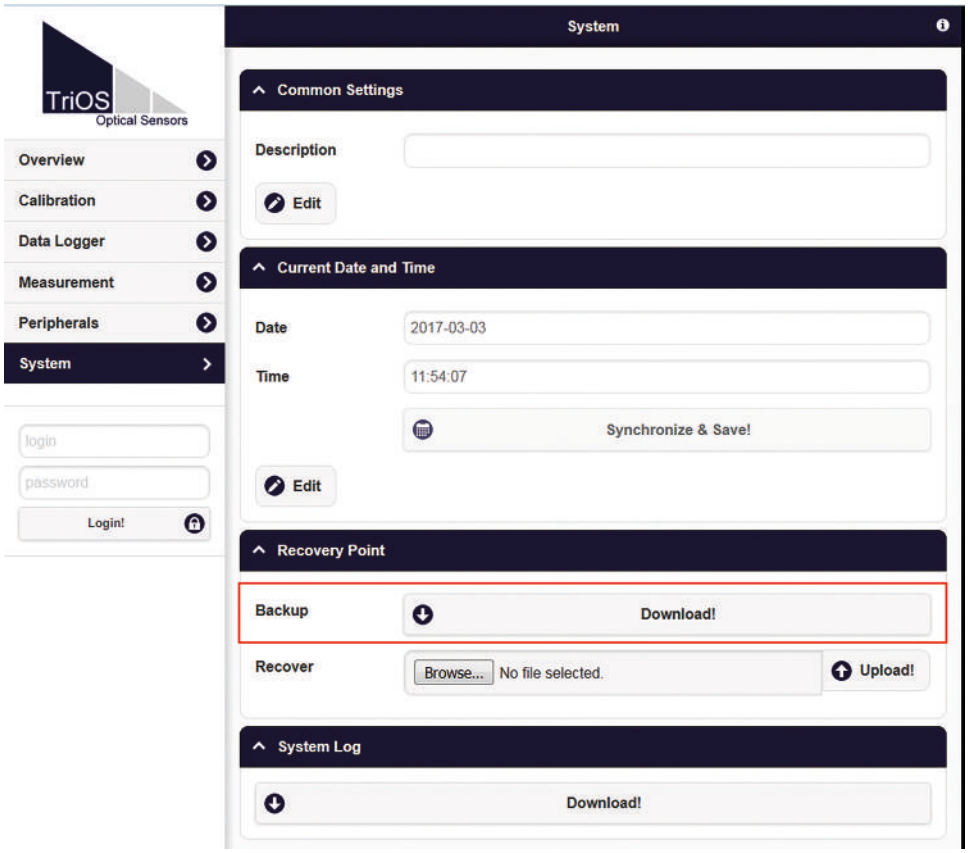
Below these values, a new zero line does not need to be drawn unless clear structures are visible that interfere with the measurement.





6.3 Troubleshooting

6.3.1 Upload Recovery Point

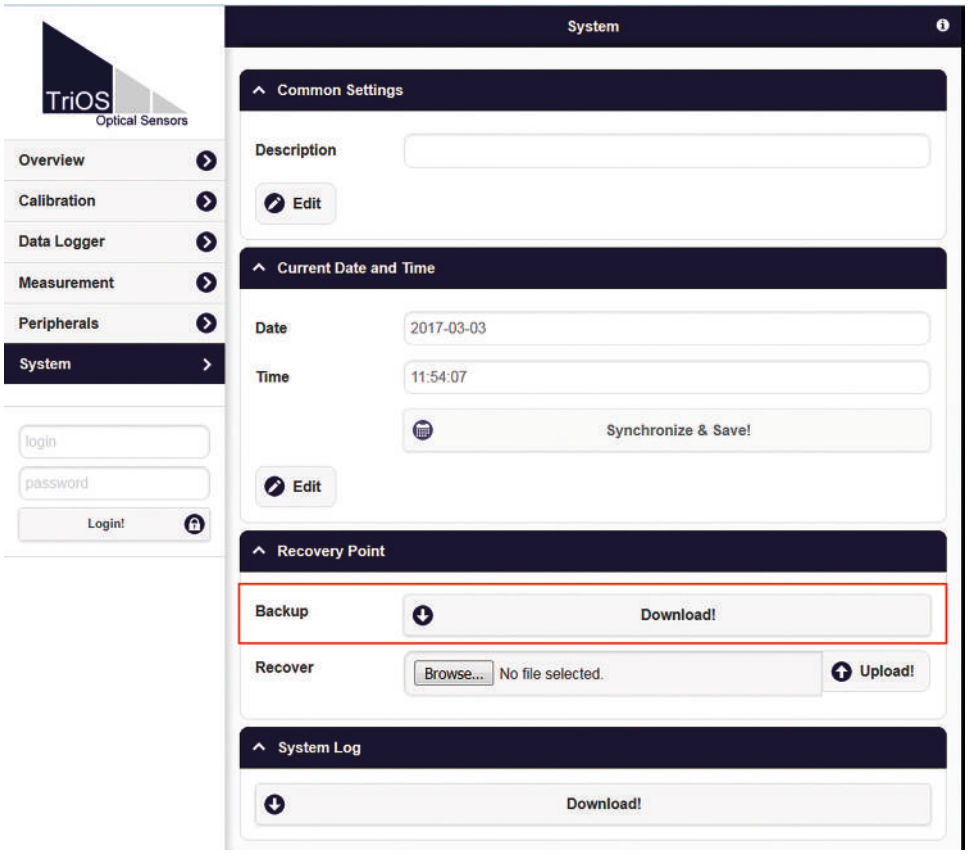


If a previously downloaded Recovery Point is to be uploaded, this can be done using the “Upload” function.

6.3.2 Upload new calibration

If service is required, a few spectra should first be sent to TriOS Technical support (see also section 2.4 Data logger and section 5.3.3).

If a calibration file created by TriOS Mess- und Datentechnik GmbH support is then to be uploaded to the OPUS, this can be done using the “Upload” function.



6.4 Return shipment

Please note the procedure for your return.

If you wish to return the sensor or the device, please contact technical support first. To ensure a smooth return process and to avoid incorrect shipments, every return shipment must first be reported to technical support. You will then receive a numbered RMA form, which you must complete in full, check and return to us.

Please stick this form with the number clearly visible on the outside of the return package or write it in large letters on the packaging. This is the only way your return can be correctly assigned and accepted.

Please note! Returns without an RMA number cannot be accepted and processed!

Please note that the sensor or the device must be cleaned and disinfected before shipping.

Use the original packaging to ensure that the goods are sent undamaged. If this is not available, ensure that safe transportation is guaranteed and that the sensors are secured with sufficient packing material.

7 Technical data

7.1 Technical specifications

Measurement technology	**Light source**	Xenon flash lamp
	Detector	High-end miniature spectrometer
		256 channels
		200 to 360 nm
		0.8 nm/pixel
Optical path	**OPUS**	0.3 mm, 1 mm, 2 mm, 5 mm, 10 mm, 20 mm, 50 mm
	OPUS aero	0.3 mm, 1 mm, 2 mm
Parameters	**OPUS**	see "Measuring ranges and detection limits OPUS", page 53 Chap. 7.2
	OPUS aero	Nitrate NO_3-N or Nitrate NO_3-N+NitriteNO_2-N
Measuring range	**OPUS**	see "Measuring ranges and detection limits OPUS", page 53 Chap. 7.2
	OPUS aero	see "OPUS aero measuring ranges", page 56Chap. 7.2
Measuring accuracy	**OPUS**	see "Measuring ranges and detection limits OPUS", page 53
	OPUS aero	± (5 % + 0,1)
Turbidity compensation		Yes
Data logger		~ 2 GB
Response time T100		2 min
Measuring interval		≥ 1 min
Housing material		Stainless steel (1.4571/1.4404) or titanium (3.7035)
Dimensions (L x Ø)		470 mm x 48 mm (with 10 mm path)
Weight	**VA**	~ 3 kg (with 10 mm path)
	Ti	~ 2 kg (with 10 mm path)
Interface	**digital**	Ethernet (TCP/IP)
		RS-232 or RS-485 (Modbus RTU)
Power consumption		≤ 8 W
Power supply		12-24 VDC (± 10 %)

Maintenance effort	≤ 0.5 h/month typical
Calibration/maintenance interval	24 months
System compatibility	Modbus RTU
Warranty period	1 year (EU: 2 years)

INSTALLATION

Max. pressure	**with Sub-conn***	30 bar
	with fixed cable	3 bar
	in flow unit	1 bar, 2...4 L/min
Protection class		IP68

*Not OPUS aero

Sample temperature	+2...+40 °C
Ambient temperature	+2...+40 °C
Storage temperature	-20...+80 °C
Approach velocity	0.1...10 m/s

7.2 Measuring ranges and detection limits OPUS

The following tables provide an overview of the measuring ranges of the various parameters as a function of the path length.

These values apply to individual substances in ultrapure water under laboratory conditions.

Path length 1 mm

Path (mm)	Parameters	Measuring principle	Measuring unit	Measuring range	Detection limit	Limit of quantification	Precision	Accuracy*
1	Nitrate $N\text{-}NO_3$	spectral	mg/L	0...100	0,3	0,5	0,05	± (5 % + 0,1)
	Nitrite $N\text{-}NO_2$	spectral	mg/L	0...150	0,5	1,2	0,12	± (5 % + 0,1)
	COD_{eq}	spectral	mg/L	0...2200***	30	100	10	
	BOD_{eq}	spectral	mg/L	0...2200***	30	100	10	
	DOC_{eq}	spectral	mg/L	0...1000	5	10	1	
	TOC_{eq}	spectral	mg/L	0...1000	5	10	1	
	TSS_{eq}	spectral	mg/L	0...1500	60	200	20	
	KHP	spectral	mg/L	0...4000	5	10	1	± (5 % + 2)
	SAC_{254}	Single wavelength	1/m	0...2200	15	50	5	
	$COD\text{-}SAC_{eq}$**	Single wavelength	mg/L	0...3200	22	73	7,3	
	$BOD\text{-}SAC_{eq}$**	Single wavelength	mg/L	0...1050	7,2	24	2,4	

* Based on a standard calibration solution

** Based on KHP (100 mg COD standard solution corresponds to 85 mg/L KHP)

*** Dependent on the composition of the COD and BOD (sum parameter)

1 mg/L $N\text{-}NO_3$ corresponds to 4.43 mg/L NO_3

1 mg/L $N\text{-}NO_2$ corresponds to 3.29 mg/L NO_2

Path length 10 mm

Path (mm)	Parameters	Measuring principle	Unit of measurement	Measuring range	Detection limit	Limit of quantification	Precision	Accuracy*
10	Nitrate N-NO_3	spectral	mg/L	0...10	0,03	0,05	0,005	± (5 % + 0,1)
	Nitrite N-NO_2	spectral	mg/L	0...15	0,05	0,12	0,012	± (5 % + 0,1)
	COD_{eq}	spectral	mg/L	0...220***	3	10	1	
	BOD_{eq}	spectral	mg/L	0...220***	3	10	1	
	DOC_{eq}	spectral	mg/L	0...100	0,5	1	0,1	
	TOC_{eq}	spectral	mg/L	0...100	0,5	1	0,1	
	TSS_{eq}	spectral	mg/L	0...150	6	20	2	
	KHP	spectral	mg/L	0...400	0,5	1	0,1	± (5 % + 2)
	SAC_{254}	Single wavelength	1/m	0...220	1,5	5	0,5	
	COD-SAC_{eq}**	Single wavelength	mg/L	0...320	2,2	7,3	0,73	
	BOD-SAC_{eq}**	Single wavelength	mg/L	0...105	0,72	2,4	0,24	

* Based on a standard calibration solution

** Based on KHP (100 mg COD standard solution corresponds to 85 mg/L KHP)

*** Dependent on the composition of the COD and BOD (sum parameter)

1 mg/L N-NO_3 corresponds to 4.43 mg/L NO_3

1 mg/L N-NO_2 corresponds to 3.29 mg/L NO_2

Opus UV: Measuring ranges as a function of the path length*

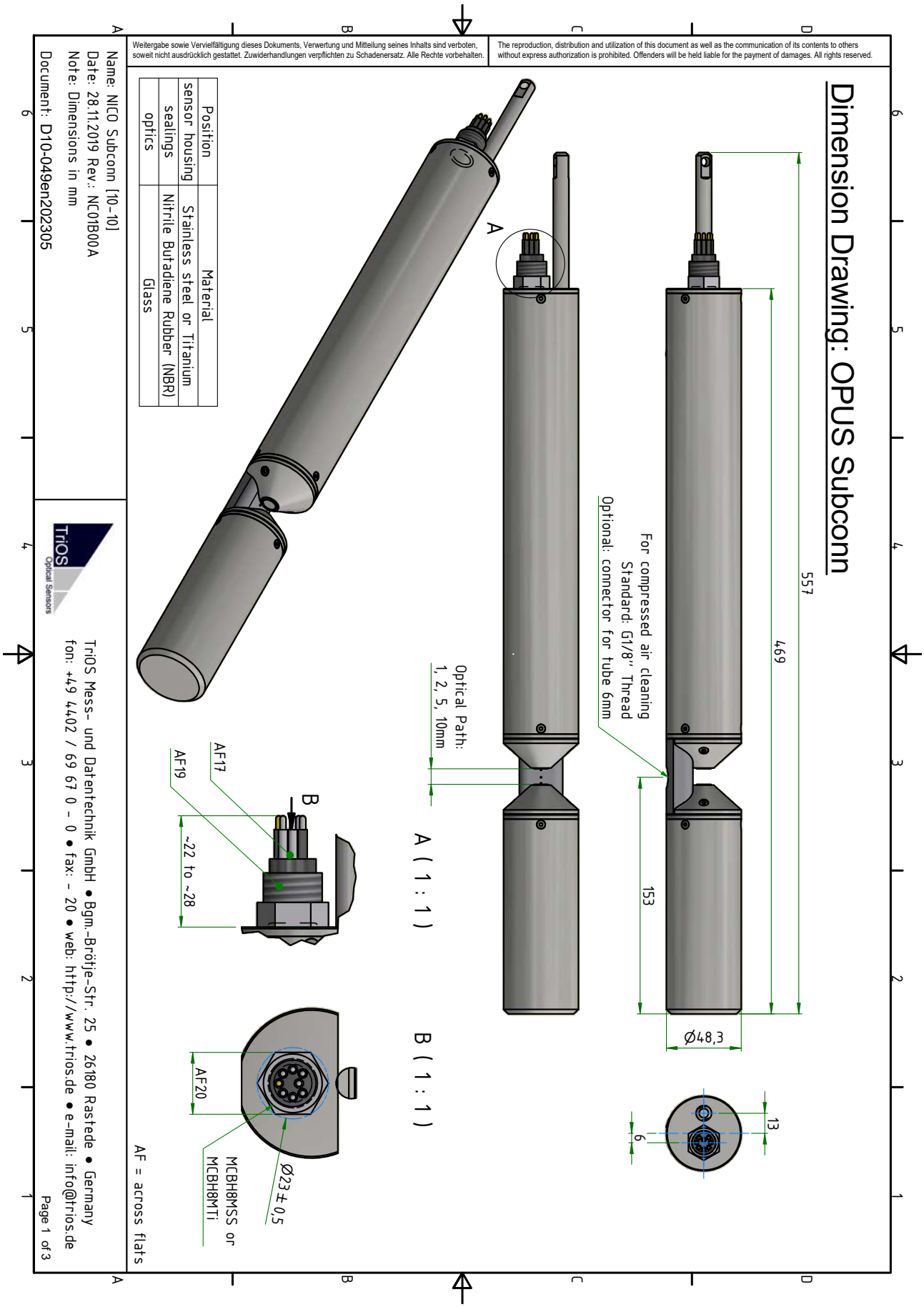
Parameters	Measuring principle	Measuring unit	Measuring factor	Path length (mm)						
				0,3	1	2	5	10	20	50
Absorption factor (au)	spectral	au**	-	0,01...2,2	0,01...2,2	0,01...2,2	0,01...2,2	0,01...2,2	0,01...2,2	0,01...2,2
Absorption coefficient (1/m)	spectral	1/m	-	50...7300	15...2200	7,5...1100	3...440	1,5...220	0,75...110	0,3 - 44
Nitrate N-NO_3	spectral	mg/L	-	1,0...330	0,3...100	0,15...50	0,06...20	0,03...10	0,015...5	0,006...2
Nitrate NO_3	spectral	mg/L	-	4,43...1460	1,33...440	0,67...220	0,27...88	0,13...44	0,067...22	0,030...9
Nitrite N-NO_2	spectral	mg/L	-	1,7...500	0,5...150	0,25...75	0,1...30	0,05...15	0,025...7,5	0,01...3
Nitrite NO_2	spectral	mg/L	-	5,6...1650	1,65...500	0,82...250	0,33...100	0,17...50	0,083...25	0,033...10
DOC_{eq}	spectral	mg/L	-	17...3300	5,0...1000	2,5...500	1,0...200	0,5...100	0,25...50	0,1...20
TOC_{eq}	spectral	mg/L	-	17...3300	5,0...1000	2,5...500	1,0...200	0,5...100	0,25...50	0,1...20
COD_{eq}	spectral	mg/L	-	100...7300***	30...2200***	15...1100***	6,0...440***	3,0...220***	1,5...110***	0,6...44***
BOD_{eq}	spectral	mg/L	-	100...7300***	30...2200***	15...1100***	6,0...440***	3,0...220***	1,5...110***	0,6...44***
KHP	spectral	mg/L	-	17...13300	5,0...4000	2,5...2000	1,0...800	0,5...400	0,25...200	0,1...80
SAC_{254}	Single wavelengths	1/m	-	50...7300	15...2200	7,5...1100	3...440	1,5...220	0,75...110	0,3...44
COD-SAC_{eq}****	Single wavelengths	mg/L	1,46	75...10600	22...3200	11...1600	4,4...640	2,2...320	1,1...160	0,44...64
BSB-SAC_{eq}*****	Single wavelengths	mg/L	0,48	24...3500	7,2...1050	3,6...525	1,44...210	0,72...105	0,36...52,5	0,15...21
TSS_{eq}*****	Single wavelengths	mg/L	2,6	130...4300	40...1300	20...650	8,0...260	4...130	2...65	0,8...26

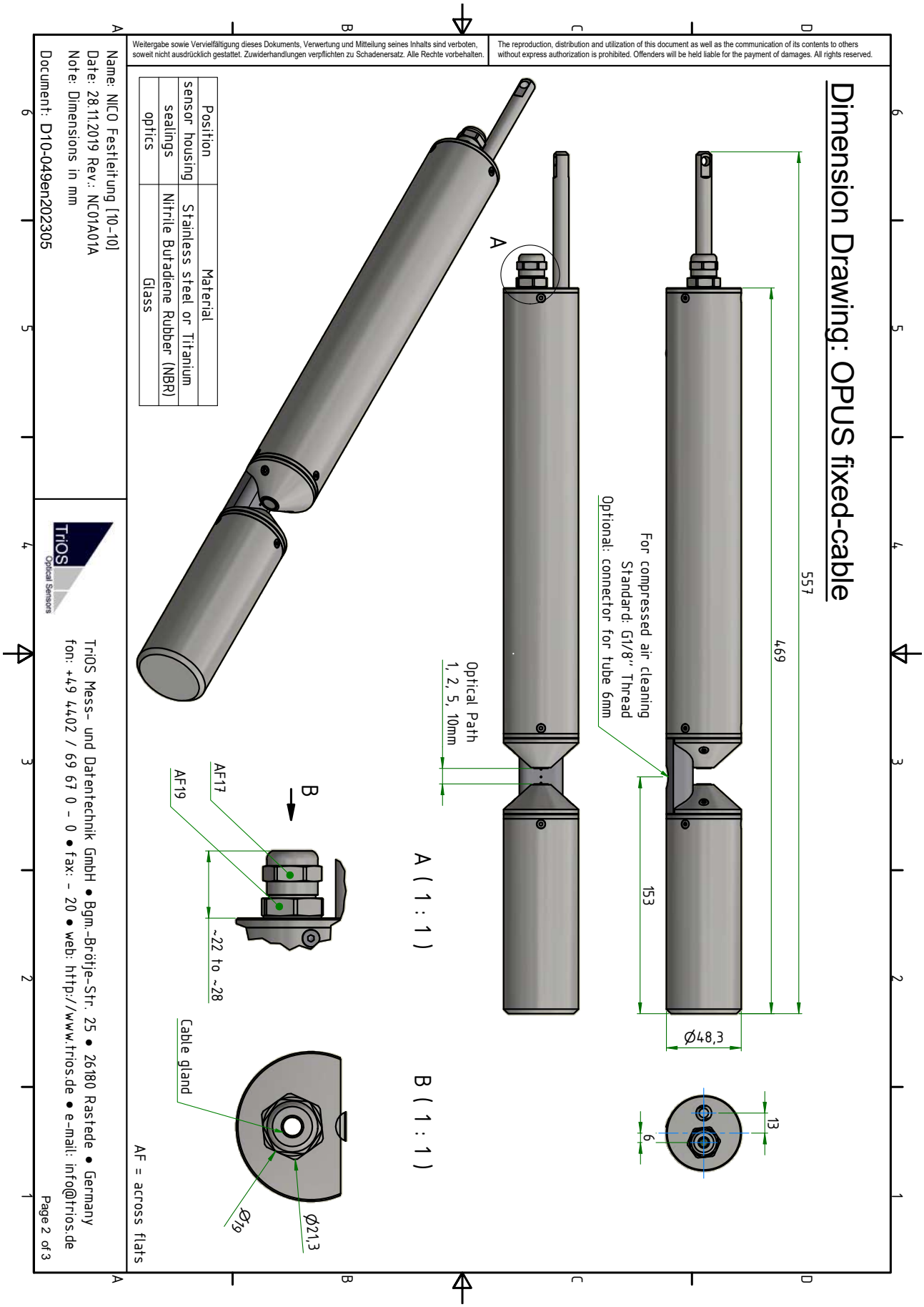
under laboratory conditions ** unit of the absorption measure *** depending on the composition of the COD or BOD (sum parameter) **** related to KHP (note: 100 mg COD standard solution corresponds to 85 mg/L KHP) ***** related to SiO2 note: 1 mg/L N-NO3 corresponds to 4.43 mg/L NO_3 1 mg/L N-NO_2 corresponds to 3.29 mg/L NO

7.3 OPUS aero measuring ranges

Path (mm)	Nitrate N-NO_3	Nitrate N-NO_2
0,3	2,4...120	4,4...220
1	0,7...36	1,3...67
2	0,35...18	0,65...33,5

7.4 Outer dimensions




Dimension Drawing: OPUS fixed-cable
557
469
153
Ø48,3
For compressed air cleaning
Standard: G1/8'' Thread
Optional: connector for tube 6mm
Optical Path
1, 2, 5, 10mm
A
A (1 : 1)
B
B (1 : 1)
AF17
AF19
~22 to ~28
Cable gland
Ø21,3
Ø19
13
6
AF = across flats
Position
Material
sensor housing
Stainless steel or Titanium
sealings
Nitrile Butadiene Rubber (NBR)
optics
Glass
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Name: NICO Festleitung [10-10]
Date: 28.11.2019 Rev.: NC01A01A
Note: Dimensions in mm
Document: D10-049en202305
TriOS Mess- und Datentechnik GmbH • Bgm.-Brötje-Str. 25 • 26180 Rastede • Germany
fon: +49 4402 / 69 67 0 – 0 • fax: – 20 • web: http://www.trios.de • e-mail: info@trios.de
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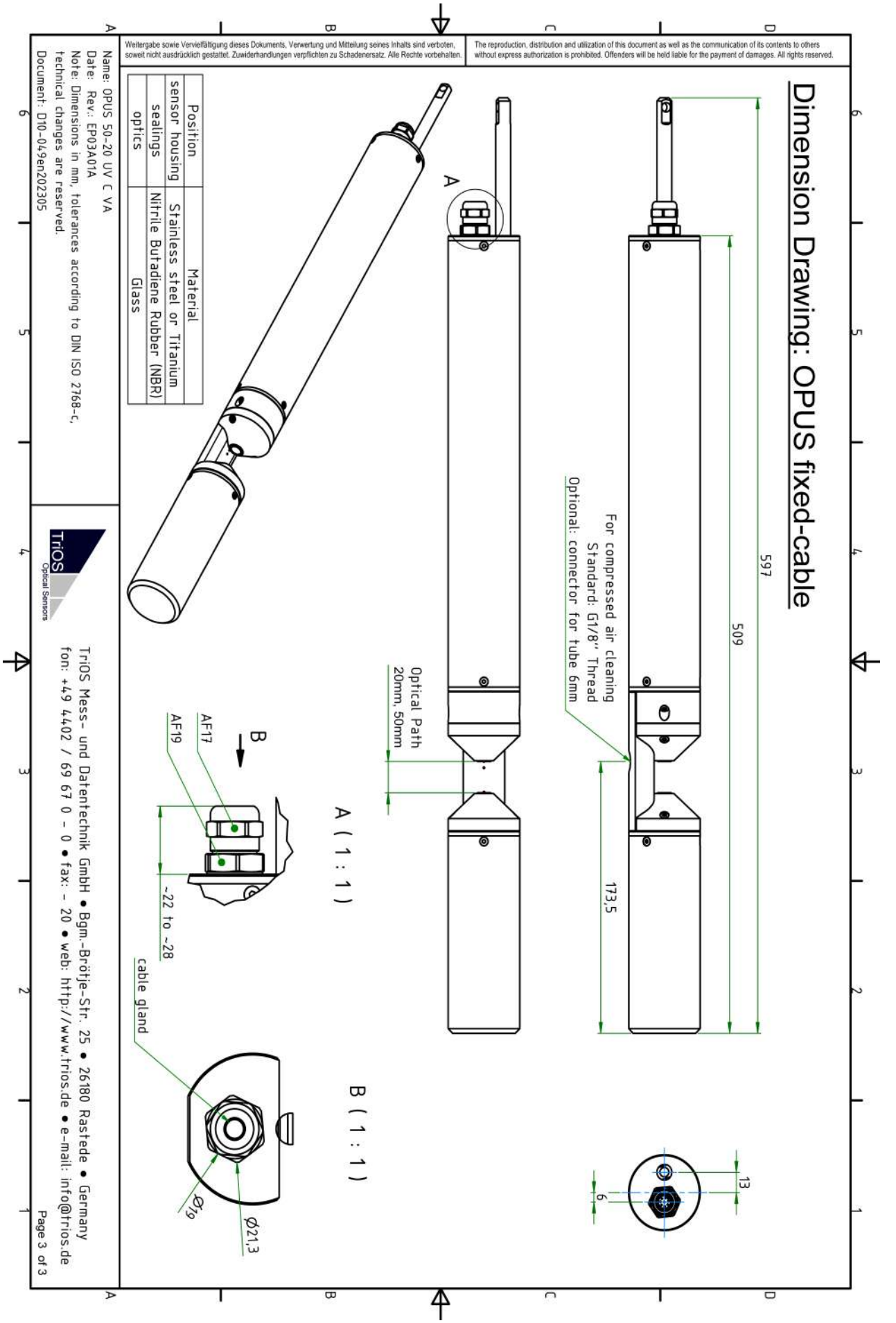
Dimension Drawing: OPUS fixed-cable
597
509
173,5
For compressed air cleaning
Standard: G1/8'' Thread
Optional: connector for tube 6mm
Optical Path
20mm, 50mm
A
A (1 : 1)
B
B (1 : 1)
AF17
AF19
~22 to ~28
cable gland
Ø21,3
Ø19
13
6
Position
Material
sensor housing
Stainless steel or Titanium
sealings
Nitrile Butadiene Rubber (NBR)
optics
Glass
Weitergabe sowie Vervielfältigung dieses Dokuments, Verwertung und Mitteilung seines Inhalts sind verboten, soweit nicht ausdrücklich gestattet. Zuwiderhandlungen verpflichten zu Schadenersatz. Alle Rechte vorbehalten.
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Name: OPUS 50-20 UV C VA
Date: Rev.: EP03A01A
Note: Dimensions in mm, tolerances according to DIN ISO 2768-c, technical changes are reserved.
Document: D10-049en202305
TriOS Optical Sensors
TriOS Mess- und Datentechnik GmbH • Bgm.-Brötje-Str. 25 • 26180 Rastede • Germany
fon: +49 4402 / 69 67 0 - 0 • fax: - 20 • web: http://www.trios.de • e-mail: info@trios.de
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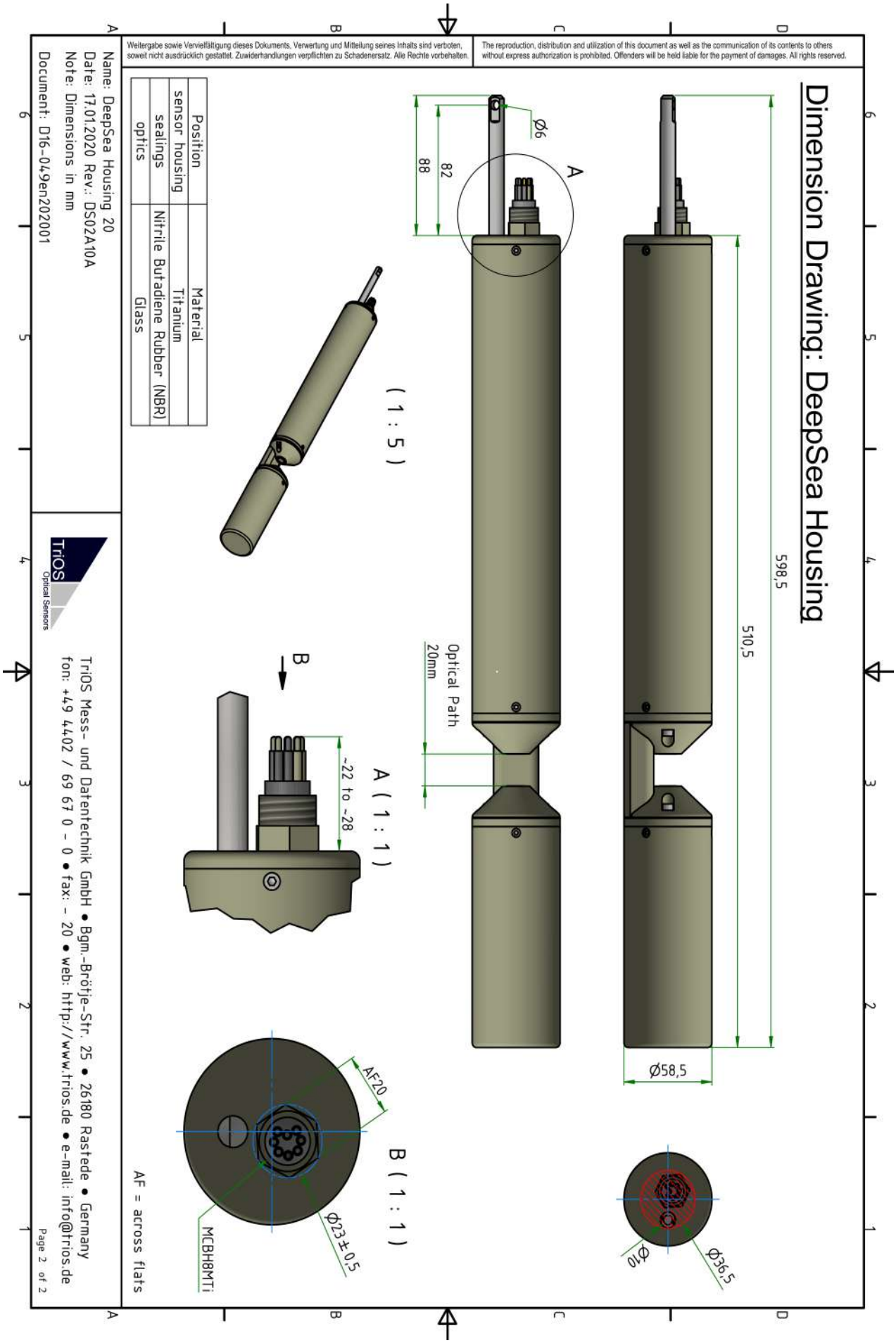
7.5 Outer dimensions deep-sea version



8 Accessories

8.1 VALtub

VALtub is used for the validation of TriOS photometers. The sample can be filled conveniently and leak-proof and analyzed without immersing the sensor.
The VALtub is also used to check and recalculate the zero values. Due to the adapted shape, only small amounts of water are required to carry out a measurement.
It is suitable for all TriOS photometers.

8.2 Controller

8.2.1 TriBox3

TriBox3 is a measuring and control system for all TriOS sensors. The device offers 4 sensor channels with selectable RS-232 or RS-485 function. In addition to Modbus RTU, various other protocols are available.
A built-in valve allows the use of compressed-air cleaning for the sensors. The TriBox3 also offers various interfaces, including an IEEE 802.3 Ethernet interface, an IEEE 802.11 b/g/n interface, a USB port and 6 analog outputs (4...20 mA).
An integrated relay can be used to trigger alarms or control external devices. Low power consumption, a robust aluminum housing and a range of interfaces makes it suitable for all applications in environmental monitoring, drinking water, wastewater treatment plants and many other areas.

8.2.2 TriBox mini

TriBox mini / TriBox mini NET are controllers with two digital sensor inputs and two 4...20 mA outputs and represent a cost-effective alternative to analog measuring points.
The TriBox mini is compatible with all TriOS sensors.
All stored measured values and diagnostic data can be read out via an integrated web browser.

8.3 G2 InterfaceBox

The G2 Interface Box is available in variants with and without WiFi. It can be used to configure and operate the G2 sensors from TriOS Mess- und Datentechnik GmbH. This is done via the web interface of the G2 sensors. Access is via a WiFi or LAN connection. The web interface can be accessed with any browser.

9 Warranty

The warranty period for our devices within the EU and the USA is 2 years from the date of invoice. Outside the EU it is 1 year. Excluded from the warranty are all normal consumables
(depending on the product, e.g. light sources or windows).

The guarantee is subject to the following conditions:

- The appliance and all accessories must be installed as described in the relevant manual and operated in accordance with the specifications.
- Damage caused by contact with aggressive and material-damaging substances, liquids or gases, as well as transport damage, are not covered by the guarantee.
- Damage caused by improper handling and use of the appliance is not covered by the warranty.
- Damage caused by modification or unprofessional attachment of accessories by the customer is not covered by the warranty.

NOTICE

Opening the device will void the warranty!

10 Technical support

If you have a problem with a TriOS sensor / a TriOS device, please contact TriOS technical support.

We recommend sending in sensors every 2 years for maintenance and calibration. To do this, please request an RMA number from technical support.

Contact technical support:

E-mail: support@trios.de
Phone: +49 (0) 4402 69670 - 0
Fax: +49 (0) 4402 69670 - 20

To enable us to help you quickly, please send us the sensor ID number (serial number with 8 digits, consisting of letters and numbers, e.g. 6700003F) by e-mail.

11 Contact us

We are constantly working on improving our devices. Please visit our website for the latest news.

If you have found a fault in one of our devices or programs or would like additional functions, please contact us:

Technical Support:	support@trios.de
General questions/sales:	sales@trios.de
Website:	www.trios.de

TriOS Mess- und Datentechnik GmbH
Bürgermeister-Brötje-Str. 25
26180 Rastede
Rastede, Germany

Telephone	+49 (0) 4402 69670 - 0
Fax	+49 (0) 4402 69670 - 20

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13 Appendix

CE Declaration of Conformity

Hersteller/Manufacturer/Fabricant: TriOS Mess- und Datentechnik GmbH
Bürgermeister-Brötje-Str. 25
D- 26180 Rastede

Konformitätserklärung
Declaration of Conformity
Déclaration de Conformité

Die TriOS GmbH bescheinigt die Konformität für das Produkt
The TriOS GmbH herewith declares conformity of the product
TriOS GmbH déclare la conformité du produit

Bezeichnung Product name Designation	**OPUS**
Typ / Type / Type	**UV**
Mit den folgenden Bestimmungen With applicable regulations Avec les directives suivantes	2014/30/EU EMV-Richtlinie 2011/65/EU RoHS-Richtlinie + (EU) 2015/863 + (EU) 2017/2102
Angewendete harmonisierte Normen Harmonized standards applied Normes harmonisées utilisées	EN IEC 61326-1:2021 EN 61010-1:2010 +A1:2019 +A1:2019/AC:2019 EN IEC 63000:2018
Datum / Date / Date 22.05.2024	Unterschrift / Signature / Signature R. Heuermann

D05-049yy202405

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Modbus RTU

Software version

This Modbus protocol refers to software version 1.3 and higher.

Serial interface

On delivery, the OPUS sensor is configured to RS485 with the following settings:

- Baud rate: 9600 bps
- Data bits: 8
- Stop bits: 1
- Parity: none

Data types

Data type name	register	format
Bool	1	false: 0x0000, true: 0xFF00
Uint8	1	8-bit positive integer. Values: 0x0000 - 0x00FF
Uint16	1	16-bit positive integer. Values: 0x0000 - 0xFFFF
Uint32	2	32-bit positive integer. Values: 0x00000000 - 0xFFFFFFFFFF
Float	2	IEEE 754 32-bit floating point number
Char[n]	$[\frac{n}{2}]$	Zero terminated ASCII character string
Uint16[n]	n	Field of n 16-bit integers (cf. Uint16)
Float[n]	2n	Field of n floating point numbers (cf. Float)

Functions

OPUS supports the following Modbus functions:

Name	Code	Description / Use
Read multiple registers	0x03	Read serial number, configuration, calibration and measurement data
Write multiple registers	0x10	Write configuration and calibration
Write single register	0x06	Triggering (calibration) measurements
Report slave ID	0x11	Read serial number

Standard Modbus server address

On delivery, the OPUS sensor is set to address 1 (0x01).

Read / Write multiple registers (0x03 / 0x10)

The registers contain the following values: Note: Before the registers from address 1000 can be read, a measurement must first be triggered.

Designation	R/W	Address	Data type	Data type Description
Modbus Server Address	RW	0	Uint16	The Modbus server address of the OPUS sensor. Permitted addresses: 1...247
Measurement timeout	R	1	Uint16	The time in [10-1 s] that the currently active measurement process will continue (see also “Trigger measurement”)
OPUS serial number	R	10	Char[10]	The serial number of the OPUS sensor
Firmware version	R	15	Char[10]	The version number of the installed firmware
Lamp serial number	R	20	Char[8]	The serial number of the lamp module
Data comment #1	RW	109	Char[64]	First comment line for the measurement data
Data comment #2	RW	141	Char[64]	Second comment line for the measurement data
Data comment #3	RW	173	Char[64]	Third comment line for the measurement data
Data comment #4	RW	205	Char[64]	Fourth comment line for the measurement data
System date and time	RW	237	Uint32	Date and time in seconds since 01.01.1970
Device description	RW	239	Char[64]	A free description of the sensor. E.g.: “southern supply line”
LSA name	R	500	Char[8]	The name of the active substance analysis
Available substances	R	504	Char[64]	In this bit field, a set bit is used to describe which substances are available in the active substance analysis (see sequence of concentration values from register 1000 / 1500). First bit $_{N\text{-}NO3}$, second bit $_{N\text{-}NO2}$, third bit bit CODeq, ...

Designation	R/W	Address	Data type	Data type Description
$_{N\text{-}NO3}$ concentration / scaled concentration	R	1000 / 1500	Float	
$_{N\text{-}NO2}$ concentration / scaled concentration	R	1002 / 1502	Float	
CODeq concentration / scaled concentration	R	1004 / 1504	Float	
BODeq concentration / scaled concentration	R	1006 / 1506	Float	
DOCeq concentration / scaled concentration	R	1008 / 1508	Float	

Designation	R/W	Address	Data type	Data type Description
HA concentration / scaled concentration	R	1010 / 1510	Float	
Salinity concentration / scaled concentration	R	1012 / 1512	Float	
TOCeq concentration / scaled concentration	R	1014 / 1514	Float	
TSSeq concentration / scaled concentration	R	1016 / 1516	Float	
Phenol concentration / scaled concentration	R	1018 / 1518	Float	
HS- concentration / scaled concentration	R	1020 / 1520	Float	
Chloride concentration / scaled concentration	R	1022 / 1522	Float	
Bromide concentration / scaled concentration	R	1024 / 1524	Float	
$_{CO3}$ concentration / scaled concentration	R	1026 / 1526	Float	
$_{NH2Cl}$concentration / scaled concentration	R	1028 / 1528	Float	
Fouling concentration / scaled concentration	R	1030 / 1530	Float	
$_{SAC254}$ concentration / scaled concentration	R	1032 / 1532	Float	
Abs360 concentration / scaled concentration	R	1034 / 1534	Float	
Abs210 concentration / scaled concentration	R	1036 / 1536	Float	
Fit-Error concentration / scaled concentration	R	1038 / 1538	Float	
KHP concentration / scaled concentration	R	1040 / 1540	Float	
Abs254 concentration / scaled concentration	R	1042 / 1542	Float	
Abs720 concentration / scaled concentration	R	1044 / 1544	Float	
$_{NO3}$ concentration / scaled concentration	R	1046 / 1546	Float	
$_{NO2}$ concentration / scaled concentration	R	1048 / 1548	Float	
SUVA concentration / scaled concentration	R	1050 / 1550	Float	
COD_SACeq concentration / scaled concentration	R	1052 / 1552	Float	
BOD_SACeq concentration / scaled concentration	R	1054 / 1554	Float	
TOC_SACeq concentration / scaled concentration	R	1056 / 1556	Float	
DOC_SACeq concentration / scaled concentration	R	1058 / 1558	Float	
SQI concentration / scaled concentration	R	1060 / 1560	Float	
$_{UVT254}$ concentration / scaled concentration	R	1062 / 1562	Float	

Designation	R/W	Address	Data type	Data type Description
Spectrum type	R	2000	Uint16	Type of the last recorded spectrum. Possible values: 0x0001: Absorption spectrum
Averaging	R	2001	Uint16	The number of individual recordings over which the last recorded spectrum was averaged
CalFactor	R	2002	Float	The normalization factor of the last recorded spectrum
Flash count	R	2004	Uint16	The number of lamp flashes during the last recording
Path length	R	2006	Uint16	The optical path length in [mm] through the medium during the last exposure
Temperature	R	2007	Float	The sensor temperature in [°C] during the last exposure
Length	R	2009	Uint16	The number of value pairs in the spectrogram. The number varies from sensor to sensor. In the case of a UV OPUS, the spectrogram is limited to the range [200nm ; 360nm], in the case of a UV/VIS OPUS to the range [200nm ; 720nm].
Abscissa	R	2100	Float [Length]	The values on the abscissa by which the spectrogram is described (wavelengths)
ordinate	R	2612	Float [Length]	The values on the ordinate by which the spectrogram is described. In the case of an absorption spectrum, this is the absorbance
Waterbase path length	R	4006	Uint16	The optical path length in [mm] through the waterbase medium

Write single register (0x06)

With the “write single register” function, special actions are carried out instead of writing values to individual registers. The following describes how this mechanism works.

Designation	Address	Address Description
Trigger measurement	1	A single measurement is recorded. The type of measurement depends on the value written: 0x0101: Absorption spectrum + substance analysis All other values are reserved for future extensions and may cause indeterminate behavior of the sensor. Note: Up to and including firmware version 1.2.4, Modbus requests may not be answered during the measurement.

Report slave ID (0x11)

Returns the sensor designation, followed by the serial number, followed by the firmware version, each as a zero-terminated ASCII character string.

Example:

O	P	U	S	0x00	7	0	7	A	0X00	1	.	3	0x00

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