
EN Version 3.1

# Operation manual

PaintChecker industrial

PaintChecker industrial n-gauge

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# 1. Introduction

## 1.1 Brief description

The PaintChecker industrial systems are photo-thermal measuring systems according to DIN EN 15042-2:2006. They are used for non-contact and non-destructive coating thickness measurement.

They are suitable for moist and dry organic coatings such as solvent-based and water-soluble paints and varnishes, powder paints and varnishes on various substrates, metals, extruded rubber and ceramics.

A PaintChecker industrial measuring system consists of a controller and sensor(s). Depending on the controller, it can be equipped with up to eight sensors. The sensors are connected to the controller via cables. These in turn can be connected to a higher-level PLC controller via various interfaces.

## 1.3 General information on the operation manual

This operation manual enables the safe and efficient use of the measuring system. The manual is part of the delivery, must be kept near the measuring system at all times and must be accessible to the staff.

The staff must have carefully read and understood this manual before using the system. A basic prerequisite for safe working with the system is compliance with all safety and work instructions given in this operation manual. In addition, the local safety requirements as well as the general safety regulations in the area of application of the measuring system also apply.

Illustrations in this operation manual are for general understanding only and may differ from the actual design.


*Fig. 1: PaintChecker industrial n-gauge with various laser and LED sensors*

The OS Manager software provided with the system can be used to perform measurements and statistically evaluate the measured values.

## 1.2 Scope of Delivery

The scope of delivery of the measuring system is specified in the documents *Data Sheet Controller industrial* and *Data Sheet Sensors industrial*.

## 1.4 Copyright

## 1.5 Customer service

The OptiSense customer service is available for technical questions::

**OptiSense GmbH & Co. KG**
Annabergstraße 120
45721 Haltern am See
GERMANY
Tel. +49 (0)2364 50882-0
info@optisense.com
www.optisense.com

# 2. Safety Instructions

### 2.1 Symbol explanation of pictograms and signal words

Safety instructions are indicated by hazard pictograms in this operation manual. These pictograms convey information about the type of danger. The signal words indicate the extent of the danger. A distinction is made between two levels of danger: *Danger* is the signal word for the serious danger categories and *Caution* is the signal word for the less serious danger categories.

DANGER!

This combination of symbol and signal word indicates a serious danger. The symbol shows the danger in case of incorrect use

DANGER!

The combination of symbol and signal word indicates a serious danger category. The symbol shows the danger in case of laser radiation.

DANGER!

The combination of symbol and signal word indicates a serious danger category. This symbol indicates a fire hazard.

DANGER!

The combination of symbol and signal word indicates a serious danger category. The symbol stands for risks caused by electricity.

CAUTION!

The combination of symbol and signal word indicates a less serious danger category. The symbol indicates the corresponding hazard.

TIPS AND RECOMMENDATIONS

This symbol highlights tips and recommendations as well as information for efficient and error-free operation.

### 2.2 Proper use

The PaintChecker industrial photothermal measuring system is used to determine the thickness of wet and dry organic coatings for quality assurance and production-related testing. Proper use includes observing all information contained in this manual. Any use outside or beyond proper use is considered improper use.

Danger in case of improper use

Improper use of the PaintChecker industrial system can lead to dangerous situations.

**Danger!**

- The light beam of the sensor must never be directed at easily flammable materials.
- The sensor must never be used in explosive areas.
- The sensor must never be used to illuminate, or dry other objects.
- The sensor must never be used for medical purposes.
- The sensor must never be immersed in liquids.
- The light beam of the sensor must never be directed at people.
- Incorrect measurement parameters may result in damage to the object being measured

### 2.3 Safety markings

#### 2.3.1 Safety labelling in the working area

The following symbols and information signs are located in the working area. They refer to the immediate environment in which they are placed.

- All safety, warning and operating instructions must be kept in a legible condition at all times.
- Damaged signs or stickers must be replaced immediately.

**Caution!**

Danger with illegible signage! Over time, stickers and signs can become dirty or otherwise unrecognisable, so that hazards cannot be recognised and necessary operating instructions cannot be followed. This creates a risk of injury

### 2.3.2 Safety marking on the measuring system

Warning sign 1
Position: Near the light source (lens of the sensor)

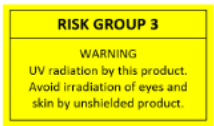
Warning sign 2
Position: Near the light source (lens of the sensor)


Warning sign 3
Position: Near the light source (lens of the sensor)


Warning sign 4
Laser class 1M
Position: over status LEDs of the controller


Warning sign 5
Laser class 3R
Position: over status LEDs of the controller


Warning sign 6
Hazard group 1
Position: over status LEDs of the controller




Warning sign 7
Danger group 3
Position: over status LEDs of the controller

Depending on the type and current level of the laser power supply used and the working distance of the sensor, the laser safety class varies.

## 2.4 Risks caused by electricity

### Danger to life due to electric current

**Danger!**

When touching live parts, there is an immediate risk of death due to electric shock. Damage to the insulation or individual components can be life-threatening.

Electrical information sign
Position: Right on controller housing

- Work on the electronics of the measuring system may only be carried out by OptiSense or by personnel trained by OptiSense.
- If the insulation is damaged, the power supply must be switched off immediately and the repair must be arranged.
- Fuses must never be bypassed or deactivated. When replacing a fuse, attention must be paid to the correct rating.
- Voltage-carrying parts must be protected from moisture. Otherwise a short circuit may occur.
- Protective covers must never be opened by the user except for installation. In the event of faults, the system must be returned immediately to OptiSense GmbH & Co. KG.
- The main plug must be disconnected before cleaning or maintenance work or when troubleshooting.
- The mains cable must be laid in such a way that it cannot be run over, kinked or pinched, come into contact with liquids, heat or the laser itself, or be damaged in any other way.
- The mains socket must always be easily accessible.

## 2.5 Dangers due to invisible light radiation from the sensor

**Caution!**

The accident prevention regulations of DGUV regulation 11 as well as the regulations of the occupational health and safety ordinance on artificial optical radiation (OStrV) must be observed.

The description of the dangers of the radiation used here depends on the equipment. The risk class applicable to the PaintChecker is indicated on the warning label of the controller. The limits for radiation duration given here have been determined in part by an expert in laser technology and are not generally applicable to other devices of this safety class.

### Incoherent radiation of risk group 1 (RG1)

Radiation in the IR-A range. There is a low risk here. Damage to the retina can be largely ruled out. Even prolonged but time-limited exposure to the light source does not cause any damage.

Irradiation of the skin near the exit aperture of the sensor can cause damage to the skin in the focus. The laser radiation itself is not visible.

| | |
|---|---|
| Source: | LED (Cube-LEDR) |
| Mode: | pulsed |
| λ: | 950 nm +- 19 nm |
| $E_e$: | 20.1 $kW/m^2$ |

### Incoherent radiation of risk group 3 (RG3)

Radiation in the UV-B range. Poses a risk in case of short exposure within the safety distance. Protective measures are essential here. When an individual threshold dose (minimum erythema dose) is exceeded, so-called sunburn (UV erythema) occurs. The maximum permissible irradiation of the skin is 64 seconds per day.

If the cornea is irradiated for more than 120 seconds within a period of 1000 seconds, impairment according to the criteria of EN 62471:2008 is to be expected.

| | |
|---|---|
| Source: | LED (Cube-LEDB) |
| Mode: | pulsed |
| λ: | 365 nm +- 9 nm |
| $E_e$: | 5.4 $kW/m^2$ |

### LARES

A health hazard due to invisible light radiation of class 1 can be excluded when used correctly (see LARES®). The radiation is accessible in this system, but so weak that any damage can be excluded. This is important because the light radiation is in the non-visible wavelength range.

### Coherent radiation of class 1M

Radiation in the IR-B spectrum. Radiation of this class can be dangerous if an optical instrument (magnifying glass, microscope, etc.) is in front of the eye. Glasses are not regarded as an optical instrument in this case.

Irradiation of the skin near the exit aperture of the sensor can cause burns in the focus. The laser radiation itself is not visible.

| | |
|---|---|
| Source: | Laser diode (Tube LLP, Angle LLP) |
| Mode: | pulsed |
| λ: | 1480 nm |
| Pmax: | < 5 mW (Laser 16 mm) |
| Pmax: | < 7 mW (Laser 35 mm) |

### Coherent radiation of class 3R

Radiation in the IR-B spectrum. Radiation of this class can be dangerous to the eye when looking directly into the laser beam. Therefore, direct irradiation of the eye should be avoided. The risk of injury increases with the duration of exposure.

Class 3R lasers should only be used when direct viewing into the beam is unlikely.

**Danger!**

Irradiation of the skin near the exit aperture on the measuring head can cause burns in the focus. The laser radiation itself is not visible.

- The laser beam must never be directed at the eyes or skin.
- The light beam must never be viewed with optical instruments such as magnifying glasses or microscopes.
- The system may only be switched on after the light beam exit aperture of the measuring head has been inspected for external damage.
- The system must be switched off immediately after the measurement and secured against being switched on again.
- If the sensor is damaged, the system must no longer be used. The sensor must be returned immediately to OptiSense GmbH & Co. KG

## 2.6 Fire hazards

**Danger!**

The light beam can easily set fire to flammable materials, liquids or gases, causing serious or even fatal injuries.

- The sensor must not be used in a potentially explosive atmosphere.
- The light beam of the sensor must not be directed onto easily flammable materials.
- Suitable extinguishing equipment (fire blanket, fire extinguisher) must be kept available.
- In the event of fire, work with the system must be

stopped immediately. The danger zone must be left until the all-clear signal is given and the fire department must be alerted.

### 2.7 Responsibility of the operator

The operator is the person who operates the measuring system for commercial or business purposes or who allows a third party to use the system and who takes legal responsibility for the product and the protection of users, personnel or third parties.

The system is intended to be used for commercial purposes. The operator of the system is therefore subject to the legal requirements for occupational health and safety.

In addition to the safety instructions in this manual, the regulations for occupational health and safety and environmental protection that apply to the system's area of use must be observed. In particular, the following applies:

- The operator must inform himself about the applicable occupational safety regulations and carry out a hazard analysis in order to determine additional risks resulting from the special working conditions at the place of use of the measuring system. These must be implemented in the form of work instructions for the users of the measurement system.
- Throughout the period of use of the measuring system, the operator shall verify that his work instructions are up to date with the current harmonised regulations and shall adapt them if necessary.
- The operator must clearly define and specify who is responsible for commissioning, operation and cleaning.
- The operator must ensure that all employees who handle the measuring system have read and understood this manual.

The operator remains responsible for ensuring that the measuring system is free from technical faults at all times. The operator must have all safety devices checked regularly for functionality and completeness.

### 2.8 Requirements for personnel

**Danger!**

If unqualified personnel carry out work with the measuring system or are in the danger zone of the measuring system, risks arise which can lead to serious injuries and considerable damage to property.

- There is a risk of injury if the personnel is not sufficiently qualified.
- All tasks must be carried out by qualified personnel only.
- Keep unqualified personnel away from the danger zone.

# 3. Product Description

### 3.1 Operating principle of photothermal coating thickness measurement

Non-contact, fast and efficient: Photothermal coating thickness measurement is a contactless method for lacquers, powder coatings and glazes on metallic and non-metallic substrates. The different thermal properties of the coating and the substrate are used to determine the coating thickness.

The surface of the coating is heated up by a few degrees with a short, intense light pulse and then cools down again by dissipating the heat into deeper areas. The thinner the coating, the faster the temperature drops. The temperature curve over time is recorded with a highly sensitive infrared sensor and converted into the coating thickness.

The light pulse can be generated in different ways. Compared to xenon flash lamps, LEDs and diode lasers offer all the advantages of semiconductor technology here, such as long service life, high efficiency and absolute vibration resistance.

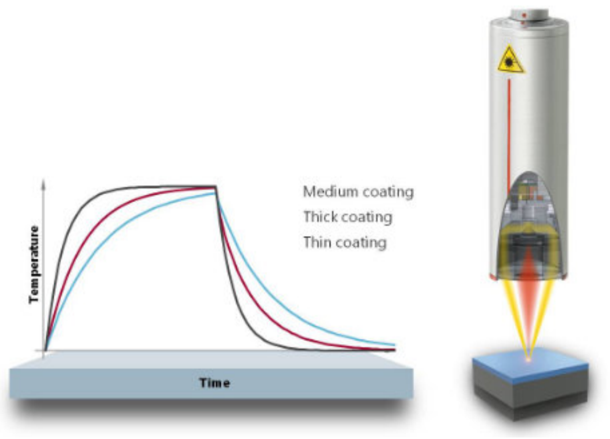



*Fig. 2: Operating principle of photothermal coating thickness measurement*

Due to the tiny measuring spot, the method is also suitable for the smallest components. The coating thickness can even be determined at bending edges, corners and curved surfaces where conventional measurement technology reaches its limits. Disturbances caused by rough surfaces or material grain are compensated by optical averaging, so that even pastes and powders can be checked before curing.

The measurement is carried out without contact from a distance of several centimetres. This means that wet and sticky layers can be measured just as easily as soft and sensitive surfaces. Contamination of the component or carry-over of coating material is excluded in principle.

### 3.2 LARES® – safety redefined

LARES® stands for **LA**ser **R**adiation **E**ye **S**afety technology and is the intelligent answer to the continuously increasing requirements in the area of personal and eye protection. Especially when working directly with lasers, these safety requirements always have the highest priority. By using the new LARES® technology in the manufacturing and process industry, people, machines and the environment are reliably protected. The handling and application of the devices can be carried out without the user having to be trained and instructed in a way that requires documentation. Thanks to LARES® technology, the devices can be used directly and without any restrictions in almost all areas of application.

The LARES® logo on the corresponding OptiSense products make the safe laser technology immediately recognisable. All devices with the LARES® logo are safe for the eye – even during prolonged irradiation.

### 3.3 Features and area of application

The PaintChecker industrial is a photothermal coating thickness measurement system for automated operation in production. It builds on OptiSense's many years of experience in the manufacture of reliable and durable coating thickness measurement systems for production-accompanying component testing as well as the production of small and thus flexibly applicable sensors.

The underlying photothermal measuring method is standardised according to DIN EN 15042-2 and is suitable for the examination of moist, powdery and dry coatings on various substrates such as metal, rubber and ceramics. The PaintChecker industrial measuring system is designed for customer integration into automatic coating systems and consists of the following components:

- 1-8 sensors (depending on controller variant)
- controller

The PaintChecker industrial systems can be flexibly integrated into the production line. There, they detect process deviations immediately after coating and thus help to avoid returns and unnecessary material waste. The measurements can be carried out both in stop-and-go operation on the stationary object and directly on the moving part when using active motion compensation.

Optimized for the specific tasks, OptiSense offers measuring systems with different optics for different measuring spot sizes and distances. For example, rough surfaces can be inspected with a large measuring spot, while a tightly focussed measuring spot is suitable for small structures.

With the PaintChecker industrial systems, a wide variety of coatings can be measured non-destructively in wet or dry condition, regardless of the geometry. Examples of coating combinations are e.g. rubber coatings wet/dry, powder coatings on metal, coated glass and coated ceramics. Further combinations can be found in the *industrial Sensors* data sheet.

### 3.4 Model overview sensors

The sensor is the heart of the measuring system. It contains a high-power diode light source with folding optics and a fast infrared detector with data acquisition controller and communication interface to the controller. The geometry of the sensor as well as the measuring distance and spot size vary according to the respective measuring requirements.

A special feature of all PaintChecker industrial systems are the extremely light sensors, which weigh only 150, 180 or 280 grams, depending on the version.

In the PaintChecker industrial product range, some laser-based sensors use the LARES® technology developed by OptiSense. These kind of sensors provide an eye-safe, laser-optical measuring system which can be operated without protective technical measures.

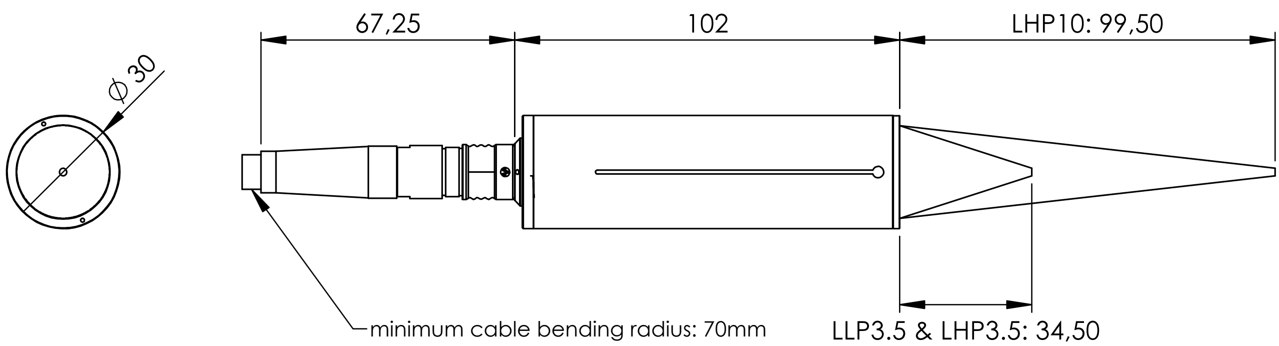



*Fig. 3: Tube LLP3.5, LHP3.5, LHP10*

### 3.4.1 PaintChecker industrial Laser-sensors *Angle* und *Tube*

The OptiSense laser sensors *Angle* and *Tube* use a diode laser as the light source – with all the advantages of semiconductor technology, such as long service life, high efficiency and absolute vibration resistance.

There are *Tube* versions with a tiny measuring spot for micromechanical applications and special *Angle* sensors with folded optics and a particularly small measuring distance, which can be used even in the tightest spaces. The models equipped with eye-safe LARES® technology (see LARES®) can be operated without further protective measures.

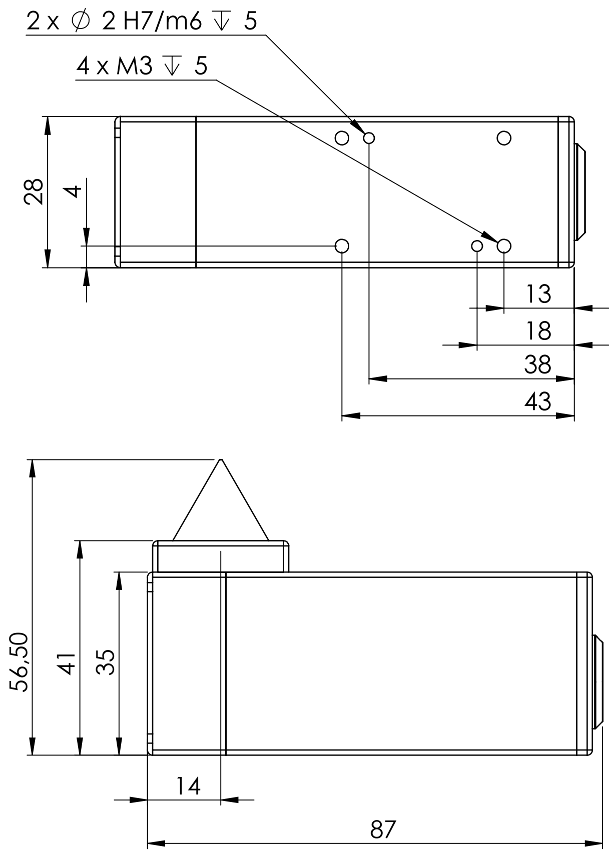



*Fig. 4: Dimensional drawing Industrial Angle sensors LLP1.6, LHP1.66*

### 3.4.2 PaintChecker industrial LED-sensors *Cube*

The LED sensors called *Cube* have a larger measuring spot than the laser versions and are particularly suitable for the rough and grainy surfaces of powders and pastes. Depending on the coating material, a choice can be made between models with infrared and UV excitation. Of course, measurements on non-metallic substrates are also possible. The compact sensors in the cube-shaped housing can be mounted particularly flexibly due to the freely selectable orientation of the cable connection while their large contact surface ensures optimum heat dissipation.

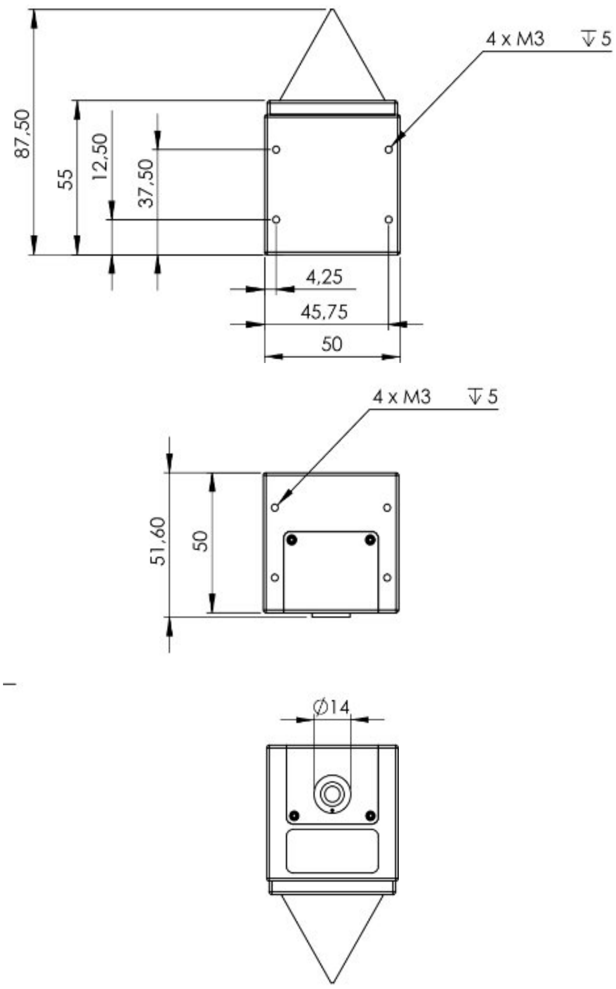



*Fig. 5: Dimensional drawing Industrial Cube sensors LEDB3.3, LEDR3.3*

### 3.4.3 High-power versions of the PaintChecker industrial sensors

Photothermal measurements on thick layers with a high glass or metal content require a stronger light output. In addition, the power requirement increases with the distance between the sensor and the component. For these applications, high-power versions of the sensors are available with the same external dimensions but with higher output power. The 10.0 version also has a larger measuring distance as well as a higher energy density, so that in many cases a precise part positioning during measurement is no longer required.

### 3.5 Controller model overview

The controller is the central element of the measuring system. It generates the necessary energy for the light pulses of the measuring sensor, but also processes the signals, stores the measuring configuration and controls the data flow to the production line PLC.


*Fig. 6: Description of the controller*

There are three different models of the controller:

#### 3.5.1 PaintChecker Industrial

The PaintChecker industrial controller is the basic version for measurements with one sensor. The controller in a robust, dust-protected aluminium housing is available in different versions for laser and LED sensors. It is connected to the sensor via a flexible cable and can also be mounted remotely. A serial interface and a Profinet IO connection are integrated for communication with the PC and plant PLC.

#### 3.5.2 PaintChecker industrial n-gauge

The PaintChecker industrial n-gauge models support multi-point measurements with up to 8 sensors. They record all measuring points simultaneously and evaluate them at the same time. Measurements on several components or different component positions are carried out in a fraction of the time without the need for cost-intensive automatic movement systems. Combined with easy integration, this results in significantly shorter throughput times, improved data quality and quality control, a reduction in cost-intensive automatic motion machines and increased efficiency. All sensors of the laser, LED or high-power series can be combined with the respective PaintChecker industrial n-gauge model.

#### 3.5.3 PaintChecker Highpower models

For measurements on thick layers with a high glass or ceramic content, the high-power versions of the controllers are recommended. The otherwise functionally identical high-power controllers from OptiSense have a reinforced power supply, which is housed in a separate enclosure for the PaintChecker industrial n-gauge HP. In addition to the higher excitation power, the associated high-power sensors have a larger measuring distance and a higher energy density, thus simplifying the positioning of the component during the measurement.

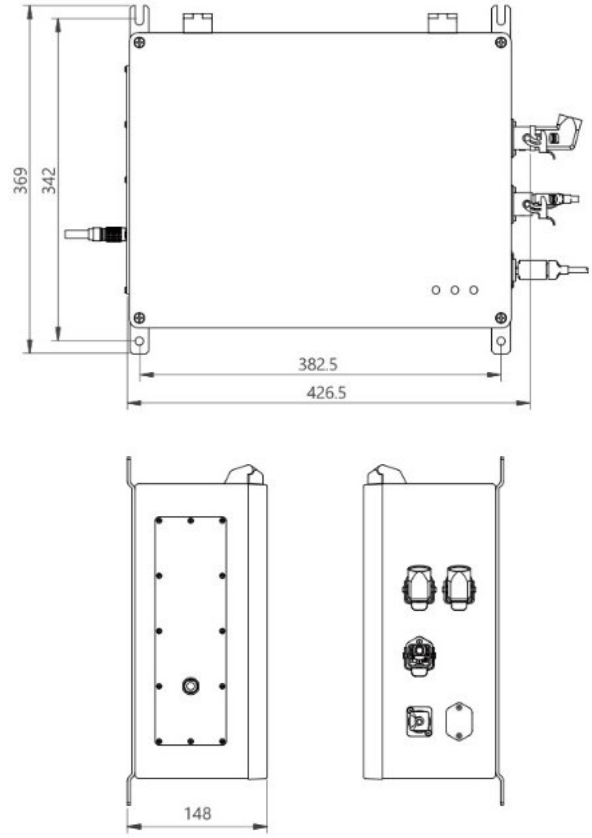



*Fig. 7: Dimensions | Controller industrial*

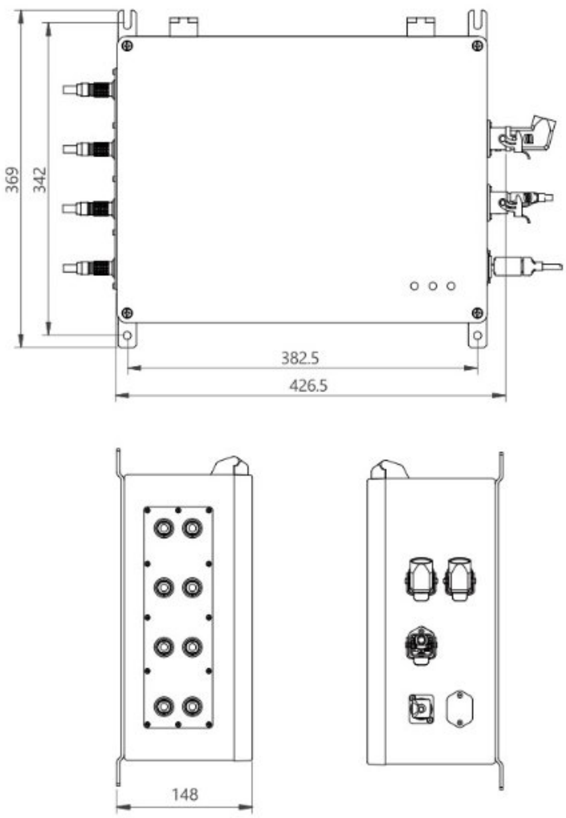



*Fig. 8: Controller industrial Multi*

### 3.6 Connections of the controller

For information on the pin assignment of the control and supply cables, see section Pin Assignments.

*Network connection RJ45*
Connection to external network-based communication software

*Power supply 110 - 230 V*
Power supply for the entire measuring system

*D-SUB DE-9 (F)*
Service interface for Anybus

*USB B 2.0*
Service interface for maintenance and calibration based on the internal OptiSense protocol (to be used by OS Manager)

*Safety circuit*
connection for laser enable (2x2 line channels) and reset control (2 lines)

*Power indicator (yellow)*
Power supply 110 - 230 V switched on

*System safe indicator (green)*
The laser is disconnected by the relay contact and the system is "safe". No measurements are possible

*Pulse indicator (red)*
Indicates pulsing of the laser or an error in the measurement process when permanently lit.

### 3.7 Communication interfaces

Depending on the equipment, the PaintChecker industrial models have various communication interfaces and protocols for system control:

Each PaintChecker controller is equipped with a USB interface. The controller can be operated via the OS-Manager software or alternatively accessed and controlled via ASCII commands as described in chapter Control commands.

| | |
|---|---|
| Baudrate: | 115200 |
| Data bits: | 8 |
| Stop bits: | 1 |
| Parity: | None |

In addition, each PaintChecker is delivered with a further interface. This must be specified when ordering. The corresponding signals are available at connector X14. If the customer does not specify an interface, the controller is equipped with Profinet IO as standard.

Alternatively, the following interfaces can be ordered:

- Profinet IO
- DeviceNet
- EthernetIP

Other interfaces are possible on request.

The PaintChecker is basically controlled via input and output registers. Their structure is described in chapter Control commands and Output signals. For the Profinet IO connection a Gdsml file as well as a TIA V14/V15 module is available from OptiSense..

### 3.8 Accessories

The optional accessories of the measuring system are listed in the *Data Sheet Controller industrial* and *Data Sheet Sensors industrial.*

# 4. Installation

## 4.1 General notes on installation and set-up of the system

The measuring system consists of two components plus a ROBOFLEX® cable:

- sensor(s)
- controller

Only cables and connections that comply with local safety regulations may be used.

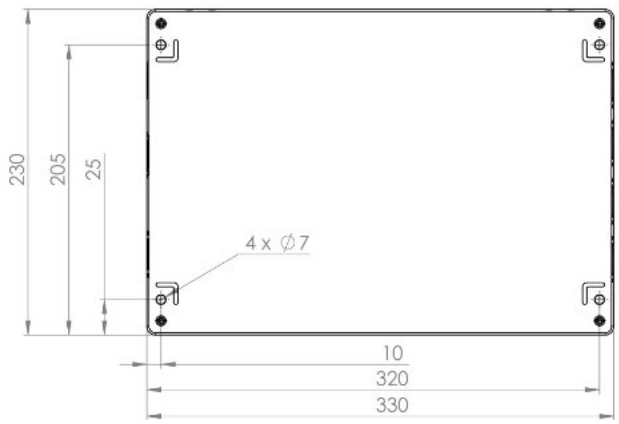



*Fig. 9: Installation dimensions*

## 4.2 Mounting the controller

The location of the controller must be chosen so that it is within reach of the connection cables of the sensors to be attached.

Access to the system should be easy and safe for maintenance work. Power is supplied via connector X16 on the controller.

Loosen the four screws on top of the controller to open the cover. Secure the controller to a wall or in a controller cabinet using the four holes on the back. Make sure you can reach all sensors with the fixed sensor cable length of 3 m or 5 m.

Connect the controller to:

- the safety circuit and reset lines via Harting connector (X15)
- the Ethernet RJ45 connector (X14) / Profinet IO or alternative interface
- the mains power via Harting connector (X16)

### 4.2.1 Connecting the controller to the safety circuit

If the control signals (see connector X15) are disconnected, the sensor's light source (LED or laser) is turned off by immediately switching off the power supply. The green safety indicator turns on. After the control signals have been closed to enable the light source, the two reset leads must be shorted to re-enable the power for the light source. If the reset line is closed while the control signals are closed, the safety circuit goes into a fault state and can only be activated again after the controller has been switched off.

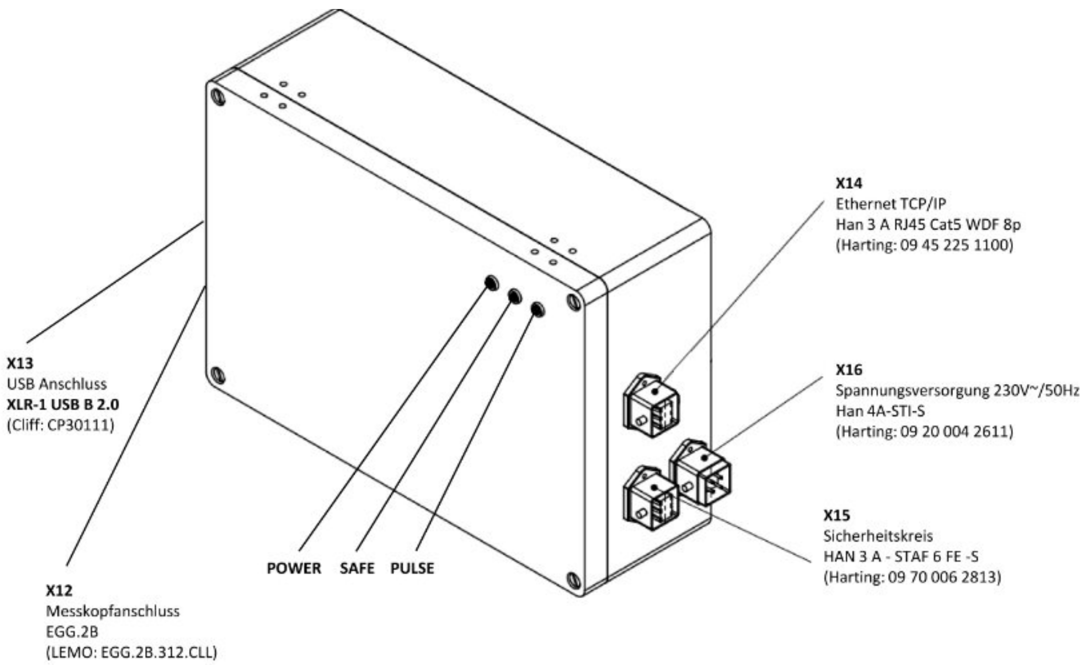



*Fig. 10: Connector assignment*

Danger due to uncontrolled restart

Danger due to uncontrolled restart: Uncontrolled restarting of the system can lead to serious injuries.

**Caution!**

- Before the system is switched on again, it must be made sure that the cause of the emergency shutdown has been removed and that all safety devices are fitted and functional.
- When there is no longer any danger, the *control signals* can be unlocked and operation can be resumed using the *reset leads*.

### 4.2.2 Connecting the communication module

Depending on the version, the PaintChecker industrial system is equipped with one or more communication interfaces via which the controller can be connected to an up-stream control unit.

The interface is provided via an internal module, the so-called Anybus converter. Depending on the interface, this module can be configured via the associated connector X14 using a PC and the IPConfig software from HMS.

With other interfaces, the configuration may have to be performed directly on the Anybus module. To do this, the PaintChecker controller needs to be opened and the settings made manually on the module.

The measuring system is connected to the up-stream control unit via the respective interface using a suitable cable.

## 4.3 Mounting the sensor

*Tube* sensors should be mounted with a clamp of Ø = 30 mm, this ensures optimal heat conduction to the rest of the mounting fixture. This is especially necessary for applications with high measurement rates.

The *Angel* and *Cube* sensors should be mounted via the screw connection in such a way that a maximum contact surface to a heat sink is ensured. (The mounting plate of the sensors is usually sufficient).

The sensor is to be mounted at a suitable location in the production line or on a motion unit. It must be ensured that the sensor reliably maintains the specific measuring distance to the part to measure.

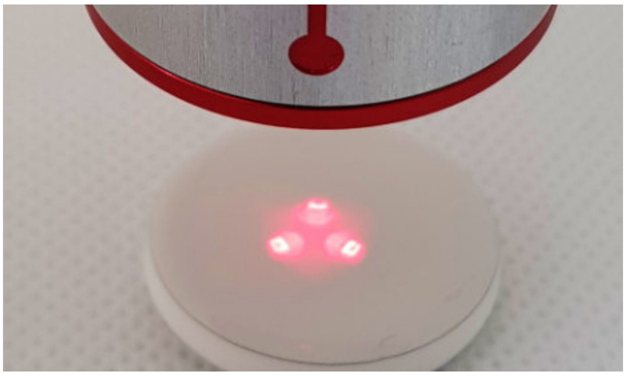


*Fig. 11: Incorrect distance to the measured part*

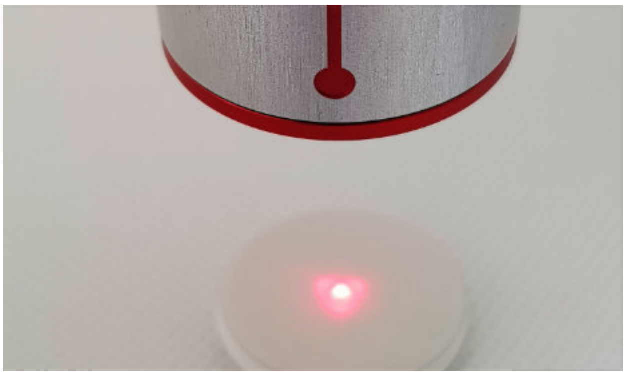


*Fig. 12: Correct distance to the measured part*

The sensor must be installed in such a way that it cannot slip or be damaged during movements.

The sensor cable is connected to the controller. The cable must not exert tensile stress on the sensor at any time. This is especially important with moving sensors.

The sequence in which the sensors are connected should be noted to simplify later identification of the sensors.

Proper heat dissipation must be ensured!

When operating at high measurement rates or in environments with high ambient temperature, the sensor may overheat under certain conditions because excess heat cannot be dissipated (sensor temperature >40°C).

Water or other liquids must never be used to cool the sensor!!

# 5. Commissioning

## 5.1 General notes on commissioning

**Danger!** If a PaintChecker industrial system is operated with an open enclosure, live parts are accessible. Electric, magnetic and electromagnetic fields emanating from live parts can interfere with the environment.

- The PaintChecker industrial Controller may only be operated with the housing closed!
- The PaintChecker industrial system can only be operated with the safety circuit closed.
- It must be ensured that the safety circuit is functioning properly and is closed!

## 5.2 Switching on the measuring system

### 5.2.1 Prerequisites

- The general instructions for commissioning have been read and understood.
- The PaintChecker industrial system has been properly installed.

The PaintChecker industrial measuring system performs the following when it is switched on:

- Load the last used measurement settings.
- Activate the installed communication interfaces.
- Establishing communication with the sensor connected to port 1.

The connector X16 of the PaintChecker industrial system has to be connected to the mains power.

## 5.3 Aligning the sensor

As photothermal measurement is non-contact, it is important to align the sensor at the correct distance from the part to measure. Depending on the sensor model, the distance as well as the allowed distance tolerances to the part varies.

In order to precisely maintain the working distance to the part, the mounting of the sensor should be designed in such a way that it always maintain the same distance – even if the mounting or the part is vibrating. When aligning the distance, the sighting LEDs built into the sensor can be used to determine the correct working distance to the part.

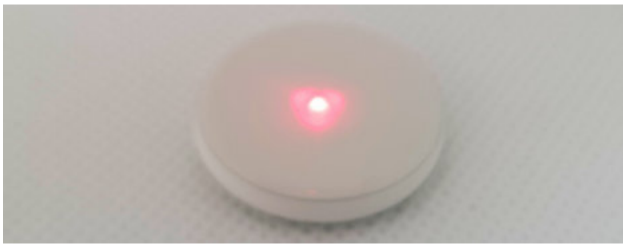


*Fig. 13: Correct distance to the measured part*

## 5.4 Establishing Communication

### 5.4.1 Prerequisites

- The general instructions for commissioning have been read and understood.
- The PaintChecker industrial Controller is switched on.
- The PaintChecker industrial Controller is connected to the up-stream control unit via a suitable interface.
- The up-stream control unit is set up for operation with the PaintChecker industrial system.

### 5.4.2 Profinet and Devicenet (user-defined interfaces)

For connection of the communication module, see Pin assignments. The measuring system has the slave address "1". The Lifebit register (table Output signals, 0.0 ) changes its value between 0 and 1 every second. Cyclical reading can be used to determine whether the measuring system is properly registered in the network.

### 5.4.3 OptiSense ASCII-Protokoll

The user connects to the measuring system via its USBUART interface. The measuring system is recognised as a COM port in the device manager of the operating system.

A terminal program (e.g. TeraTerm) should be used to establish communication with the measuring system. The following parameters should be used for the serial interface:

| | |
|---|---|
| Baud rate: | 115200 |
| Data bits: | 8 |
| Stop bits: | 1 |
| Parity: | None |

To check whether the measuring system is properly registered in the network, an sd command is cyclically sent to the system and the response string is checked for the lifebit abbreviation (table Output signals, 0.0). Its value changes between 0 and 1 every second.

# 6. Calibration

### 6.1 Introduction

The PaintChecker systems use the photothermal measuring method to determine the thickness of coatings on a wide variety of substrates. This non-contact, non-destructive method is ideal for measuring paints, powder coatings and glazes on metallic and non-metallic substrates.

The photothermal measurement method does not measure coating thickness values directly, but derives them indirectly from the evaluation of the photothermal measurement signal. Therefore, the individual thermal properties of the coating material and substrate must be taken into account.

Thick, heavy layers need more energy to heat up and cool down more slowly than thin, light layers. During the measurement process, it is therefore important, similar to photography, to optimally adjust the strength of the light source and the measurement time to the respective situation in order to obtain accurate and reproducible measurement results.

In the case of powder coatings and paints, there is also the fact that the user often does not want to know the thickness of the powder or wet film that has just been applied, but the later, final thickness after curing or drying. For this purpose, the device includes the expected shrinkage of the coating material during curing in the calculation.

For this purpose, it is necessary to calibrate the measuring system against reference coating thickness values using samples with a known coating thickness. Such calibrations contain information about the correct laser power, measurement duration, evaluation models and calibration coefficients for the specific material combination. These calibrations can be used directly for measurements on produced parts.

### 6.2 Included calibrations

Calibrations that are specifically relevant to the particular customer are stored by OptiSense on each instrument in the form of system calibrations. The scope of delivery may include calibrations for standard situations, which already cover a large part of the typical applications.

In addition, each customer receives a system calibration tailored specifically to his application. This is created by OptiSense using coating samples provided. Additional system calibrations can be ordered from OptiSense as a calibration service and can be permanently stored in the instrument.

The calibration to be used can be activated by the up-stream control unit. The coating thickness is then calculated based on the currently active calibration.

### 6.3 User calibration

Process-related deviations from the system calibration lead to a discrepancy between the displayed measured value and the actual layer thickness. The user can compensate for this deviation with a user calibration so that the actual layer thickness is displayed again.

For this purpose, a variant of the system calibration is generated, which can be modified and saved by the user without changing the underlying system calibration. User calibrations can then be selected as the basis for measurements in the same way as system calibrations.

**TIPP!**

Calibration is performed using OptiSense's OS Manager software. Please refer to the OS Manager Software manual for full details of the various calibration options

### 6.4 Reference samples and reference masters

#### 6.4.1 Reference samples

Since the measurement system operates on the thermal properties of the coating of the sample, it is essential that the reference sample has the same material properties as the parts to be measured later. Furthermore, it is necessary that the coating thicknesses of the reference samples are distributed as evenly as possible over the coating thickness range to be measured in the application. Layer thicknesses outside the calibrated measuring range may deviate significantly from the actual thicknesses under certain conditions.

#### 6.4.2 Reference Master

For all users who require a particularly high level of safety, accuracy and reliability from their coating thickness measurement, the reference masters from OptiSense, certified by a DAkkS laboratory, are the ideal solution. The reference masters are used for regular checking of the measuring system and the calibration. Reference masters are not part of the measuring system, but may be ordered as an option.

Reference masters are paint samples with a well defined coating thickness that are attached to a test specimen. They are custom-made and are provided with exactly the same coating that will later be used in production.

The reference master is therefore often made directly from an original part.

*Fig. 14: Reference Master*

Our reference masters are certified by a DAkkS laboratory and are regarded as a high standard in terms of accuracy and traceability

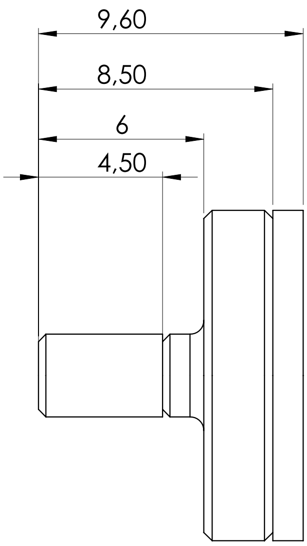



*Fig. 15: Dimensional drawing of a reference sample*

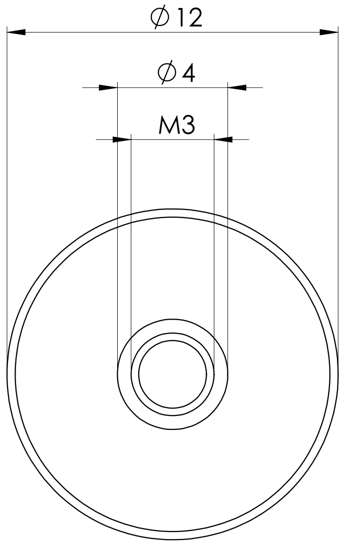



*Fig. 16: Dimensional drawing of a reference sample*

In addition to the standard M3 thread, other sizes are also available.

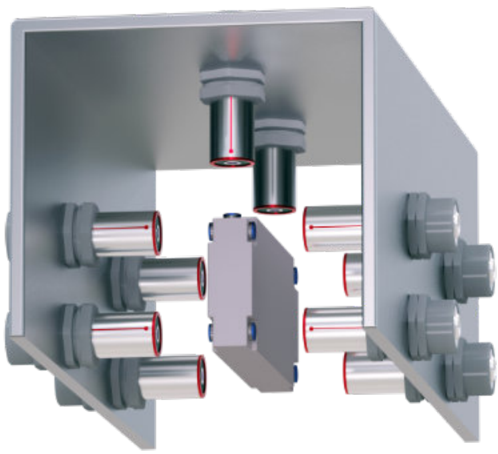


*Fig. 17: Typical application of a Reference Master*

# 7. Operation

## 7.1 Measuring procedure

### 7.1.1 Prerequisites

- The general instructions for commissioning have been read and understood by the user.
- The sensors are properly connected.
- The PaintChecker industrial Controller is switched on.
- The PaintChecker industrial Controller is connected to the up-stream control unit via a suitable interface.
- The up-stream control unit is set up for operation with the PaintChecker industrial system.
- Communication between the control unit and the measuring system has been established

### 7.1.2 Execution

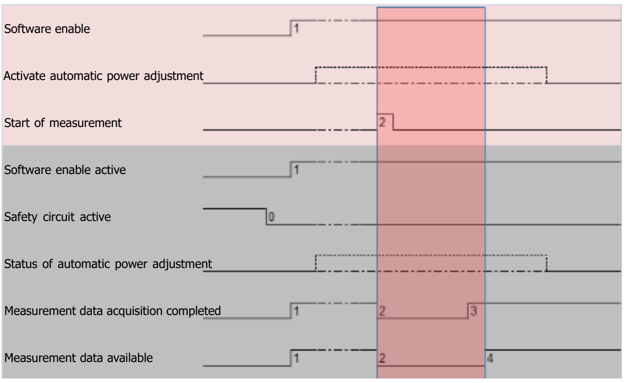



*Fig. 18: Typical measurement sequence*

The figure shows the typical measurement sequence of an automated coating thickness measurement. The fields shown in red correspond to the commands from the up-stream control unit. The fields highlighted in grey represent the feedback signals from the measuring system.

The following steps are required to carry out coating thickness measurements.

1. With PaintChecker industrial, the sensors to be used must be activated via control channels 1.0 - 1.7. The connection status is indicated on output channels 21.0 - 21.7. The sensor at the first port is automatically activated.
2. After that, a suitable calibration must be loaded via input signal bits 0.8 to 0.11 (table Input signals). The active calibration is indicated on output channel 10.
3. Now it must be made sure that the safety circuit is closed. This is indicated on output channel 0.4 (table Output signals).
4. The software release (table Control commands, 0.0) must be activated. The successful release is indicated on the software release active flag (table Output signals, 0.3). It is recommended to leave the software release active until the safety circuit is switched. In addition, the signals *Measurement data recording* completed (table Output signals, 0.1) and *Measurement data available* (table Output signals, 0.5) are activated. Sensors must be connected to all activated ports to be able to activate the software release.
5. If the measured part is positioned correctly, the measurement is triggered (Table Control commands, 0.4). Subsequently, the signals Measurement data acquisition completed and Measurement data available are deactivated. Make sure that the sensors are not moved during measurement data acquisition.
6. After the measurement data has been acquired, the signal *Measurement data acquisition completed* is activated. The sensors can now be moved to the next measuring point.
7. After measurement data processing is complete, the signal *Measurement data available* is activated. The measured values can now be retrieved.
8. The measurement is done.

The PaintChecker industrial Controller has an automatic power adjustment that is activated via Control commands, 0.7). This adjusts the excitation power of the light source so that optimal measurement results can be achieved. However, this is sometimes associated with a longer measurement time because the power of each individual sensor needs to be adjusted during the measurement.

It is recommended to use this function, if needed, only at the beginning for the first point of a measurement series. This bit is only used for special applications in consultation with OptiSense.

The further measurements are then carried out with the power settings determined at the first point. The status of the automatic power adjustment can be read out in Output signals 0.6.

## 7.2 Self-test

As described in the photothermal standard DIN EN 15042-2:2006, the basic functional test of the measurement system should be carried out with an optically impermeable homogeneous test specimen with proper long-term stability. This check ensures proper operation and should be repeated at regular intervals.

A reference glass (NG1) with well defined optical and thermal properties which can be used as a test specimen is available from OptiSense as an accessory. During the test, this glass should be positioned exactly at the working distance (see Technical Data).

After positioning the reference sample, the measuring system can be set to self-test mode with the help of Control commands 0.12. This transfers the necessary measurement settings to all activated sensors.

Afterwards, the reference measurements can be carried out as described in Measuring procedure. The measured time signal of each sensor is now output on the channels for the layer thickness. The strength of the photothermal signal can be read out on the channels for the photothermal amplitude. The values indicate the percentage of deviation from the target values stored in the respective sensor.

If one of the above values is outside of the permitted specifications, this is indicated as an error message on the error channel of the respective sensor.

# 8. Communication Protocols

## 8.1 Introduction

Depending on the equipment, various communication interfaces are available for controlling the PaintChecker industrial system. The most common interfaces Profinet IO, deviceNet, NativeIP: RJ45, USB and the OptiSense ASCII protocol are described in the tables below.

The control commands are described in table Control commands. The output parameters are described in table Output signals.

## 8.2 Modbus RTU

To control the measuring system via Modbus RTU, the register entries of the Modbus RTU register column specified in table Control commands and table Output signals must be used. The measuring system is accessible as a Modbus slave via address "1".

The serial interface of the up-stream control unit must be set to the following parameters beforehand:

Baud rate: 57600
Data bits: 8
Stop bits: 1
Parity: None

The registers of the control commands (table Control commands) can be sent completely with the function code Write multiple coils (0x0f) as well as individually with the code Write single coil (0x05).

The register structure of the output signals (table Output signals) can be read with the function code Read Input Register (0x04). The cycle time is 50 ms.

## 8.3 Profinet

The Profinet interface is implemented via a protocol converter that is connected as a master to the Modbus RTU slave interface. The 2-byte values are output as little-endian.

To connect the up-stream control unit to the measuring system, the corresponding configuration file (GDSML) of the converter must first be integrated in the up-stream control unit (see manual of the control unit)

Then the register addresses specified in table Control commands and table Output signals can be written or read out. The cycle time is 20 ms. New commands are transmitted when the signals change (Update-on-Change).

## 8.4 OptiSense ASCII protokoll

The PaintChecker industrial controller is controlled by ASCII commands via the serial interface of the measuring system.

The serial interface of the up-stream control unit must be set to the following parameters beforehand:

Baud rate: 115200
Data bits: 8
Stop bits: 1
Parity: None

The character strings listed in column "ASCII command" are to be used for communication.

| Input | Meaning | Response |
|---|---|---|
| oce,1,1 | Sensor 1 activated | con1,1 |
| oce,1,0 | Sensor 1 deactivated | con1,0 |
| fe,1 | Software release granted | mse,1 |
| fe,0 | Software release withdrawn | mse,0 |
| tt | Trigger measurement, after measurement output layer thickness | cth,535 |

*Table 1: Application examples ASCII protocol*

A response is given by the entries in column ASCII abbreviation. If several quantities are output simultaneously, they are separated by a semicolon.

Example

- Output line: dnh,0;dnl,12;dth,0;dtl,12345.
- Output of number of measurements (12) and
- system runtime (12345ms)

In addition to the messages of the measuring system in response to command inputs, the current measurement data status and the current system status can be queried via the commands sd and si.

All output values are coded as UINT16. For correct conversion of the measurement data, their respective output format described in the unit column in Output signals must be observed.

### 8.5 Error codes

In case of measurement errors, the error messages are output via the respective error signals for the controller and each sensor separately (table Output signals). The error messages are coded bit by bit so that several error messages can be output simultaneously on one channel. These can then be broken down using the Error Bits table.

Example:

Error code 134 is output. This corresponds to error bits 1,2 and 7, since 21 + 22 + 27 = 134

| Error bit | Error description | Corrective action |
|---|---|---|
| 0 | Measurement was triggered, but software enable is not activated | Activate software release |
| 1 | Measurement was triggered, but safety circuit is not activated | Close safety circuit and reset safety switch |
| 2 | Warning of increased sensor temperature | • If possible, reduce measuring frequency<br>• mount the sensor in a heat-dissipating holder |
| 3 | Sensor overheated | • If possible, reduce measuring frequency<br>• mount the sensor in a heat-dissipating holder. |
| 4 | Laser power too low | Please contact OptiSense Service |
| 5 | Photothermal signal too weak | Use a measurement setting with higher laser power |
| 6 | Photothermal signal too high | Use a measurement setting with lower laser power |
| 7 | Component temperature too low (< 0° C) | Warm up the component to room temperature |
| 8 | Error in laser supply | Please contact OptiSense Service |
| 9 | Amplitude signal of the reference measurement out of specification | • Make sure that the reference surface is clean and free of scratches<br>• check the correct positioning of the reference sample to the sensor<br>• if the error persists, please contact OptiSense Service. |
| 10 | Time signal of reference measurement outside specifications | • Make sure the reference surface is clean and free of scratches<br>• check the correct positioning of the reference sample to the sensor<br>• if the error persists, please contact OptiSense Service. |
| 11 | Layer thickness above calibration limit | Use a calibration with a higher boundary layer thickness |
| 12 | Layer thickness below calibration limit | Use a calibration with lower boundary layer thickness |
| 13 | Photothermal signal below calibration limit | Use calibration with lower photothermal signal limit |
| 14 | Sensor not connected | Make sure that the sensor is connected to the activated port of the sensor |

*Table 2: Error bits*

# 9. Maintenance

## 9.1 Spare parts

**TIP!** An annual inspection and maintenance of the measuring system by OptiSense or by personnel instructed by OptiSense is recommended.

The following spare parts are available from OptiSense GmbH & Co. KG

- Sensor
- Sensor cable
- Controller
- Harting connector set (power supply, network and safety circuit)

Spare parts fitting to the particular measuring system can be obtained from OptiSense by quoting the serial number of the controller and the equipment.

E-mail: info@optisense.com
Tel. +49 23 64 50 882-0

## 9.2 Replacing the sensor cable

To replace a defective cable, first ensure that the mains power for the controller is interrupted. If this is not possible due to the up-stream control unit, the connector X16 should be removed. All LEDs of the controller must be inactive (off).

The plugs of the defective cable must now be disconnected at the controller and sensor end. Remove the cable and insert the new cable into the cable guide (red side on the sensor and black on the controller). The plugs are to be positioned so that the red points on the plug and socket are facing each other. Then insert the plug until it snaps into place.

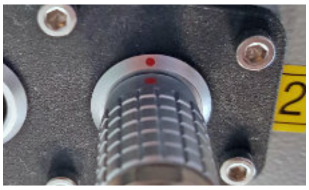
| Plug | |
|---|---|
| **Controller** | **Sensor** |
|  |  |
|  |  |

*Table 3: Sensor cable connector*

## 9.3 Replacement of Controller

If a replacement controller has been ordered for a particular installation, it is already set up to be used with the existing sensors and the respective measurement task. However, the specific network parameters of the installation must be entered.

First, all plugs on the defective controller are removed and each sensor cable is marked to identify into which socket it was plugged. Then the defective controller is removed from the system.

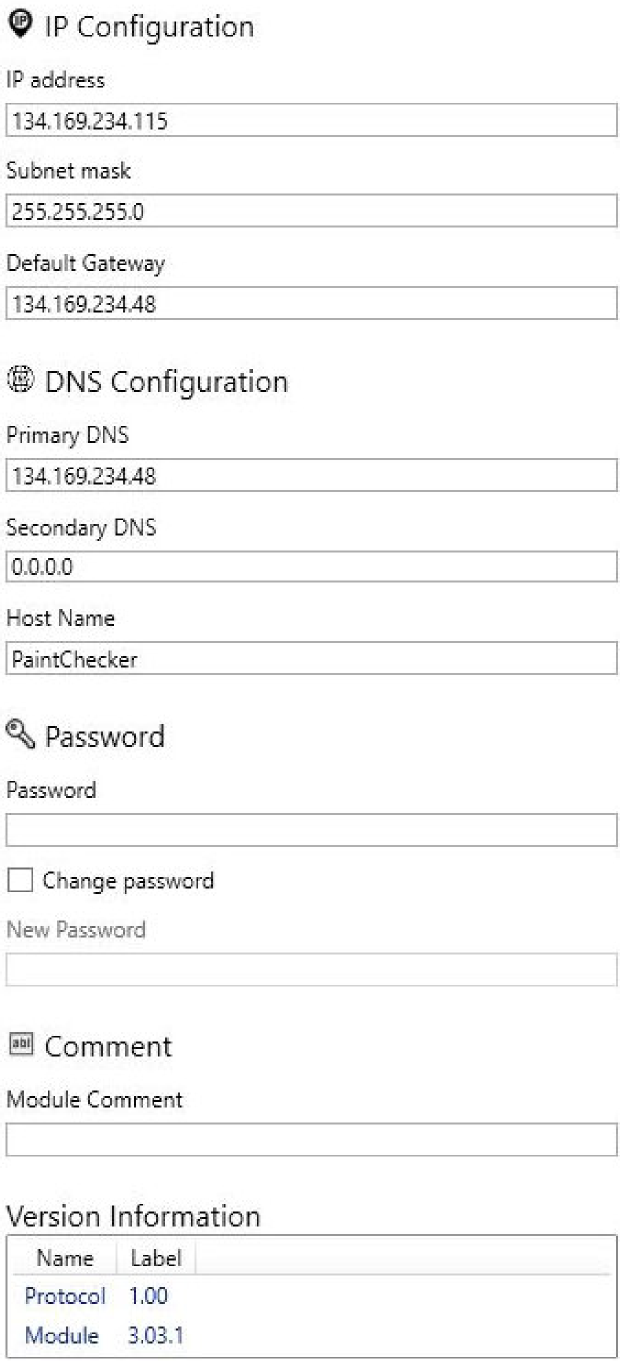



*Fig. 19: System configuration*

After installing the new controller, all plugs are reconnected to their corresponding sockets. Cable X16 must be plugged in last so that the controller is not powered up before the sensor cables are plugged in.

A PC with the IPConfig software from HMS installed is required for the network setting of the new controller. This software can be downloaded free of charge from the following link:

https://www.anybus.com/technical-support/pages/files-and-documentation/?ordercode=AB7013

First, a network connection is established between the PC and the controller (either via the respective switch or directly via connector X14) and then the IPConfig software is started.

The Update button in the upper left corner is used to select the corresponding Anybus (default setting on delivery: PaintChecker DHCP: ON, see fig. 20).

Now the network settings for the system can be entered in the right-hand side of the window and applied by pressing the Apply button. The settings become active after cycling the power of the controller.

### 9.4 Replacing a Sensor

To replace a defective sensor, first ensure that the mains power for the controller is interrupted. If this is not possible due to the up-stream control unit, the connector X16 should be removed. All LEDs of the controller must be inactive (off).

Then, if necessary, unplug the red end of the cable from the sensor.

After the controller's power supply has been restored, the LEDs on the sensor will first flash and then light up permanently as soon as the software release has been given by the up-stream control unit. The sensor is now functional.

To align the distance between the sensor and the part to be measured, the sensor must be positioned so that the three LED dots of the illuminated sight converge in one point. For optimal adjustment, several measurements with slightly varying distance should be carried out. The sensor is correctly adjusted if the Photothermal Amplitude value is at maximum.

### 9.5 Transport and storage

The controller and sensor should be stored under the following conditions:

- Do not store outdoors
- Store in a dry and dust-free place
- Do not expose to aggressive substances
- Protect from sunlight
- Avoid mechanical shocks

Improper storage can lead to material damage at the measuring system.

### 9.6 Cleaning and maintenance

All maintenance work must be carried out exclusively by OptiSense GmbH & Co. KG. In particular, the controller unit must never be opened by unqualified personnel and the front ring of the sensor must never be unscrewed.

**Caution!**

The use of corrosive, abrasive and scratching cleaning agents can severely damage the materials of the sensor.

- Never use solvents for cleaning.

Please use only lens cleaning cloths suitable for optical lenses. In case of severe contamination, wipe the controller and sensor with a damp, soft cloth.

### 9.7 Transport and storage

*Fig. 20: Disposal*

# 10. Technical Data

## 10.1 System specifications

### 10.1.1 Sensor models

The aluminium sensors are designed for mounting on fixed receptacles.

The readily assembled cable between sensor and controller has a length of 3 m, but is also available in a 5 m version.

**Technical Data | Industrial Sensors**

| **Model** | **Angle-LLP1.6** | **Angle-LHP1.6** | **Tube-LLP3.5** | **Tube-LHP3.5** | **Tube-LHP10** | **Cube-LEDR3.3** | **Cube-LEDB3.3** |
|---|---|---|---|---|---|---|---|
| Design | Laser, Angle | | Laser, Cylinder | | | LED, Cube | |
| Measurement range | 1 - 1000 µm | | | | | | |
| Measurement rate | max. 2.5 Hz | | | | | | |
| Measurement time | 125 - 1000 ms | | | | | | |
| Operating mode | pulsed operation | | | | | | |
| Resolution | 1 % of reading | | | | | | |
| Accuracy | 3 % of reading | | | | | | |
| Measuring distance from lens | 16 mm | | 35 mm | | 100 mm | 33 mm | |
| Distance tolerance | ± 1 mm | | ± 2.5 mm | | ± 5 mm | ± 3 mm | |
| Angular tolerance | ± 45 ° | | | | | | |
| Size of measuring field | 0.2 mm | | 0.3 mm | | 0.5 mm | 1 mm | |
| Maximum pulse energy | 650 mJ | 1250 mJ | 650 mJ | 1250 mJ | 1250 mJ | 1700 mJ | 850 mJ |
| Wavelength | 1470 nm | | | | | 980 nm | 360 nm |
| Laser class | 1M | | 3R | | | Risk 1 | Risk 3 |
| Eye safety | yes | no | yes | no | | yes | |
| Dimensions (L x W x H) | 87 x 28 x 41 mm | | Ø 30 x 102 mm | | | 50 x 51.6 x 55 mm | |
| Weight | 180 g | | 150 g | | | 280 g | |
| IP Code | IP 50 | | | | | | |

*Table 4: Sensor specifications*

## 10.1.2 Controller

The controller contains the power supply and control circuitry for up to 8 sensors, as well as the components for data acquisition and storage of measurement configuration settings in a robust IP50 aluminium housing.

Communication with a connected PC is performed via serial interface and/or Profinet IO. The complete control of the measurement process and storage of the measurement data is available on a PC by using visualisation software provided by OptiSense.


**Technical Data | Controller industrial**

| **Model** | **LP** | **LED** | **HP** | **n-gauge** | **n-gauge LED** | **n-gauge HP** |
|---|---|---|---|---|---|---|
| Sensor outputs | 1 | 1 | 1 | 4/8 | 4/8 | 8 |
| Sensor type | Laser | LED | High-power Laser | Laser | LED | High-power Laser |
| Eye-safe | yes | yes | no | yes | yes | no |
| Power supply | 100 - 230 V AC, 50 - 60 Hz | | | | | |
| Operating Voltage | 150 W | 200 W | 150 W | 150 W | 200 W | 300 W |
| Power supply | integrated | | | | | separate |
| Dimensions (L x W x H) | 330 x 272 x 110 mm | | | | | 2 x |
| Weight | 6,4 kg (+ 5.4 kg for the additional power supply of the Industrial PaintChecker n-gauge HP) | | | | | |
| Interfaces | ProfinetIO / deviceNet / NativeIP: RJ45<br>USB | | | | | |
| Humidity | 0 - 90 %, non-condensing | | | | | |
| Operating temperature | 10 - 40 °C | | | | | |
| Storage temperature | 0 - 50 °C | | | | | |
| IP Code | IP50 | | | | | |
| Standards | DIN EN 15042-2 | | | | | |

*Table 5: Controller specifications*

### 10.1.3 Circuit Diagram

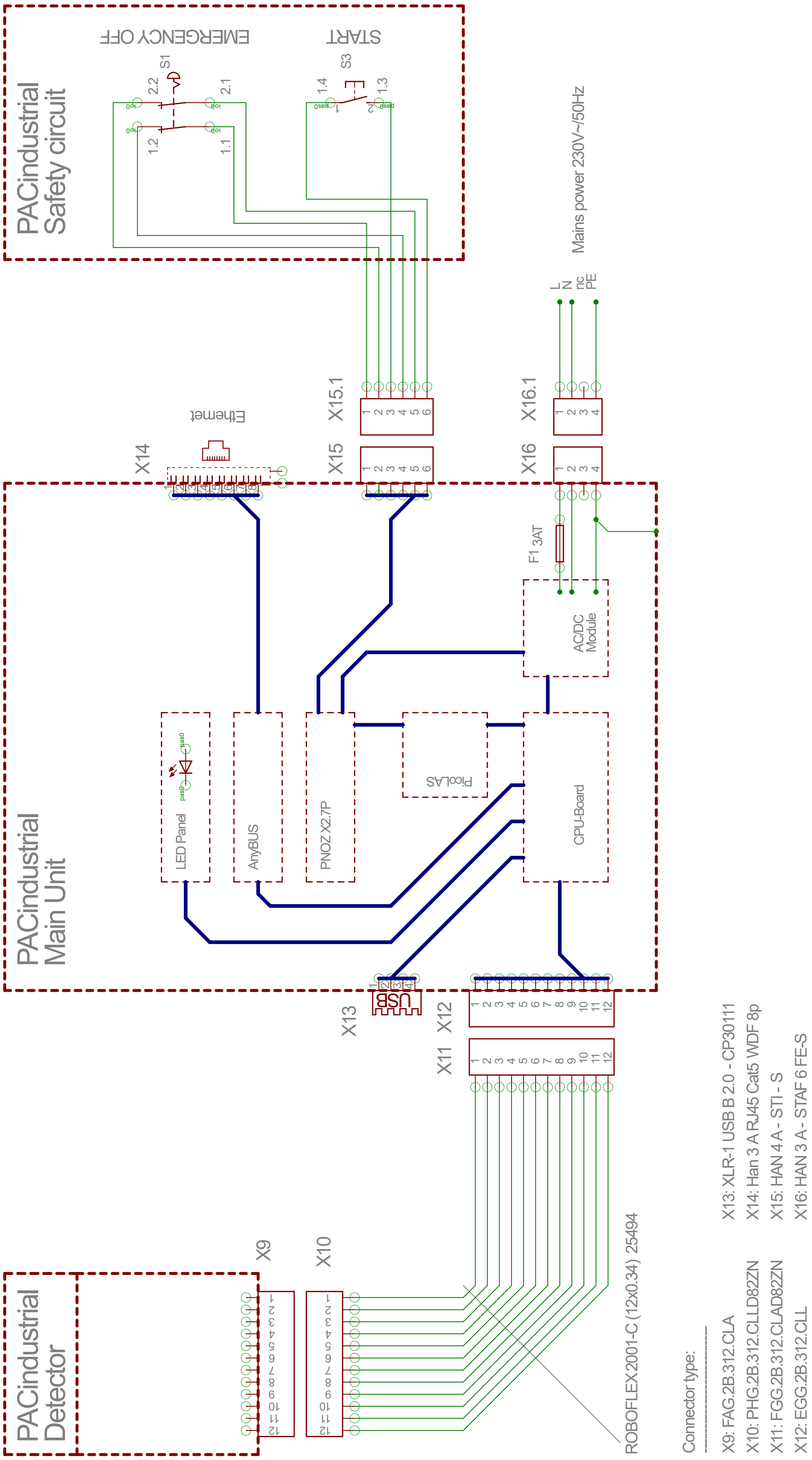



*Fig. 21: Circuit diagram*

### 10.1.4 Pin assignments

| X14: TCP/IP-Connector at Controller (cable length max. 35m) | | | | |
|---|---|---|---|---|
| **Function** | **Harting RJ Industr. IP67Data3A** | **Wire number** | **RJ45 female/male Control** | **RJ45 Pin number** |
| Tx+ | 1 | 1 | Tx+ | 1 |
| Tx- | 7 | 2 | Tx- | 2 |
| Rx+ | 3 | 3 | Rx+ | 3 |
| Rx- | 9 | 4 | Rx- | 6 |

*Table 6: Pin assignment X14*

| X15 / X15.1: Safety circuit at Controller (Max. cable length see 1* below) | | | |
|---|---|---|---|
| **Function** | **Harting housing male/female** Han 4A-STI-S | **Wire number** | **Connection controls** |
| START (Laser enable) | X15.3 | 1 | S3 / 1.3 |
| | X15.6 | 2 | S3 / 1.4 |
| NOT-Aus 1 | X15.1 | 3 | S1 / 1.1 |
| | X15.4 | 4 | S1 / 1.2 |
| NOT-Aus 2 | X15.5 | 5 | S1 / 2.1 |
| | X15.2 | 6 | S1 / 2.2 |

*Table 7: Pin assignment X15 / X15.1*

| X16 / X16.1: Power supply 230V~/50Hz (Cable length max. 35m) | | | | |
|---|---|---|---|---|
| **Function** | **Harting housing male** Han 3A-STAF 6 FE -S | **Harting housing female** Han 3A-STAF 6 | **Wire number** | **Supply port 230V~/50Hz** |
| L | X16.1 | X16.1.1 | 1 | ~ L |
| N | X16.2 | X16.1.2 | 2 | ~ N |
| Reserve | X16.3 | X16.1.3 | 3 | Reserve |
| PE | X16.4 | X16.1.4 | PE | PE |

*Table 8: Pin assignment X16 / X16.1*

| X17: Anybus PC Connector (Cable length max. 35m) | | | |
|---|---|---|---|
| **Anybus** Function | **Anybus** PC Connector | **Sub-D** Function | **LTW housing female** DB-09PFFS-SL7001 |
| GND | 1 | GND | X17.5 |
| GND | 2 | GND | X17.5 |
| RS232 Rx | 3 | RS232 Tx | X17.3 |
| RS232 Tx | 4 | RS232 Rx | X17.2 |

*Table 9: Pin assignment X17*

1* Calculation of the max. cable length $I_{max}$ in the input circuit: $I_{max} = R_{Imax}/(R_I/km)$
with $R_{Imax}$ = total cable resistance and $R_I/km$ = cable resistance/km

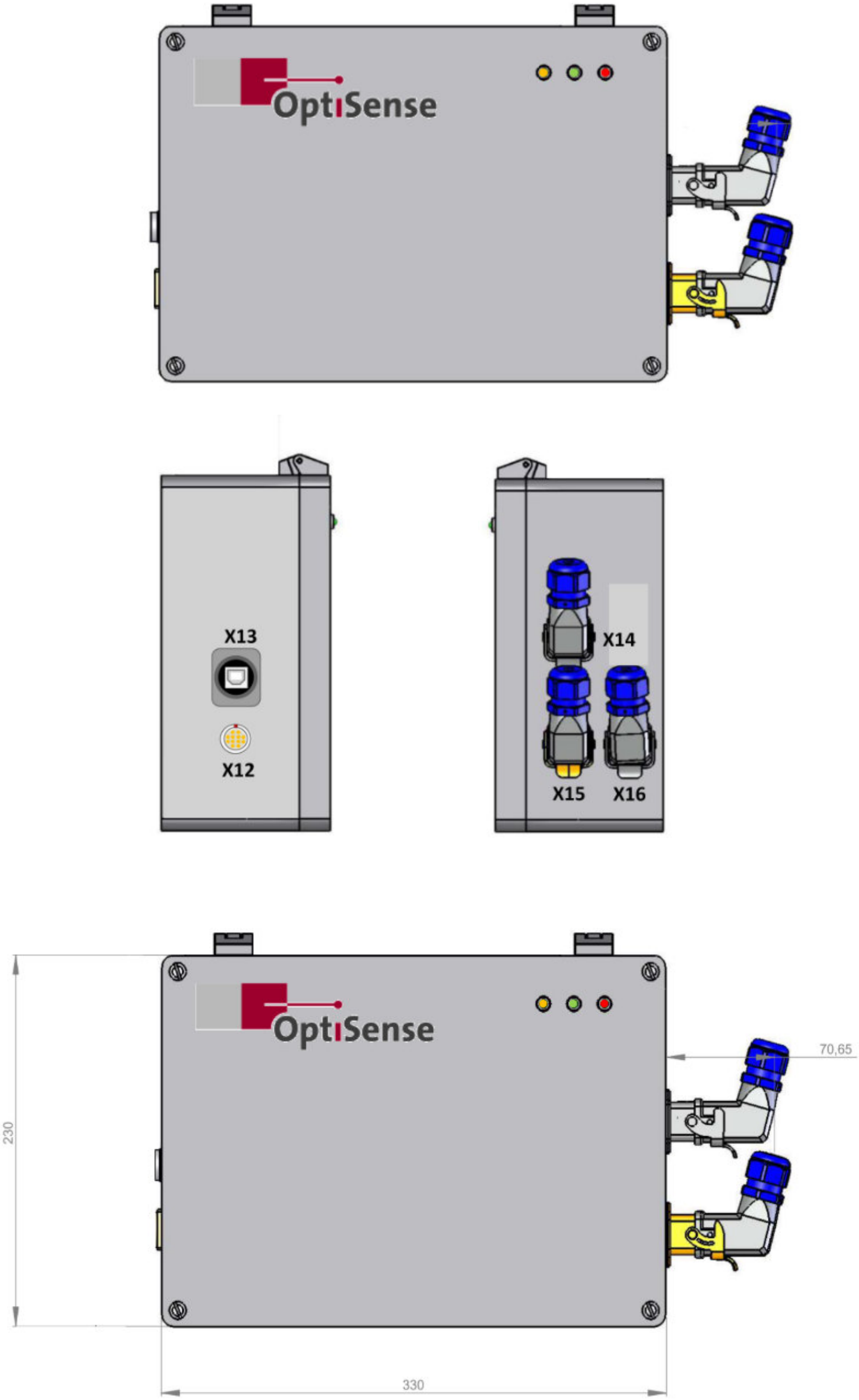



*Fig. 22: Connector locations*

## 10.2 Measurement system control protocol

### 10.2.1 Control commands

| | | | | Modbus-RTU Register | | ASCII | | Profi-Net IO |
|---|---|---|---|---|---|---|---|---|
| # | Designation | Unit | Size | Byte | Bit | Command | Abbr. | Range |
| 0 | Digital input register 1 | | 2 Byte | 0 | | | | 0 - 15 |
| 0.0 | Software enable | # | 1 Bit | 0 | 0 | fe,<#> | mse | 0 |
| 0.1 | Not used | # | 1 Bit | 0 | 1 | | | 1 |
| 0.2 | Not used | # | 1 Bit | 0 | 2 | | | 2 |
| 0.3 | Not used | # | 1 Bit | 0 | 3 | | | 3 |
| 0.4 | Start of measurement | # | 1 Bit | 0 | 4 | tt | cth | 4 |
| 0.5 | Not used | # | 1 Bit | 0 | 5 | | | 5 |
| 0.6 | Reset error counter | # | 1 Bit | 0 | 6 | r | ecc | 6 |
| 0.7 | Activate automatic power ad-justment | # | 1 Bit | 0 | 7 | fa,<#> | aas | 7 |
| 0.8 | Select measurement settings Bit 0 | 1-16 | 1 Bit | 0 | 8 | cla,<#> | acg | 8 |
| 0.9 | Bit 1 | 1-16 | 1 Bit | 0 | 9 | | | 9 |
| 0.10 | Bit 2 | 1-16 | 1 Bit | 0 | 10 | | | 10 |
| 0.11 | Bit 3 | 1-16 | 1 Bit | 0 | 11 | | | 11 |
| 0.12 | Activate self-test with gray glass sample | # | 1 Bit | 0 | 12 | fs,<#> | sts | 12 |
| 1 | Digital input register 2 | | 2 Byte | 1 | | | | 16 - 31 |
| 1.0 | Activate sensor 1 | # | 1 Bit | 1 | 0 | oce,1,<#> | con1 | 16 |
| 1.1 | Activate sensor 2 | # | 1 Bit | 1 | 1 | oce,2,<#> | con2 | 17 |
| 1.2 | Activate sensor 3 | # | 1 Bit | 1 | 2 | oce,3,<#> | con3 | 18 |
| 1.3 | Activate sensor 4 | # | 1 Bit | 1 | 3 | oce,4,<#> | con4 | 19 |
| 1.4 | Activate sensor 5 | # | 1 Bit | 1 | 4 | oce,5,<#> | con5 | 20 |
| 1.5 | Activate sensor 6 | # | 1 Bit | 1 | 5 | oce,6,<#> | con6 | 21 |
| 1.6 | Activate sensor 7 | # | 1 Bit | 1 | 6 | oce,7,<#> | con7 | 22 |
| 1.7 | Activate sensor 8 | # | 1 Bit | 1 | 7 | oce,8,<#> | con8 | 23 |

*Table 10: Input signals*

### 10.2.2 Output signals

| | | | | Modbus-RTU Register | | ASCII | | Profi-Net IO |
|---|---|---|---|---|---|---|---|---|
| # | Designation | Unit | Size | Byte | Bit | Command | Abbr. | Range |
| 0 | Digital output register | # | 2 Byte | 0 | | | dmo | 0 - 15 |
| 0.0 | Lifebit of measurement con-troller | # | 1 Bit | 0 | 0 | si | lbc | 0 |
| 0.1 | Measurement data acquisition completed | # | 1 Bit | 0 | 1 | si | mfh | 1 |
| 0.2 | Layer thickness calculation completed | # | 1 Bit | 0 | 2 | si | cfl | 2 |
| 0.3 | Software enable active | # | 1 Bit | 0 | 3 | si | mse | 3 |
| 0.4 | Safety circuit active | # | 1 Bit | 0 | 4 | si | sce | 4 |
| 0.5 | Measurement data available | # | 1 Bit | 0 | 5 | si | mdu | 5 |
| 0.6 | Status of automatic power ad-justment | # | 1 Bit | 0 | 6 | si | aas | 6 |
| 0.7 | Status of laser driver (High Power Controller only) | # | 1 Bit | 0 | 7 | si | lco | 7 |
| 0.8 | Status self test with gray glass | # | 1 Bit | 0 | 8 | si | sts | 8 |
| 1 | Layer thickness (at sensor 1) | 0,1 µm | 2 Byte | 1 | | sd | cth | 16 - 31 |
| 2 | Not used | 0,01 W | 2 Byte | 2 | | sd | lap | 32 - 47 |
| 3 | Temperature of target object (at sensor 1) | 0,01 °C | 2 Byte | 3 | | sd | bgt | 48 - 63 |
| 4 | Temperature of sensor (at sensor 1) | 0,01 °C | 2 Byte | 4 | | sd | det | 64 - 79 |
| 5 | Number of measurements (High-Word) | # | 2 Byte | 5 | | sd | dnh | 80 - 95 |
| 6 | Number of measurements (Low-Word) | # | 2 Byte | 6 | | sd | dnl | 96 - 111 |
| 7 | Running time (High-Word) | ms | 2 Byte | 7 | | sd | dth | 112 - 127 |
| 8 | Running time (Low-Word) | ms | 2 Byte | 8 | | sd | dtl | 128 - 143 |
| 9 | Photothermal amplitude (at sensor 1) | 0,01 °C | 2 Byte | 9 | | sd | pam | 144 - 159 |
| 10 | Number of current measure-ment setting | # | 2 Byte | 10 | | sd | acg | 160 - 175 |
| 11 | Not used | 0 | 2 Byte | 11 | | sd | 0 | 176 - 191 |
| 12 | Not used | 0 | 2 Byte | 12 | | sd | 0 | 192 - 207 |
| 13 | Not used | 0 | 2 Byte | 13 | | sd | 0 | 208 - 223 |
| 14 | Not used | 0 | 2 Byte | 14 | | sd | 0 | 224 - 239 |
| 15 | Not used | 0 | 2 Byte | 15 | | sd | 0 | 240 - 255 |

| | | | | Modbus-RTU Register | | ASCII | | Profi-Net IO |
|---|---|---|---|---|---|---|---|---|
| # | **Designation** | **Unit** | **Size** | **Byte** | **Bit** | **Command** | **Abbr.** | **Range** |
| 16 | Not used | 0 | 2 Byte | 16 | | sd | 0 | 256 - 271 |
| 17 | Not used | 0 | 2 Byte | 17 | | sd | 0 | 272 - 287 |
| 18 | Counter of error messages | # | 2 Byte | 18 | | sd | ecc | 288 - 303 |
| 19 | Error code for sensor 1 | # | 2 Byte | 19 | | sd | err | 304 - 319 |
| 20 | Error code for measurement controller | # | 2 Byte | 20 | | sd | ecl | 320 - 335 |
| 21 | Register connection status sensors | # | 2 Byte | 21 | | sd | scr | 336 - 351 |
| 21.0 | Sensor 1 connected | # | 1 Bit | 21 | 0 | si | con1 | 336 |
| 21.1 | Sensor 2 connected | # | 1 Bit | 21 | 1 | si | con2 | 337 |
| 21.2 | Sensor 3 connected | # | 1 Bit | 21 | 2 | si | con3 | 338 |
| 21.3 | Sensor 4 connected | # | 1 Bit | 21 | 3 | si | con4 | 339 |
| 21.4 | Sensor 5 connected | # | 1 Bit | 21 | 4 | si | con5 | 340 |
| 21.5 | Sensor 6 connected | # | 1 Bit | 21 | 5 | si | con6 | 341 |
| 21.6 | Sensor 7 connected | # | 1 Bit | 21 | 6 | si | con7 | 342 |
| 21.7 | Sensor 8 connected | # | 1 Bit | 21 | 7 | si | con8 | 343 |
| 22 | Layer thickness at sensor 2 | # | 2 Byte | 22 | | sd | cth2 | 352 - 367 |
| 23 | Layer thickness at sensor 3 | # | 2 Byte | 23 | | sd | cth3 | 368 - 383 |
| 24 | Layer thickness at sensor 4 | # | 2 Byte | 24 | | sd | cth4 | 384 - 399 |
| 25 | Layer thickness at sensor 5 | # | 2 Byte | 25 | | sd | cth5 | 400 - 415 |
| 26 | Layer thickness at sensor 6 | # | 2 Byte | 26 | | sd | cth6 | 416 - 431 |
| 27 | Layer thickness at sensor 7 | # | 2 Byte | 27 | | sd | cth7 | 432 - 447 |
| 28 | Layer thickness at sensor 8 | # | 2 Byte | 28 | | sd | cth8 | 448 - 463 |
| 36 | Temperature of target object at sensor 2 | # | 2 Byte | 36 | | sd | bgt2 | 576 - 591 |
| 37 | Temperature of target object at sensor 3 | # | 2 Byte | 37 | | sd | bgt3 | 592 - 607 |
| 38 | Temperature of target object at sensor 4 | # | 2 Byte | 38 | | sd | bgt4 | 608 - 623 |
| 39 | Temperature of target object at sensor 5 | # | 2 Byte | 39 | | sd | bgt5 | 624 - 639 |
| 40 | Temperature of target object at sensor 6 | # | 2 Byte | 40 | | sd | bgt6 | 640 - 655 |
| 41 | Temperature of target object at sensor 7 | # | 2 Byte | 41 | | sd | bgt7 | 656 - 671 |

| | | | | Modbus-RTU Register | | ASCII | | Profi-Net IO |
|---|---|---|---|---|---|---|---|---|
| # | Designation | Unit | Size | Byte | Bit | Command | Abbr. | Range |
| 42 | Temperature of target object at sensor 8 | # | 2 Byte | 42 | | sd | bgt8 | 672 - 687 |
| 43 | Temperature of sensor 2 | # | 2 Byte | 43 | | sd | det2 | 688 - 703 |
| 44 | Temperature of sensor 3 | # | 2 Byte | 44 | | sd | det3 | 704 - 719 |
| 45 | Temperature of sensor 4 | # | 2 Byte | 45 | | sd | det4 | 720 - 735 |
| 46 | Temperature of sensor 5 | # | 2 Byte | 46 | | sd | det5 | 736 - 751 |
| 47 | Temperature of sensor 6 | # | 2 Byte | 47 | | sd | det6 | 752 - 767 |
| 48 | Temperature of sensor 7 | # | 2 Byte | 48 | | sd | det7 | 768 - 783 |
| 49 | Temperature of sensor 8 | # | 2 Byte | 49 | | sd | det8 | 784 - 799 |
| 50 | Photothermal amplitude at sensor 2 | # | 2 Byte | 50 | | sd | pam2 | 800 - 815 |
| 51 | Photothermal amplitude at sensor 3 | # | 2 Byte | 51 | | sd | pam3 | 816 - 831 |
| 52 | Photothermal amplitude at sensor 4 | # | 2 Byte | 52 | | sd | pam4 | 832 - 847 |
| 53 | Photothermal amplitude at sensor 5 | # | 2 Byte | 53 | | sd | pam5 | 848 - 863 |
| 54 | Photothermal amplitude at sensor 6 | # | 2 Byte | 54 | | sd | pam6 | 864 - 879 |
| 55 | Photothermal amplitude at sensor 7 | # | 2 Byte | 55 | | sd | pam7 | 880 - 895 |
| 56 | Photothermal amplitude at sensor 8 | # | 2 Byte | 56 | | sd | pam8 | 896 - 911 |
| 57 | Error code of sensor 2 | # | 2 Byte | 57 | | sd | err2 | 912 - 927 |
| 58 | Error code of sensor 3 | # | 2 Byte | 58 | | sd | err3 | 928 - 943 |
| 59 | Error code of sensor 4 | # | 2 Byte | 59 | | sd | err4 | 944 - 959 |
| 60 | Error code of sensor 5 | # | 2 Byte | 60 | | sd | err5 | 960 - 975 |
| 61 | Error code of sensor 6 | # | 2 Byte | 61 | | sd | err6 | 976 - 991 |
| 62 | Error code of sensor 7 | # | 2 Byte | 62 | | sd | err7 | 992 - 1007 |
| 63 | Error code of sensor 8 | # | 2 Byte | 63 | | sd | err8 | 1008 - 1023 |

*Table 11: Output signals*

# OptiSense.
# At your service, worldwide.

**Headquarter Germany**

**OptiSense GmbH & Co. KG**
Annabergstraße 120
45721 Haltern am See
GERMANY
Tel. +49 2364 50882-0
info@optisense.com
www.optisense.com

**America**
**USA** | UPA Technology Inc.
**Brazil** | groupwork Serviços de Representação Comercial Ltda.

**Europe**
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